MODELLING THE SPATIAL-TEMPORAL MOVEMENT OF TOURISTS

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DECLARATION

This thesis contains no material that has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution. This thesis contains work of mine alone and the best of my knowledge and belief contains no material previously published or written by another person, except where due reference is made in the text. Furthermore, the work presented has been carried out after the official starting date of the program.

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LIST OF ACRONYMS

ABM	Agent-Based Models
AI	Artificial Intelligence
CA	Cellular Automata
CBR	Case-Based Reasoning
CCTV	Closed Circuit Television Monitoring
CPM	Computational Process Models
EM	Expectation Maximisation
ESRI	Economic and Social Research Institute
FMCW	Frequency-Modulated Continuous Wave
GCRTSim	Grand Canyon River Trip Simulator
GIS	Geographic Information System(s)
GPS	Global Positioning System(s)
IBM	Individual-Based Models
KCC	Koala Conservation Centre
LBS	Location-Based Service
MC	Markov Chains
NN	Nearest Neighbour
ORDBMS	Object Relational Database Management System
PDA	Personal Digital Assistant(s)
RBSim	Recreation Behaviour Simulator
STIS	Space-time Information System
SPSS	Statistic Package for the Social Science
WEKA	Waikato Environment for Knowledge Analysis
WTO	World Tourism Organization
WUSM	Wilderness Use Simulation Model

ABSTRACT

Tourism is one of the most rapidly developing industries in the world. The study of Spatio-temporal movement models of tourists are undertaken in variety of disciplines such as tourism, geography, mathematics, economics and artificial intelligence. Knowledge from these different fields has been difficult to integrate because tourist movement research has been conducted at different spatial and temporal scales. This thesis establishes a methodology for modelling the spatio-temporal movement of tourists and defines the spatial-temporal movement of tourists at both the macro and micro level.

At the macro level, the sequence of tourist movements is modelled and the trend for tourist movements is predicted based on Markov Chain theory (MC). Log-linear models are then adopted to test the significance of the movement patterns of tourists. Tourism market segmentation based on the significant movement patterns of tourists is implemented using the EM (Expectation-Maximisation) algorithm. At the micro level, this thesis investigates the wayfinding decision-making processes of tourists. Four wayfinding models are developed and the relationships between the roles of landmark and wayfinding decision-making are also discussed for each type of wayfinding process The transition of a tourist movement between the macro and micro levels was examined using the spatio-temporal zooming theory.

A case study of Phillip Island, Victoria, Australia was undertaken to implement and evaluate the tourist movement models established in this thesis. Two surveys were conducted on Phillip Island to collect the macro and micro level movement data of tourists. Results show particular groups of tourists travelling with the same movement patterns have unique characteristics such as age and travel behaviours such as mode of transport. Effective tour packages can be designed based on significant movement patterns and the corresponding target markets. Tourists with various age groups, residency, gender and different levels of familiarity with the physical environment have different wayfinding behaviours.

The results of this study have been applied to tourism management on Phillip Island and the novel methods developed in this thesis have proved to be useful in improving park facilities and services provided to tourists, in designing tour packages for tourism market promotion and in understanding tourist wayfinding behaviours.

CHAPTER 1 INTRODUCTION AND OUTLINE

1.1 INTRODUCTION

Tourism is one of the most rapidly developing industries in the world (Leiper 1995). The total number of world international tourist arrivals has increased from 25 million in 1950 to 808 million in 2005 (World Tourism Organization 2006b). International tourism receipts globally were US$681.5 (AU$892.6) billion in 2005 (World Tourism Organization 2006a). Australian total receipts amounted to US$14.9 (AU$19.5) billion in 2005. The expenditure by international visitors in Victoria was over AUS$2.5 billion in 2004 (Tourism Victoria 2004). It is not surprising then that study of tourist movements is one of the most important areas of tourism research (Pearce 1987). Tourist movements can be studied from a number of different discipline perspectives. For example, geographers are interested in the spatio-temporal distribution of tourists (Pearce 1987). Psychologists are more likely to seek the reasons behind tourist movements (Allen, G. 1999a). Tourist movements are considered by economists as a starting point for provision of services (Leiper 1995; Ogilvie 1933). Environmentalists are concerned with minimising environmental damage as a consequence of tourist movements (Arrowsmith and Inbakaran 2002; McLaren 2003). Knowledge from these different fields has been difficult to integrate because the tourist movement research has been conducted at different spatial and temporal scales. For example, tourist movements can be considered as a long-term or a short-term event, or cover movement across vast or small distances.

This thesis defines the spatio-temporal movement of tourists from a geographic perspective on two levels: the macro and the micro. Movements at the macro level in terms of spatial scale refer to motion from one location (area) to another. Temporal resolution of movements at the macro level is measured in hours, days, weeks or years. At the micro level, a sequence of movement is represented as a collection of spatial points (x, y) in a coordinate system and in temporal resolution of minutes or even seconds. Economists, therefore, can determine the provision of services based on the tourist movement research at the macro level conducted by geographers. Environmentalists and psychologists can share knowledge of tourist movements at the micro level with geographers.

In this thesis, a methodology is developed to model spatial and temporal movement, herein after called spatio-temporal movement at both the macro and micro level. At the macro level, the research focuses on modelling the physical movement of tourists, while at the micro level this research models the tourist wayfinding decision-making process.

A case study was carried out to investigate macro level tourist movement around nine attractions on Phillip Island, Victoria, Australia. Modelling methods such as Markov Chain (MC) models and log-linear models are applied and evaluated using this macro level movement data. In addition, micro level tourist movements around the Koala Conservation Centre (KCC), one of the attractions on Phillip Island, are studied to evaluate the cognitive decision-making models developed in this thesis.

This thesis does not attempt to provide cognitive decision-making models for the modelling of tourist movement at the macro level, because the factors that affect decision-making by tourists decisions-making regarding travel on a large scale over a long-term period are hard to predict. However, Markov Chain models can be used to estimate the probabilities of a sequence of attractions visited by tourists and predict the trend of tourist movements at this level.

Nor is this thesis meant to predict continuous physical movement of tourists at the micro level using mathematical models, but rather attempts to model the tourist wayfinding decision-making processes at this level and to understand how tourists use landmarks and other wayfinding strategies. The information about the physical movement of tourists at the micro level is used to validate cognitive decision-making models.

1.2 RESEARCH OBJECTIVES

The primary aim of this research is to develop a methodology to model the spatio-temporal movement of tourists at the macro and micro levels. In order to achieve this objective, it will be necessary to understand who the tourists are, how they move about tourist locations and the purposes for their visits. Such knowledge is useful for tourist managers in establishing suitable park management policies or marketing strategies. In addition, the concepts, theories and methods established in this thesis can be used to further clarify and develop the knowledge of tourist movements. This research aim raises a number of research questions; they are:

1. What are the spatial and temporal scale issues related to modelling the spatio-temporal movement of tourists?
2. How can the spatio-temporal movement of tourists be characterised?
3. What methods are currently used to monitor the spatial and temporal movements of tourists at the macro and micro levels?
4. What methods can be used to model the spatio-temporal movement of tourists at the macro level?
5. How can these methods be used to develop a spatio-temporal movement model at the macro level?
6. What methods can be used to test the significance of the spatio-temporal movement patterns of tourists at the macro level?
7. What methods are available to conduct tourism market segmentation based on the significant movement patterns at the macro level?
8. What are the factors that affect tourist wayfinding decision-making at the micro level?
9. How can tourist wayfinding models be developed at the micro level?
10. What are the relationships between tourist wayfinding decision-making and the use of landmarks in different situations?

1.3 RESEARCH RATIONALE

The recent global growth in tourism has led to fierce market competition among tourist organisations. In order to attract more tourists and make the most profitable use of existing tourist assets, it is essential for tourist organisations to understand not only aggregate tourist behaviours, such as, how many tourists visit a country or an attraction during a certain period of time, but also individual tourist behaviours, for example, what kinds of tourists visit a country or an attraction? What other countries or attractions have tourists visited during the same trip? When did they visit these countries or attractions? How did tourists travel around these countries or attractions? Why do tourists to visit these countries or attractions? How do tourists determine their itineraries for the trip? This tourist behaviour information enables tourist organisations to position themselves in the target market and to provide personalised services. Research into the spatio-temporal movement models of tourists has been conducted in the context of tourism, geography, mathematics, economics and artificial intelligence since 1930's (Bierlaire 1998; Gimblett 2002; Golledge 1999; Kemeny and Snell 1976; Miller 2005; Ogilvie 1933; Pearce 1987). Four types of movement models have been developed including spatially explicit models, individual based models, mathematical and economic models, and spatial cognitive models. This research will establish a methodology for modelling the spatio-temporal movement of tourists at the macro and micro levels using mathematical models and spatial cognitive models in order to better understand, predict and optimise tourist movement behaviours. Four benefits of this research aimed at tourists, tourist agencies or organisations and researchers have been identified. They are:

(1) Reviews and comparisons of counting and tracking techniques for tourist organisations and researchers;
(2) Design of tour itineraries or packages for tourists and tourist agencies;
(3) Design of effective agent-based modelling rules for tourist organisations and researchers;
(4) Knowledge of tourist wayfinding behaviours for tourist organisations.

1.4 RESEARCH METHODOLOGY

This section describes the thesis structure and outlines the research methodology. The thesis is organised into eight chapters. These chapters briefly discuss the theories and methods used in modelling the spatio-temporal movement of tourists. The research questions set out for the thesis are also addressed in these chapters.

Chapter 2 reviews the relevant literature regarding the modelling of the spatio-temporal movement of tourists. Four types of movement models are discussed in detail including spatially explicit models, individual based models, mathematical and economic models, and spatial cognitive models. Research questions 4 and 9 are addressed in this chapter. The methods for modelling the spatio-temporal movement of tourists at the macro level and for modelling the wayfinding process of tourists at the micro level are determined.

Chapter 3 establishes and depicts a theoretical framework for the spatio-temporal movement of tourists. This framework is made up of two parts: objective travel ontology and subjective travel ontology. The section on objective travel ontology addresses the first two research questions. The spatial and temporal scale issues related to modelling spatio-temporal movement of tourists are discussed. The definition of tourist physical movements at the macro and micro levels are outlined in this section as well as representation and database design methods .The transition of a tourist movement between the macro and micro levels is also examined using on the spatio-temporal zooming theory. The section on the subjective travel ontology addresses the research question 8. Factors that could affect the tourist wayfinding decision-making processes are discussed. The wayfinding models are developed in chapter 6 based on these factors.

Chapter 4 addresses research question 3. Counting and tracking techniques at the macro and micro levels are compared and reviewed in this chapter. Each review includes a summary of the advantages and disadvantages of the techniques and identifies suitable applications for each technique. Based on the evaluation of each technique, data collection methods used in this study are discussed in detail.

Chapter 5 establishes methods of modelling the spatio-temporal movement of tourists at the macro level in three stages. The first stage addresses research question 5 and discusses the development of the tourist movement model based on MC theory. This model is used to estimate the probabilities of the tourist movement patterns. The second stage addresses research question 6 and investigates the method of testing the significance of the tourist movement patterns using log-linear models. The third and final stage addresses research question 7 and describes the procedure of tourism market segmentation based on the significant movement patterns.

Chapter 6 documents the development of the four cognitive wayfinding models based on four situations at the micro level. The relationships between roles of landmarks and tourist wayfinding decision-making in each wayfinding situation are also discussed. The last two research questions are addressed in this chapter.

Chapter 7 discusses the implementation and evaluation of the methods and theories of modelling the movement of tourists at the macro and micro levels on Phillip Island. There are six steps in this case study. Step 1 applies and evaluates the technologies for tracking the spatio-temporal movement of tourists at the macro and micro levels on the island. In step 2 implementation of spatio-temporal zooming theory is undertaken to visualise the spatio-temporal movement of tourists at the macro and micro levels and also the transition of the tourist movement between these two levels. Step 3 models the tourist movement at the macro level on the island using MC models. The significance of the movement patterns of tourists is tested in step 4 using log-linear models. Step 5 discusses the implementation of the tourism market segmentation methods presented in chapter 5, and step 6 evaluates the cognitive wayfinding models designed in chapter 6.

Chapter 8 reveals and discusses the major research findings. The limitations of the methods and theories established and implemented in this thesis are discussed. The chapter also addresses the future direction of this research and reiterates the research objectives and the questions set out in this thesis.

1.5 CONCLUSIONS

This chapter established objectives and rationale of the research on the modelling of the spatio-temporal movement of tourists. The research methods necessary to achieve the corresponding objectives in this thesis were outlined in each chapter description. The next chapter will review the relevant literature regarding tourist movement modelling methods.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

In the previous chapter, the objectives and key questions were presented. In addition to discussing the research rationale, the methodology for modelling the spatio-temporal movement of tourists was also outlined. This chapter begins by discussing a short history of research on tourist movements. A review of previous modelling methods related to the spatio-temporal movement of tourists then follows. The modelling methods reviewed are spatially explicit models, individual-based models, mathematical and economic models and spatial cognitive models.

2.2 A SHORT HISTORY OF RESEARCH ON TOURIST MOVEMENTS

Research into the spatio-temporal movement of tourists can be studied from a number of different aspects. Stemming from the 1930s, Tourist movements were considered to be the starting-point of tourist service research. Ogilvie (1933) established methods for the measurement of external movement, length of stay and the expenditure of tourists based on their movements. From an economic point view, this is one of the earliest research projects on this topic. Since the 1950's, tourism has become a mass phenomenon, and particularly after 1975, tourism has grown to be an important industrial organisation (Leiper 1995). As tourism booms, more attention has been paid to the economic geography (that is, spatial patterns in tourism supply and demand analysis) (Saarinen 2003). The tourist movement, in the tourism context, is considered as a foundation for tourism demand research (Cooper *et al.* 1998). The tourist movement is modelled as motion from a "tourist generating region" to a "tourist destination region". A "transit route region" is considered these intermediate places where tourists are routed through (Leiper 1990). Pearce (1987) modelled tourist flows and analysed tourist travel patterns at a variety of scales in order to link markets, destinations and transit regions. The methods for modelling tourist flows and tourism demand were summarised by Smith (1995). These methods include the Gravity Model, the Probabilistic Travel Model, the Simple Regression Analysis and the Delphi Technique. The gravity model is the best known method and has been extensively used to analyse travel patterns of tourists between destination and origin regions (Smith 1995).

From the 1960's, Geographers became interested in tourist movement study (Pearce 1979). They concentrated almost exclusively on understanding of how people moved around particular locations and modelled what was observed in a tourist movement. Hägerstrand (1970) conceptualized the space-time path as an individual's continuous physical movement through space and time, and illustrated this as a three-dimensional graph. His work provided a conceptual framework for time geography (Miller 2005). Based on space-time path theory, Lenntorp (1976) and Burns (1979) established the earliest operational formulations to measure the accessibility of individuals in space and time. Gober and Mings (1984) examined aggregate patterns of movement of non-permanent residence using Factor Analysis. Higham et al. (1996) also analysed the tourist movement patterns using a method of coupling case-based reasoning (CBR) with geographic information systems. However, they focused on identification of the similarities of movement patterns. A preliminary typology of temporary population movement is proposed by Bell and Ward (1998) by comparing characteristics of temporal movers and their spatial distribution including origins and destinations. Forer and Simmons (1998) measured tourism flows for a better understanding of tourist movement patterns and the role of transport in these tourist experiences.

Since the 1990s, modelling of tourist movements in space and time has become mainstream. Spatially explicit models, individual-based models, mathematical and economic models and cognitive models are extensively used in modelling the spatio-temporal movement of tourists (Forer 2002; Gimblett 2002; Gulinck and Dumont 2002; Higham *et al.* 1996).

2.3 SPATIALLY EXPLICIT MODELS

Two main types of spatially explicit models have been used extensively in modelling the tourist movement. The first type of models generally focuses on spatial movement modelling, which can be further divided into two subtypes: network-based models and cell-based models. The second type of spatially explicit models considers movement in both space and time. The methods and theories related to these models will be reviewed and compared in this section.

2.3.1 Network-based models and cell-based models

Geographers have paid more attention to spatially explicit movement models. They tend to organise, represent and analyse the spatial movement of tourists (Forer *et al.* 2002; Tobler 1997). Network-based models and cell-based models are the main types of spatially explicit movement models. In terms of the network-based models, tourist movements are modelled spatially as a linear network (Itami 2003). The structure of space, for example, the network of pathways in a park, constrains or defines the route of tourist movement. Forer *et al*. (2002) developed a preliminary computer-based data management system to model relationships between the number of visitors and its impacts on available natural assets in terms of network-based models. Cell-based models were developed based on the theory of Cellular Automata (CA) (Schelling 1971; Wolfram 2002). Space is modelled as a two-dimensional grid of cells. The tourist movement process can be presented by a collection of finite, countable number of states. Each of the cells can be in one of a number of states of movement. The transition from one cell to another or one step of the movement to another is determined by decision rules and a geometric configuration of neighbour cells (Davidson and Wainer 2000). Dijkstra *et al*. (2001) developed a multi-agent cellular automata model to describe the process of pedestrian movement and decision-making within the built environment. Simple rules were defined to determine the transition of cell states.

2.3.2 Space-time models

Two types of space-time models have been developed since the1970’s: space-time path models and space-time prism models. Space-time path models based on the theory of space-time paths are established by Hägerstrand (1970). Space-time paths show the approximating trajectories of movements in space with respect to time. The slope of the trajectories shows the relationship between time and space. A steeper slope indicates less velocity, while a vertical path indicates static motion. The space-time path models explicitly present and analyse information about changes of movements. The space-time prism model was based on the space-time path model (Miller 2005). It delimits the potential path area, which the locations of activities fall into and measures the accessibility of locations by individuals given activity locations, durations of fixed activities and a maximum possible speed from a starting point to an ending point (Miller 2004) (see figure 2.1and figure 2.2).

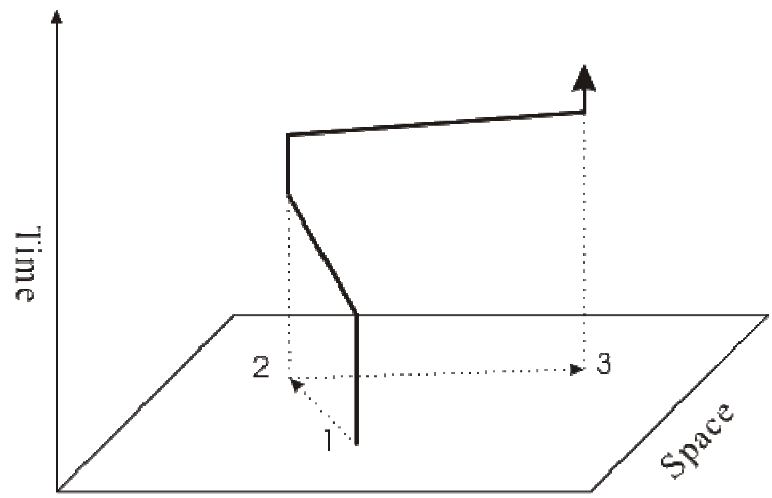

Figure 2.1 A space-time path

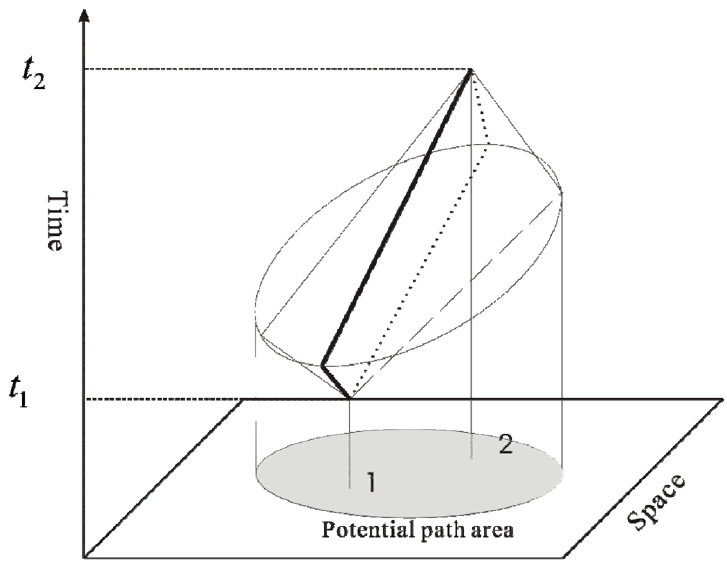

Figure 2.2 A space-time prism

Since the 1970's, numerous research has been undertaken to improve the space-time model from the conceptual level to the computational level (Kwan 1998; Lenntorp 1976; Miller 1991). The earliest operational formulations of the space-time model were conducted by

Lenntorp (1976) and Burns (1979) to measure the accessibility of locations by individuals in space and time. Miller (1991) established operational space-time measures of individuals' accessibility using a network-based GIS (Geographic Information System) method. A space-time model was also formulated by Kwan (1998) using a different network-based GIS method to measure gender or ethic differences in accessibility. Miller (2005) established a measurement theory for the space-time model. His work provided a foundation for modelling the spatial and temporal movement of tourists from a geographical perspective.

2.3.3 Individual-based models

Individual-based models (IBM) are "simulations based on the global consequences of local interactions of members of a population" (Reynolds 1996). Individual-based models are also called *entity* or *agent* based models. An agent can be anything, such as animals, cars, or human beings. In a tourism context, an agent can be an individual tourist or a group of tourists moving about collectively. An agent tourist can be viewed as perceiving their environment through sensors and acting upon that environment through effectors (Russell and Norvig 1995). Agent-based models (ABM) are one branch of Artificial Intelligence (AI). Agent tourists have characteristics of autonomy, social ability, responsiveness and proactiveness (Russell and Norvig 1995). This means that agent tourists can move around their virtual environment without central control. Agent tourists can communicate with other agents and change their movement behaviours according to the changes of environment or information obtained from the other agents. An intelligent agent can even predict changes of environment and act in advance to deal with an expected difficulty that has occurred in the virtual environment. For example, agent tourists view a traffic jam in a road intersection and would then choose another road for travel (Batty 2003).

Individual-based models for modelling the tourist movement are usually spatially explicit and agents have mobility. They can move along linear network-based (continuous) or cell-based (discrete) spaces (Higham *et al.* 1996; Itami 2003; Weifeng *et al.* 2003). In contrast to aggregation models, individual agents change their behaviours based on the predefined rules and their characteristics through time. A global behaviour on a higher level of abstraction can emerge based on behaviours of individuals and their interactions. On the other hand, aggregation models simulate changes of averaged characteristics of the whole population (Gimblett 2002; Reynolds 1996).

One of the well-known ABM for modelling the spatio-temporal movement of tourists is Recreation Behaviour Simulator (RMSim), which is "a computer program that simulates the behaviour of human recreators in high use natural environments" (Itami 2003). It is a spatially explicit mobile agent simulation system and combines agent techniques and GIS. Geographic information systems provide the environment or stage for tourist agent to roam around. Some other research groups have implemented agent-based modelling in tourism management, for example, Wilderness Use Simulation Model (WUSM) (Shechter and Lucus 1978); GCRTSim (Grand Canyon River Trip Simulator) (Gimblett *et al.* 2000)

2.4 MATHEMATICAL AND ECONOMIC MODELS

Generally two types of mathematical and economic models have been established and applied in modelling travel behaviours of people. Discrete choice models are popular modelling methods in the transportation discipline for predicting route choice of travellers. Markov Chain models have been used in many disciplines for modelling the sequence of events. However, there is no particular research using MC models to predict the movement sequence of tourists. This thesis establishes a novel method to model the spatio-temporal movement of tourists based on MC theory.

2.4.1 Discrete choice models

In the last 25 years, discrete choice models, one type of econometric model, have been widely used in transportation modelling for understanding, predicting, controlling or optimising route choice decisions and departure times (Bierlaire 1998). This type of models is the individual-based models. The transportation demand is the result of individual's decision-making (Meyer 1997-2005). The major assumption of discrete choice models is based on the Random Utility Theory, which states that the utility of an individual route alternative is associated with some degree of uncertainty. Travellers are presumed to choose the alternative route with the highest utility (Sandefur *et al.* 1996). Some of most used discrete choice models are the Multinomial Logit Model, the Nested Logit Model and the Generalized Extreme Value Model (Bierlaire 1998). For example, Yun and O'Kelly (2003) applied a nested logit model to test a hypothesis that shopping activity choice is dependent on the day of the week. One of the limitations of discrete choice models was summarised by Kwan and Golledge (1996). They stated that this type of model focused on identifying the factors affecting the final route decision instead of understanding the processes of the route choice decision. In addition, when the decision choice set is excessively large the choice probability is impossible to be evaluated. Therefore, the discrete choice models cannot be used to predict the route choice. In these situations, MC models are demonstrated to be more practical and effective in forecasting probabilities of travel behavioural patterns (Yamamoto *et al.* 2001).

2.4.2 Markov Chain models

The theory of MC is a powerful technique, which has been used widely in various disciplines, for analysing a series of events which are linked together by first-order dependence and the trends and outcomes of events (Iosifescu 1980; Isaacson and Madsen 1976; Kemeny and Snell 1976; Stewart 1994). For example, MC models have been recently used to model activity-travel decisions. These models assume that activities conducted by people are correlated and successive. Based on the dependences of activities, MC models can predict probabilities of activity patterns (Zwerts 2005). Yamamoto *et al.* (2001) applied MC models to predict effects on activity travel patterns resulting from the introduction of transportation policy measures. MC models have been also used to understand migration patterns of people (Constant and Zimmerman 2003; Tobler 1997) and model random walks of people (Simon 1973; Spitzer 2001). In this thesis, a method for modelling the spatio-temporal movement of tourists at the macro level using MC models is presented. The probabilities of tourists visiting a sequence of attractions will be estimated. This is discussed in chapter 5.

2.5 SPATIAL COGNITIVE MODELS

There are two types of spatial cognitive models relating to modelling tourist movements (Ramming 2002). One model is based on the discipline of cognitive psychology. Spatial structure of the environment is represented in memory as a cognitive map. This mental map will help tourists find their way in reality. The second model is based on the discipline of cognitive science. Computers are used to model cognitive behaviour of tourists. Tourist movement behaviour rules are studied first. A computational model, such as an agent-based model is used to simulate the movement process based on these tourist behaviour rules.

Cognitive maps were originally used by Tolman (1984) who regards them as representations formed within the mind that have the same function as hardcopy cartographic maps. Golledge (1999) defines a cognitive map as the internal representation of the physical environment. The development and use of cognitive maps are an essential part of wayfinding (Darken and Peterson 2004). In this thesis, a cognitive map is regarded as a virtual map that is related to spatial knowledge as well as spatial ability. Two types of cognitive map are discussed at two levels of spatial scales: the global cognitive map (macro level) and the local cognitive map (micro level). Different levels of cognitive maps facilitate the tourist wayfinding in various ways (see chapter 6).

A landmark is an important concept in constructing a cognitive map. The characteristics of landmarks are singularity or salience, which means their distinct qualities contrast to the background (Lynch 1960; Raubal and Winter 2002; Saaty 1980). Landmarks are used as references to help people memorise and recognise routes, and locate themselves in terms of their ultimate destination (Sorrows and Hirtle 1999). For example, a river can offer tourists a linear reference to a particular attraction. Well known large architectural buildings can be sighted from a long distance away and used as symbolic landmarks by tourists. Landmarks in the tourism context are extensively utilised as a navigation tool. Asper (1996) divided tourist wayfinding signs into eleven types including “region welcome signs”, “region trailblazer”, “gateway markers” and “resource direction signs” and applied these to the Pocono Mountains wayfinding signing program. Landmarks can also be regarded as spatial reference points that humans can use to organise cognitive spaces. In this thesis, relationships between landmark utility and wayfinding decision-making will be studied based on levels of familiarity with the environment of tourists.

Decision-making in human wayfinding is the process of deciding which path to traverse when faced with a series of alternatives. Cognitive scientists tend to observe the tourist movement or wayfinding process and develop tourist behavioural rules based on a compensatory decision rule such as economic utility maximisation or the tourist strategies of path choice (Ramming 2002). For example, Golledge (1999) developed wayfinding strategies such as shortest path, least time taken, fewest turns, or most scenic. However the decision maker may not be completely conscious of using specific wayfinding strategies or criteria. Because of the complexity of wayfinding tasks, people can apply heuristic rules to simply their wayfinding decision-making (Ramming 2002). Hirtle and Gärling (1992) developed heuristic rules called the Nearest Neighbour (NN). They claimed that travellers chose next locations based on the local minimum distance from the actual locations.

Based on the decision rules of movements, computational process models (CPM) are developed to simulate travel behaviours. One of the first CPM of travel choices was developed by Kuipers (1978). It is called the TOUR model. This model simulates the tourist wayfinding procedures based on cognitive map theory. The other prevailing computational process models related to travel behaviours are NAVIGATOR 9 (Gopal and Smith 1990; Leiser and Zilberschatz 1989), TRAVELLER (Leiser and Zilberschatz 1989), STARCHILD (Recker *et al.* 1986a; Reeker *et al.* 1986b), SCHEDULER (Gärling *et al.* 1989) and GISCAS (Kwan 1995).

Individual differences such as gender, age, education, occupational or cultural differences can directly or indirectly influence wayfinding (Allen, G. 1999b). There has been much discussion about gender differences on wayfinding. Schmitz (1999) investigated sex roles in wayfinding strategies and environmental knowledge acquisition, and found that unlike men, women prefer the use of landmarks rather than being given route directions. Gender differences in wayfinding strategies were studied further by Lawton and Kallai (2002), who stated that men are more likely to be accurate in landmark location and use cardinal directions, whilst women are more reliant on their memory to identify landmarks.

Sjölinder (1998) discussed the individual differences in spatial cognition in a virtual environment. Wayfinding routes were classified by Arrowsmith *et al.* (2005) based on gender, age, and education differences. This thesis emphasizes identifying individual differences based on levels of familiarity with the environment. Allen (1999a) categorised wayfinding tasks into three types: travel to a familiar destination; travel to a novel destination; and exploratory travel in an unfamiliar environment. People behave differently when they are undertaking these three kinds of wayfinding tasks. The different roles of landmarks will be clarified based on this categorisation.

2.6 CONCLUSIONS

This chapter reviewed previous research regarding the modelling of tourist movements. A brief history of tourist movement research was reviewed first. Then the models being used in modelling the tourist movement since 1990s were discussed. Spatially explicit models are well-known methods in the geographic discipline. Mathematical and economic models are popular methods in transportation and economic modelling. Individual-based models and spatial cognitive models are extensively used in AI and the discipline of cognitive psychology.

The trend of research on tourist movements has been moving from qualitative to a combination of qualitative and quantitative study since the 1930's. Mathematical methods and computer technologies are extensively used to model and simulate tourist movement. In particular, AI and cognitive psychological technologies have been recently adopted in this area, which has made models of tourist movements more applicable.

However, based on the reviews of previous work in this research area, confusion has been created by introducing different technologies from various disciplines into the research on modelling of spatio-temporal movement of tourists. Knowledge from these different fields has been difficult to integrate because the tourist movement research has been conducted at the different spatial and temporal scales. For example, tourist movements can be considered as a long-term or a short-term event, or cover movements across vast or small distances. Researchers from different disciplines use different terminologies to express the same things.

This thesis will develop a theoretical framework and methodology to model spatio-temporal movement of tourists. The theoretical framework focuses on clarifying the concepts and theories related to the definition, database design and representation of tourist movements in terms of scale issues. Some well known methods such as Markov Chain theory are applied to modelling tourist movement.

The next chapter will establish a theoretical framework of modelling the spatio-temporal movement of tourists and the wayfinding process of tourists. The concepts and theories related to the definition, database design and representation of tourist movements at the both micro and macro levels will be discussed. The issues related to modelling tourist wayfinding decision-making process will be also presented. In addition, the transition of the tourist movement between the macro level and micro level will be examined by spatio-temporal zooming theory.

CHAPTER 3 BUILDING A THEORETICAL FRAMEWORK FOR MODELLING THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS

3.1 INTRODUCTION

The previous chapter briefly reviewed modelling methods for tourist movements. Four types of models, spatially explicit models, mathematical and economic models, individual-based models and spatial cognitive models were described. This chapter will discuss the definitions, terminologies and concepts of modelling the spatio-temporal movement of tourists. The framework for modelling the spatio-temporal movement of tourists consists of objective travel ontology and subjective travel ontology.

3.2 ONTOLOGY OF THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS

Ontology is the specification of a conceptualisation. The ontology of the spatio-temporal movement of tourists is the description of the conceptions, properties, structures and relationships that can exist for the domain of the spatio-temporal movement of tourists. It forms the heart of the knowledge representation and enables sharing and reusing knowledge of tourist movements (Chandrasekaran *et al.* 1999; Gruber 1993).

From a philosophical perspective, an ontology is a systematic account of existence (Gruber 1993). For a tourist spatio-temporal movement system, what "exists" is of two parts: objective existence (visible travel ontology) and subjective existence (invisible travel ontology) (see figure 3.1)

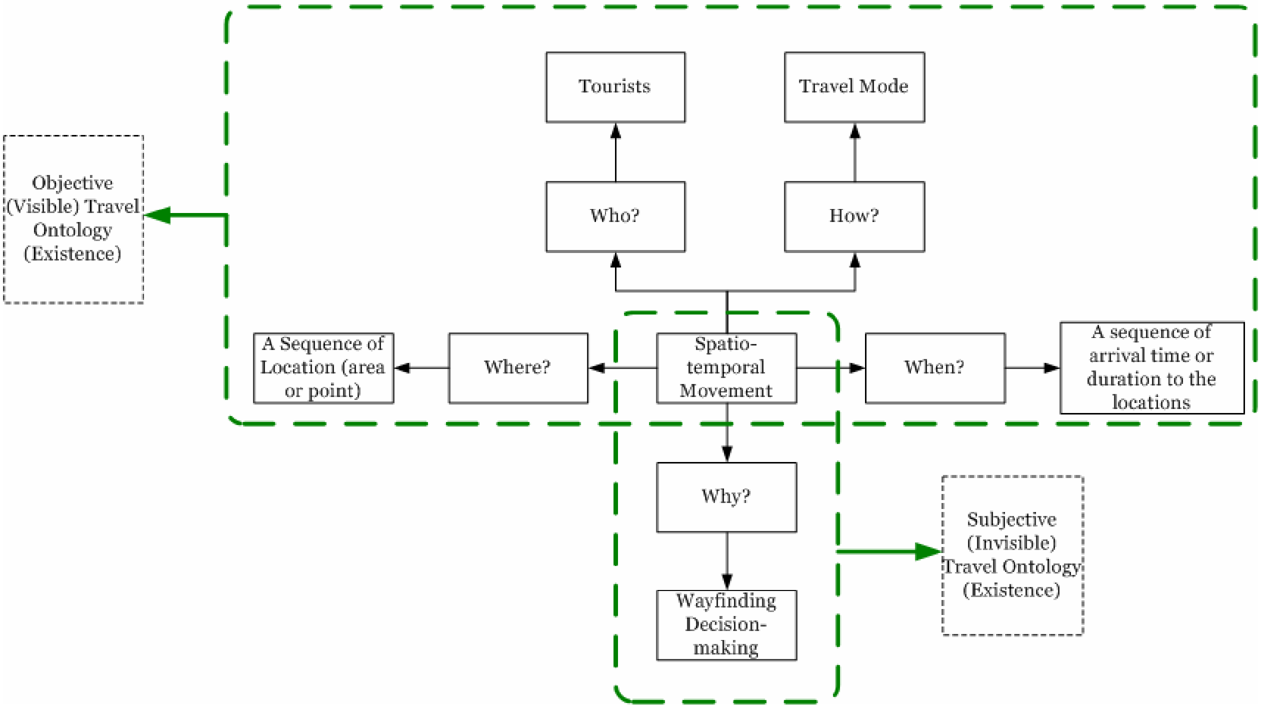

Figure 3.1 General map of the spatio-temporal movement of tourists

When considering the objective travel ontology in modelling the spatio-temporal movement of tourists, there are four questions that need to be asked:

- *Who are the tourists that are present? Tourists travelling around the attractions with their co-travellers, such as family and friends or other tourists, influence the wayfinding decision.*
- *How do the tourists move about the tourist location? In other words, what are their travel modes? For example, at a large scale (that is, macro) a car or bus may be used, at the local scale (that is, micro), walking or cycling could be travel mode.*
- *Where do the tourists visit? Or what are the movement sequences of the tourists? It could be a sequence of attractions at the macro level or a sequence of points at the micro level (see details in section 3.3.3 or section 3.3.4).*
- *When do the tourists visit? What is the corresponding arrival time or duration for the sequence of movements?*

Tourist movements are controlled by human decisions that can be difficult to predict, which is called "Subjective Travel Existence". The Subjective Travel Existence will focus on human wayfinding decision-making. How are tourist movements determined by various wayfinding decision-making factors?

3.3 OBJECTIVE EXISTENCE OF THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS

The objective travel ontology domain is comprised of the tourists, their travel modes and physical movements. The objects within this domain are visible and therefore easier to be quantified, measured and predicted. This section discusses terms or elements of the physical movement of tourists including:

- Tourists and their travel mode
- Scale issues
- Spatio-temporal movements at the macro level
- Spatio-temporal movement at the micro level
- Spatio-temporal zooming theory

These findings have important implications for developing models of the spatio-temporal movement of tourists. Each of the travel elements are discussed in section 3.3.1 to 3.3.4.

3.3.1 Tourists and Travel modes

The properties of tourists include name, age, gender, residency, and education (see figure 3.2). Names are necessary to identify individuals; however, because of ethical issues individual names are not discussed in this system.

Travel modes represent how tourists travel to and around attractions. Travel modes include visit frequency, modes of transport (such as car, bus, bike or aircraft) and the types of travel groups they travel with. The *visit frequency* refers to how many times tourists visit the same attraction. It shows the visiting habits of tourists. From a tourist management perspective, the more frequently tourists visit attractions, more facilities or services should be established. In addition, where larger numbers of tourists are recorded on roads, the more efforts should be made to maintain the roads. *The types of travel group* refer to whom the tourists travel with. Do they travel individually, or do they travel with their partners, families with children, friends or with organized groups? Tourists could use different *modes of transport* to travel to or around attractions. Independent travellers usually drive their own cars or ride bicycles or motorcycles, while groups of tourists usually travel by bus.

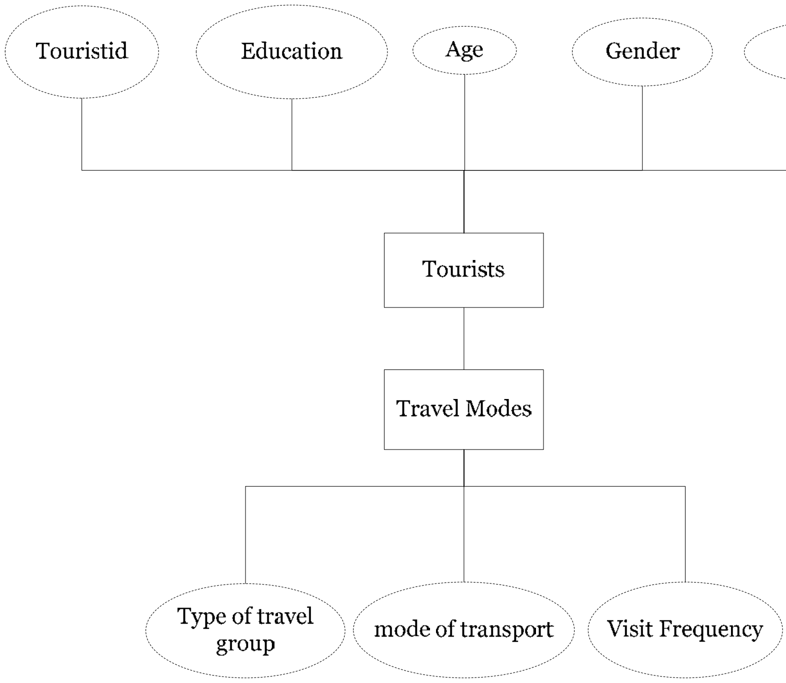

Figure 3.2 Attributes of tourists and their travel modes

3.3.2 Scale issues in the spatio-temporal movement of tourists

The different levels of scale (that is, macro and micro levels) of spatial and temporal tourist behaviours can be hierarchically structured (Car *et al.* 2001). Higher levels of scale (macro level) are associated with higher levels of simplification. Spatial behaviour can be broken down into several spatial scales or hierarchical levels. For example, if a tourist wishes to drive from Melbourne to Sydney, a high level of abstraction is required to navigate (that is, the highway which connects Melbourne to Sydney: Melbourne – highway – Sydney). However, a low level of abstraction is required to move from home to the highway that connects Melbourne to Sydney. This tourist is moving from a simple highway road network down to a complex road network of alternative pathways. Hierarchical structures can reduce the complexity of spatial reasoning, and enable the manipulation of spatial reasoning to manageable levels (Timpf and Frank 1997). The transition from one level of scale to another among the hierarchies can be interpreted by the spatial and temporal zooming theory.

This thesis will model the spatio-temporal movement of tourists at the macro and micro levels. Modelling the spatio-temporal movement of tourists at the macro level aims to represent the general travel patterns of tourists, such as the association between tourist profiles and their spatio-temporal movement sequences for tourist marketing or facility management. Macro-level movement is generally represented with a low level of spatial resolution. Usually the size of the study area is large. For example, travel from China to Australian or from Beijing to Melbourne. In terms of temporal scale, the tourist movement at the macro-level is represented by a collection of time-stamps that corresponds to the sequence of locations or attractions such as a year, a week, a day or an hour. Temporal attributes of movement are arrival time and duration at an attraction.

However, tourist movements modelled at the micro level concentrate on real-time tracking, location-based service (LBS), and security or emergency management. Micro-level movement is conceptualised as a collection of spatial points in a coordinate system (x, y) and represented with a high level of spatial resolution. In terms of temporal scale, the tourist movement at the micro-level is measured by seconds.

Section 3.3.3 defines the spatio-temporal movement of tourists and discusses the organisation and representation of movement data at the macro level. Section 3.3.4 gives the definition of spatio-temporal movement and describes methods of database design and the representation of the tourist movement at the micro level. Section 3.3.5 discusses the transition between the two levels of the movement based on the spatio-temporal zooming theory.

3.3.3 Spatio-temporal movement of tourists at the macro level

This section will define the spatio-temporal movement of tourists at the macro level first, and a discussion on methods to organise the movement data at this level based on relational database design theory follows. Finally, the representation of movement at the macro level is examined (see figure 3.3).

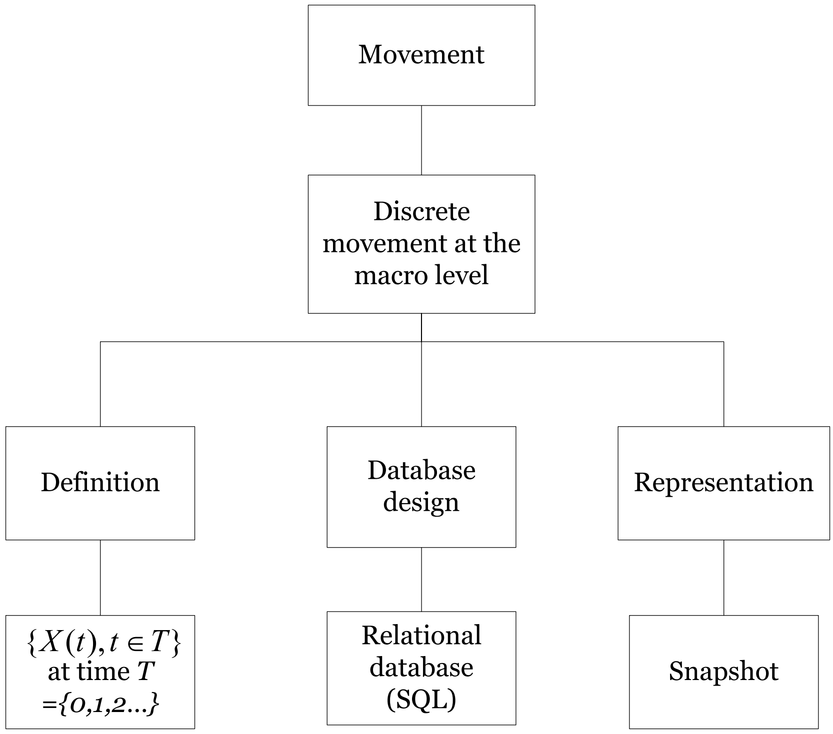

Figure 3.3 Tourist movements at the macro Level

- *Definition of the tourist movements at the macro level*

The tourist movement at the macro level can be defined as a discrete stochastic process $\{S = X(t), t = T\}$. Here, the S is usually specific tourist locations which could be located some distance apart (up to thousands of kilometres). $X(t)$ denotes states of movement at time T ={0,1,2…}. For example, if there are nine attractions visited by the tourists, then S will consist of these nine states for the nine relevant time instances (Kemeny and Snell 1976; Murthy *et al.* 1990). At this level, the tourist movement is conceptualized as being discrete and simplified as a sequence of movements in geographic space between one attraction and another. In other words, A movement pattern is simplified as a combination of attractions (Hornsby and Egenhofer 2002).

If the attraction $A_{i,n}$ is used to indicate the spatial location of individual *i* at destination *n*, then the spatial movement sequence (itinerary) for tourist *i* is then represented as the set of attractions:

$$M_{si} = (A_{i1}, A_{i2}, ..., A_{in}) \tag{3.1}$$

Where M_{si} is spatial movement pattern for individuals, this defines tourist i being at attraction A_{i1} at destination 1 and moving to attraction A_{i2} at destination 2. At the end of the trip, tourist i may be found at A_{in}. Here n is defined as the number of destinations visited by tourist i.

Temporal movement is represented as an ordered set of arrival times relating to each destination. However, the arrival time is given as time points such as 9:30 a.m. (or 09:30), or 9:31 pm (21:31). With this level of granularity or resolution, it is difficult to identify major time sequence patterns. For example, consider two tourists, one arrives at attraction A at 16:00, attraction B at 20:00 and attraction C at 21:00, the other arrives at attraction A at 16:01, attraction B at 19:59 and attraction C at 21:02. Should these two tourists have the same temporal movement pattern? It depends on the granularity of time defined for the temporal movement pattern. If the granularity of time is low (that is, hour), these two tourists have the same temporal movement pattern. Otherwise, if the granularity of time is high (that is, second), these two movement patterns are considered to be different. Therefore, one question raised from this example is, how to determine the granularity of the temporal movement? Should the granularity be second, hour, day or year? Even when hour is chosen, should it be one, two or even six hours?

A method to determine the granularity of the temporal movement pattern at the macro level is to categorise time points into time intervals using clustering methods. Clustering is a method used to group similar time points together. The members of the cluster should be similar to each other and be different from members of other clusters. Time interval is defined as ordered pairs of points, with the first time point being less than the second (Allen, J. F. 1983). The length of time intervals defines the granularity of temporal movement. The length of time intervals can be same or different. For example, all the length of time intervals are the same (that is, one hour), or some of them are 6 hours, the others are 1 hour. It depends on the real data. The temporal movement patterns can be denoted as follows:

$$M_{ti} = (TC_{i1}, TC_{i2}, ..., TC_{in}) \tag{3.2}$$

Where M_{ti} is the temporal movement pattern for individuals, a time interval TC_{ij} is a time cluster identified using a clustering method. Tourist i being destination 1 at time point 1, which is assigned into a time interval TC_{i1}, and moving to destination 2 at time points 2, between time interval TC_{i2}. At the end of the trip, tourist i may be found at destination n at time point n, between time interval TC_{in}.

To give a simple example, 500 arrival time points at attractions in a park are collected and three arrival time intervals are identified by clustering methods. The first cluster, [8:00, 12:00] is symbolised as '1', the second cluster of arrival times [12:00, 19:00] is called '2' and the third [19:00 23:00] is called '3'. These time intervals are broken up into parts of a day and given a description as follows: interval 1 can be specified as 'morning', interval 2 as 'afternoon' and interval 3 as 'evening'. If a tourist arrived at attraction A at 16:00, attraction B at 20:00 and attraction C at 21:00, then '16:00' can be assigned into time interval 2, '20:00' can be assigned into time interval 3 and '21:00' can be assigned into time interval 3. Therefore, the temporal movement pattern of this tourist is '233'. This pattern can be interpreted as three attractions visited by a tourist. One is in the afternoon and two in the evening.

- *Database design*

Tourist spatio-temporal data can be organised in a relational database. All the information is presented as a collection of relations. Each relation is shown as a table. Columns are attributes and rows ("tuples") are specific instances of entities (Dilip 2005). Relationships are expressed by foreign keys in one table (such as tourist ID) that match those of records in a second table. Data in relational databases can be defined, managed, queried and analysed using Structured Query Language (SQL) based on the value in a certain field in a record. Multiple query can join, nest, set union or differences of tables. For example, SQL query is able to select the spatio-temporal movement patterns with the same initial attraction visited by tourists from a database.

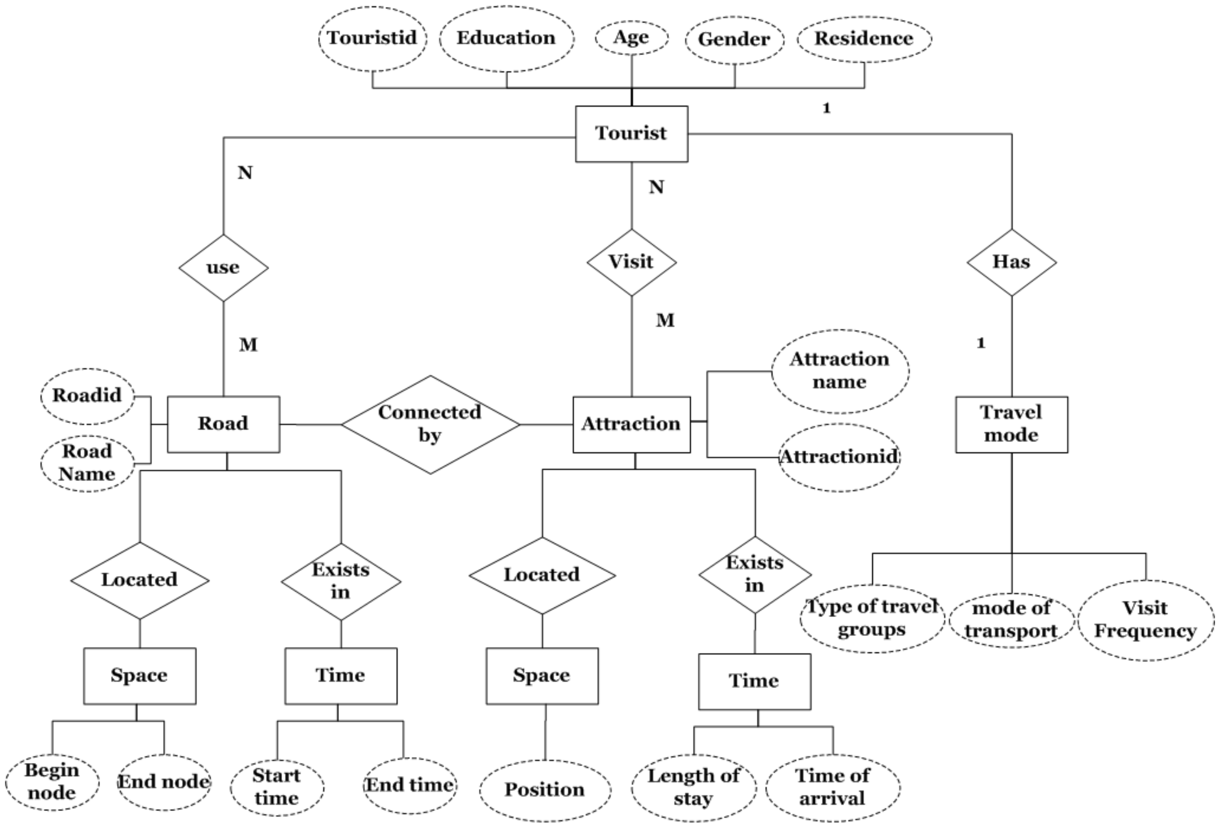

Figure 3.4 Spatio-temporal movement databases of tourists at the macro level

The Entity-Relationship (ER) model in figure 3.4 shows that the basic entities in a "tourist movement" database as tourists, roads, attractions, travel mode, space, and time. The attributes of tourists include ID, age, gender, residency, and education. Different tourists might have various travel modes, visit different attractions and use different roads. Travel mode refers to the form of transport used, visit frequency and the type of travel group. Attractions visited by tourists are located in space with an attribute being position. From a spatial reference, the tourist movement is defined as a sequence of attractions visited by tourists within a geographic space. From a temporal reference, the tourist movement, defined as a sequence of time intervals, has attributes of length of stay and time of arrival at attractions. Attractions are connected by roads used by tourists. The attributes of road are a road ID, name, a starting node of the road, the arrival time at this starting node by a tourist, an ending node of the road and the departure time from the road by the tourist.

- *Representation*

Snapshots are "an impression or view of something brief or transitory" (Merriam-Webster 2005) and can be used to represent the spatio-temporal movement of tourists at the macro level. A discrete movement process is illustrated as a collection of time stamped states. Each state of the movement is one snapshot at a particular time (Worboys and Duckham 2004). If a movement process is simplified as a sequence of movements in geographic space between one attraction and another, then one attraction is one state of movement spatially and is represented as one instance at a particular time. A collection of snapshots shows the dynamic process of movement as a sequence of attractions. One example of a snapshot will be explained in details in section 7.5.

3.3.4 Spatio-temporal movement of tourists at the micro level

This section will focus on the spatio-temporal movement of tourists at the micro level. The definition, database design and representation of tourist movements at the micro level are outlined in figure 3.5.

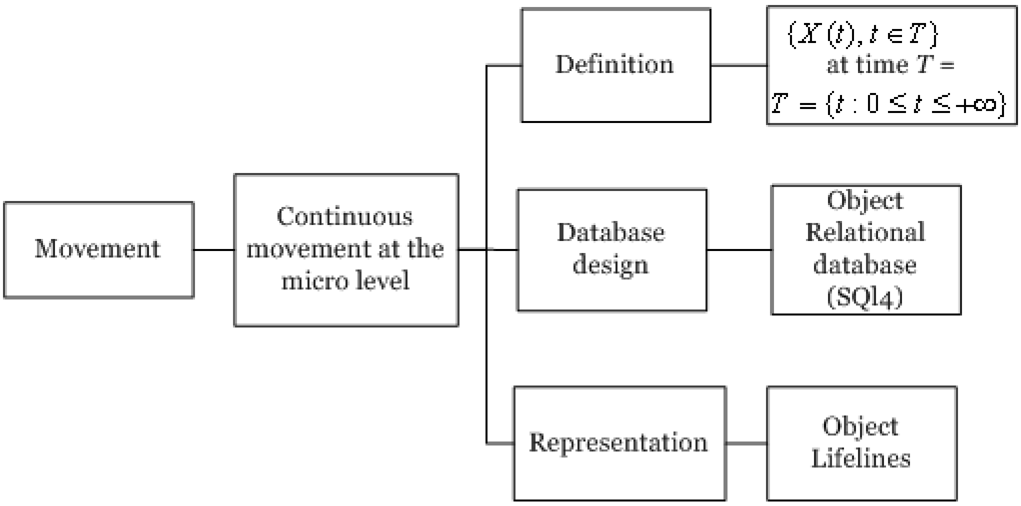

Figure 3.5 Tourist movements at the micro level

- *Definition of movement at the micro level*

The tourist movement at the micro level can be presented by a continuous or discrete stochastic process $\{X(t), t \in T\}$ defined for a given possible state by the parameter *t,* where *t* varies over some index set $T = \{t : 0 \leq t \leq +\infty\}$ (Stewart 1994). *X(t)* takes values in a state space S consisting of various spatial points (that is, (*x, y*)) representing the locations of tourists undergoing movements for all time instances over a certain time interval (Murthy *et al.* 1990). The sequence of movement can be represented accurately as a collection of spatial points in a coordinate system with high resolution. However, whilst movements along a pathway are continuous, current technologies can only record locations at discrete points. For example, GPS will record a designated location only when a receiver receives a signal from the satellites. Therefore it is necessary to utilise algorithms to predict locations where signals are missing. For example, linear interpolation is used to predict in-between sampled positions. Collections of line segments that are drawn between sampled points compose the trajectory of movement (Pfoser 2002) (see figure 3.6).

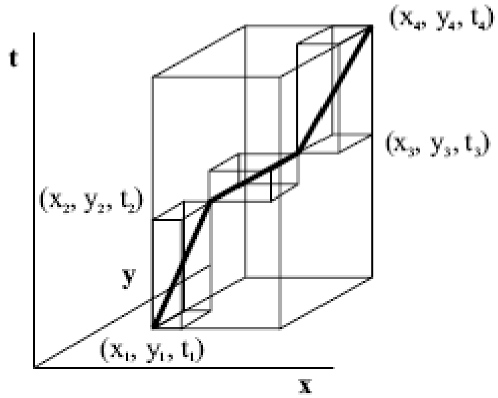

Figure 3.6 Approximating trajectories (Pfoser 2002)

- *Database design*

Motion information, which includes positions (*x, y*), corresponding time, speed, directions, modes of transport, and the number of stops can be managed in an Object Relational Database Management System (ORDBMS). An ORDBMS incorporates object-oriented methods within a relational database environment and aims to map objects such as trajectories of movement into tables. Data types and structures in an ORDBMS are more complex and richer than ones in relational database. For example, ORDBMS can define complex spatial data types such as points, lines or polygons. Indexing techniques such as R-tree, are used to record the current and expected line segments of mobile objects such as tourists or vehicles (Saltenis and Jensen 2002). Based on these indexing techniques, Pfoser (2002) summarised the types of spatio-temporal query (see table 3.1). The query language used for ORDBMS can be extended SQL (SQL4) or ObjectSQL. The advantage of ORDBMS is that they are capable of dealing with complex data types and reuse and share data and products.

Table 3.1The types of spatio-temporal query (Pfoser 2002)

Query Type		Operation	Signature
Coordinate-based Queries		overlap, inside, etc.	range
Trajectory-based Queries	Topological Queries	enter, leave, cross, bypass	range × {segments} →{segments}
	Navigational Queries	travelled distance, covered area (top or average), speed, heading, parked	{segments}→int {segments}→real {segments}→bool

- *Representation*

A continuous movement process can be represented by object lifelines. An object lifeline describes a process of the tourist movement by three elements, ID, LOCATION and TIME. ID is the identifier of a tourist, LOCATION is a spatial position (*x, y*) of a tourist in a defined two dimensional environment and TIME is a timestamp at a particular location as the third dimension of the coordinate system. Therefore, lifelines represent the *space-time path of the movement* that is firstly presented by Torsten Hägerstrand's "Time Geography" model (1970) (see details in section 2.3.2). The object lifeline extends the snapshot representation by explicitly representing information about changes of movements (Worboys and Duckham 2004). An example of representation of tourist movements at the micro level by object lifelines is illustrated by the step two of the case study in section 7.3.2.

3.3.5 Spatio-temporal zooming between the tourist movement at the macro level and micro level

This section discusses the transition of spatial movement of tourists between the macro and micro level based on spatial zooming theory. The temporal zooming theory is then used to examine the transition of the temporal movement of tourists between the macro and micro level.

- *Spatial zooming theory*

Scale plays a central role in understanding and interpreting the spatial behaviour of geographic entities. People's perception of space and spatial behaviour is scale-dependent and experience-based (Freundschuh and Egenhofer 1997). For example, a person who is familiar with a particular location will be able to identify that location with greater accuracy because of their spatial knowledge built from experience of that space. Lynch (1960) defined space at the micro level as a spatial node where space can be perceived from one position. At the macro level, a spatial region must be explored over time, by moving through the environment. Garling and Golledge (1989) opted for three levels of spatial scale in order to overcome the limitations with two levels. Their three levelled approach adopted, 'room size' to represent small areas, 'building footprints and neighbourhoods' to represent medium areas and finally large areas were extended neighbourhoods where some movement was required to view all locations in the area of interest.

The zooming lens of a camera can be used as a metaphor for moving between these scales of space. When the camera zooms in to a small area of space, more detailed information of geographic entities is revealed. Conversely, if the camera zooms outward to show a larger geographic area, the detailed information will be contextualised and shown at large spatial scale (Bundapest 2003; Hornsby 2001; Searle 1985). This process is a single zooming action. One resolution is considered as one zooming 'step'. However, new techniques such as the Level of Detail (LOD) permit multiple zooming (Frigioni and Tarantino 2003). Multiple zooming enables the user to see a geographic location in terms of detail at the micro level whilst maintaining a large spatial overview at the macro level (Frigioni and Tarantino 2003).

Spatial zooming between the macro and micro level represents the transition from the conception or planning level to the practical level. The level of detail is defined by the user, planner or researcher, and will depend on the applications for the modelling of movement. For example, tourist movements from Melbourne to Beijing can be viewed at the macro level, or at the micro level, for movements around a particular attraction such as the Forbidden City. Then, the camera zooms in on the Forbidden City. The individual tourist movement in this small area becomes evident and parameters of movement such as the position, speed, direction and time can be studied in more detail (Freundschuh and Egenhofer 1997; Muehrcke and Muehrcke 1992). Zooming out from the micro level to the macro level can be undertaken in two steps: selection and amalgamation. Selection keeps the nodes (attractions) needed at the macro level and hides the non-selected nodes from view. Amalgamation redraws the path connecting the attractions (Stell and Worboys 1999; Timpf and Kuhn 2003). Zooming in from the macro level to the micro level is the process of partition of space. Motion information is stored in a hierarchical structure: the top of the hierarchy contains the least detailed motion information whilst the most detailed motion information is stored at the base (Timpf 1998).

- *Temporal zooming theory*

Geographic entities can be perceived and examined at not only different levels of spatial resolution but also at different levels of temporal detail. The changes in geographic entities are usually modelled in multiple steps (discrete timestamps or instances). Each step is represented as one state or ‘view’. The degree of detail included in each view is dependent on the level of temporal resolution, defined in seconds, minutes, hours, days, weeks, or years. Zooming between these temporal granularities alters the levels of detail of information included in the model. A coarser-grained view of an object over time incorporates less detailed information or a greater level of ‘abstraction or generalisation’. A finer-grained view of an object over time is more detailed or ‘articulated’. The transition from abstraction to articulation is an expanding process, whereas the shift from articulation to abstraction is a compressing process. These shifts between different levels of temporal resolution of objects are referred to as temporal zooming (Hornsby 2001; Hornsby and Egenhofer 1999).

An example of spatio-temporal zooming in tourist movements at the macro and micro level will be given in chapter 7.3.2. Tourist movement data collected from Phillip Island are used to illustrate the transition between the two levels of the movement from both space and time perspectives. The objectives for this case study are to visualise the two levels of movement and the transition between these two levels of the movement conceptually (see section 6.2 for details).

3.4 SUBJECTIVE EXISTENCE OF THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS

Movement is controlled by human decisions that are invisible, random to a certain extent, non-periodic and hence difficult to predict (Zhou and Golledge 2000). Human decision making for the movement is called subjective travel existence. Decision-making for movement is the process of deciding which path to traverse when faced with a series of alternatives. This process is also a human wayfinding process. In resolving which path to take, decisions can be made according to criteria such as shortest path, least time taken, fewest turns, or most scenic. However, the decision maker may not be completely conscious of using specific wayfinding strategies or criteria (Golledge 1999).

During the wayfinding process, the cognitive and behavioural abilities of humans are drawn upon to find a way from an origin to a destination which cannot be directly seen by others (Golledge 1999). How people find their way depends on their cognitive, spatial and social abilities, as well as their knowledge of the region they are visiting, their levels of familiarity with the environment and their individual motivation. Other factors include navigation aids, such as maps, GPS, PDAs (Personal Digital Assistants) or guides, the configuration of the physical environment as well as spatial and temporal constraints (see figure 3.7).

Figure 3.7 shows the framework of subjective travel ontology. Each of the travel elements are discussed in section 2.4.1 to 2.4.6.

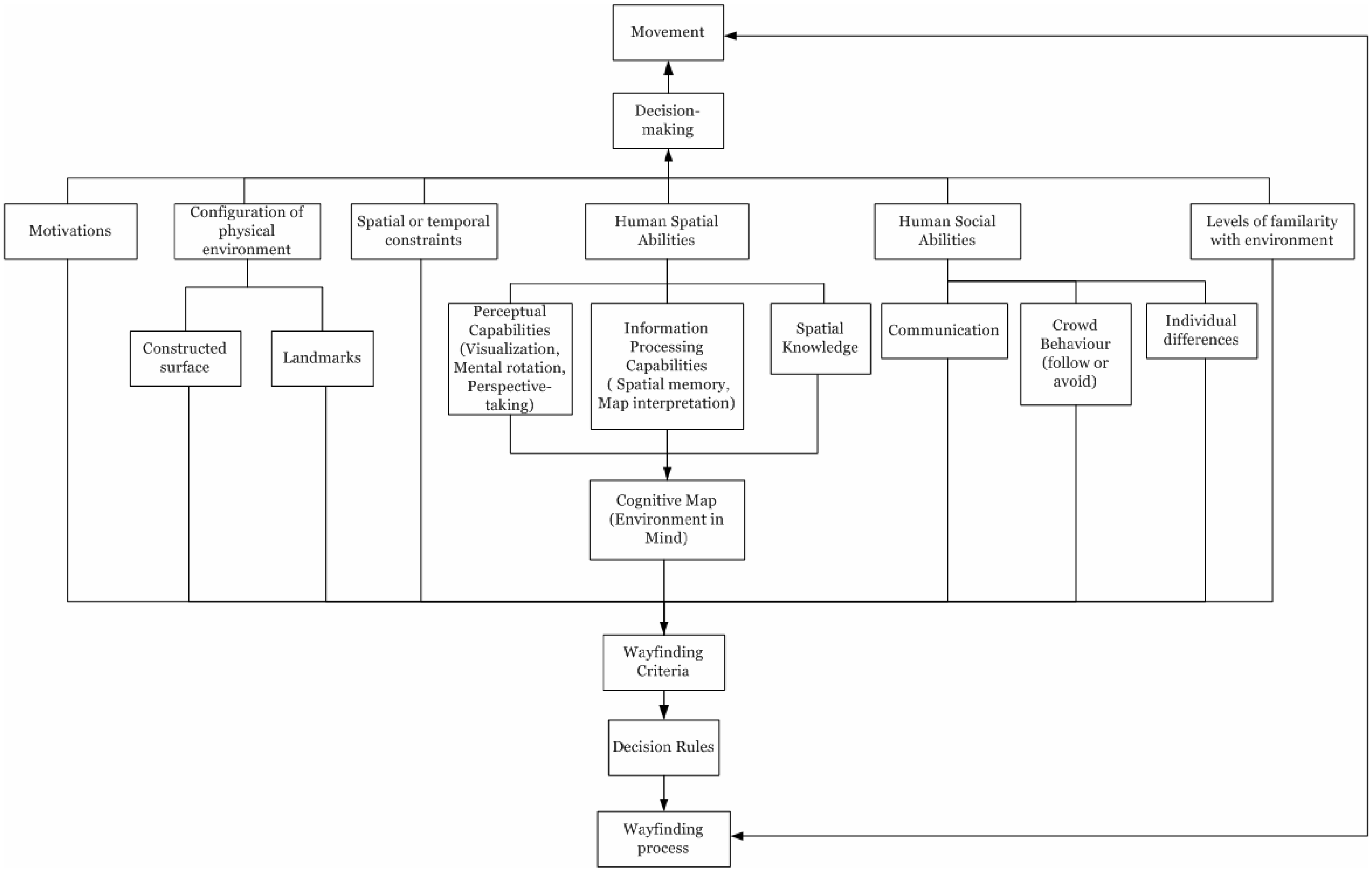

Figure 3.7 Subjective travel ontology

3.4.1 Motivation

Wayfinding is usually the purposeful, directed, and motivated means for travelling from a point of origin to a given destination. Wayfinding decisions are goal-oriented. The experience a tourist gains from an attraction will depend upon their motivational interests (see table 3.2).

Table 3.2 Motivation and wayfinding criterion

Motivation	Wayfinding criterion
To rest and relax	Minimising effort
To experience a natural environment	Most scenic or aesthetics
To socialise with family or friends	Minimising effort
To escape the everyday routine	Different from previous route taken (variability seeking)
To view wildlife in their natural environment	First noticed,
To work as a tour guide	Following routine
To exercise	Maximise/regulate efforts
To obtain the natural, historical, or cultural knowledge (for education purposes)	Most scenic or aesthetic

For example, if the trip motivation is to rest and relax, a tourist prefers easy wayfinding tasks and will minimise effort during their wayfinding process. In contrast, if a tourist would like to escape the everyday routine they could try something different and explore an unfamiliar environment. Therefore, their wayfinding criterion would be "variety seeking". However, if wayfinding is part of their job (that is, tour guides), they follow routine and minimise wayfinding effort.

3.4.2 Configuration of physical environment

The physical environment offers a seat or platform for tourists to move around, and it is typically unmovable (Frank 2003). Lynch (1960) classified physical forms of a city into five types of element: paths, edges, districts, nodes and landmarks. Paths are the tracks or channels along which the objects move. Edges are the linear boundaries between two paths, path and region, or two regions. Districts are the medium-to-large section of a city. Nodes are points that could be conjunctions of paths. Landmarks are wayfinding references (such as salient buildings, signposts, street name, direction arrows, a river, and special vegetations). These five elements form the basic structure of the physical environment of a city. These five elements could also be used to construct a natural park. However, because parks are designed for the travelling of tourists in a natural area, the concrete objects for these five elements in a park could be different from objects in a city. table 3.3illustrates the structural difference between cities and tourist parks.

Table 3.3 Comparison of structure between a city and a tourist park

Name	**Examples for cities**	**Examples for tourist parks**
Landmarks	Churchs	Sign posts
Paths	Streets	Walking tracks
Edges	Boundaries between two suburbs	Rivers between two attractions
Districts	Suburbs	Attractions
Nodes	Intersection between streets	Intersection between walking tracks

A landmark is a salient object that is used as a reference to help people memorise and recognise routes, and locate themselves in terms of their ultimate destination (Sorrows and Hirtle 1999). Landmarks can be natural, for example, a rock outcrop or large tree stand or artifact, for example, a building or street corner (Golledge 1999). The characteristics of landmarks are singularity or salience (that is, a striking point or feature) (Lynch 1960; Merriam-Webster 2005; Raubal and Winter 2002). However, there are other factors that affect human wayfinding using landmarks, for example, the levels of familiarity with environment or landmarks, visual access, plan configuration, and tourist individual differences (Lynch 1960; Weisman 1981; Winter *et al.* 2004).

Lynch (1960) categorised landmarks into two groups: distant landmarks and local landmarks. Distant landmarks are visible from many positions and are only used for general directional orientation. An example of a distant landmark is the Eiffel Tower. Local landmarks are able to be seen in restricted localities and are regarded as facilitators of path selection, such as a signpost (Lynch 1960).

Landmarks can also be used as wayfinding references in parks. But the types of landmarks designed for a park could be different from landmarks in a city. Instead of salient buildings or street names, signposts or directional posts are very important to assistant tourists in finding their way. They inform tourists where they are, what attractions are near them and in which direction the tourists can reach them. Paths are designed to connect attractions where attractions represent path nodes. A district could be the area of park or an attraction depending on the scale.

3.4.3 Spatial and temporal constraints

Both temporal and spatial scales are important factors for the tourist wayfinding performance, especially for trips with no preconceived plans. Time may regulate how much wandering can take place. For example, time constraints placed on package tour visitors to a destination will reduce a visitors' ability to wander. Temporal constraints will influence a tourist's route-selection criteria. Because of time limitation, tourists usually choose the fastest route or avoid congestion to reach their destination.

Spatial area will determine the level of wandering that takes place. The spatial scale regulates the degree to which a person will wander totally unaided. For example, a person may be quite comfortable wandering around a small park totally unaided, however, the same person wandering around a large city or wilderness area may reduce the spatial extent to which he or she will wander.

3.4.4 Spatial ability

Spatial ability refers to a person's ability to acquire, structure, memorise, analyse, and recall spatial information (Allen, G. 1999b; Raubal 2001). During the wayfinding process, as tourists move through the real world, topological relationships between objects and the physical structure of those objects are perceived, visualised, rotated, transformed, memorised and stored as cognitive maps based on previous spatial knowledge. These cognitive maps are then recalled and matched against the physical environment through which tourists are passing (Allen, G. 1999a).

Tolman (1984) regards cognitive maps as representations formed within the mind. The cognitive maps have the same function as hardcopy cartographic maps. Golledge (1999) defines a cognitive map as the internal representation of the physical environment. This representation denotes ‘spatial knowledge of the environment regardless of form’ (Kitchin and Freundschuh 2000). The development and use of cognitive maps is an essential part of wayfinding (Darken and Peterson 2004). The physical spatial environment can be abstracted as points, lines, and polygons. During the wayfinding process, people comprehend and remember routes by ‘chunking’ routes into a set of discrete path segments, decision points (turns) and landmarks that are located along decision points or along that route (Jackson, 1998). The cognitive map can be built through personal experience of the physical world or through reading and learning route maps.

3.4.5 Social ability

Social ability is the capability of interacting with other people, and relates to how individuals communicate and react to others. For example, some tourists in a park will be detracted from a location because of a crowd, whereas others will be attracted to this crowd that are the landmarks they used to the destination (Raubal 2001). Therefore, a crowd is considered by tourists as a landmark.

Individual differences such as gender, age, education, occupational or cultural differences could directly or indirectly influence wayfinding performance. There has been much discussion on the influence that gender difference has on wayfinding process. Schmitz (1999) investigated sex roles in wayfinding strategies and environmental knowledge acquisition, and found that unlike men, women prefer the use of landmarks rather than being given route directions. Gender differences in wayfinding strategies were studied further by Lawton and Kallai (2002), who stated that man are more likely to be accurate in landmark location and use cardinal direction, whilst women are more reliant on their memory to identify landmarks. Sjölinder (1998) discussed the individual differences in spatial cognition in a virtual environment. Wayfinding routes were classified by Arrowsmith et al. (2005) based on gender, age, and education differences. This paper emphasises identifying individual differences based on level of familiarity with the environment.

These behaviours are also influenced by cultural backgrounds. For example, tourists from eastern backgrounds, such as China, are more frequently attracted by a crowd than tourists from western backgrounds, such as Australia (Hofstede 2001).

3.4.6 Levels of familiarity with environment

Allen (1999a) categorised wayfinding tasks into three types: travel to a familiar destination, travel to a novel destination, and exploratory travel in an unfamiliar environment. People respond in various ways depending upon whether they are familiar or unfamiliar with the environment through which they are wayfinding. For example, when people drive home every day, they regularly follow the same order or sequence of routes, turn at the same intersections and use the same landmarks to recognise their path home. While tourists wander around in an unfamiliar attraction, if it is a small area they may change direction purely by a chance, or on a whim or serendipity. Otherwise if it is a large area they have to use wayfinding aids such as maps to travel around the attraction.

3.5 CONCLUSIONS

This chapter has established a theoretical framework of the spatio-temporal movement of tourists and their wayfinding process. The conceptions and theories are addressed in order to understand fully the issues in relation to the spatio-temporal movement of tourists. There are two parts comprising a tourist spatio-temporal movement system: objective travel ontology and subjective travel ontology. Objective existence deals with the visible part of movement such as tourists, their travel mode and physical movement. Subjective existence factors for tourist wayfinding decision-making include trip motivation, configuration of physical environment, spatial and social abilities of tourists, spatial and temporal constrains and levels of familiarity with environment.

The next chapter will compare and review the spatio-temporal movement of tourist acquisition techniques at the macro and micro levels. In addition to summarising the advantages and disadvantages for the techniques, this chapter identifies suitable applications for each technique.

CHAPTER 4 TECHNIQUES FOR COUNTING AND TRACKING THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS

4.1 INTRODUCTION

In the previous chapter, a theoretical framework for the spatio-temporal movement of tourists and their wayfinding decision-making process was established. This chapter will commence by representing spatio-temporal movement data of tourists. A review and comparison of counting and tracking techniques for tourist movements at the macro and micro level will then follow. Each review includes a summary table of advantages and disadvantages for the techniques and identifies suitable applications for the techniques. This review of techniques has provided guidance in the choice of suitable tracking techniques for this thesis.

4.2 SPATIO-TEMPORAL DATA OF TOURIST MOVEMENTS

In this section, three types of data regarding tourist movements will be examined as follows:

(1) Spatial movement data

- Position of points
- Sequence of movements
- Direction and speed
- The number or density of tourists and travel flow

(2) Temporal movement data

- Time point
- Time interval
- Time span
- Time sequence

(3) The other tourist information data related to tourist movements

- Profile of tourists
- Visiting characteristics

The tourist information data are regarded as independent variables for modelling spatio-temporal movement of tourists. They can be used to explain or predict the spatial and temporal movement of tourists.

4.2.1 Spatial data

This section discusses spatial movement data including position of points, sequence of movements, speed and directions, the number or density of tourists and travel flow.

- **Position of points**

A spatial point at the macro level encompasses an **area (region)** but at the micro level a spatial point is a **point.** For example, at the macro level, the tourist movements could be from one country to another. So the position of the point is considered to be the spatial location of the country. At the micro level, tourist movements are defined as a collection of points (x, y), so the position of points should be a point (x, y) (Erwig *et al.* 1999).

- **Sequence of movements**

At the macro level, a sequence of movements is the ordered locations in which a tourist moves, for example, an ordered set of attractions visited by tourists during their trip. A sequence of movements at the micro level is recorded as a collection of points (such as (X_1,Y_1), (X_2,Y_2), (X_3, Y_3)…) (Xia and Arrowsmith 2005). Sequence of movement is an important data set for analysing tourist movements as it represents the process of spatial and temporal movement. Based on this information, park managers can provide better road service to ensure tourists' safety or develop better tour packages for market promotion.

- **Speed and directions**

Speed is a scalar quantity and refers to "how fast a tourist is moving" (such as 4 mph). Speed of movement could be influenced by speed limits on the road, the trip motivation of tourists, the activities that they take, and their individual differences such as age, physical abilities etc. For example, during the process of travelling to an attraction, the speed of movement is usually higher. But when the tourists are travelling around an attraction they might slow down to enjoy beautiful scenery or stop at a lookout to take a picture.

Directions refer to the line or course on which something is moving to or along which something is pointing or facing (Merriam-Webster 2005). Direction is especially important for the movement at the micro level. The tourist movement at this level is defined as a continuous process. Current tracking techniques such as GPS can only record discrete position points of movements. Therefore, the direction is the key to help people predict the missing positions of tourist movements between the position points recorded by GPS (Ashbrook 2002).

- **The number of tourists, tourist density and flow**

The number of tourists refers to how many tourists visit an attraction or park. Tourist density is defined as the number of tourists per unit of area, for example, the number of tourists per square kilometre. Tourist flow is the number of tourists passing along a road during a certain period of time (see equation 3.1). Therefore, tourist density indicates the degree of crowd in an area, while the tourist flow shows the degree of crowd at a certain position during a particular period of time. For example, if the number of tourists in an attraction is over its carrying capacity, which is the maximum number of tourists that an attraction could support, then traffic jams could occur on the roads towards the attraction. The overcrowding in the attraction will have an impact on the biophysical environment of the attraction and the quality of the visitor experiences (Manning and Lawson 2002). On the other hand, the more tourists use roads, the more popular the roads are. It could be important information for park managers to assist in maintaining roads, putting up road signs or erecting advertising boards.

$$\text{Flow (tph)} = \text{Speed (km/h)} * \text{Density (tpm)} \qquad (3.1)$$

Tph = tourists per hour per road, **km/h** = kilometre per hour; **tpm** = tourists per kilometre per road

4.2.2 Temporal data

This section discusses temporal movement data including time point, time interval, time span and time sequence.

- **Time point**

A time point (that is, chronon or instant) is a time expression for a specified point in time such as the time of arrival or departure at an attraction (Koncz and Adams 2002). It can be recorded by a clock (10:30a.m.) and / or a date (Tuesday, June 29, 2004).

- **Time interval**

Basically, a time interval is an ordered pair of time points, with the first time point being less than the second (Allen, J. F. 1983). For example, if a tourist arrived at an attraction at 10:00am and departed from the attraction at 10:30, then the time interval for this trip can be denoted as [10:00 10:30). The time interval is usually used in dynamic movement database design in order to indicate the start and end time of an event such as a tourist trip.

- **Time span (Duration)**

A time span is the length of a time interval. It refers to how long tourists stay at an attraction or how long they spend in travelling from one attraction to another (such as 10 hours, 2 days). The sum of the set of time intervals is the total travel time. The time span and the time point may be important information provided to a park manager for the determination of time schedule of services offered to tourists within an attraction (Arrowsmith and Chhetri 2003).

- **Time Sequence**

A time sequence is a set of ordered time points and time spans (such as 10:30 o'clock, 11:00, 12:00, 13:30…) or (morning, afternoon…). For example, at the macro level, a time sequence of the tourist movement is a collection of time intervals (time spans). On the other hand, a time sequence of the tourist movement at the micro level is defined as a series of arrival time points to a set of attractions (see section 3.3.3).

4.2.3 Individual tourist data

In addition to the spatio-temporal movement data, there is the other information related to tourist movements such as profile of tourists and visiting characteristics. Individual tourist data are independent information and can be used for tourist movement prediction.

- **Profile of tourists**

The profile of tourists refers to the characteristics of tourists including age, sex, education, travel group type (such as travelling alone, travel with family), country of residence, and country of birth, lifecycle (such as young single, young family, mature family), income and occupation. Profile information could be used to explain the reasons for tourist movements. For example, because of age differences, the speed or distance of tourist movements could vary. In addition, with a global growth in tourism, cultural differences are becoming a more important issue to help understand tourist travel behaviours. Reisinger (2003) proposed that tourists from an eastern country such as China intend to follow the crowd during their trip. While the tourists from a western country such as Australia may prefer to avoid the crowd.

- **Visiting characteristics**

Visiting characteristics consist of travel mode, type of accommodation, activities of visit, and motivation of visit. This information shows the how and why of tourist movements. For example, the motivation of visit could explain why the tourists visited one attraction instead of another. What types of travel mode do tourists use (that is, car or bus)?

4.3 TOURIST MOVEMENT ACQUISITION TECHNIQUES

A variety of techniques have been used to gather tourist movement information. (Arrowsmith, Itami *et al.* 2005; Batty 2003; Chhetri *et al.* 2004; Coch 2002; Fennell 1996; Gimblett 2002; Hull and Stewart 1995; Lawson, S., R.M. Itami, H.R. Gimblett & R. Manning 2004; Lawson, S. R. *et al.* 2003; O'Connor, A. *et al.* 2005; Rauhala *et al.* 2002; Wang and Manning 1999). One of the traditional methods is to follow tourists and record their movement patterns, or stand at a position such as an entrance or exit point of a road or a building to count the number of tourists (Wang and Manning 1999). This technique is simple and the results can be easily applied. However, this method requires excessive amounts of time and cannot be used over extended time periods. It, therefore, is difficult to collect enough data and the results of movement data analysis are often unreliable (Heikkila and Silven 2004). Modern counting and tracking techniques gather information using advanced, automated and accurate instruments. For example, cameras, video sensors, GPS, detectors and counters are utilised to track and count tourists. These techniques can measure a large number of populations in a short period of time with high resolution. However, such techniques require expensive instruments, and the data analysis requires extensive interpretation of the results and the implications at the practical level.

4.3.1 Modern technological counting techniques

Counting techniques are utilised to count the number of people and vehicles on roads or in buildings or areas. The techniques for counting are usually categorised into different groups based on the wavelength of energy sensors installed in counting instruments. For example, infrared sensors can receive infrared waves whose length is between 700nm and 1mm. The counting techniques, such as cameral counting system, infrared sensors, thermal sensors, microware sensors, magnetic sensors and pressure sensors will be discussed in this section.

- **Camera-based counting systems**

Camera-based counting systems are usually composed of a counting system and image-based counting software. The major part of the counting system is a camera that is sensitive to light. The camera transfers light signals into electric signals and records a sequence of images. These images then are analysed using computer software to identify and count people or vehicles.

Camera-based counting systems have been used in various applications. Space Syntax Group (1997; 2003) adopted the closed circuit television to record the movement of pedestrians in buildings. This technology can be easily used to obtain the density of people in an area, but it is difficult to track an individual's path. Heikkila (2004) utilised camera based counting systems to classify pedestrians and cyclists, as well as to count the number of these two types of people.

The advantage of camera-based counting systems is that they can collect movement data with high resolution and work in such diverse ways as surveillance, counting and tracking tool and are non-intrusive as well. However, they are widely utilised as surveillance or security rather than for counting. The main disadvantages of these systems are their sensitivity to vibrations and levels of light. Height and temperature can also degrade their performances. Another disadvantage of camera-based counting systems is the high cost of equipment.

- **Infrared sensors**

Infrared light is electromagnetic radiation with a wavelength longer than visible light but shorter than microwave radiation. Infrared radiation is invisible to human eyes, but detectable by infrared sensors (Yoshiike et al. 1995). Objects (i.e. animals or human) can generate heat and infrared radiation at the same time. Therefore, infrared sensors could be used to detect the existence of a human being.

Infrared sensors can be classified as active infrared sensors or passive infrared sensors. Active infrared sensors comprise a transmitter and receiver. The transmitter emits infrared light and the receiver detects the reflected or scattered light from a human or vehicle and converts it into electrical signals. A count of people who pass by the field of vision of a sensor can be generated by detecting a new object on the thermal image (Hashimoto *et al.* 1998). The advantage of active infrared sensors is that they are not influenced by external temperature and light conditions as they have their own light source. Therefore, they are suitable for both external and internal environments. The other advantages of the active infrared sensors are that they are not intrusive, easier to install and can cover a wide entrance. However, the infrared light transmission can be affected by scattering caused by smoke, dust, water droplets, and other particles in the lower part of atmosphere.

Passive infrared sensors detect the changes in luminosity or temperature in the view of the sensor's field when a person or vehicle enters the target area. Therefore, they can't identify static objects in the field. Once a change in temperature is detected, a count is registered (Infodev 2004). The advantage of passive infrared sensors is that they can detect objects at a greater range than sensors that use visible wavelengths. Passive infrared sensors are also non-intrusive and low cost. However, the accuracy of the detector can be degraded by heavy rain or snow (McFadden *et al.* 2001). In addition, passive infrared counters cannot distinguish individuals in a group, which can lead to undercounting. In addition, miscounting might be the result of changes in the background (Gasvoda 1999). A passive infrared system is sometimes used to trigger an external camera (Gasvoda 1999).

- **Pressure pads or mats**

Pressure pads are pads or mats buried under a path surface or mounted in the entrance or exit of doors or on the steps of a bus, which can sense a person's weight and register a count (see figure 4.1) (Infodev 2004).

Pressure pad trail counters have been used extensively to count the number of visitors in the national parks in Australia and New Zealand (TRAFX 2004). Figure 4.1 shows an example of a pressure pad and where the pressure pad can be mounted in a path. In order to identify whether the provision of visitor facilities were effective at Creag Meagaidh Nature Reserve, Scotland, pressure pads were used to monitor visitor numbers (Scottish Natural Heritage 1999). Dixon (2004) counted visitors to understand the utilitiy of roads in the Trossachs close to Callander, Scotland. In addition, he compared the changes to vegetation and soil condition along paths with the fluctuation in the number of visitors who passed by these paths during a certain period of time to determine the carrying capacity of the paths.

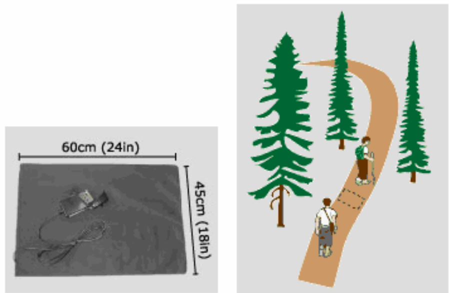

Figure 4.1 A pressure pad example Source: (TRAFX 2004)

Pressure pads have a number of advantages. Firstly, they can be easily hidden. Therefore, they can count pedestrians without intrusion and are less prone to vandalism. Secondly, because of long-life batteries the data loggers of pressure pads can be left unattended for up to a month before the data is downloaded into a computer. However, pressure pads also have a number of limitations. For example, pressure mats are expensive to install and are only used along tracks or gateways etc. The instruments of pressure mats can be frozen up in winter and miscount can occur because people step over them (Infodev 2004; Scottish Natural Heritage 1999).

- **Magnetic detectors**

Magnetic detectors can detect an automobile by discovering a bias in the earth's magnetic field as an automobile passes it. They are usually buried in the road or mounted on the side of the road. The primary use of magnetic detectors is to supplement or enhance data for other types of traffic detectors, although they are occasionally used in stand-alone applications (Klein 1995). The advantages of magnetic detectors are low cost of the equipment, and they are non-intrusive and unaffected by weather. However, their disadvantages are low resolution and difficult in discriminating longitudinal separation between closely spaced vehicles.

- **Inductive loop detectors**

Inductive loop detectors are composed of one or more turns of insulated wire, a lead-in cable, and an electronic unit. This type of detector can sense a vehicle by detecting the decrease of its inductance as the vehicle passes by. This is converted into a digital signal and a count is registered (see figure 4.2) (Klein 1995).

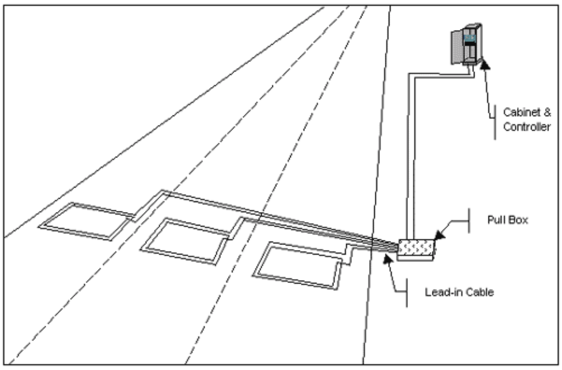

Figure 4.2 A typical inductive loop configuration example Source: (Carvell *et al.* 1997)

Inductive loop detectors are a mature technology. They can be easily installed, have excellent counting accuracy and not subjected to environment conditions. Therefore, inductive loop detectors have become the most widely used traffic detector technology today (Klein 1995) .

However, this type of detector is likely to be damaged by heavy vehicles and during road repair. They are very sensitive to the installation process and only able to be installed in pavements in relatively good condition. Therefore, it is not often used in an undeveloped road.

- **Microwave detectors**

Two types of microwave detectors are used in vehicle counting. The first type of microwave detectors emits electromagnetic energy at a constant frequency and analyses the differences in frequency between the transmitted and received signals using Doppler principle. A count is registered as the difference is detected. The microware detectors can also be used to measure the speed of vehicles. The second type of microwave radar emits a “frequency-modulated continuous wave” (FMCW) that changes in frequency with time. Therefore, this type of microwave detector can sense the presence of both a moving and a stationary vehicle (McFadden *et al.* 2001) (See figure 4.3). Compared to loop detectors, microwave detectors are low-cost, small, lightweight and easy to install and can perform well in inclement weather. Microwave detectors have been used extensively in security applications (Klein 1995).

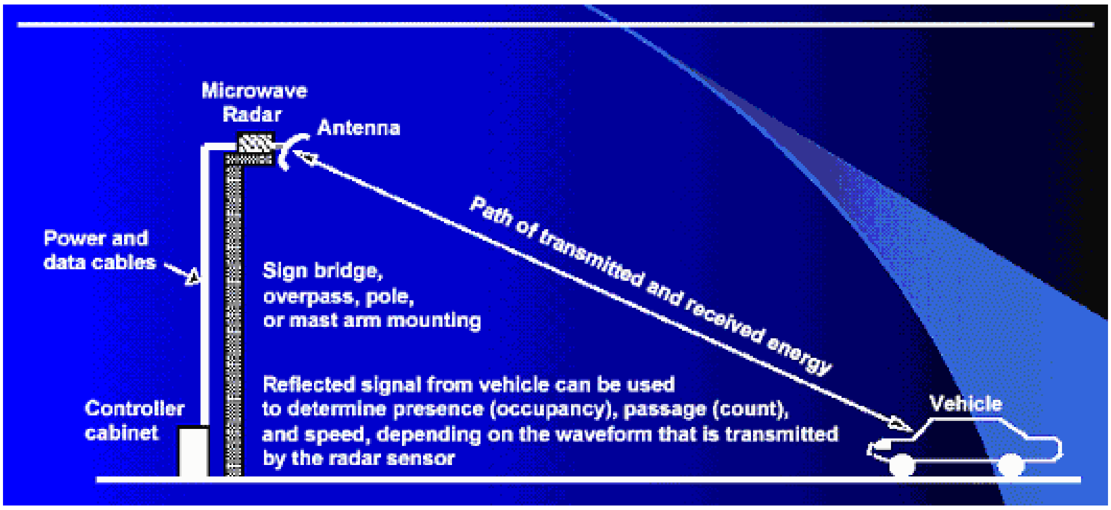

Figure 4.3 A microwave radar operation Source: (Klein 1995)

- **Ultrasonic detectors**

Ultrasonic detectors transmit sound waves at a selected frequency between 20 and 65 KHZ, and measure the time for the signal to return to the detectors (see figure 4.4). As it takes less time for ultrasonic detectors to receive waves reflected back from vehicles than road surface background they can sense the presence of a vehicle and register a count. Ultrasonic detectors are non-intrusive, small in size, easy to install and perform well in inclement weather, but they can be sensitive to changes of temperature, air turbulence and humidity (Skszek 2001).

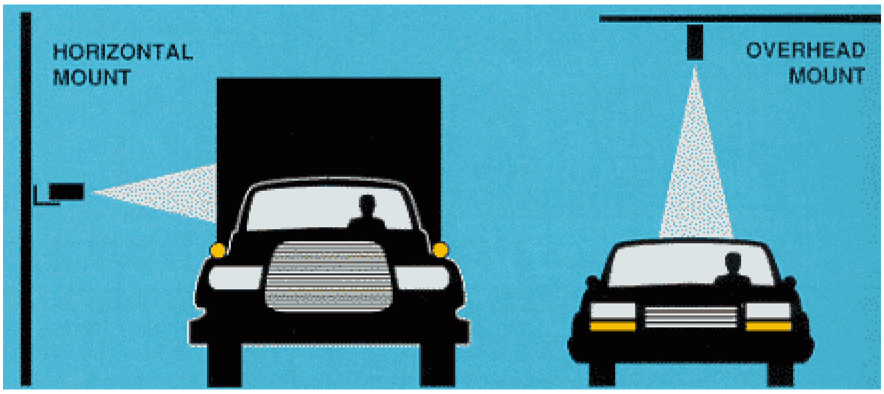

Figure 4.4 Mounting of ultrasonic range-measuring sensors Source: (Carvell *et al.* 1997)

4.3.2 Modern tracking techniques

Numerous tracking techniques are available for the collection of tourist spatial and temporal movement data. This section reviews several tracking techniques extensively used including, observation and interviews, self-administered questionnaire, GPS, timing systems, Personal Digital Assistant (PDA), mobile phone tracking, virtual questionnaires, and closed circuit television.

- **Observation and interviews**

Observation is a flexible tracking technique. The tracking procedure for the observation technique requires the researcher to follow individual tourists and record their route, arrival time and length of stay at each attraction (Dumont *et al.* 2004). Batty (2003) modelled pedestrian movement throughout the Tate Gallery in London using an agent-based simulation based on movement data obtained by observation. Similarly, tourist behaviours at the Melbourne Zoo were recorded by Broad & Smith (2004) using this technique. In addition to tracking pedestrians, the observation technique is also used in tracking traffic movement. Observers stand at a traffic route and then count and record the time and number of vehicles that pass by. Arrowsmith et al. (2005) conducted a project with aims to simulate the movement of boats. Here, several observers stood along the boats' route and recorded information such as the name and time of passing boats.

The observation technique is often integrated with interviews where researchers prepare a sequence of questions related to the topic with the intention of leading into a conversation. Since this method allows direct communication with visitors, researchers are able to collect data on the spot regarding tourist movements, their wayfinding decisions as well as qualitative feedback on the visitors' attitude towards the location.

The advantage of observation and interview technique is its flexibility. The researcher can communicate with tourists face to face. Therefore, a variety of information such as wayfinding decisions at a particular intersection can be acquired. However, it can be very time-consuming to track tourists by observation. Therefore, the sample size obtained from a survey using observation technique is usually small. In addition, this technique is intrusive.

- **Self-administered questionnaire**

The self-administered questionnaire is a traditional method used to track tourist movement. As a part of the questionnaire, participants are asked to trace or retrace their spatial movement on a cartographic map (Fennell 1996; Wang and Manning 1999). This requires participants to draw their trip route and write down any visited attractions, their approximate arrival time and length of stay on a map, based on their memory.

The accuracy of survey data depends on when the survey is conducted, the participant's spatial ability, spatial knowledge and levels of familiarity with the environment (Li 2004). The accuracy of the data also depends on the memory of tourists; the less time between visiting a location and drawing it on the map, the more accurate the data will be. The ease at which a tourist is able to recall their travels increases if the tourist has a higher spatial ability and knowledge. Also, the more familiar with an environment the tourist is, the easier it is for tourists to draw their travel routes on a map.

The advantages and disadvantages of the self-administered questionnaire technique are similar to these of observation and interview techniques. However, more sample data can be collected using the self-administered questionnaire technique than with observation and interviews. On the other hand, the observation and interview technique is more flexible to use than the self-administered questionnaire.

- **Global Positioning System (GPS) tracking**

Global Positioning System is a worldwide radio-satellite navigation system that relies on a constellation of 24 satellites and their ground stations providing precise position, velocity and time data to users around the world, 24 hours a day (Chadha and Osthimer 2004). A GPS receiver receives signals from satellites to determine its geographic location. They can work in any weather condition and there are no subscription fees or setup charges to use GPS. Compared to manual tracking techniques, GPS tracking has the advantage of spatial accuracy, but can also provide details relating to speed and direction of movement. However, because GPS signals can be blocked by buildings and attenuated by trees or leaves, GPS is not suitable for tracking objects in buildings, between high building or in forests with dense foliages (Chadha and Osthimer 2004). In addition, if objects are moving slowly or completely stopped, the direction of travel recorded by GPS can have considerable errors. It can be intrusive to ask tourists to carry a GPS unit when they are walking around attractions and there is also a risk of loss of GPS equipment. The sample size is usually low when using GPS to track tourists.

Recent GPS research has been undertaken to track both pedestrian and vehicle movements (see figure 4.5). Ashbrook (2002) clustered the location data of people collected by GPS and incorporated these locations into a Markov model to predict their next movement. Chhetri and Arrowsmith (2004) attempted to identify and understand the underlying dimensions influencing visitor experiences through natural landscapes. They incorporated location data of visitor movements collected by GPS and related physical environment parameters (such as elevation, ruggedness, visibility) into a model that assessed the environment influences on the visitor's experiences. From the study by Chhetri *et al.* (2004), the major limitation of the GPS tracking technique was the cost of GPS equipment. Consequently their sample data was considered undersized, as only a small number of GPS receivers were available.

Figure 4.5 A GPS tracking example source: (VeriLocation 2004)

- **Timing systems**

Timing systems are generally used in sports tracking. This tracking technique can not only record the location and time of movements but also identify individuals. Most timing systems consist of two components: 1) transmitters or transponders that are attached to an individual's clothes or shoelaces and, 2) data loggers and sensors (receivers) that are installed at necessary locations. O'Connor *et al.* (2005) used the Alge timing system (ALGE-TIMING 2005) to track tourists and developed tourist typologies based on their spatial behaviours at the Twelve Apostles. Battery life and the data logger memory capacity were found to be a limitation for this study. In addition, the high cost of equipment limits the density of the receiver network. The advantage of the timing system is its ability to log a unique identifier for each person, as well as being able to track the spatio-temporal movement of people in high resolution.

- **PDA tracking and Location-Based Services (LBS)**

Personal Digital Assistant tracking is an integration technology of GPS and Geographic Information Systems (GIS). The PDA was originally conceived as a small device with the basic functions of a personal organiser such as contact lists, calendars, diaries and calculators (Casademont *et al.* 2004). In PDA tracking applications, the PDA is used as a platform to communicate with mobile phone networks or a GPS system and download spatio-temporal data from the Internet. The GIS is integrated into the PDA so that spatio-temporal data can be displayed in real-time on a map and users can access information for a particular time or location using the map. Through the PDA, users are also able to access Location-Based Services (LBS). The LBS can provide location-based services or information to users. For example, tourists can be informed of the closest restaurant to their current location and receive a brief text description about that restaurant (see figure 4.6).

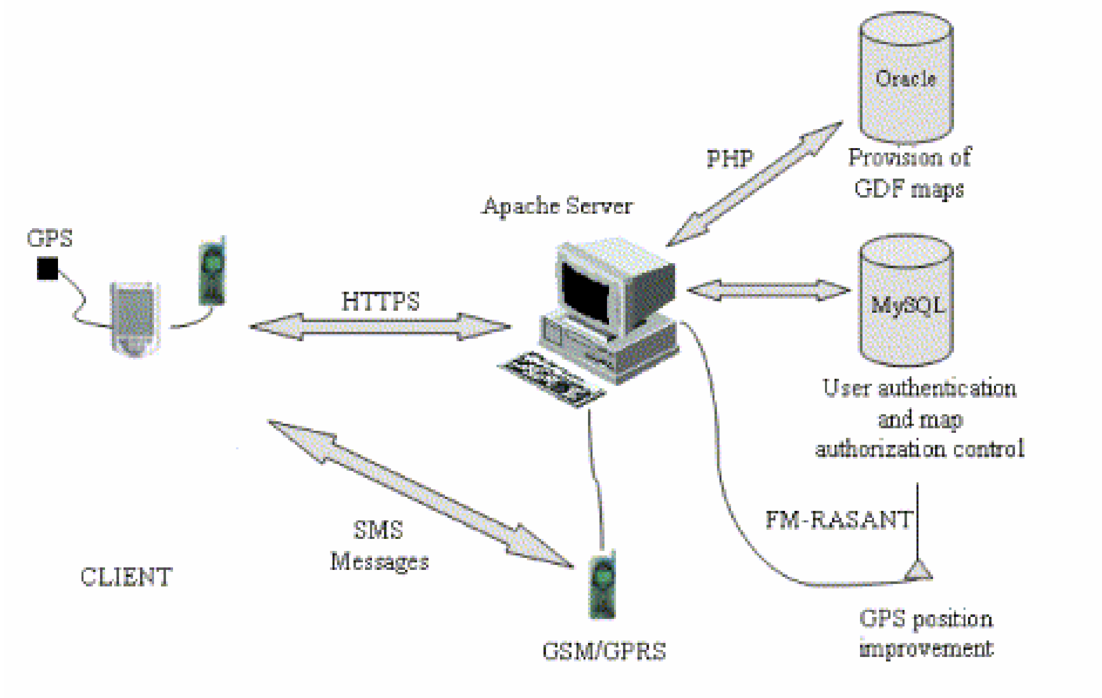

Figure 4.6 A PDA system structure (Casademont *et al.* 2004)

Several studies have been conducted recently using the PDA technique to track tourist movement. Hadley *et al.* (2003) incorporated LBS into PDA to provide location-based information such as "a koala 10 metres away on your right" to tourists while they walked through an attraction. Research by Loiterton & Bishop (2005) involved the use of the PDA and mobile phone technology to track tourists' wayfinding decision-making processes in urban parks and gardens. A location-based questionnaire was integrated into the PDA. As tourists moved around the park with the PDA they were required to answer questions regarding their choice of routes when confronted with a turning point.

Because the main component of PDA tracking is GPS, PDA tracking has the same disadvantages as GPS. However, PDA tracking can be designed to communicate with tourists in real-time and to track not only the physical movement of tourists but also the decision-making process.

PDA tracking is still very much in a theoretical state. Not many industry application of PDA tracking have been conducted recently. Even so, there is great potential for its integration into LBS applications for research purposes. In addition, other techniques such as mobile phone tracking and virtual questionnaires can also be used to understand tourist movements.

- **Mobile phone tracking**

Mobile phone tracking is a technique to track tourists by obtaining tourist mobile phone locations. Permission is required from tourists and their phone company. VeriLocation is a web-based system that enables registered users to track the locations of consenting mobile phone users. The mobile phone signals of users from the United Kingdom’s major network operators (such as T-Mobile, Orange, O2, and Vodafone) are detected, recorded and displayed on corresponding street maps in a web browser. The price of tracking through VeriLocation is £30 (around AU $70) to locate 100 mobile phones, or £125 (around AUD$292) to locate 500 mobile phones (VeriLocation 2004).

Mobile phone tracking is a simple and low cost tracking technology. However, the big issue for this technology is security and many tourists are reluctant to provide their mobile phone number. In addition, this technology is not mature and the current accuracy of location information ranges from 250 metres to 2500 metres, depending on its distance to the nearest mobile phone network (VeriLocation 2004).

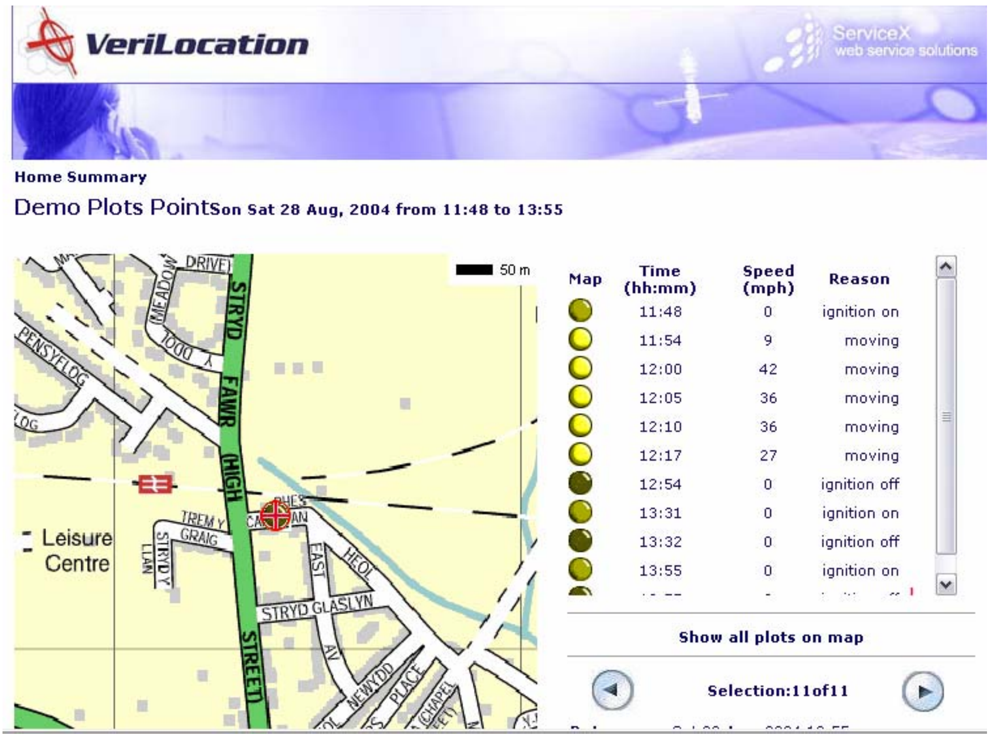

Figure 4.7 A mobile phone tracking example from VeriLocation

- **Virtual questionnaire**

The virtual questionnaire is an experimental simulation model that is designed for tracking tourists' decision-making processes. The virtual questionnaire is completed through a touch screen computer while participants travel through a simulated tourist environment. Participants are asked to indicate the first attraction they visited. They are then required to "touch" the next destination and the road they travelled on. The virtual tourist (agent) then begins the specified journey within the virtual environment. At the first attraction they are then required to indicate the second destination and the road travelled. Tourists indicate their reason for travelling on a particular road from the first destination to the second by choosing from a list of wayfinding strategies. When the agent arrives at a crossroad, the participant will be asked to specify next destination, travel direction and the reason. At the end of trip, the agent will inform the participant of the shortest route and time required to travel between the specified destinations before a choice is made as a suggestion. Background and general information of tourists such as age, gender, education and postcode is also collected.

The virtual questionnaire is composed of a physical environmental model, a knowledge model, decision models, and an agent-based model. The objectives of the simulation are: to create a representation of tourist cognitive maps, to develop a tourist movement database, and to identify tourists' topology and preference. The concept behind the virtual questionnaire for tracking tourist movement is still very much in a theoretical state.

- **Closed circuit television monitoring (CCTV)**

The CCTV has been extensively used for surveillance or security. For example, Bogaert (1996) designed *PASSWORDS*, an intelligent video image analysis system used to detect dangerous situations (such as a person with agitated behaviour) and inform the appropriate authorities. Similarly, *W4* (*Who? When? Where? What?*), constructed by Haritaoglu (1998), is a real time system used to detect and track people and their body parts in monochromatic imagery in order to acquire information such as what are people doing, where and when do they do it. KaewTrakulPong and Bowden (2003) developed a variety of probabilistic models for tracking multiple independent targets in outdoor visual surveillance scenes. Closed circuit television monitoring is a technique that is limited to small areas.

There are many factors that can affect the accuracy. This includes light variation and vibrations, the quality of the optical components and the image analysis software. Light variation, especially a sudden intensive light in a monitored area, can cause the camera to record images incorrectly. The relocation of a camera lens caused by vibrations can also lead to erroneous image recordings and inaccurate count. Therefore, camera-based counting systems are better suited for interior environments.

Different image analysis software can also influence the accuracy of counting. Recognising objects, and tracking their movements in a complex real scene using a sequence of images are the most difficult tasks in computer vision (Bogaert *et al.* 1996). Early image analysis software had a low accuracy rate. However, Heikkila (2004) has utilised a Kalman filtering algorithm to improve the quality of the tracker. He has also developed Learning Vector Quantization algorithms for classifying the observations into pedestrian and cyclist. The accuracy of counting and classification is around 80-90%.

4.4 EVALUATION AND COMPARISON OF COUNTING AND TRACKING TECHNIQUES

The previous sections reviewed various counting and tracking technologies respectively. This section provides information on which techniques are suitable for collecting particular types of data and evaluating each technique's capabilities (see table 4.1), the advantages and disadvantages of each technique (see table 4.2) and the type of application best suited for each technique (see table 4.3).

The counting and tracking techniques discussed in section 3.3 have been evaluated according to the variables of movements shown in table 4.1. A positive sign (+) indicates that the counting and tracking technique is capable of collecting the variable. A negative sign (-) indicates that the technique is incapable of collecting the variable. When a particular variable for a technique cannot be categorised as capable or incapable, a zero (0) is used. Table 4.2 summarises the advantages and disadvantages of the counting and tracking techniques discussed in section 3.3. The advantages and disadvantages are allocated to each technique based upon the following significant factors: resolution, cost, intrusive, non-intrusive and sample size. Table 4.3 provides a list of applications and the counting and tracking techniques that are best suited for a given application.

Table 4.1 Summary of capabilities of various counting and tracking technologies (Infodev 2004; Ivanov *et al.* 2002; Klein 1995)

	Camera Based systems	Active Infrared Sensors	Passive Infrared sensors	Pressure pads or mats	Magnetic detectors	Inductive loop Detectors	Microwave detectors	Ultrasonic detectors	Observation and interview	Self-administered questionnaire	Camera-based systems	GPS tracking	Timing systems	Mobile phone tracking
Number of tourists	+	+	+	+	-	-	-	-	+	-	+	-	+	-
Number of vehicles	+	+	+	+	+	+	+	+	+	-	-	-	+	-
Location	0	-	-	-	-	-	-	-	0	0	0	+	+	+
Time point	+	-	-	-	-	+	-	-	-	0	+	+	+	+
Speed	-	+	-	+	+	+	+	+	-	-	-	+	0	+
Direction	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Classification	+	+	-	-	+	+	+	+	+	+	+	-	-	-
Resolution	Very high	High	Low	Low	Low	High	High	Low	Low	Low	High	Very High	Very High	Very High
Cost	High	High	Low	Low	Low	Medium	Medium	Medium	Low	Low	High	High	Very High	Low
Effect of weather	Fair	Fair	Fair	Fair	Excellent	Excellent	Excellent	Fair	Poor	Poor	Fair	Fair	Fair	Fair
Status of intrusive	Intrusive	Non-intrusive	Non-intrusive	Non-intrusive	Non-intrusive	Intrusive	Non-intrusive	Non-intrusive	Intrusive	Intrusive/Non-Intrusive	Intrusive	Intrusive	Non-Intrusive	Non-Intrusive

Note: + means capable; - means incapable; 0 means either capable or incapable

Table 4.2 Summary of advantages and disadvantages of various counting and tracking technologies (Infodev 2004; Klein 1995; Skszek 2001)

Technique	Advantage	Disadvantage
Pressure pads or mats (People/bicycle counting)	▪ Low cost ▪ Non-intrusive ▪ Variety of size suitable for different purpose ▪ Can work with small long-life batteries up to one month	▪ Low resolution ▪ Inclement weather or too low temperature could degrade performance. ▪ Can take more time to install depending on ground condition
Camera Based systems (People /vehicle counting)	▪ Non-intrusive ▪ High resolution ▪ Can work as surveillance, counting, and tracking tool	▪ Vibrations and changes in light, height, and temperature could degrade performance. ▪ Expensive
Active Infrared (People /vehicle counting)	▪ Non-intrusive ▪ Uninfluenced by sudden temperature and light change ▪ Ease of install covering wide entrance	▪ Affected by obscurants in the atmosphere and weather ▪ Expensive
Passive Infrared sensors (People /vehicle counting)	▪ Non-intrusive ▪ Low cost ▪ Uninfluenced by sudden temperature and light change	▪ Affected by heavy rain or snow ▪ Affected by change of background
Microwave detectors (Vehicle counting)	▪ Non-intrusive ▪ High resolution ▪ Mature technology ▪ Ease of install ▪ Good performance in inclement weather	▪ Overhead installation requires the presence of existing structure for mounting the device
Inductive loop Detectors (Traffic counting)	▪ High accuracy ▪ Mature technology ▪ Good performance in inclement weather	▪ Intrusive ▪ Could be damaged by heavy vehicles and road repair
Magnetic detectors (Vehicle counting)	▪ Non-intrusive ▪ Low cost ▪ Unaffected by weather	▪ Low resolution ▪ Difficulty in discriminating longitudinal separation between closely spaced vehicles
Ultrasonic detectors	▪ Non-intrusive ▪ High resolution ▪ Mature technology ▪ Ease of install ▪ Good performance in inclement weather	▪ Affected by temperature and air turbulence
GPS tracking	▪ High resolution ▪ Mature technology ▪ Ease to use	▪ Intrusive ▪ Low sample size ▪ GPS signals blockage from buildings and foliage ▪ High risk of loss of GPS equipment ▪ Expensive
Timing systems	▪ Non-Intrusive ▪ High resolution ▪ High sample size	▪ Expensive ▪ Limited by battery life and data logger memory

		capacity
Mobile phone tracking	▪ Non-intrusive ▪ High resolution	▪ Low-cost ▪ Privacy security issue ▪ signals blockage from buildings and foliage
PDA Tracking	▪ High resolution ▪ Can communicate with tourists in real-time ▪ Can track their decision-making process	▪ Intrusive ▪ Low sample size ▪ GPS signals blockage from buildings and foliage ▪ High risk of loss of PDA equipment ▪ Expensive
Manual observation and interview	▪ Can communicate with tourists deeply ▪ Can classify vehicles more accurately ▪ Can count or track tourists more flexibly	▪ Intrusive ▪ Time-consuming ▪ Low resolution ▪ Low sample size
Self-administered questionnaire	▪ Can acquire non-spatial and approximate spatio-temporal information of tourist ▪ Can count or track tourists more flexibly	▪ Intrusive ▪ Time-consuming ▪ Low resolution ▪ Low sample size
Virtual questionnaire	▪ Non-Intrusive ▪ Can acquire non-spatial information of tourist ▪ Can acquire approximate spatio-temporal information of tourist ▪ Can track tourists' decision-making process	▪ Low resolution ▪ Expensive

Table 4.3 Counting and tracking technology applications to tourism management

APPLICATION	OBJECTIVES	TRACKING TECHNIQUE	C OMMENT
Route planning (Loiterton and Bishop Slater 2002)	To explore the decision-making process of tourists movement to identify optimum route for them	• PDA tracking •GPS+self-administered questionnaire	There needs to be route recording as well as wayfinding decision tracking when estimating tourists' movement and their wayfinding decisions.
Wildlife protection (Chen and Morley 2005)	To monitor tourists' movement patterns in parks or reserves in order to protect wildlife	• GPS tracking • Mobile phone tracking •Self-administered questionnaire • Observing	There needs to be route recording as well as simple counting when estimating tourists' movement and their number.
Tourist behaviour research	To identify and understand visitor	• GPS Tracking • Pressure pads and mads	There needs to be route recording, visitor

(Chhetri *et al.* 2004)	experiences of natural landscapes	• PDA Tracking •Self-administrative questionnaire • Observing • Timing system	experience tracking as well as simple counting when estimating tourists' movement, their experiences of natural landscapes and number of them.
Tourist behaviour research (Fennell 1996)	To examine the relationship between tourism group movement patterns and their motivation for visiting parks	• GPS Tracking • Timing system •Self-administered questionnaire	There needs to be route as well as visiting characteristics recording when deciding the tourist group based on movement information
Tourist behaviour research (Arrowsmith and Chhetri 2003; O'Connor, A. *et al.* 2005)	To validate model of tourist behaviour prediction	• GPS Tracking • Video image processor • Timing systems • PDA Tracking •Self-administered questionnaire	There needs to be route recording when estimating tourists' movement behaviour.
Traffic congestion (O'Connor, A. N. and Zerger 2002)	To assess the volume or density of **pedestrians** at attractions or road intersection in order to improve traffic conditions in parks	• Timing system • Pressure Pad or mad • Passive infrared • Light barriers • Video image processor	There needs to be time recording as well as simple counting when estimating traffic congestion.
Traffic congestion (Itami 2003)	To assess the volume or density of **vehicle** at car park or road intersection or attractions in order to improve traffic conditions in parks	• Passive infrared • Laser radar •True-presence microwave radar •Doppler microwave detector • Ultrasound • Video image processor	There needs to be time recording as well as simple counting cars when estimating traffic congestion.

Table 4.1, 2 and 3 summarise the capabilities, advantages and disadvantages and applications of both counting and tracking techniques. All the counting techniques mentioned above can count vehicles. However, only camera-based systems, active infrared sensors, passive infrared sensors, pressure pads or mats and observing can be used to count tourists. Furthermore, camera-based systems, active infrared sensors, inductive loop detectors and microwave detectors can count tourists or vehicles at higher resolution compared to the other counting techniques such as observation, passive infrared sensors, pressure pads and magnetic detectors.

Of the eight tacking techniques reviewed in section 3.3, all techniques can be used to track individual tourist movement. Global Positioning Systems, timing systems, and mobile phone tracking techniques can also used to track the movement of vehicles with high resolution. The traditional tracking techniques such as observation, interview and self-administered questionnaires are able to track spatial and temporal information related to the movement of people in low resolution but could obtain a great deal of detailed information. However, modern tracking techniques such as GPS, timing systems, PDA tracking and mobile phone tracking can track not only the spatial and temporal motion information of tourists but also their speed and direction, which could be very useful information for some applications such as movement prediction. One important disadvantage of these modern tracking techniques is that the equipment is usually expensive and has a high risk of being lost.

To sum up, each technique has its own advantage and disadvantage, and it is important to apply them in suitable situations (see table 4.3). Tracking techniques instead of counting techniques are mainly applied to record the location of tourists, corresponding arrival time at the location and tourist demographic information in this thesis. As detailed in the chapter 3, tourist movements can be divided into two levels, the macro and micro levels. The macro level focuses on the movements from one specific location (area) to another. The micro level can be considered as the determination of movements at a specific location (spatial point (x, y)) where tourist movement patterns are localised in geographic extent.

At the macro level, the movement information including location visited, corresponding arrival or departure time, duration of stay, visiting characteristics, and tourist demographic information needs to be collected. In terms of the low resolution requirement at the macro level, observation and interview, the self-administered questionnaire, and the virtual questionnaire could be used to track the movement of tourists. The self-administered questionnaire was used to collect tourist movement information at this level in this thesis (see details in chapter 6) because of immature techniques of the virtual questionnaire and the limitation of sample size of observation and interview.

At the micro level, higher resolution of movement data is required. Movement information such as location, time, direction and speed needs to be collected. The goal of this thesis at the micro level is to record tourist routes and identify their wayfinding decision-making processes. Closed circuit television monitoring (camera based systems), GPS and timing systems can be used to track tourists at this level. PDA tracking, self-administered questionnaire and interview are able to acquire tourist wayfinding decision-making processes. In this thesis, GPS is used to track tourist movements. Self-administered questionnaire and interview techniques are adopted to collect the characteristics of tourist, travel behaviours and wayfinding decision information. There are a few reasons why the other tracking techniques were not chosen. Closed circuit television monitoring can track the route of tourists with high resolution. However, it is limited to a room-sized area and is not suitable for using in large areas. Timing systems can count tourists passing the road intersections and record their route choices as well. However, corresponding tourist characteristics data (see details in section 2.2.3) is unable to be tracked by timing systems and the equipment is too expensive to access. Therefore, these two techniques will not be considered for this research. PDA tracking is especially suitable to track tourist wayfinding decision-making. However, the technique is not mature and PDA equipments are too expensive to be applied. Consequently, it is not realistic to use it for this study. Therefore, GPS, self-administered questionnaire and interview techniques were adopted to track tourist movements at the micro level in this thesis (see details in chapter 6).

4.5 CONCLUSIONS

This chapter compared and reviewed tracking techniques for the spatio-temporal movement of tourists. Each technique has been evaluated based on the capability of the technique and the type of information each technique can collect. Each technique has also been evaluated based on the level of resolution achieved, whether it is an intrusive or non-intrusive technique, the size of sample it can record and its suitability for particular applications.

The next chapter will develop a method of modelling the spatio-temporal movement of tourists at the macro level using MC models. Log-linear models will be adopted to test the significance of spatio-temporal movement patterns of tourists. A data mining method to implement tourism market segmentation based on the significant movement patterns of tourists will then be discussed.

CHAPTER 5 MODELLING THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS AT THE MACRO LEVEL

5.1 INTRODUCTION

In the previous chapter, the techniques for counting and tracking tourist movement at the macro and micro levels were reviewed and compared. This chapter establishes a methodology to model the spatio-temporal movement of tourists at the macro level (see definition in section 2.3.3). It commences by discussing a method to model the process of the spatio-temporal movement of tourists at the macro level and calculate the probabilities of the spatio-temporal movement patterns of tourists using MC theory. Then Log-linear models are used to test the significance of movement patterns of tourists in section 5.3. In section 5.4, a method is developed for tourism market segmentation based on the significant movement patterns of tourists using the EM algorithm. This method will assist park managers to design new tour packages for marking promotion.

5.2 MODELLING THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS USING MARKOV CHAINS

Modelling is the process of distilling essential behaviour from a system. A model, therefore, is considered as an abstraction of a real world system and simplifies reality. Once the model has been defined, it can be used to predict the behaviour of the system, or parameterised to represent the alternative behaviours under different situations (Lazowska *et al.* 1984).

The spatio-temporal movement of tourists is a complex process, and can be modelled very differently based on desired levels of accuracy, purposes of trips, or scale levels. For example, spatio-temporal movement can be modelled as a continuous process with high resolution or as discrete process with low resolution (Hornsby and Egenhofer 2002). Resolution can be measured in both spatial terms (recording movements to the nearest centimetre, metre, or kilometre) or in temporal terms (recording movements to the nearest second, minute, hour, day, or year). If the objective of the research is to understand detailed movements, then modelling will need to be at the micro-level (Batty 2003; Gimblett 2002; Itami 2003; Raubal 2001; Timpf 1998; Wang and Manning 1999; Weifeng *et al.* 2003). Otherwise, it should be modelled at the macro-level(Forer and Simmons 1998; Ogilvie 1933).

The individual movement behaviour of a tourist is extremely difficult to predict, while the movement behaviours of tourists in large numbers reveal some regularity or certain habitual patterns. Therefore methods based on probability theory could be suitable for modelling movement behaviour of large numbers of tourists. MC techniques have been used to understand the migration pattern of people (Constant and Zimmerman 2003; Tobler 1997), model random walks of people (Simon 1973; Spitzer 2001) and predict population distribution within an area for a certain time interval (Donnelly 2005). In this section, a method for modelling the spatio-temporal movement of tourists at the macro level using MC analysis is presented. The theory of MC is a powerful technique which has been used widely in various disciplines for analysing series of events which are linked together by first-order dependence and are used widely in various disciplines to analyse the trends and outcomes of events (Iosifescu 1980; Isaacson and Madsen 1976; Kemeny and Snell 1976; Stewart 1994). This technique to estimate the probabilities of tourists visiting a sequence of attractions is applied in this thesis.

5.2.1 Markov Chains

A stochastic process is defined as a family of random variables $(X_t)_{t\in T}$ defined on a given probability space and indexed by *t* belonging to a parameter set *T*. The set *T* is often regarded as the time sequence of the process and is either discrete or continuous. In the discrete case $T=\{1,2,...\}$ and in the continuous case $T=[0,\infty)$. The range of X_t produces the *state space S* which could again either be discrete or continuous. When S is often finite or countable, the process is often referred to as a *discrete stochastic process*.

A discrete stochastic process is referred to as a *MC* if the future evolution of $(X_t)_{t\in T}$ is only dependent on its present state. Mathematically, this is described as follows:

A stochastic process Xt, $t \geq 0$, taking values in a discrete set S, which can be considered as the set of positive integers for convenience, is a Markov process if, for any n = 0, 1, … and $t_0 < t_1 < t_2 < ... < t_n < t$ and values $i_{0,}i_1,...,i_n$ and $j \in S$, the following identity involving conditional probabilities holds:

$$\Pr(X_t = j \mid X_{t_n} = i_n, X_{t_{n-1}} = i_{n-1}, \ldots, X_{t_1} = i_1, X_{t_0} = i_0) = \Pr(X_t = j \mid X_{t_n} = i_n) \qquad (5.1)$$

A comprehensive coverage of the theory of Markov processes can be obtained from excellent sources such as (Iosifescu 1980; Kemeny and Snell 1976; Stewart 1994).

When $T = \{1, 2, ...\}$, the set of conditional probabilities:

$$\Pr(X_{n+1} = j \mid X_n = i) = p_{ij}(n) \qquad (5.2)$$

for $i, j \in S$ and n = 1, 2, … is called the set of one-step transition probabilities of the MC. From the rules of probability, one-step transition probabilities satisfy

(i) $p_{ij}(n) \geq 0$ for all pairs $i, j \in s$.

(ii) $\sum_{j\in s} p_{ij}(n) = 1$

If the distribution of the initial state (that is, X_1) is known, say:

$$\Pr(X_1 = i) = v_i$$

$i \in S$, then, applying the product rule of probability and identity (1), the joint probability of the event

$$\{X_1 = i_1, X_2 = i_2, X_3 = i_3, ..., X_n = i_n\}$$

is given by

$$\Pr(X_1 = i_1, X_2 = i_2, X_3 = i_3 ... X_n = i_n) = v_{i_1} p_{i_1} p_{i_2}(1) p_{i_2} p_{i_3}(2) p_{i_3} p_{i_4}(3) ... p_{i_{n-1}} p_{i_n}(n-1) \qquad (5.3)$$

A MC is *stationary* if its one-step transition probabilities $p_{ij}(n)$ are independent of n. In other words, the probability of moving from one state to another is invariant of the epoch at which the jump takes place. In this case, $p_{ij}(n) = p_{ij}$ for all i, j and the joint probability (5.3) can be simplified to

$$\Pr(X_1 = i_1, X_2 = i_2, X_3 = i_3 \ldots X_n = i_n) = v_{i_1} p_{i_1} p_{i_2} p_{i_2} p_{i_3} p_{i_3} p_{i_4} \ldots p_{i_{n-1}} p_{i_n} \tag{5.4}$$

One-step transition probabilities of a stationary MC can be arranged in a matrix, denoted by **P**, called a *one-step transition probability matrix*, where

$$P = \begin{pmatrix} p_{11} & p_{12} & p_{13} & \cdots \\ p_{21} & p_{22} & p_{23} & \cdots \\ p_{31} & p_{32} & p_{33} & \cdots \\ \vdots & \vdots & \vdots & \vdots \end{pmatrix}$$

When the state space S is finite with cardinality m, then **P** is a finite matrix with dimension m.

The *n-step transition probabilities* $\Pr(X_{n-1} = j | X_0 = i)$ of a stationary MC will be denoted by $p_{ij}^{(n)}, i, j \in S$. Since

$$\Pr(X_{n-1} = j \mid X_0 = i) = \sum_{i_{n-2},\ldots,i_2,i_1} X_{n-1} = j_{n-1}, X_{n-2} = i_{n-2}, \ldots, X_1 = i_1 \mid X_0 = i\ ) \tag{5.5}$$

It is a routine exercise, on applying (4), to show that $p_{ij}^{(n)}$ is the (i, j) element of the matrix

$$P^n = P \times P \times \ldots \times P \tag{5.6}$$

which is obtained by multiplying the same matrix P by itself n times.

5.2.2 Markov Chains for modelling the spatio-temporal movement of tourists

Spatio-temporal movements of tourists can be modelled at the *micro* or *macro* level. At the micro level, they are represented by a continuous stochastic process $(X_t)_{t \in T}$, where $T = [0, \infty)$, taking values in a state space S. If S consists of various spatial points representing the locations of the persons undergoing movements, then it is a continuous state space. On the other hand, for a natural tourist destination such as a park, there will be a number of attractions such as various lookouts and geomorphologic features situated in the park. The state space S may be considered as comprising these attractions and other auxiliary locations, therefore, S is discrete.

At the macro level, the tourist movement is represented by a discrete stochastic process $\{X_t, t \in T\}$, where $T = \{1,2,\ldots\}$. In this section, the movement process will be focused on at the macro level and also assume that S is discrete. Let $S = \{A_1, A_2, \ldots, A_k\}$ where A_i, $i = 2, 3, \ldots, k$ are the tourist attractions and A_1 represents the state "OUT" that is the region exterior to the space S where the tourist sites are located. The stochastic process will be modelled representing the tourist movement within S by a *stationary discrete MC* where each movement occurs after a unit step. Thus the movement of a tourist over a sequence of times from $t = 1$ to $t = m$ will be represented by the sequence

$$\mathrm{M}(m) = (A_{i1}, A_{i2}, A_{i3}, \ldots, A_{im}) \tag{5.7}$$

where the last state reached is always A_1, i.e. "OUT". This is because the trip would always end by a tourist leaving the park. In addition, this state will be assumed to be an *absorbing state* since the process terminates once it reaches that state. Due to the absorbing state, the other attractions are *transient states*, and, starting from any attraction, and assuming that the process is allowed to go on for a long time, it would eventually reach the absorbing state.

By the Markov property (refer to (5.3))

$$\Pr(M(m)) = \Pr(A_{i_1})\Pr(A_{i_2} \mid A_{i_1})\Pr(A_{i_3} \mid A_{i_2})\ldots\Pr(A_1 \mid A_{j_{m-1}}) \tag{5.8}$$

Note that the last state reached is "OUT". Further, the one-step transition probability matrix of the process is given by

$$P = \begin{pmatrix} 1 & 0 & 0 & \cdots & 0 \\ \Pr(A_2(n+1) \mid A_2(n)) & 0 & \Pr(\mathrm{A}_3(\mathrm{n}+1)|\mathrm{A}_2(\mathrm{n})) & \cdots \Pr(\mathrm{A}_\mathrm{k}(\mathrm{n}+1)|\mathrm{A}_2(\mathrm{n})) \\ \Pr(\mathrm{A}_1(\mathrm{n}+1)|\mathrm{A}_3(\mathrm{n}) & \Pr(\mathrm{A}_1(\mathrm{n}+1)|\mathrm{A}_3(\mathrm{n}) & 0 & \cdots \Pr(\mathrm{A}_\mathrm{k}(\mathrm{n}+1)|\mathrm{A}_3(\mathrm{n})) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \Pr(\mathrm{A}_1(\mathrm{n}+1)|\mathrm{A}_\mathrm{k}(\mathrm{n}) & \Pr(\mathrm{A}_2(\mathrm{n}+1)|\mathrm{A}_\mathrm{k}(\mathrm{n}) & \Pr(\mathrm{A}_3(\mathrm{n}+1)|\mathrm{A}_\mathrm{k}(\mathrm{n}) & \cdots & 0 \end{pmatrix}$$

Since stationary have been assumed, the one-step transition probability matrix P will be independent of *n*. Where *I* represents state A_i, *i=1,2,…, k*. Note that $p_{11}=1$ since A_1 is an absorbing state.

5.2.3 Model validation

This thesis has applied a MC technique in modelling the spatio-temporal movement of tourists and to calculate the probabilities of various movement patterns has been applied. However, the key question now is how well are these movements modelled by MC? In other words, how close are the observed frequencies of movement patterns to those that would be expected when equation (5.8) is used to calculate probabilities of different patterns? In this section, a method of validation of MC a Chi-Square Goodness of Fit test will be discussed (Devore 2004).

A data mining approach is adopted by dividing the tourist movement data set into two parts: *training data* and *test data*. The training data will be used to fit the MC model that is to estimate the transition probability matrix **P** and initial probability of movement state vector ***v***. The expected values obtained using equation (5.8) will then be compared with the frequencies observed in the test data using a Chi-Square Goodness of Fit test. If the computed Chi-Square statistics are not statistically significant, then the Markov model will fit to the data.

- **Goodness of Fit Test**

The selection of training data was implemented by a random sampling method called EPSEM (equal probability of selection method sampling) (Kish 1965) using the STATISTIC package (StatSoft 2003). Seventy percent of the data is selected as training data first, leaving the remainder as test data and then repeat the whole process again by selecting 60% of the data as training data. The objective here is to gauge the effect sampling bias on the results obtained.

The Chi-Square Goodness of Fit test is used to compare a set of observed frequencies O_i with a set of expected frequencies E_i where *i*= 1, 2,…, k ranges over the different movement sequences associated with a fixed number of visits *n* .

The observed frequency O_i is the number of records in the test set corresponding to pattern *i*. Let $\hat{p}_i$ denotes the probability of pattern *i* estimated from the test set data using the MC technique. The expected frequency is then given by $E_i = N\hat{p}_i$ where N refers to the total number of records in the test set with a fixed length of size *n*. The Chi-square goodness of fit test statistic has the form

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} = \frac{(O_1 - N\hat{p}_1)^2}{N\hat{p}_1} + \frac{(O_2 - N\hat{p}_2)^2}{N\hat{p}_2} + \ldots + \frac{(O_k - N\hat{p}_k)^k}{N\hat{p}_k} \tag{5.9}$$

The test statistics (5.9) have approximately a Chi-square distribution with k-1 degrees of freedom (Devore 2004). If the observed frequencies are distributed differently from the expected frequencies, the test statistics will be significantly large and the data offers some evidence against the model, otherwise, the observed data will tend to confirm the hypothesis that the MC distribution provides a good fit to the data.

A case study was conducted on Phillip Island using a stationary discrete MC to model the movements of tourists between each attraction from the moment they entered the island until they completed their visits (see details in chapter 7).

5.3 TESTING OF THE SIGNIFICANCE OF THE SPATIO-TEMPORAL MOVEMENT PATTERNS OF TOURISTS USING LOG-LINEAR MODELS

In this section, a methodology is established to test the significance of the tourist movement patterns using log-linear models. Log-linear models are generalised linear models and used to analyse the association of categorical or grouped variables using the log link function with a Poisson response (Agresti 2002, p. 314). The likelihood ratio chi-square statistic is adopted to test for the significance of the movement patterns in a data set. A *p*-value of 0.05 or less indicates a statistically significant movement pattern at the 5% level. Knowledge about the significant spatio-temporal movement patterns of tourists would enable park managers to better understand which attractions are visited most frequently by tourists and how tourists schedule their trip.

As defined in chapter 3, the tourist movement at the macro level is simplified as a sequence of movement in geographic space between one attraction and another during a certain period of time. Therefore, a spatial movement sequence is an ordered set of attractions. The spatial movement pattern (M_i) for tourist i is represented as a set of attractions. A_{in} indicates an attraction visited by tourist i at step n. A_n is the movement variable denoted as a set of attractions visited by tourists at step n.

$$M_i = (A_{i1}, A_{i2}, ..., A_{in}) \tag{5.9}$$

This section intends to test the significance of movement patterns of tourists. The significant movement pattern denotes that the movement pattern involves attractions that have strong interactions between each other, for example, if there is a significant relationship between attractions A_{i1}, A_{i2}, ..., and A_{in}, then the movement pattern M_i is considered to be a significant pattern.

There are many statistical methods used for testing the relationships between variables, such as *t*-test, Chi-squared test and log-linear models. Most statistical methods are only suitable for numeric data, such as *t*-test. Only few testing methods, such as Chi-square test and log-linear models can be used to test relationships between categorical or grouped data. Chi-squared statistic is generally used to test the statistical significance of interactions between two categorical variables. If the aim is to test interactions between more than two categorical variables, log-linear models are preferred (Agresti 1990; Goodman 1984). Generally more than two attractions are visited by tourists during a trip, which means more than two categorical movement variables are concerned in tourist movement modelling. Therefore, log-linear models are an appropriate method to test the interaction between movement variables.

Log-linear models have been used extensively in various disciplines to analyse the relationship between several categorical variables (Agresti 2002; Fienberg 1980; Goodman 1984; Howell 2002; Knoke and Burke 1980). In this section, log-linear models are used to identify statistically significance of the interaction between movement variables and test the strength of interaction between values of movement variables that contribute to the interaction between movement variables. Note that the values of movement variables are attractions visited by tourists. If there is a significant interaction between movement variables then the strength of the interaction between attractions will be tested. The Movement patterns with the strong interaction between attractions of movement variables will be regarded to be significant. A *p*-value is the parameter of log-linear models to indicate the significance of movement patterns. It is also called observed significance level, which is the smallest level of significance at which null hypothesis (H_0) would be rejected when a specified test procedure is used on a given data set (Devore 2004, p. 341). For example, in this section, the null hypothesis could be that there is no statistically significant interaction between attractions of movement variables. The likelihood ratio Chi-square test is used to calculate *p*-value on the movement data. Given a significance limit of *0.05,* the null hypothesis will be rejected if the *p*-value of a movement pattern is equal or less than 0.05. Therefore, there is a significant interaction between attractions of movement variables. The movement patterns comprised of these movement attractions are considered to be important for the study.

To take a simple example, supposed that a significance of movement pattern 'DF' will be tested by log-linear model. 'D' is the attraction that the tourist visited at the first step or the first destination. 'F' is the attraction that the tourist visited at the second step or the second destination. So there are only two attractions visited by a tourist during the trip. Significance of movement pattern 'DF' denotes that the pattern 'DF' statistically frequently occurs in a two-attraction movement data set, which is comprised of movement patterns with two attractions visited by tourists. Let the movement variable A_1 denoted as a set of attraction visited by tourists at step one (the first destination) and movement variable A_2 visited by tourists at step two (the second destination). The formation of a log-linear model is given by

$$\log m_{ij} = \mu + \lambda_i^{A_1} + \lambda_j^{A_2} + \lambda_{ij}^{A_1 A_2} \qquad (5.10)$$

Where m_{ij} denotes the expected frequencies of two-attraction movement patterns $\lambda_i^{A_1}$ denotes the main effect of variable A_1, $\lambda_j^{A_2}$ denotes the main effect of variable A_2. $\lambda_{ij}^{A_1 A_2}$ denotes the interaction effect of variables A_1 and A_2.

Because the model (5.10) includes all the effects of parameters (main effects, association effects and interaction effects), it is called a **saturated** model. Therefore, the expected frequencies of two-attraction movement patterns are equal to the observation frequencies. In order to test whether there is an interaction between the movement variable A_1 and A_2, the $\lambda_{ij}^{A_1A_2}$ effect parameters in equation 5.10 will be set to zero, then m'_{ij}, the expected frequencies of two attraction patterns will be calculated using the equation:

$$\log m'_{ij} = \mu + \lambda_i^{A_1} + \lambda_j^{A_2} \tag{5.11}$$

The likelihood ratio Chi-square statistic test will be used to compare $\log m_{ij}$ with $\log m'_{ij}$. If the likelihood ratio Chi-square G^2 is significantly large and the $\log m'_{ij}$ is considerably different from $\log m_{ij}$ the effect $\lambda_{ij}^{A_1A_2}$ eliminated from the saturated model is important to explain data distribution. There is a significant interaction between A_1 and A_2. The likelihood ratio Chi-square statistics can also test significance of interactions between values of variables in the model. For example, 'D' is the value of the movement variable A_1 and 'F' is the value of the movement variable A_2, a *p*-value examines whether there is a statistically significant interaction between value 'D' of A_1 and 'F' of A_2. A *p*-value of 0.05 or less indicates a statistically significant movement pattern 'DF' at the 5% level.

A case study on identification of the statistically significant movement patterns was conducted on Phillip Island using log-linear models to evaluate these methods. See details in chapter 7.

5.4 DATA MINING OF TOURISM MARKET SEGMENTS BASED ON SIGNIFICANT SPATIO-TEMPORAL MOVEMENT PATTERNS OF TOURISTS

Data mining can be viewed as the process of discovering "golden nuggets" of information in a large set of data (Han and Kamber 2006; Witten and Frank 2000). These "golden nuggets" or patterns are extracted, analysed, interpreted and displayed, which can provide a wealth of information that could offer economic advantage to a particular locality or industry. Today market competition among companies is fierce. Fast and accurate market positioning and personalised service are the key factors for company success. There is considerable research that has been undertaken to identify the customer purchasing behaviour in the retail industry. Some of this research has been focused on developing new data mining algorithms to extract customer's purchase patterns from data (Min and Han 2005; Yada et al. 2004; Yan and Han 2002; Zhang et al. 1997). Existing data mining algorithms have been also applied to specific tourism segmentation applications (Bloom 2005; Emel and Taşkın 2005; Wedel and Kamakura 2000)

This section applies existing data mining methods to identify the tourist segments based on the significant movement pattern of tourists. Traditionally, tourism market segmentation based on a particular product such as an attraction. However, tourists usually visit several attractions during a trip. If these attractions are considered as a product, called as tour packages, to be promoted to tourist markets, more financial profits could be generated to tourism organisation than a single attraction. So far, there is a little evidence of research on identification of the significant tourist movement patterns using log-linear models. Furthermore, there is limited research on tourist market segmentation for the major tourist movement patterns using data mining methods (Jurowski and Reich 2000). the movement patterns of tourists, which is conceptualized as being discrete and simplified as a sequence of movement in geographic space from one location to another, in other words, a sequence of attractions visited by tourists (Xia and Arrowsmith 2005). Tourism segments are the tourist groups with relatively similar characteristics. Identification of tourism segments will assist tourism organisations designing tour packages and promote the tourism markets.

This section will establish a method for tourism market segmentation based on significant movement patterns of tourists. It commences by defining concepts of tourism market segmentation based on the significant spatial movement patterns and reviewing the research on tourism market segmentation undertaken recently. A discussion on methods used to decide on segmentation variables, segment tourist markets, select target markets, and design tour packages then follows.

5.4.1 Tourism market segmentation based on significant spatial movement patterns of tourists

Tourism market segmentation is a process of dividing a tourism market into relatively homogeneous groups (Weinstein 2004), where tourists in the same group are similar to each other. Tourism market segmentation based on significant movement patterns is defined as a process of dividing tourists who travelled with the same significant movement pattern into several different groups with similar characteristics or travel behaviours. The aim of tourism market segmentation based on significant movement patterns is to identify the characteristics of tourists who travelled with a particular movement pattern. The results of this research can assist park managers to design better tour packages and also help tourists schedule their trips.

Market segmentation has been used as a valuable method to understand the distinct characteristics of tourists and develop marketing strategies (Chandra and Menezes 2001; Haley 1968; Kotler and Armstrong 2003; Lee *et al.* 2005; Mykletun *et al.* 2001). Different objectives of segmentation require the utilities of various tourist variables and the application of different segmentation technologies. Bloom (2005) applied the self-organising neural network to complement the segmentation of international tourist markets based on tourist trip characteristics, perceptions and demographics. British tourists visiting Turkey were segmented based on their socio-demographic characteristics and holiday-taking patterns using multi-step cluster analysis (Andreu *et al.* 2005). Jang *et al.* (2001) identified the segments of the Japanese outbound travel market using factor-cluster analysis based on demographic and trip-related characteristics of these markets.

5.4.2 Determination of segmentation variables

Generally tourist groups are divided in terms of geographic, socio-demographic, psychographic, and travel behavioural variables (Wedel and Kamakura 2000). However, the determination of segmentation variables is dependent on the objectives of tourism market segmentation. For example, Bigné and Andreu (2004) identified tourist emotional-based segments and analyse which one is most satisfied and loyal to leisure and tourism services based on socio-demographic variables, multiple-item scales of emotions, satisfaction, and behavioural intentions. The objectives of market segmentation were summarised by Myers (1996) as follows:

- Identifying and characterising groups of tourists
- Focusing advertising efforts for greater impact
- Identifying likely targets for new tourist products
- Improving existing product/service design
- Looking for new product service opportunities
- Assessing the impact of a competitor's new offering

- Establishing a better tourist attraction image

The objective of the tourism market segmentation in this section belongs to the first category to identify groups of tourists with similar characteristics and travel behaviours for the significant spatial movement pattern. Therefore, the geographic, socio-demographic and trip-related behavioural variables are used.

5.4.3 Determination of tourism market segmentation techniques

There are a number of techniques used to identify tourism market segments. These can be divided into two categories: *Post Hoc* segmentation using cluster analysis or finite mixture models, and *a-priori* segmentation or classification using discriminate analysis and multidimensional scaling (MDS) (Chandra and Menezes 2001). *Post Hoc* segmentation is also called the bottom-up approach. The algorithm starts with single instances that are viewed as separate clusters , then groups similar clusters together into larger clusters (Punji and Stewart 1983; Wedel and Kamakura 2000). Therefore, the number of clusters or segments is unknown until the whole clustering process is finished. *A-priori* segmentation or classification is also called the top-down approach. Data are manipulated as a whole set and divided into successively smaller clusters. The classification method requires each data instances to be labelled with the classes of interest and the independent variables of the instances are identified to predict classes that instances could belong to (Day 1980).

This section intends to identify tourist segments based on the significant spatial movement patterns using clustering methods such as EM algorithm. Tourists cannot be labelled with a particular class or characteristic because there is no prior knowledge or expectation about them. Some unexpected or significant tourist characteristics could be identified by clustering algorithms. Then the cluster descriptions to determine whether there are any significant groupings of tourists will be examined.

Clustering is a method to group tourists that are similar to each other together. The tourists in the same group should be very similar to each other and be very different from tourists in the other groups. It is assumed that the tourists are unlabelled and there is a certain degree of association among them. Algorithms for clustering require a measure of distance between tourists. If the values of tourist attributes, such as age or lifecycle are numeric, Euclidean distance is usually used. There are a considerable number of algorithms for numeric data. If the attribute values are symbolic (for example, "international", and “domestic") other distance measures need to be found. There are only as small number of algorithms that can be used with symbolic attributes. The EM algorithm is used in this section since it can accept both numeric and symbolic attributes (Witten and Frank 2000). Given an input file of tourist socio-demographic and travel behavioural data for a significant movement pattern, the EM algorithm identifies tourist groups for this movement pattern, assigns each instance to one of the tourist group, and gives a description of each class.

5.4.4 Selection of target markets

Target markets can be defined as market segments that are selected for a certain purpose such as positioning a product or service based on certain criteria (Myers 1996). For example, in order to discover the most profitable market, tourist mean expenditures in the segments can be evaluated (Jang *et al.* 2001). The aim of market segmentation in this section is to identify the socio-demographic characteristics of tourists and their travel behaviours for significant spatial movement patterns. There could be several market segments identified for a movement pattern, however, the segment with the heaviest users is selected as the target segment (Myers 1996). For example, if there are three different market segments identified for a movement pattern, the target market segment is the one with highest percentage of members.

5.4.5 Design of tour packages

The last step in the process of tourism market segmentation based on the significant movement patterns is to develop the tour package for the target market. There are three issues to be considered in the design of the tour package. The first is to determine which attractions could be packaged together for a tourist trip. The second is the possible time schedule to arrange attractions for a trip. The final issue is to determine the target market for the promotion of the tour package (Wedel and Kamakura 2000).

This section intends to select attractions for a tour package based on the movement pattern. A spatial movement pattern is defined as a combination of attractions visited by tourists. The attractions that compose a significant spatial movement pattern have statistically strong interactions between each other. In other words, tourists could more frequently include these attractions into their trips. Therefore, the attractions that comprise a significant movement pattern are selected in the design of a tour package.

Determination of the possible time schedule for the tourist visit of these attractions is another issue for designing a tour package. Each physical movement of a tourist is comprised of at least two types of information: spatial and temporal movement. A tourist visited a sequence of attractions at a collection of arrival time points. This collection of arrival time points can be regarded as a temporal movement pattern corresponding to a spatial movement pattern. However, if the resolution of time points is high (that is, 12:12:12 p.m.) then it is very difficult to find the significant temporal movement patterns. To solve this problem, the clustering method can be adopted to group arrival time points into time intervals. Therefore, the temporal movement pattern can be defined as a sequence of arrival time intervals or categories instead of a sequence of time points (see detail in section 3.3.3). Usually more than one temporal movement patterns match a spatial movement pattern. This section proposes that the most frequent temporal movement pattern is chosen to determine the schedule for the tour package. However, if there is more than one most frequent temporal movement pattern matching a spatial movement pattern, then the target market will be another factor assisting the final decision (see an example in chapter 7.3.5).

The last issue is to determine a target market for a tour package. In this section, a target market identified for a significant spatial movement pattern will be considered as the target market for the tour package, because the tour package is designed based on a significant spatial movement pattern. The method to identify the target market for a significant spatial movement pattern is described in section 5.4.4.

In chapter 7, a case study of tourism market segmentation based on the spatio-temporal movement of tourists on Phillip Island will be described. The tourist segmentation methods established in this section will be applied and evaluated using the sample data collected from Phillip Island. The EM algorithm for clustering will be implemented using Waikato Environment for Knowledge Analysis (Weka) software environment for data mining (Witten and Frank 2000).

5.5 CONCLUSIONS

This chapter established a method to model the spatio-temporal movement of tourists at the macro level. The method of modelling the process of tourist movements and calculating the probabilities of movement patterns of tourists using MC were developed first. Then, a method to test the statistical significance of movement patterns using Log-linear models were established. Finially, a method to implement tourism market segmentation based on the significant movement pattern using EM algorithm was discussed. The next chapter will discuss models of the wayfinding processes of tourists. Four wayfinding situations are summarised based on levels of familiarity with the physical environment of tourists, pre-planned or unplanned trip and tourist spatial and temporal constrains. The relationships between decision-making and landmark utility are categorised. The roles of landmarks and wayfinding decision-making are also discussed for each type of wayfinding process.

CHAPTER 6 MODELLING THE WAYFINDING PROCESS OF TOURISTS AT THE MICRO LEVEL

6.1 INTRODUCTION

In the previous chapter, the methods of modelling the spatio-temporal movement of tourists at the macro level were developed. This chapter will present methods to model the tourist wayfinding processes at the micro level. The models will be built based on levels of familiarity of environments, whether a trip is replanned or unplanned and, the different spatial and temporal scales. The relationships between roles of landmarks and wayfinding decision-making for the models are also discussed.

6.2 MODELS OF THE WAYFINDING PROCESS

Four conceptual models are proposed to illustrate the processes that take place when wayfinding. These wayfinding models are summarised in figure 6.1, 2, 3 and 4. The models differ with the level of familiarity with the environment as suggested by Allen (1999a) and are developed to clarify the relationships between the human wayfinding decision-making process and landmark utility. In particular, these models can be used to assist in resolving the following questions: When are landmarks used? Are landmarks used before people make decisions or after? What are the roles of landmarks to assist people's decision-making during the wayfinding process?

6.2.1 Wayfinding where the tourist is familiar with the pathways

Figure 6.1 illustrates a wayfinding process, when the wayfinder is familiar with the environment through which they are travelling. Wayfinding can be achieved through a fully comprehensive cognitive map as the basis for wayfinding.

In figure 6.1, tourists first decide their global context for wayfinding. For example, a regular tourist visiting a museum who lives some distance from the museum needs to make two decisions when going to the museum from home. The first decision is to determine what time to depart home. This is not seen as part of the wayfinding process. However the second decision is to determine what mode of transport should be used to go to the museum, and it results in a global direction or orientation to be formed. The tourist may decide to walk, take the train, ride a bike, or travel by car from home to the museum. Once that decision with regard to mode of transport to be undertaken by the tourist has been made, there are no more other wayfinding decisions need to be made. This tourist will generally take the shortest or quickest routes to the museum that have previously been determined over times of travelling.

Once the mode of transport has been decided upon, the wayfinding route is selected. The global cognitive map then is broken into more spatially manageable ‘segments’. These are called local cognitive maps, but are different from the global cognitive map, where more detailed information is ‘displayed’ on these maps. For example, the tourist who has decided to go to the museum by train must now navigate a pathway using a predetermined local cognitive map from home to the station. The train transports the tourist to the station closest to the museum, and the tourist again extracts wayfinding information from the local cognitive map to orientate from the train station to the museum. This becomes an iterative process for each of the smaller segments.

In utilising these local cognitive maps, a conscious effort is made to extract virtual landmarks, turning points, and pathways. This becomes the “Map Extraction Process” in figure 6.1. Before wayfinding, these virtual landmarks, decision points and pathways are matched with the real world by the tourist as input into the “Map Transformation Process”. Navigation then proceeds from station to the museum as the “Wayfinding Action Process” in figure 6.1. It may however, be necessary for the tourist to take a bus or walk from the station to the museum and this will necessitate the local direction or orientation process to be reinstated as illustrated as a repetitive loop in figure 6.1. Again landmarks and decision points are extracted from the local cognitive map and translated into real world objects for each segment.

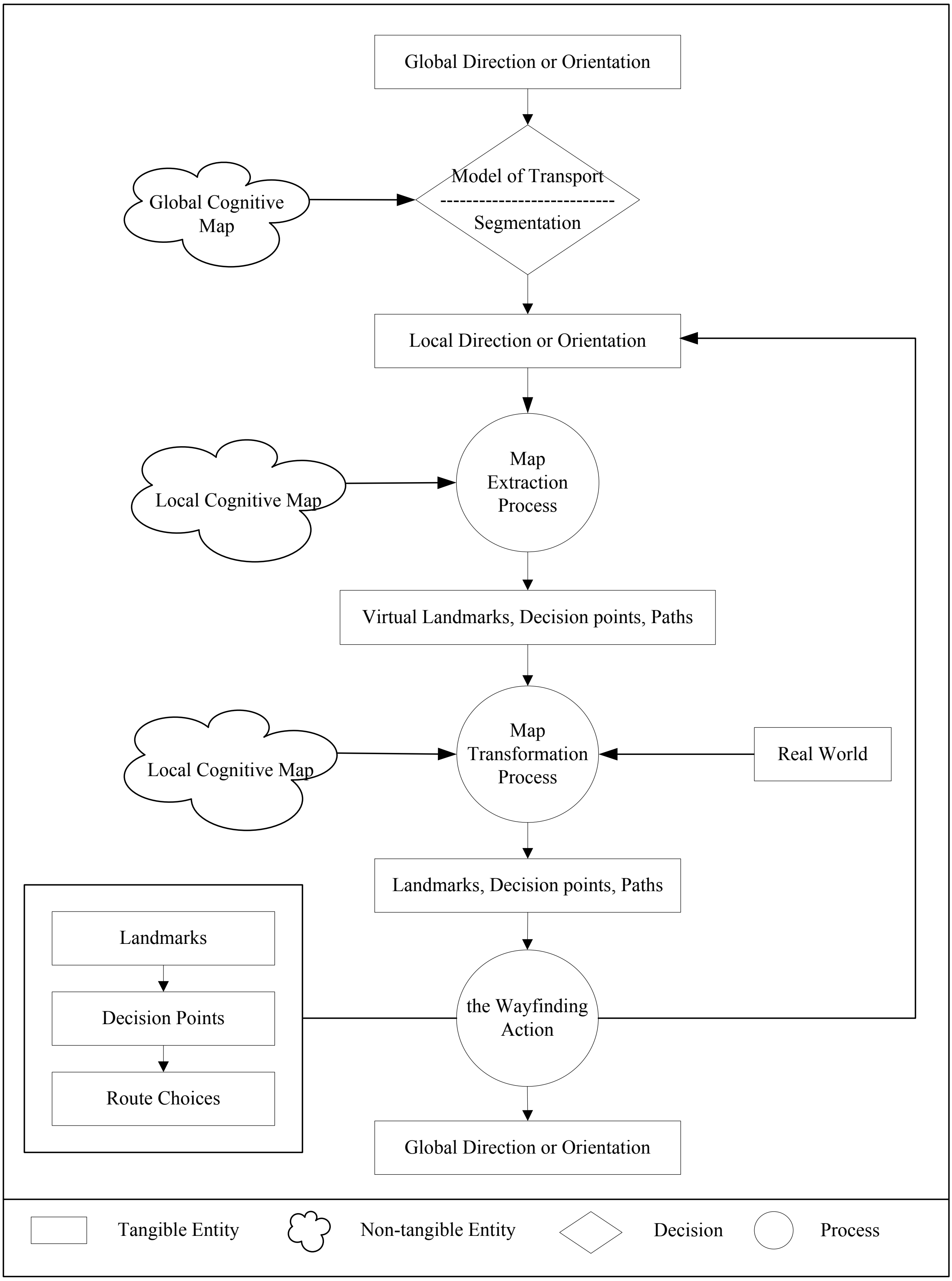

Figure 6.1 The wayfinding process based on a completed cognitive map

In this process therefore, a completed cognitive map of routes is developed prior to travel through a high level of familiarity with the physical environment. Landmarks have been chosen and positioned in the cognitive map. Travel routes are selected and highlighted in the mind before making the trip. The wayfinding process is the process of transforming the virtual cognitive map into reality or action (Kitchin and Freundschuh 2000). The tourist recognises the landmarks around the decision points or along the routes and decides to choose the route during their wayfinding. So the role of the landmark is to act as an aid to the tourist to recognise a pathway. Wayfinding decision-making is unnecessary in this process because the route choice has already been made prior to the trip. Landmarks are used merely to facilitate directional change. Therefore this completed cognitive map will include all the possible alternative routes, street names, decision points, landmarks as well as spatial knowledge including distance, direction, and topological relationships.

6.2.2 Wayfinding where the tourist is only partially familiar with the pathways

Where tourists are only partially familiar with environment they are travelling through a partial cognitive map of routes developed prior to travel (see figure 6.2). The tourists in this situation have some prior knowledge of the destination to which they are travelling. The global direction of the destination is clear, however, the local direction of specific travel paths remains unknown. Therefore, decisions to break the routes into manageable segments need to be undertaken based on the global cognitive map. For example, tourists drive from hotel to a well known attraction that these tourists have been to perhaps once or twice before. Therefore, this well known attraction is their global direction. They could divide routes into three parts: hotel to the highway, along the highway to the attraction entrance, and finally navigate through the attraction itself.

Once segmentation has been undertaken, local cognitive maps for each segment need to be generated prior to departure. Landmarks, turning points, and paths are conceptualised into a spatial knowledge-base and becomes part of the cognitive map. During the wayfinding process, this information is extracted from the local cognitive map and matched with the real world. However, because these tourists may not be familiar with the physical environment, they may not be able to readily identify a particular landmark, path or turning point that they have planned to use. In addition, using an incorrect landmark in the real world may result in a wrong decision being undertaken. Therefore, these tourists will need to check maps or books and generate a new cognitive map. This process will be reiterated for each segment until the global destination is finally reached.

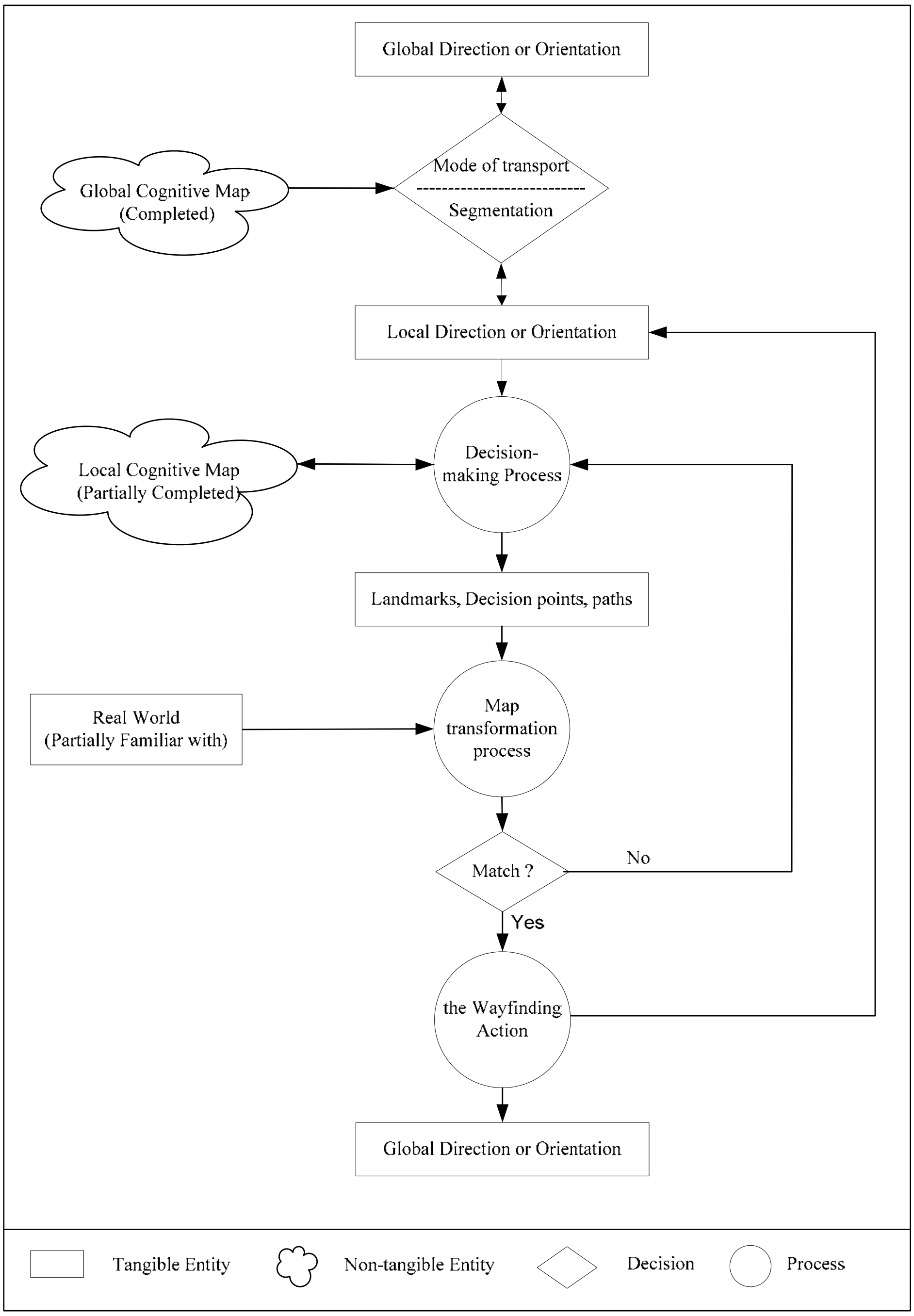

Figure 6.2 The wayfinding process based on a partially completed cognitive map

There are two subtypes of wayfinding where tourists are only partially familiar with pathways:

- The same wayfinding process has been experienced before but infrequently.
- No previous wayfinding experience but path planning in advance prior to travel when heading to a new destination.

The differences between these two types of wayfinding process are the ways tourists obtain the knowledge of the route. For the first type of wayfinding process, the knowledge comes from their own experience. But for the second one, they learned the routes from maps or books or other people's experiences.

During the wayfinding process where the tourists are only partially familiar with environment, travellers are still in the process of developing local cognitive maps which can be referred to as the path planning process. An interaction exists between the decision-making and the landmark utility to guide wayfinders. The roles of landmarks are to facilitate the wayfinding direction and path memory (Cornell and Heth 2000; Presson and Montello 1988)

6.2.3 Wayfinding where the tourist is unfamiliar with the pathways to be taken

Where tourists are unfamiliar with a particular pathway or the way to a particular destination, no cognitive map will have been generated prior to travel. The pathway to be navigated could be a random walk in a small unknown nature park. With no pre-planned itinerary, the tourist is unfamiliar with the pathways to be taken from one location to the next destination. Both temporal and spatial scales become increasingly important for the tourist with no preconceived plans. Time will regulate how much wandering can take place and spatial scale will determine the level of wandering that takes place. For example, time constraints placed on package tour visitors to a destination will reduce a visitors' ability to wander. The spatial scale will also regulate the degree to which a person will wander totally unaided. For example tourists may be quite comfortable wandering around a small parkland totally unaided, however tourists wandering around a large city may reduce the spatial extent to which they will wander (that is, the city business district). Two possibilities for using landmarks exist.

- *No wayfinding aids are offered to the tourist in a small area*

The first possibility is that there are no specific landmarks used and no specific destination aimed for except to return by a specified time. This could be considered as 'aimless wandering' or 'randomised exploration'. For example, some people like to go window shopping without any specific purpose or item in mind to purchase. In a park setting, people may be satisfied to just wander along pathways and happy to absorb the surrounding ambience. Changing direction will be based purely on chance, whim or serendipity. These directional changes are almost impossible to pre-empt or determine because they are dependent upon ephemeral features such as sunlight position, climate or other non-tangible attributes. However, it may be possible to predict probabilities of movements and directions selected at decision points based on biophysical features. That is, the majority of tourists may turn towards running water or a waterfall.

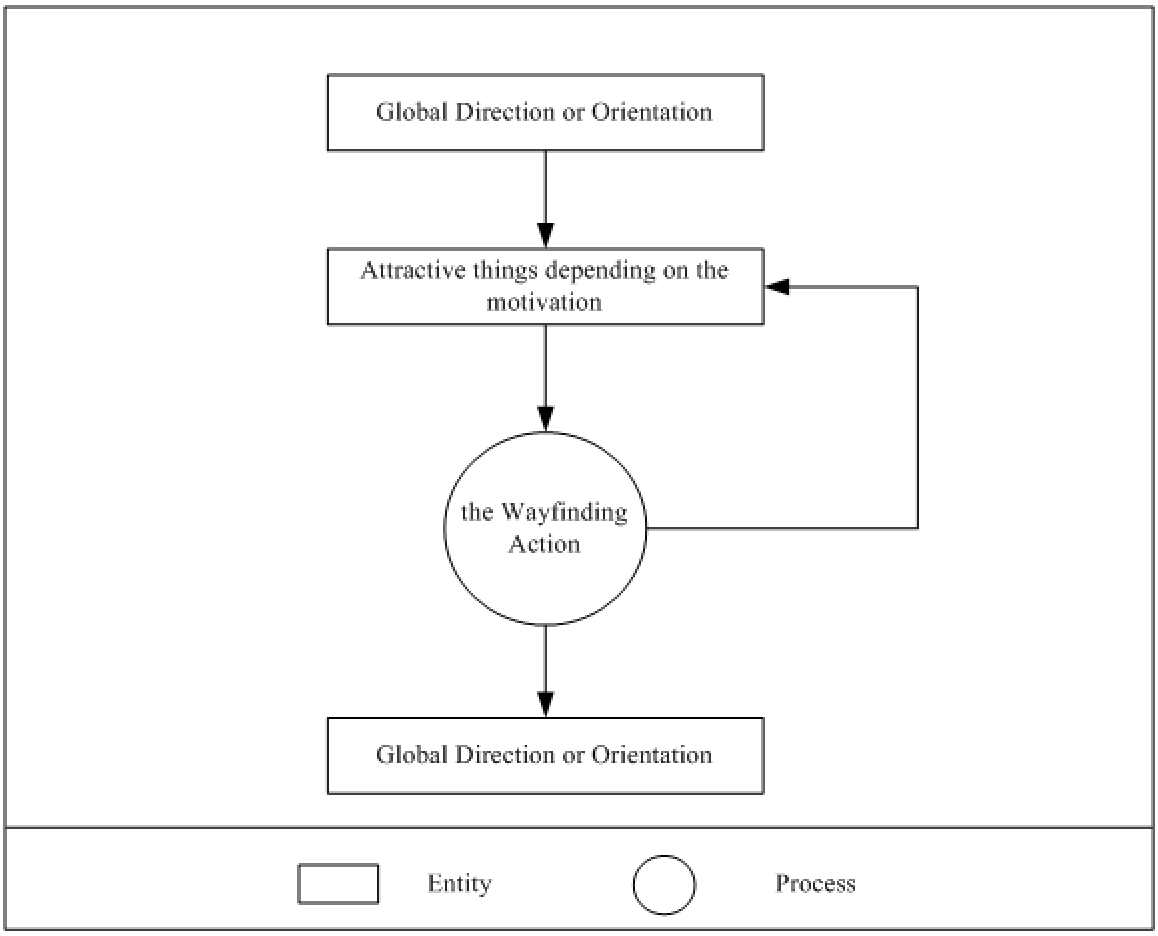

Figure 6.3 The wayfinding process without a cognitive map assembled prior to travel and without landmark utility

In this situation landmarks do not assist in the decision-making process but can be used in developing a cognitive map. Figure 6.3 illustrates the scenario where the tourist has no preconceived plans for wayfinding and does not utilise special landmarks in the wayfinding process. The tourist wayfinding mostly depend on their motivation for the trip and can be influenced by the external environment. For example, some people will be drawn by a crowd towards some activity that may or may not be occurring. Others will be repelled by the same crowd.

- *Wayfinding aids are offered to the tourist in a small area*

The second possibility is where tourists will have no specific destination in mind but nevertheless will utilise landmarks to navigate their way through a pathway. For example, tourists may want to visit the Melbourne Central Business District with no specific sights in mind. However, using a series of street signposts they will turn left or right at random depending on the whim of each person. Any street signs, buildings or other features that could act as a landmark in the previous scenarios are not used as such under these conditions. Rather tourists will wander from one attraction to another with no pre-planned itinerary.

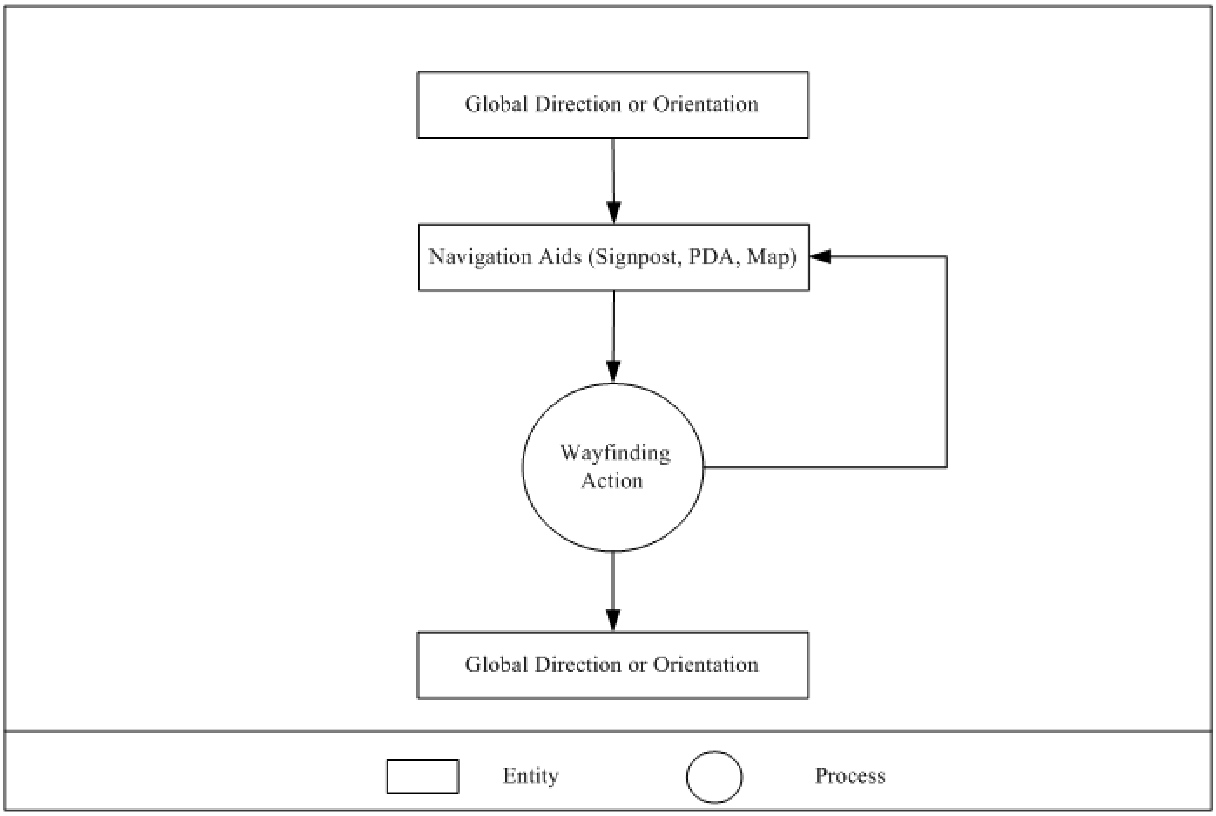

Figure 6.4 The wayfinding process without a cognitive map assembled prior to travel but with landmark utility

In this situation, landmarks aid the wayfinding process to facilitate tourists wandering around a small area. Direction signs or other navigation aids such as mobile phones, or PDA with location based services can be used by tourists to achieve their wayfinding goals (see figure 6.4).

The application of more advanced portable technologies, such as PDA's, mobile location based services and GPS to facilitate wayfinding of visitor in unfamiliar settings without prior planning, may become more common. Spatial scale may no longer be an impediment to wandering in unfamiliar territory. The tourist would not feel lost even in a large area when assisted by a PDA. More research will need to be undertaken to determine the role of these mobile technologies to support visitor movements in unfamiliar settings.

6.3 SUMMARY OF THE MODELS

The tourists who belong to the first type of wayfinding situation are familiar with the attractions or pathways. The cognitive map had been generated prior to the trip. During this wayfinding process, landmarks, turning points, and pathways are extracted from the cognitive map, and matched with the real world by the tourist in step of "Map Transformation Process". Based on this information, the tourist will undertake the wayfinding action. Wayfinding decision-making is unnecessary in this process. Landmarks are used merely to recognise the pathway and facilitate directional change.

In the second type wayfinding situation, tourists are partially familiar with the environment. They are still in the process of developing local cognitive maps (or the path planning process). Sometimes a particular landmark, path or turning point that has been planned to be used cannot be matched with the real world. This may result in a wrong decision being undertaken. The tourist will either need to check maps or other navigation tools and generate a new cognitive map. Therefore, an interaction exists between the decision-making and the landmark utility. The role of landmarks is to facilitate the wayfinding direction changes and memorise pathways.

In the third type of wayfinding situation, tourists wander around a small unfamiliar area without wayfinding aids. They change direction purely on chance, whim or serendipity.

Landmarks are mainly used to identify the different natural environment and direct the way. No cognitive map is generated (with no pre-planned itinerary prior to the trip).

Tourists, in the fourth type of wayfinding situation, are also unfamiliar with the environment and have no specific destination. However, wayfinding aids such as landmarks are important for achieving their wayfinding task. Landmarks are utilised to navigate their way through a pathway wayfinding. New navigation aids, such as mobile phones, or PDA could change tourist wayfinding behaviours dramatically, which can be an interesting future study on the tourist wayfinding.

6.4 CONCLUSIONS

This chapter presented models of the wayfinding process. Four wayfinding situations were summarised based on levels of familiarity with the physical environment of tourists, whether they pre-planned or unplanned trip and differing spatial and temporal scales. The roles of landmarks and the tourist wayfinding decision-making process were also analysed in each type of wayfinding process. The next chapter will present a case studies conducted on Phillip Island. This case study will implement and evaluate the theories and methods of modelling the spatio-temporal movement of tourists discussed in this thesis.

CHAPTER 7 CASE STUDY: PHILLIP ISLAND

7.1 INTRODUCTION

The previous chapter developed four models of the wayfinding process. The relationships between tourist wayfinding decision-making and roles of landmarks were discussed for the four wayfinding types. This chapter will firstly give a brief introduction to the case study area, Phillip Island, and follow with a discussion of a case study conducted on Phillip Island. The case study implements and evaluates the concepts, theories and models related to modelling of the spatio-temporal movement of tourists at both macro and micro levels, as described in chapters 3 to 6.

This case study consists of six steps. Step one is about movement data collection. This step applies and evaluates the techniques for tracking the spatio-temporal movement of tourists at the macro and micro level based on the results of review and comparison of tracking technologies discussed in chapter 4.

Step two focuses on representation of tourist movements at the macro and micro level. This step of the case study implements the spatio-temporal zooming theory to visualise the spatio-temporal movement of tourists at the macro and micro level and transition of the spatial movements of tourists and the spatio-temporal movement of tourists between these two levels. The spatio-temporal zooming theory was discussed in chapter 3.

Modelling tourist movements at the macro level is discussed in step three. MC theory is used to model the process of tourist movements on Phillip Island and estimate the probabilities of the tourist movement patterns. The MC theory and model design were presented in chapter 5.

Although the probabilities of the movement patterns indicate the strength of movement patterns, they cannot tell us which patterns are statistically significant. Therefore, in step four, log-linear models are used to test significance of the movement patterns. These statistically significant movement patterns will be used in the next step of the case study for tourism market segmentation. The method to test the significance of the tourist movement patterns was discussed in chapter 6.

In terms of the outcomes of step four, The EM algorithm is used to segment Phillip Island's tourist markets based on the significant movement patterns of tourists in step five. Then target markets are identified and tour packages are designed for this island's tourism market promotion. The method of the tourism market segmentation was also investigated in chapter 6.

Step six of the case study is to evaluate the models of the tourist wayfinding process designed in chapter 6. The tourist wayfinding process in this thesis is based on the tourist movement at the micro level, which was tracked by GPS. The routes of the tourist movements, characteristics of tourists and their wayfinding behaviours relating to each model are compared for the evaluation of the wayfinding models.

7.2 CASE STUDY AREA

Phillip Island, located at the mouth of Westernport bay, is 140 kilometres south-east of Melbourne, Australia (see figure 7.1). Phillip Island covers an area of about 100 km^2, is 20 km long and 13 km wide. The permanent population on the island is around 7000 but almost 1.5 million visitors travel around the island each year (Hallahan and Bomford 2005; Phillip Island Internet Services 2005)

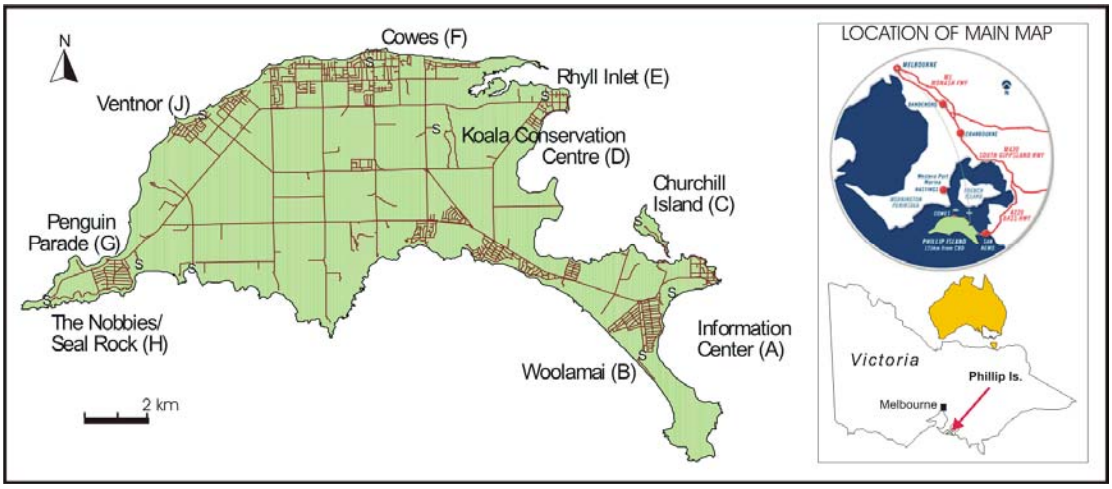

Figure 7.1 Map of Phillip Island (Phillip Island Nature Park 2005)

Phillip Island was first discovered by George Bass in 1798 and was used as a military post, for farming, game hunting and cattle and sheep grazing at the early stage. In the late 1920s, because of the tourism boom, Phillip Island became a popular tourist site. There are a large number of natural tourist resources on the island, such as wildlife, such as fairy penguins, koalas, seals and natural features, such as wetlands, sandy beaches and rugged rocky cliff faces. The popular attractions on Phillip Island are the Penguin Parade, the Koala Conservation Centre (KCC), Churchill Island, Cowes, Rhyll Inlet, Woolamai and the Nobbies. (Phillip Island Nature Park 2005) (see figure 7.1). Many recreational activities are undertaken by tourists on the island around the year, such as wildlife viewing, water sports and fishing.

7.2.1 Koala Conservation Centre (KCC)

The KCC is centrally located on Phillip Island (see figure 7.2). It was established in 1991 to protect the koala population and provide close viewing opportunities for tourists. The KCC is composed of six hectares of enclosed woodland, a 0.5 hectare koala viewing area that includes two boardwalks, a nine hectare plantation and an information centre. A further seven hectares is available for the expansion of the woodland habitat (Reed 2000).

There are on average 120,000 tourists visiting the KCC each year. The KCC features a treetop boardwalk for the tourists to observe the koalas at a close range (see figure 7.3). Tourists can also walk through the eucalypt bush to observe more koalas in a natural environment (see figure 7.4). The KCC conducts research on understanding koala behaviour and methods of returning koalas back into the wild successfully (Hallahan and Bomford 2005).

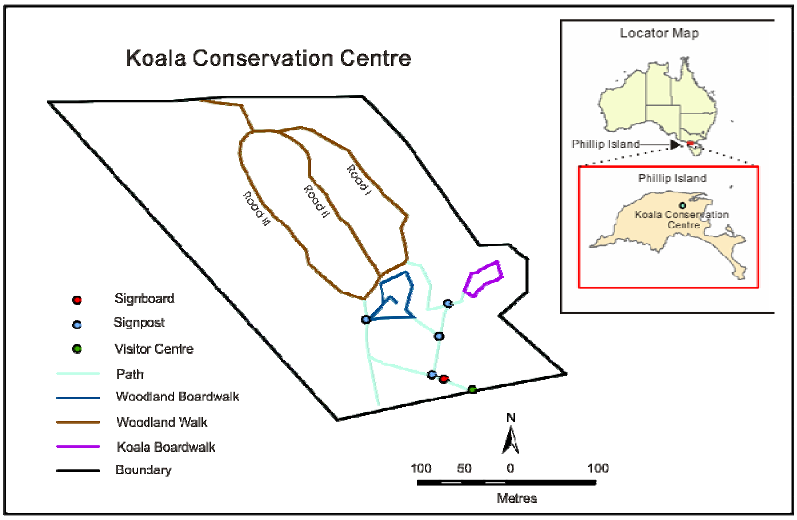

Figure 7.2 Map of the Koala Conservation Centre

Figure 7.3 The Koala Conservation Centre Boardwalk

Figure 7.4 Koalas in the Koala Conservation Centre

7.2.2 Penguin Parade

The Penguin Parade is one of the most popular wildlife attractions in Australia (Hallahan and Bomford 2005). After sunset the world smallest penguins come ashore to breed and moult. Tourists can view the nightly spectacle of little penguins parading along the beach from stands or along the boardwalks (see figure 7.5 and figure 7.6). The Penguin Parade visitor centre also provides educational facilities such as interactive computers, glass-sided nesting boxes and a theatre for acquainting the tourists with information about little penguins. More than half a million people visit the Penguin Parade every year (Hallahan and Bomford 2005).

Figure 7.5 The Penguin Parade (Phillip Island Nature Park 2005)

Figure 7.6 World famous little penguins (Phillip Island Nature Park 2005)

7.2.3 The Nobbies

The Nobbies, a large rock platform formed by volcanic outpourings 40 to 60 million years ago, is located at the western tip of Phillip Island (Hallahan and Bomford 2005). A cliff top boardwalk around the Nobbies provides tourists with views of seals, dolphins, birds and the magnificent coastline (see figure 7.7). About 1.5 km offshore from the Nobbies are Seal Rocks, which is home to the largest fur seal colony in Australia (see figure 7.8) (Hallahan and Bomford 2005; Walkabout 2006).

Figure 7.7 The boardwalk at the Nobbies

Figure 7.8 Seal Rocks

7.2.4 Churchill Island

Churchill Island is a small island (57 hectares) off the northeast coast of Phillip Island. In 1872, Samuel Amess bought the island and built farm buildings and a homestead for his family. The Victoria government bought the island in 1976 and opened it to the public in 1981. The major attractions for tourists on Churchill Island are Roger's cottage and the 1872 homestead and gardens (see figure 7.9) Tourists can also stroll along the circular waking tracks to view wild birds such as wading birds and seabirds and the ancient Moonah forests (Hallahan and Bomford 2005).

Figure 7.9 Churchill Island cottage

7.2.5 Cowes

Cowes, originally called ‘Mussel Rocks’, is the principal town on Philip Island. It was the main port for the ferry from the mainland before the bridge linking San Remo and Newhaven was built. Cowes is a centre of culture, art and recreation on Phillip Island. It has many art galleries, craft and souvenir shops and a theatre and a cinema. It is also the main location for shopping, dining and accommodation. There are many beautiful beaches with fine sand facing French Island and the Mornington Peninsula (see figure 7.10 and figure 7.11).

Figure 7.10 Phillip Island Tourist Road at Cowes

Figure 7.11 A beach at Cowes

7.3 A CASE STUDY ON MODELLING THE SPATIO-TEMPORAL MOVEMENT OF TOURISTS AT THE MACRO AND MICRO LEVEL

A case study was undertaken on Phillip Island to implement and evaluate the methods and theories of modelling the spatio-temporal movement of tourists. There are six steps included in this case study. The six steps of the case study presented the modelling process of the tourist movement on this island.

7.3.1 Step one: Implementation and evaluation of technologies for tracking tourist movements

Based on reviews and comparisons of current tracking techniques in chapter 4, the self-administered questionnaire technique was determined to collect tourist movement data at the macro level. At the micro level, GPS, self-administered questionnaire and interview techniques were chosen to track tourist movements. In order to apply and evaluate these tracking techniques, two surveys were conducted on Phillip Island. The first survey was undertaken to gather the general spatio-temporal movement of tourists at the macro level covering the whole island. The second survey tracked the tourist spatio-temporal movement at the micro level and collected the tourist wayfinding decision-making information such as path choice, the uses of landmarks and wayfinding strategies at the KCC.

- *Applying the self-administered questionnaire tracking techniques at the macro level*

The self-administered questionnaire technique was used to track the daily movement of tourists on Phillip Island at the macro level. Eight hundred questionnaires were distributed between the 6th and 8th of March 2004 and between the 17th and 20th of January 2005 at the Phillip Island Information Centre, Churchill Island, the KCC and the Penguin Parade. The Penguin Parade is the major sample attraction, because more than 90% of tourists visited this attraction on the island. The Penguin Parade is generally the last attraction visited by tourists during a one-day trip since the penguins arrive on shore at roughly between 7:00 to 10:00 pm. From a total of 500 questionnaires returned, 34 were incomplete and were discarded. The remaining 466 were entered into the database.

Three categories of questions were asked in the questionnaire (see appendix 1). The first category aimed to acquire socio-demographic data or profiles of tourists. The second category aimed to collect information regarding visit characteristics of tourists such as travel mode, length of stay and whom the tourist is travelling with. The final category gathered information on tourist movements. Here tourists were asked to write down their approximate arrival time and duration of stay at each attraction they visited over the period of one day. Tourists were also required to draw the route of travel to each attraction on a street map of Phillip Island.

A major limitation of this technique was the failure of participants to enter details such as the arrival time and length of stay correctly. A reason for this includes an inability of the participant to remember the exact time and route taken. Even though Phillip Island has a well developed and clear road infrastructure system, tourists still found it difficult to record the roads travelled on to reach each attraction. This was especially the case for international tourists. Since most international tourists travelled by bus or coach, a majority of participants did not bother to remember the name of the roads they travelled on. Another limitation of this technique is that not all tourists will visit the sample attractions and therefore they could not be included in the study sample. For example, some domestic tourists only visited Cape Woolamai or Rhyll Inlet for a one-day surfing trip. The percentage of tourists not included in the survey conducted on Phillip Island was estimated to be about 5%.

- *Applying the self-administered questionnaire, GPS and interview at the micro level*

A survey was conducted at the KCC on Phillip Island from 17th to 20th of January 2005. The movements of 124 tourists, six group tour guides and two rangers were tracked by GPS (eTrex personal navigation) and interviewed after their visits. The information gathered from GPS includes spatial position, time, speed, direction or path choice, user ID, and log data, which can precisely describe the spatio-temporal movement of tourists. Tourist socio-demographic data was obtained through a self-administered questionnaire. In addition, this questionnaire included questions related to wayfinding decision-making (how people found their way) such as landmarks used by tourists, wayfinding strategies, and wayfinding types that are categorised based on the levels of familiarity with the environment, whether trips are pre-planned or unplanned and the different spatial and temporal scales.

The self-administered questionnaire consisted of two parts, a pre-visitor survey and a post-visitor survey. The pre-visitor survey was given to tourists at the entrance of the KCC. After they finished this survey, GPS receivers were set up and handed to them. Then tourists would travel around the KCC with the GPS receivers. After their visits, post-visit questionnaires were given to them to fill in and movement data was downloaded from the GPS receivers. Finally, the tourists were asked a few questions about their movements based on the information recorded by the GPS receivers. For example, why did they choose Road I rather than Road III to commence their Woodland (bush) walk? Or did they use any landmarks to find their way when they faced the first intersection?

A limitation of GPS tracking for this case study is, as summarised in the review of tracking techniques, that the signals of GPS are not stable. At times, trees or leaves could attenuate signals. As with the study by Chhetri and Arrowsmith (2004), sample size was also a critical issue for this research. In addition, the factors that could influence wayfinding decision-making are very contingent. It is hard to quantify and validate the wayfinding decision-making process.

7.3.2 Step two: Application of spatio-temporal zooming theory in representation of the tourist movement at the macro and micro levels

This step of the case study visualises the spatio-temporal movement of tourists and applies the spatio-temporal zooming theory to present the transition of tourist movement between the macro and micro level using data collected from Phillip Island. The spatio-temporal zooming theory was discussed in chapter 3.

- **Transition of the spatial movement of tourists between the macro and micro levels**

In chapter 3, the zooming lens of a camera was used as a metaphor for explaining the transition of spatial movement of tourists between the macro and micro level. Detailed information of the movement of tourists is revealed when the camera zooms to the micro level space. However, when the camera zooms out, the tourist movement at the macro level will be shown. For example, the tourist movement around Phillip Island from one attraction to another are viewed as being at the macro level, while movements around a particular attraction such as the KCC are regarded as the micro level. When the camera zooms in from the whole island to the KCC, the resolution will increase from 1:300,302 to 1:6951.

Figure 7.12 illustrates the transition of a tourist movement on Phillip Island between these two levels. The top graph of figure 7.12 represents a tourist movement at the macro level. The tourist movement displayed in the graph includes the attractions visited, corresponding arrival time, duration, and travel routes. For example, the top graph shows that three attractions were visited by a tourist (the KCC, Cowes and Penguin Parade). The tourist started the daily trip at 14:00 and spent two hours at the KCC, then moved to Cowes for dinner at 17:00 and stayed one hour. From Cowes, this tourist travelled to the last destination, the Penguin Parade at 19:00 and stayed for 3 hours. The red points in the graph symbolise the duration. The size of point is in proportion to the time that the tourist spent at an attraction. The bottom graph in figure 7.12 represents the movement at the micro level at the KCC. The thick black lines show the route of the tourist movement and the arrow indicates the direction of the movement.

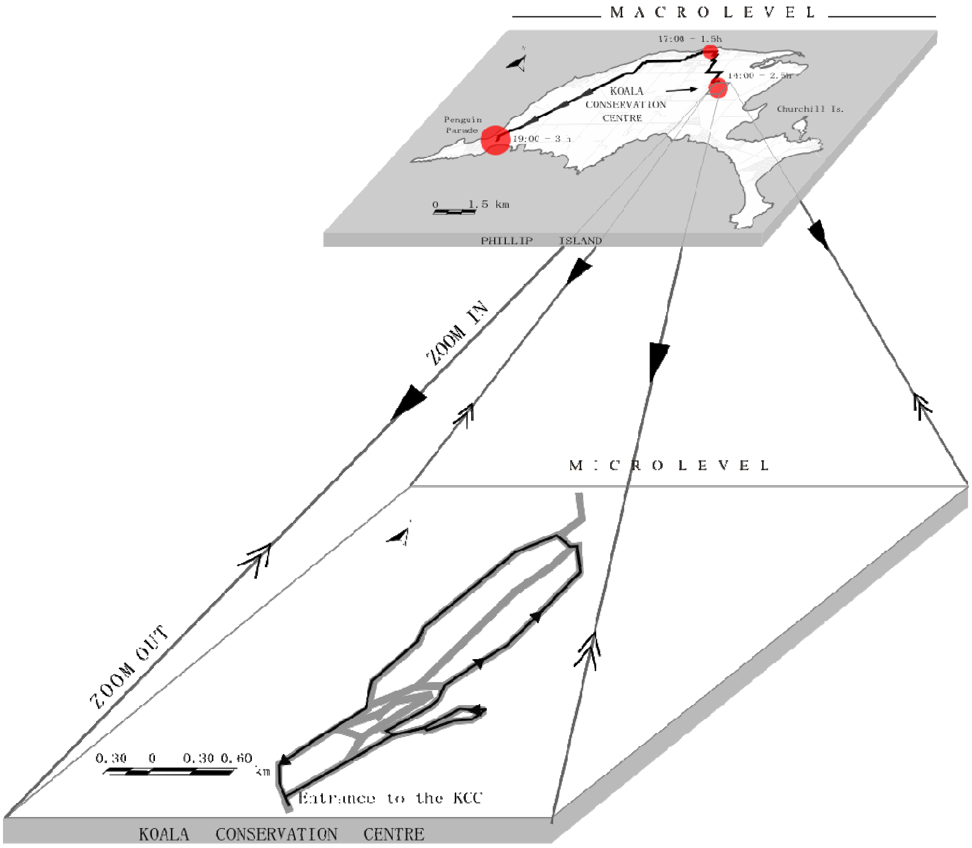

Figure 7.12 Spatial zooming of tourist movements between the macro and micro levels

- **Transition of the spatio-temporal movement of tourists between the macro and micro level**

Figure 7.13 illustrates the spatio-temporal zooming between the tourist movement at the macro and micro level on Phillip Island. A general movement pattern at the macro level is represented on the left side of graph. There were three attractions visited by the tourist on the island. The process of movement of this tourist is simplified into three views: View 1(14:00, 2.5 hours), View 2 (17:00, 1.5 hours), View 3 (19:00, 3hour) (see figure 7.13). Each view represents a state of the movement when the tourist arrives at an attraction. The order of each view coincides with the sequence of the tourist movement. The bottom view shows the start of the trip. The top view represents the end of trip. The whole itinerary of the trip is displayed in the top graph. In the view, the size of point for each attraction represents the duration of the visit. The path that connects the two attractions is the route that the tourist travelled along. The arrow shows the direction of the route. For example, in figure 7.13, View 1 shows that the first attraction visited by the tourist is the KCC. Arrival time is 14:00. Duration is 2.5 hours. In View 2, the tourist arrived at Cowes (the second attraction) at 17:00 and spent 1.5 hours there. The thick black line on the map of Phillip Island shows the route that the tourist used to move from the KCC to Cowes. It took this tourist half an hour to travel between these two attractions. View 3 shows the whole itinerary of the trip. This tourist arrived at the last attraction, the Penguin Parade at 19:00. When the micro level is zoomed to, the time resolution increases to the nearest minute. The continuous movement of the tourist at the micro level is displayed in the right side of graph (see figure 7.13). Geospatial lifelines are used to illustrate a continuous individual tourist movement at the KCC. Continuous lifelines are made up of a collection of linear segments. The endpoints of segments are sampled data (x, y, time point) collected by GPS.

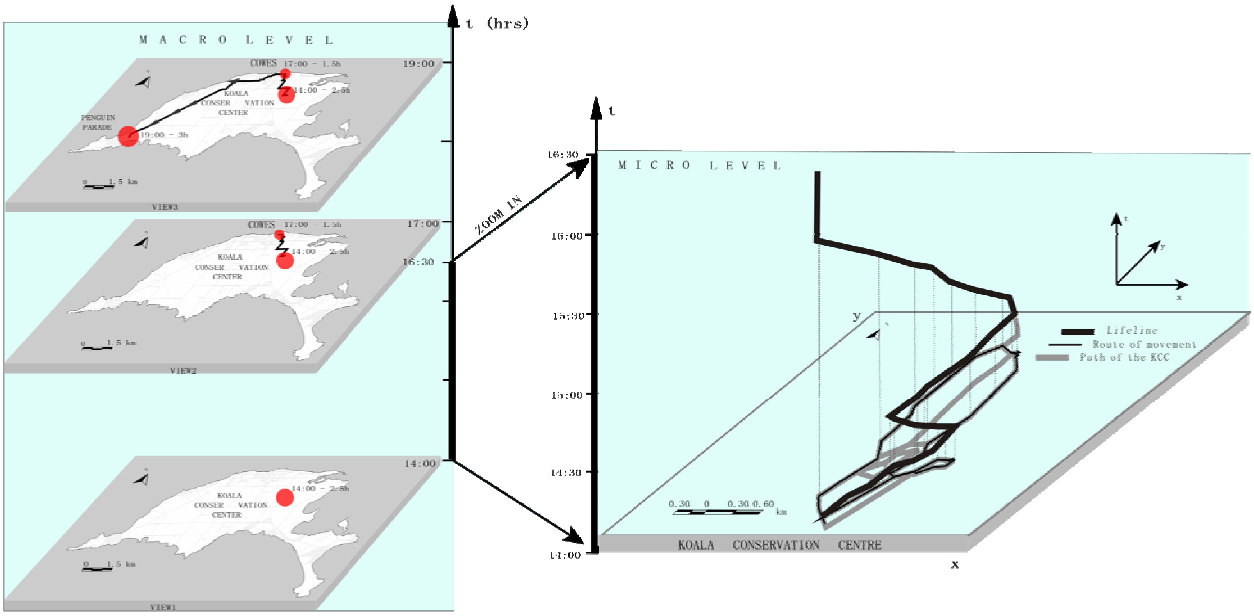

Figure 7.13 Spatio-temporal zooming of tourist movements between the macro and micro levels

7.3.3 Step three: Implementation and evaluation of Markov Chain models in modelling the spatio-temporal movement of tourists at the macro level

This step of the case study will use tourist movement data at the macro level collected from Phillip Island to model the spatio-temporal movement of tourists based on the stationary discrete MC theory. The probabilities of movement patterns will be calculated and the model will then be validated.

- **Model design**

As defined in chapter 5, a stochastic movement process is a family of random movement states $(X_t)_{t\in T}$ on a given probability space S and indexed by *t* belonging to a parameter set T. The set T is regarded as the time sequence of the process $T = \{1, 2, ...\}$. The family of random movement states $(X_t)_{t\in T}$ can be represented as a set of attractions that a tourist visited. Table 7.1 shows the codes used for the attractions on Phillip Island.

Table 7.1 The attractions of Phillip Island

A	B	C	D	E	F	G	H	J	OUT
Information Centre	Cape Woolamai	Churchill Island	Koala Conservation Centre	Rhyll Inlet	Cowes	Penguin Parade	The Nobbies	Ventnor	Outside the Island

The tourist movement on Phillip Island is considered as moving around nine attractions listed in table 7.1. A stationary discrete MC will be used to model the movements of these tourists between each attraction from the moment they enter the park until they have completed their visits.

The states of the chain are the nine attractions visited with an additional absorbing state which is labelled as “OUT” and signals the completion of their daily trip. The maximum number of attractions visited by each tourist on a daily trip is seven. The transition probability of the MC is the conditional probability of moving from one attraction to another. For example, using the rule of conditional probability, the transition probability of going from attraction A_i to attraction A_j , $i \neq j$ from time *n* to *n + 1* where the attractions belong to the above set is given by

$$\Pr(A_j(n+1) \mid A_i(n)) = \frac{\Pr(A_j(n+1) \cap A_i(n))}{\Pr(A_i(n))} \tag{7.1}$$

where $\Pr(A_j(n+1) \cap A_i(n))$ is the probability of visiting both attraction A_i and A_j , with attraction A_i being visited first then followed by A_j . The event $A_i(n)$ can be partitioned into mutually exclusive events, i.e.

$$A_i = \bigcup_{j=1}^{k} (A_i(n) \cap A_j(n+1))$$

Hence, from (1)

$$\Pr(A_j(n+1) \mid A_i(n)) = \frac{\Pr(A_j(n+1) \cap A_i(n))}{\sum_{j=1}^{k} \Pr(A_i(n) \cap A_j(n+1))} \tag{7.2}$$

By the assumption of stationary, the transition probabilities (7.1) and hence (7.2), will be the same for all *n*.

A graph tree (see figure 7.14) is drawn which summarises all sequences of movements by tourists and frequency of visits at each attraction as well as frequency of movements from one attraction to the next. From Equation (7.3), the probability of any sequence of movements from the time a tourist enters the park until the time the tourist leaves it can be calculated once the transition probability matrix (see table 7.2) and the initial probabilities (see table 7.3) are obtained. These are estimated using the graph tree. Notice that there are seven destinations and six transitions displayed in the graph.

$$\Pr(X_1 = i_1, X_2 = i_2, X_3 = i_3 ... X_n = i_n) = v_{i_1} p_{i_1} p_{i_2} p_{i_2} p_{i_3} p_{i_3} p_{i_4} ... p_{i_{n-1}} p_{i_n} \tag{7.3}$$

The initial probability of visiting an attraction A_i, $\Pr(A_i(1))$, is estimated by counting the number of visits to the attraction as a first destination divided by the total number of visits to all first attractions. For example, in the case of attraction D

$$\Pr(\mathrm{D}(1)) = \frac{95}{451} = 0.21$$

The estimation of (2) is also straightforward using the data contained in the graph tree. For example, to estimate the conditional probability of going from D to C, $\Pr(\mathrm{D(n)} \cap \mathrm{C(n+1)})$ is calculated first as follows:

(1) Count the number of movements that satisfy the profile $\mathrm{D(n)} \cap \mathrm{C(n+1)}$ for n = 1,2,…,m-1 where m is the maximum number of possible visits. For example, $\mathrm{N(D(1)} \cap \mathrm{C(2))}$ is the number of movements where tourists began their trips at D and then next move to C.

(2) Sum these frequencies, i.e. $\sum_{\mathrm{n=1}}^{\mathrm{N-1}} \mathrm{N(D(n)} \cap \mathrm{C(n+1))}$

(3) Repeat Step 1 and 2 for all states in *S* not including *D* and sum all these frequencies to obtain the total number of one-step movement patterns.

(4) Divide the number obtained in (2) by that of (3).

For the denominator of (7.3), the above steps are repeated but this time these steps are done for all other attractions to get the required probability.

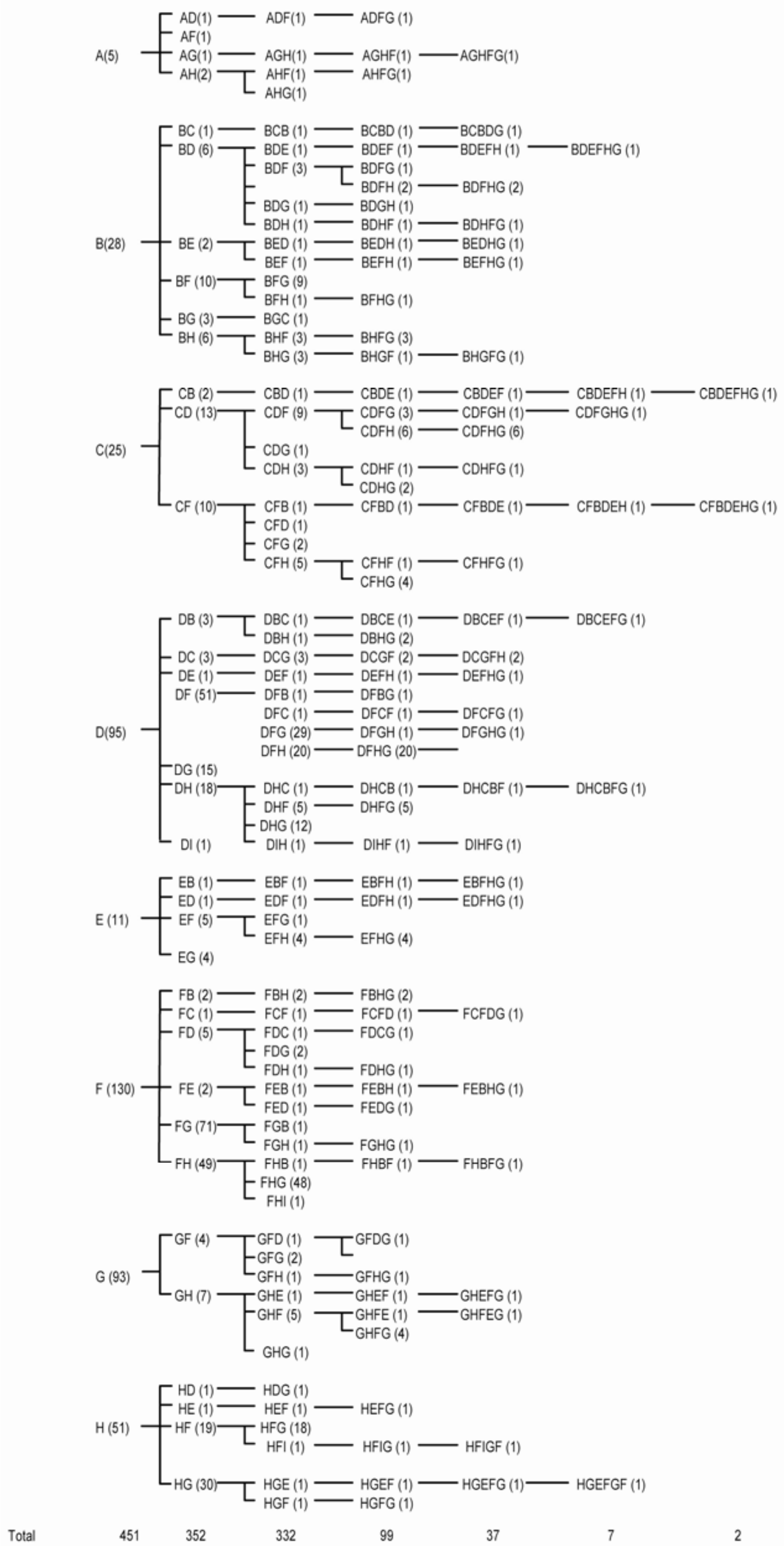

Figure 7.14 The graph tree

Table 7.2 A transition probability matrix

	OUT	A	B	C	D	E	F	G	H	J
OUT	1	0	0	0	0	0	0	0	0	0
A	0	0	0	0	0.2	0	0.2	0.2	0.4	0
B	0.043	0	0	0.043	0.217	0.043	0.284	0.088	0.239	0.043
C	0.103	0	0.102	0	0.333	0.026	0.308	0.102	0.026	0
D	0.052	0	0.022	0.03	0	0.03	0.481	0.193	0.185	0.007
E	0	0	0.077	0	0.115	0	0.577	0.193	0.038	0
F	0.014	0	0.017	0.01	0.031	0.01	0	0.568	0.339	0.011
G	0.948	0	0	0.002	0	0.002	0.022	0	0.026	0
H	0.014	0	0.005	0.005	0.019	0.01	0.191	0.746	0	0.01
J	0	0	0.133	0	0	0.133	0.2	0.4	0.134	0

Table 7.3 Initial probabilities

	Pr(A)	Pr(B)	Pr(C)	Pr(D)	Pr(E)	Pr(F)	Pr(G)	Pr(H)	Pr(J)
Initial Probability	0.01	0.06	0.07	0.20	0.03	0.33	0.18	0.10	0.01

The probabilities of movement patterns can be computed using equation (7.3) once the one-step transition probabilities and the distribution of the initial state have been estimated. For example, the probability of the travel pattern $D \rightarrow F \rightarrow G$, i.e. the KCC (*D*) is the first attraction visited, followed by Cowes (*F*) with the Penguin Parade (*G*) being the last attraction is calculated using table 7.2 and table 7.3 as follows:

$$\begin{aligned}\Pr(\text{DFGOUT}) &= \Pr(\text{D}) \times \Pr(\text{F}|\text{D}) \times \Pr(\text{G}|\text{F}) \times \Pr(\text{OUT}|\text{G}) \\ &= 0.20 \times 0.48 \times 0.57 \times 0.95 = 0.05\end{aligned}$$

In order to be able to identify the significant movement patterns from the data collected, it is essential and logical that the sequences of movements are further categorised by the number of attractions visited during each visit to the park. To do this, the probability of each pattern consisting of n visits, $n = 1, 2, \ldots, 7$ is simply divided by the sum of the probabilities of all patterns consisting of n attractions. For example, for $n = 1$, the probabilities of the events *G*, *D* and *C* are estimated as 0.168, 0.01 and 0.008 respectively, giving a total probability of 0.186 for a one-attraction pattern. The conditional probability of visiting a single attraction *G*, *D* or *C* is therefore equal to 0.168/0.186 = 0.903; 0.01/0.186 = 0.054 or 0.008/0.186 = 0.043 respectively. Thus, G is the most significant pattern for a one attraction visit to the park. This is summarized in table 7.4. In tables 7.5 to 7.9, the same process for $n = 2, \ldots, 7$ patterns is repeated. The most significant patterns correspond to the ones with the highest probabilities of occurring.

Table 7.4 Probability of movement patterns (n = 1)

Pattern	G	D	C
Probability	0.903	0.054	0.043

Table 7.5 Probability of movement patterns (n = 2)

Pattern	FG	HG	DG	EG	BG	FD	CB	CF	HD	AF
Probability	0.59	0.25	0.12	0.02	0.02	0	0	0	0	0

Table 7.6 Probability of movement patterns (n = 3)

Pattern	FHG	DFG	DHG	CFG	HFG	BHG	EFG
Probability	0.34	0.22	0.11	0.05	0.05	0.05	0.04
Pattern	BFG	CDG	AHG	GHG	GFG	FDG	FJG
Probability	0.04	0.02	0.02	0.01	0.01	0.01	0.01
Pattern	JFG	JHG	DCG	HDG	CFD	FGB	BGC
Probability	0	0	0	0	0	0	0

Table 7.7 Probability of movement patterns (n = 4)

Pattern	DFHG	CFHG	EFHG	BFHG	DHFG	BDFG	FGHG
Probability	0.34	0.08	0.07	0.06	0.06	0.05	0.05
Pattern	CDHG	BHFG	FDHG	FBHG	GFHG	HGFG	DBHG
Probability	0.05	0.02	0.02	0.01	0.01	0.01	0.01
Pattern	ADFG	AHFG	GHFG	FHJG	JEFG	HEFG	DFBG
Probability	0.01	0.01	0.01	0.01	0.01	0	0
Pattern	HFJG	FEDG	FDCG	GFDG	BDGH	HJFD	
Probability	0	0	0	0	0	0	

Table 7.8 Probability of movement patterns (n = 5)

Pattern	CDFHG	BDFHG	DFGHG	DEFHG	CFHFG	CDHFG	EDFHG	BEFHG
Probability	0.31	0.17	0.11	0.09	0.09	0.05	0.05	0.04
Pattern	BDHFG	EBFHG	DFCFG	BHGFG	FHBFG	FEBHG	BEDHG	DHFJG
Probability	0.03	0.02	0.02	0.01	0.01	0	0	0
Pattern	GHEFG	BCBDG	AGHFG	FCFDG	HFIGF	GHFEG	DCGFH	
Probability	0	0	0	0	0	0	0	

Table 7.9 Probability of movement patterns (n = 6 and n = 7)

Pattern	CDFGHG	BDEFHG	DHCBFG	DBCEFG	Pattern	CBDEFHG
Probability	0.67	0.3	0.01	0.01	Probability	0.99
Pattern	FBDJHG	JEFCHG	JBJBJG	HGEFGF	Pattern	CFBDEHG
Probability	0	0	0	0	Probability	0.01

- *Model validation*

In this chapter, MC has been applied to model the spatio-temporal movement of tourists and to calculate the probabilities of various movement patterns. However, the key question now is how well are these movements modelled by MC? In other words, how close are the observed frequencies of movement patterns to those which would be expected when equation (3) is used to calculate probabilities of different patterns? In this section, The results were validated using a Chi-Square Goodness of Fit test (Devore 2004).

A data mining approach was adopted by dividing the data set, consisting of 464 records, into two parts: training data and test data. The training data will be used to fit the MC model (that is, to estimate the transition probability matrix **P** and initial probability vector). The expected values obtained using (4) will then be compared with the frequencies observed in the test data using a Chi- Square Goodness of Fit test. If the computed Chi-Square statistics are not statistically significant, then the Markov model is proved to fit to data.

Four hundred and sixty four records in the data set are divided by a random sampling method called EPSEM (equal probability of selection method sampling) using the STATISTIC package. Seventy percent of the data are selected first as training data, leaving the remainder as test data and then the whole process is repeated and 60% of the data as training data is selected. The objective here is to gauge the effect sampling bias has on the results obtained.

Then a set of observed frequencies O_i is compared with a set of expected frequencies E_i where *i*= 1, 2,…, *k* ranges over the different movement sequences associated with a fixed number of visits *n* using the Chi-Square Goodness of Fit test.

For example, two one-attraction-movement patterns are identified from the training data (70% of the total data) *C* and *G.* their probabilities are calculated using MC model (see table 7.10), then the probability of each pattern is divided by the sum of the probabilities of these two patterns to calculate $\hat{p}$. i.e. the $\hat{p}$ of pattern C is calculated as follows:

$$\hat{p}_i(C) = \frac{p_i}{\sum_{i=1}^{n} p_i} = \frac{0.006972}{0.006972 + 0.201258} = 0.033$$

After that, the Chi-Square $\chi^{2(70\%)}_{(n=1)}$ of C is computed as:

$$\chi^{2(70\%)}_{(n=1)} = \sum_{i=1}^{2} \frac{(O_i - E_i)^2}{E_i} = \frac{(O_1 - N\hat{p}_1)^2}{N\hat{p}_1} + \frac{(O_2 - N\hat{p}_2)^2}{N\hat{p}_2}$$

$$= \frac{(0.703 - 0.033 \times 21)}{0.033 \times 21} + \frac{(20.296 - 0.966 \times 21)}{0.966 \times 21} = 0.1297$$

Table 7.10 The Chi-squared test for movement pattern n=1 when 70% of data is used for training

Pattern	Probability	Sum	Probability ˆp	Observed	Chi-Square
C	0.006972	0.20823	0.033482	1	0.1296995
G	0.201258		0.966518	20	

In table 7.11 and table 7.12 the results are summarised based on the Chi-squared test statistics for different number of visits *n* and different size of training data. The *p*-values given in the tables indicate the degree of significance in the results. Note that a *p*-value of 0.05 or less signifies a significant result, i.e. the model provides a poor fit to data. As can be seen from the tables, in the majority of cases, the MC distributions provide a good fit to data. However, the fit is poor when *n* is large, leading one to suspect that the stationary assumption breaks down when there is a large number of visits. The more general equation (7.3) in chapter 5.2.1 should be used in such cases. This is to be expected since for longer trips, it is anticipated that the choice of destinations would depend on which stage of the trip the decision has to be made, an assumption which is ignored when one assumes stationarity.

Table 7.11 Chi-squared test statistics when 70% of data is used for training

n=1	n=2	n=3	n=4	n=5	n=6
$\chi 2 = 0.13$ *p*-value = 0.72 (Not significant)	$\chi 2 = 3.27$ *p*-value = 0.20 (Not significant)	$\chi 2 = 3.39$ *p*-value = 0.07 (Not significant)	$\chi 2 = 15.19$ *p*-value = 0.004 (Significant)	$\chi 2 = 4.39$ *p*-value = 0.11 (Not significant)	$\chi 2 = 28.67$ *p*-value = 0.000 (Significant)

Table 7.12 Chi-squared test statistics when 60% of data is used for training

n=1	n=2	n=3	n=4	n=5
$\chi 2 = 0.37$ *p*-value = 0.83 (Not significant)	$\chi 2 = 1.60$ *p*-value = 0.45 (Not significant)	$\chi 2 = 6.92$ *p*-value = 0.14 (Not significant)	$\chi 2 = 2.32$ *p*-value = 0.31 (Not significant)	$\chi 2 = 4.12$ *p*-value = 0.04 (Significant)

7.3.4 Step four: Application of log-linear models in testing significance of the spatio-temporal movement patterns of tourists at the macro level

The step four of the case study applies the method developed in section 5.3 to test the statistical significance of the movement patterns of tourists on Phillip Island using log-linear models. The log-linear models are implemented using a statistics package, SPSS 13.0 (Statistical Package for the Social Sciences) based on the macro level movement data. This package can perform log-linear analysis and calculate the observed and expected counts or frequencies of movement patterns and derive the corresponding statistics from these counts. A *p*-value is used to indicate the significance of movement patterns.

- **Identification of significant spatial movement patterns using Log-linear models**

The movement at the macro level is defined as a motion from one attraction to another. The maximum number of attractions tourists could visit per day on this island is nine because there are nine attractions included in the survey. However, based on the results of the survey, the longest movement pattern is a combination of seven attractions. These patterns are then categorised in terms of the number of attractions in the patterns. Therefore, seven groups of movement patterns are derived. Each group of movement data are modelled using ‘model selection loglinear analysis’ function and ‘general loglinear model (GENLOG)’ function with the SPSS package to identify the relationships between movement variables and to calculate *p*-values of the movement patterns.

To give a simple example, the significant two-attraction movement patterns will be identified from data. The saturated two-attraction log-linear model is defined as:

$$\log m_{ij} = \mu + \lambda_i^{A_1} + \lambda_j^{A_2} + \lambda_{ij}^{A_1 A_2} \qquad (7.4)$$

There are 124 two-attraction patterns collected from Phillip Island. Seven categories of attractions are for variable A_1, and four for A_2 . The first step of this modelling procedure is to calculate the observed and expected frequencies of the two-attraction movement patterns using the saturated model (1) (see table 7.13). This procedure can be implemented by the GENLOG function with the SPSS. Here the observed frequencies of movement patterns are identical to the expected frequencies. The saturated model is proved to perfectly fit to the data.

Table 7.13 Observed and expected frequencies for two-attraction movement patterns

A_1	A_2	Observed		Expected	
		Count	%	Count	%
Cowes	Penguin Parade	69.500	50.4%	69.500	50.4%
Cowes	Koala Conservation Centre	1.500	1.1%	1.500	1.1%
Nobbies or Seal Rock	Penguin Parade	29.500	21.4%	29.500	21.4%
Nobbies or Seal Rock	Cowes	.500	.4%	.500	.4%
Nobbies or Seal Rock	Koala Conservation Centre	1.500	1.1%	1.500	1.1%
Nobbies or Seal Rock	Cape Woolamai	.500	.4%	.500	.4%
Koala Conservation Centre	Penguin Parade	14.500	10.5%	14.500	10.5%
Koala Conservation Centre	Cowes	1.500	1.1%	1.500	1.1%
Churchill Island	Penguin Parade	.500	.4%	.500	.4%
Churchill Island	Cowes	1.500	1.1%	1.500	1.1%
Churchill Island	Cape Woolamai	1.500	1.1%	1.500	1.1%
Cape Woolamai	Penguin Parade	2.500	1.8%	2.500	1.8%
Rhyll Inlet	Penguin Parade	4.500	3.3%	4.500	3.3%
Information Centre	Cowes	1.500	1.1%	1.500	1.1%
Information Centre	Cape Woolamai	.500	.4%	.500	.4%

The second step is to delete interaction effect $\lambda_{ij}^{A_1A_2}$ from the saturated model to check whether there are interactions between A_1 and A_2. A new model is formed as:

$$\log m'_{ij} = \mu + \lambda_i^{A_1} + \lambda_j^{A_2} \qquad (7.5)$$

The likelihood ratio Chi-square statistic test compared $\log m_{ij}$ with $\log m'_{ij}$ (see table 7.14). The test statistics G^2 (123.186) is significantly large and $\log m'_{ij}$ is considerably different from $\log m_{ij}$ the effect $\lambda_{ij}^{A_1A_2}$ eliminated from the saturated model is important to explain data distribution. There is an interaction between A_1 and A_2. This procedure was implemented by the 'model selection loglinear analysis' function with the SPSS.

Table 7.14 The results from the likelihood ratio Chi-Square test

Delete Effects	Chi-Square(G^2)	df	p-value
$A_1 * A_2$	123.186	18	.000

The likelihood ratio Chi-square statistics can also test significance of interactions between values of variables in the model. Here the values of movement variables are attractions. If there is a significant interaction between an attraction of movement variable A_1 and an attraction of movement variable A_2 , then a movement pattern comprised of these two attractions is significant. A p-value of 0.05 or less indicates a statistically significant movement pattern at the 5% level. Table 7.15 presents the significant two-attraction movement patterns identified from the data set. The movement patterns, such as 'Cowes–Penguin Parade' with the p-values less than 0.05 are considered to be significant. 'Count' shows the importance of movement patterns. For example, 'Cowes–Penguin Parade' is the most important two-attraction movement patterns used by the tourists visiting Phillip Island based on the survey data.

Table 7.15 Parameter estimates for two-attraction spatial movement patterns

A_1	A_2	Counts	p-value
Cowes	Penguin Parade	68	0.001
Nobbies or Seal Rock	Penguin Parade	29	0.004
Koala Conservation Centre	Penguin Parade	14	0.019

Table 7.16 Parameter estimates for three-attraction spatial movement patterns

A_1	A_2	A_3	Counts	p-value
Cowes	Nobbies or Seal Rock	Penguin Parade	46	0.001
Koala Conservation Centre	Cowes	Penguin Parade	27	0.005
Nobbies or Seal Rock	Cowes	Penguin Parade	17	0.013
Koala Conservation Centre	Nobbies or Seal Rock	Penguin Parade	12	0.026
Cape Woolamai	Cowes	Penguin Parade	9	0.042

Table 7.16 and table 7.17 show the significant three-attraction movement patterns and four-attraction movement patterns respectively. The frequencies of major movement patterns composed of five, six and seven attractions are tabulated respectively, instead of using the log-linear model to calculate counts and p-values of the movement patterns (see table 7.18),

because there are a small number of tourists visiting more than five attractions during a day trip on Phillip Island.

Table 7.17 Parameter estimates for four-attraction spatial movement patterns

A_1	A_2	A_3	A_4	Counts	p-value
Koala Conservation Centre	Cowes	Nobbies or Seal Rock	Penguin Parade	20	0.009
Koala Conservation Centre	Nobbies or Seal Rock	Cowes	Penguin Parade	5	0.105
Penguin Parade	Nobbies or Seal Rock	Cowes	Penguin Parade	4	0.140
Churchill Island	Cowes	Nobbies or Seal Rock	Penguin Parade	4	0.140
Rhyll Inlet	Cowes	Nobbies or Seal Rock	Penguin Parade	4	0.140

Table 7.18 Frequencies of for five, six and seven-attraction spatial movement patterns (Code of attractions see section 7.4.3)

Patterns	Number of attractions	Counts
CDFHG	5	6
BDFHG	5	2
DCGFH	5	2
JBJBJG	6	2
CBDEFHG	7	1
CFBDEHG	7	1

Output from the log-linear model shows that the count of significant movement pattern is usually above eight (between eight and twelve), at which its corresponding p-value is less than 0.05. The method to identify the significant spatial movement patterns is also applicable to discover significant temporal movement patterns. The next section presents the results of identification of the significant temporal movement patterns using log-linear models.

- **Identification of major temporal movement patterns using Log-linear models**

As defined in chapter 3, the temporal movement for tourist i at the macro level is represented as the set of arrival time clusters:

$$M_i = (TC_{i1}TC_{i2}...TC_{in}) \quad (7.6)$$

Where TC_{i1} is the time interval (cluster) at which tourist *i* arrived at the first attraction *1*. TC_{i2} is the time interval at which tourist *i* arrived at the second attraction *2*. TC_{in} is the time interval at which tourist *i* arrived at the last attraction *n* during a daily trip.

The time intervals can be identified using the EM clustering algorithm. (The details of EM algorithm will be discussed in step five of the case study) Based on the survey conducted to track tourist movements at the macro level, 1211 arrival time points were collected from Phillip Island. The EM algorithm was used to group these arrival time points into homogenous time intervals. Three time intervals were identified from the data and each time interval is given a label and meaning (see table 7.19).

Table 7.19 Time clusters

Time intervals	Label	Meaning
07:00-16:15	1	Day
16:20-18:40	2	Late Afternoon
18:45-24:00	3	Night

For example, a tourist day trip itinerary might start from Cowes at 16:00, move to the Nobbies at 18:00, and then end at Penguin Parade at 19:00. The arrival time point 16:00 can be categorised into time group 1 [7:00 16:15], time point 18:00 into group 2 [16:20 18:40], and time point 19:00 into group 3 [18:45 24:00]. The temporal movement pattern for this itinerary can be coded as "123". This tourist arrived at Phillip Island during the *day* time and visited Cowes first, then moved to the Nobbies in the *late afternoon*, at *night* visited Penguin Parade.

One hundred and twenty two temporal movement patterns were collected from Phillip Island. These data were analysed using log-linear models by SPSS. Table 7.20 represents the major two-attraction temporal movement patterns on Phillip Island. If tourists plan to visit two attractions during a day trip, they mainly arrange their trip broken into separate time intervals. For example, they could visit one attraction in the late afternoon and one in the evening. Table 7.21 shows the major three-attraction temporal movement patterns.

Table 7.20 Parameter estimates for two-attraction temporal movement patterns

Patterns	**23**	**13**	**12**
Counts	59	29	12
***p*-value**	0.00	0.01	0.02

Table 7.21 Parameter estimates for three-attraction temporal movement patterns

Patterns	123	223	113	112	122	233
Counts	43	30	17	12	11	8
***p*-value**	0.00	0.00	0.04	0.014	0.019	0.05

The outcomes of log-linear models shows that if tourists visit only two attractions during a day trip, they are more likely to visit one in the late afternoon and one at night. If three attractions are visited by tourists per day, two temporal movement patterns are popular: '123' (day- late afternoon-night) and '223' (late afternoon-late afternoon-night).

7.3.5 Step five: Implementation of tourism market segmentation based on the significant spatio-temporal movement pattern of tourists at the macro level

Step five of the case study is designed to apply the EM algorithm to segment the tourism market of Phillip Island based on the significant movement patterns of tourists. The target markets are selected from the market segments that are identified from the EM algorithm for the significant movement patterns. Tour packages are then designed based on the significant spatio-temporal movement patterns of tourists and the corresponding target markets. The methods for tourism market segmentation have been discussed in chapter 5. The EM algorithm is implemented by Weka (Waikato Environment for Knowledge Analysis) software environment for data mining (Witten and Frank 2000).

- **Tourism market segmentation based on the significant movement pattern of tourists**

This section commences by giving an example of segmenting tourism markets using the EM algorithm for the significant movement pattern (DG: the KCC and Penguin Parade). Study findings of tourism market segments for the significant movement pattern are then discussed. Finally, the target market is selected for the significant movement pattern.

(1) Tourism market segmentation based on the movement pattern (DG) using the EM algorithm

Twenty six tourists travelling with the movement pattern (DG) are grouped into two clusters based on five socio-demographic variables and four travel mode variables using the EM algorithm with Weka (see table 7.22). Approximately 58% tourists belong to cluster 1 and the remainder of the tourists (42%) are in cluster 2. Significant differences between these two groups are highlighted in the table 7.22 . The 'Type of visitor' is one of the important variables for clustering the tourists. For the cluster 1, about 16 (15.99) tourists out of a total 17 (17.2) are international visitors and only one (1.22) of them is domestic. However, in the cluster 2, domestic tourists dominate (17.2/18.2). Therefore, cluster 1 can be called an international tourist group and cluster 2 a domestic tourist group. The other key variables are 'Age', 'Lifecycle' and 'Times to visit Phillip Island' (see appendix 1, Questionnaire at the macro level).

Therefore, it can be concluded that there are two types of tourists travelling with movement pattern 'DG'. One type is the young international tourists visiting these two attractions for the first time. The other one is the middle family domestic tourists (Children 6-15 years) who have visited these two attractions more than three times.

Table 7.22 An example of tourism market segments for the significant movement patterns

Attribute	Description	Cluster 1	Cluster 2
Gender	Female	8.21	8.79
	Male	9	4
	Total	17.2	12.8
Type of visitor	Domestic visitors	1.22	11.78
	International visitors	15.99	1.01
	Total	17.2	12.8
Age	18-29 YEARS	10.18	1.82
	30-39 YEARS	4.03	3.97
	40-49 YEARS	1	7
	50-59 YEARS	1	1
	60 + YEARS	4	2
	Total	20.2	15.8
Education	Primary	2	1
	Some secondary	1	5
	Completed secondary	9	5
	Tertiary	7.2	3.8
	Total	19.2	14.8

Lifecycle	Young single	8	1
	Young couple/no children	3.16	1.82
	Young family (Youngest child younger than 6 years)	1	2
	Middle family (Children 6-15 years)	1.01	7.99
	Mature family (Children older than 15 years)	3.02	1.97
	Older couple/no children at home	4.99	1
	Mature single	0	2.01
	Total	21.2	17.8
Times to visit PI	Once	16.01	2.99
	Twice	1.16	2.82
	Three times	1	2
	More than three times	1.01	6.99
	Total	19.2	14.8
Type of group	Travelling alone	0	1
	Travelling with spouse/partner only	4.99	4.82
	Travelling with spouse/partner and children	1.03	1.01
	Travelling with friends/relatives	11.16	6.97
	Travelling in organised group/club	2	2
	Total	19.2	15.8
Transport	Car	12.21	10.79
	Bus/coach	3	1
	Campervan/motorhome	3	1
	Bike	1	2
	Motorcycle	1	1
	Total	20.2	15.8
Duration	Less than 1 hour	1	1
	Half a day	7.2	8.8
	All day	7	3
	1-3 day	4	1
	1 week	1	2
	More than 1 week	1	1
	Total	21.2	16.8

(2) Tourism market segments for the significant movement patterns

Based on the results of step four of the case study, there are nine significant movement patterns identified from the data collected from Phillip Island (see Table 7.23). This section represents the results of tourism market segmentation based on these significant movement patterns using the EM algorithm with Weka. The tourism market for the significant movement pattern had around two to four segments. The details are as follows:

G --- Penguin Parade (N=4)

There are four types of tourists who only visited the Penguin Parade on Phillip Island:

(1) First-time domestic tourists who are young singles or couples travelling with their friends or relatives by car spent half a day or a whole day on Phillip Island (38%).
(2) Repeat domestic tourists who are from the middle family group with children 6-15 years travelling with their spouse or partner and children visited Phillip Island by car in half a day (28%).
(3) First-time international tourists who are elderly couples travelling with their friends or relatives or spouse or partner only by car spent all day on Phillip Island (23%).
(4) First-time international tourists who are young singles travelling in organised groups with their friends or relatives by tour bus or coach spent half a day on Phillip Island (9%).

HG----the Nobbies - Penguin Parade (N=2)

There are two types of tourists who visited the Nobbies first then to the Penguin Parade on Phillip Island:

(1) Repeat domestic tourists from the middle family group with children 6-15 years travelling with their spouse or partner and children by car spent half a day or 1-3 days on Phillip Island (79%).
(2) First-time international tourists who are young singles or couples without children travelling in organised groups or clubs with their friends or relatives by tour bus or coach (21%).

FG----- Cowes - Penguin Parade (N=4)

There are four types of tourists who visited Cowes first then went to the Penguin Parade on Phillip Island:

(1) Repeat domestic tourists from the middle family group with children 6-15 years travelling with their spouse or partner and children by car spent half a day on Phillip Island (32%).
(2) First-time domestic tourists who are young singles travelling with friends or relatives spent all day on Phillip Island (25%).
(3) First-time international tourists who are young couples without children travelling with their spouse or partner only by car spent 1-3 days on Phillip Island (17%).
(4) Repeat international tourists who are old couples and mature singles travelling with their friends or relatives by car spent half a day on Phillip Island (12%).

DG-----the KCC- Penguin Parade (N=2)

There are two types of tourists visiting the Koala Conservation Centre first then the Penguin Parade:

(1) International tourists who are young singles or older couples without children at home travelling with their friends or relatives spent half a day on Phillip Island (67%).
(2) The middle age domestic tourists travelling with their friends or relatives or spouse or partner and children (33%).

DFG----- the KCC- Cowes - Penguin Parade (N=3)

There are three types of tourists visiting the KCC first then Cowes to the Penguin Parade:

(1) First-time international tourists who are mainly male young couples without children travelling with their friends or relatives or spouse or partner by car spent half a day on Phillip Island (47%).
(2) First-time international tourists who are young single travelling in organised groups or clubs along by a tour bus or coach spent half a day on Phillip Island (29%)
(3) Repeat domestic tourists from middle family with children 6-15 years travelling with their spouse or partner and children by car spent half a day on Phillip Island (24%).

FHG ----- Cowes – the Nobbies – Penguin Parade (N=2)

There are two types of tourists travelling with this movement pattern:

(1) The middle age domestic tourists from the middle family group with children 6-15 years travelling with their spouse or partner and children by car spent half a day on Phillip Island (56%).
(2) International tourists who are young singles or young couples without children travelling with their friends or relatives or spouse or partner only by car or tour bus or coach spent half a day on Phillip Island (44%).

HFG ---- the Nobbies– Cowes – Penguin Parade (N=3)

There are three types of tourists visiting the Nobbies first then Cowes to the Penguin Parade:

(1) First-time international tourists who are young singles travelling in an organised group or club along at by car or tour bus or coach spent half a day on Phillip Island (50%).
(2) First-time mature domestic tourists or old couples travelling with their friends or relatives by car spent half a day on Phillip Island (28%).
(3) Repeat domestic tourists from the middle family group with children 6-15 years travelling with their spouse or partner and children by car spent half a day on Phillip Island (22%)

BFG ---- Cape Woolamai – Cowes – Penguin Parade (N=3)

There are three types of tourists travelling with this movement pattern:

(1) Repeat domestic tourists from the middle family group with children 6-15 years travelling with their spouse or partner and children visited Phillip Island for half a day (64%).
(2) First-time domestic tourists who are old couples without children at home visited Phillip Island for 1-3 days (9%).

(3) Repeat domestic tourists who are mature singles travelling with their friends or relatives for half a day or 1-3 days (27%).

DFHG ----- the KCC- Cowes – the Nobbies – Penguin Parade (N=1)

First-time international tourists who are young couples without children or old couples without children at home travelled by car to visit Phillip Island.

(3) Selection of target markets

The outcomes from the EM algorithm show that usually more than one market segment is identified for a total market. In this thesis, the market segment with the highest percentage of tourists is chosen as the target market for the movement pattern. For example, there are four tourism market segments discovered for the tourism market of movement pattern ‘G’. The first segment with the highest percentage of tourists (38%) is the target market for the movement pattern ‘G’. Table 7.23 summarises tourism market segments for the significant movement patterns identified by the EM algorithm. The target market for the movement pattern is listed as the first segment in the table.

Table 7.23 summarises the tourism market segments for the significant movement patterns. The cells highlighted in the table indicate the characteristics of tourists in the segments.

Table 7.23 Tourism market segments for the significant movement patterns

Movement Patterns	Segment	Gender		Type of visitor		Age		Lifecycle							Times to visit			Type of group				Transport				
		Female	Male	Domestic visitors	International visitors	18-29	40-49	Young single	Young couple no children	Young family	Middle family	Mature family	Mature Single	Older couple	Once	More than three times	Alone	With spouse partner only	With spouse/partner and children	With friends, relatives	In organised group, club	Car	Bus coach	Half a day	All day	1-3 days
G	1																									
	2																									
	3																									
	4																									
HG	1																									
	2																									
FG	1																									
	2																									
	3																									
	4																									
DG	1																									
	2																									
DFG	1																									
	2																									
	3																									
FHG	1																									
	2																									
HFG	1																									
	2																									
	3																									
BFG	1																									
	2																									
	3																									
DFHG																										

Note: each No. 1 segment for the movement patterns is considered as the target market highlighted by red colour ; See the movement pattern codes in above section

- **Design of daily tour packages**

In this section, daily tour packages will be designed based on the results of the tourism market segmentation. As discussed in chapter 4, there are three issues to be considered in the design of a daily tour package: attractions, schedule and a target market. The attractions that comprise the significant movement pattern will be selected for the design of the tour package. The schedule for the tour package is determined by the significant temporal movement patterns corresponding to the significant spatial movement patterns. Finally, the target market identified for the movement pattern can also be adopted as part of the tour package.

Table 7.24 Frequency table of the tourist spatio-temporal movement patterns

Movement sequence	G	FG	FHG	HG	DFG	DFHG	HFG	DG	DHG	BFG	All Groups
3	72	0	0	0	0	0	0	0	0	0	72
23	0	37	4	16	0	0	0	5	0	0	63
123	0	0	12	0	11	0	8	0	4	5	44
13	0	21	1	4	0	0	0	3	0	0	30
223	0	0	12	0	7	0	7	0	1	0	30
113	0	0	2	0	1	0	3	0	1	4	17
12	0	4	0	1	0	0	0	5	0	0	12
112	0	0	5	0	4	0	0	0	0	0	12
1113	0	0	0	0	0	0	0	0	0	0	12
122	0	0	4	0	3	0	0	0	3	0	11
1123	0	0	0	0	0	1	0	0	0	0	11
2	5	2	0	0	0	0	0	0	0	0	10
1223	0	0	0	0	0	5	0	0	0	0	10
Totals	81	68	48	29	28	19	18	14	11	9	452

Table 7.24 shows the frequencies of spatio-temporal movement patterns of tourists on Phillip Island based on the survey data. The numbers highlighted by red colour indicate a high correlation between spatial and temporal movement patterns.

The determination of the schedule for the tour package is based on the most frequent temporal movement pattern. This temporal movement pattern coincides with the significant spatial movement patterns that the tour package is based on. However, according to the table 7.24, sometimes more than one most frequent temporal movement pattern matches a significant spatial movement pattern. It is necessary to check which temporal movement patterns are used more frequently by tourists in the target market than other patterns. For example, both temporal movement pattern '223' and '123' are most frequent patterns for spatial movement pattern ‘FHG’. However, more tourists travelled with temporal pattern ‘223’ than ‘123’ in the target market for pattern ‘FHG’. Therefore, the pattern ‘223’ will be chosen in the design of the schedule for the tour package. The daily tour packages designed for Phillip Island are listed in table 7.25.

Table 7.25 Tour packages

	Tour Package One
Package	Penguin Parade (G)
Schedule	Only visit Penguin Parade at night (3)
Target market	First-time domestic tourists, young singles or couples, travelling with friends or relatives
	Tour Package Two
Package	The Nobbies – Penguin Parade (HG)
Schedule	Visit the Nobbies in the late afternoon, then go to Penguin Parade at night (23)
Target market	Repeat domestic tourists, from the middle family group, travelling with their spouse or partner and children
	Tour Package Three
Package	Cowes - Penguin Parade (FG)
Schedule	Visit Cowes in the late afternoon or day time, then go to Penguin Parade at night (23)
Target market	Repeat domestic tourists, from the middle family group, travelling with their spouse or partner and children
	Tour Package Four
Package	The KCC - Penguin Parade (DG)
Schedule	Visit the KCC in the late afternoon, then go to Penguin Parade at night (23) Visit the KCC in the day time, then go to Penguin Parade in the late afternoon (12)
Target market	First-time international tourists, young singles or old couples without children at home, travelling with their friends or relatives by car
	Tour Package Five
Package	The KCC- Cowes - Penguin Parade (DFG)
Schedule	Visit the KCC in the day time, then go to Cowes in the late afternoon, finish

	the trips at Penguin Parade at night (123)
Target market	First-time international tourists which are mainly male or young couples without children travelling with their friends or relatives or spouse or partner by car
	Tour Package Six
Package	Cowes – the Nobbies – Penguin Parade (FHG)
Schedule	Visit Cowes and the Nobbies in the late afternoon, then go to Penguin Parade at night (223)
Target market	Repeat domestic tourists, from the middle family group, travelling with their spouse or partner and children
	Tour Package Seven
Package	the Nobbies– Cowes – Penguin Parade (HFG)
Schedule	Visit the Nobbies and Cowes in the late afternoon, then go to Penguin Parade at night (223)
Target market	First-time international tourists, young singles, travelling by tour bus or coach in an organised group or club
	Tour Package Eight
Package	Cape Woolamai – Cowes – Penguin Parade (BFG)
Schedule	Visit Cape Woolamai and Cowes in the day time, then go to Penguin Parade at night (113)
Target market	Repeat domestic tourists from the middle family group, travelling with their spouse or partner and children
	Tour Package Nine
Package	DFHG ----- the KCC- Cowes – the Nobbies – Penguin Parade
Schedule	Visit the KCC in the day time, then go to the Nobbies and Cowes in the late afternoon, finish the trips at Penguin Parade at night (1223)
Target market	First-time international tourists, young couples without children or old couples without children at home, travelling by car

7.3.6 Step six: Evaluation of the wayfinding process of tourists at the micro level

In chapter 6, four wayfinding models based on levels of familiarity with the physical environment, whether a trip is planned or unplanned and the spatial and temporal scales were proposed. In order to test these models, a survey was conducted at the KCC (see figure 7.15), from 17th to 20th of January 2005. One hundred and twenty four tourists, six group tour guides and two rangers were tracked by GPS receivers and interviewed before and after their visit. Global Positioning System surveys enabled spatio-temporal movements to be ascertained whilst interviews and questionnaires provided demographic data and wayfinding methods employed by the participants. This step of the case study was used by park management to assist in the provision of wayfinding aids.

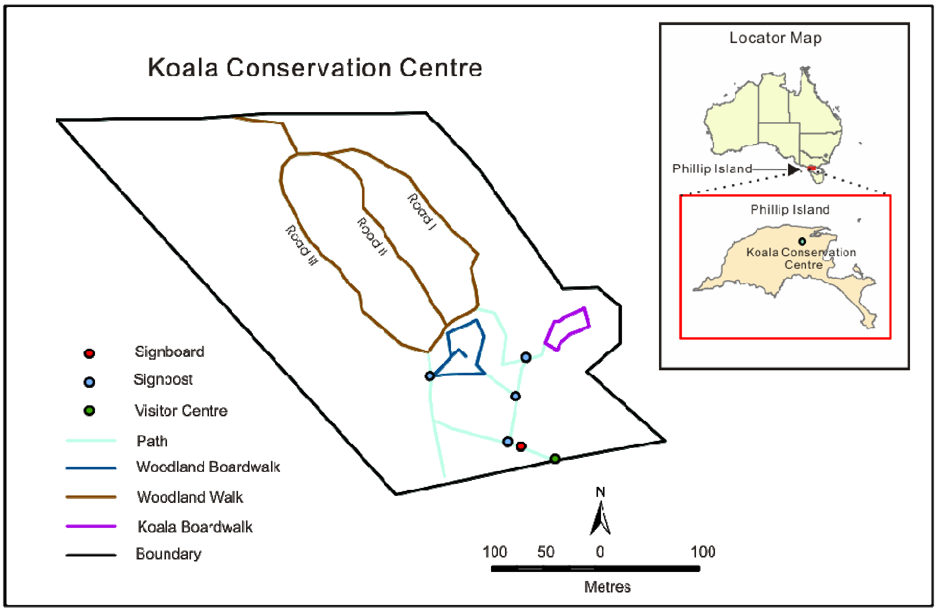

Figure 7.15 Map of the Koala Conservation Centre

Figure 7.16 shows the number of tourists for each type of wayfinding method at the KCC. Of the 132 survey participants, nine (6%) had previously visited the KCC and could therefore be classified as being familiar with the physical environment through which they were walking (wayfinding method type 1). A further 11 (8%) had previously visited the KCC but perhaps on only one or two previous occasions. These were classified as meeting the requirements for wayfinding method type 2. The remaining 112 survey participants could be considered as the first-time visitors and therefore, would meet the requirements for adopting wayfinding method Type 3a and 3b. Of the 112 participants, 11 chose to wander rather than to use official wayfinding aids and were classified as belonging to the group where wayfinding aids are offered, but ignored.

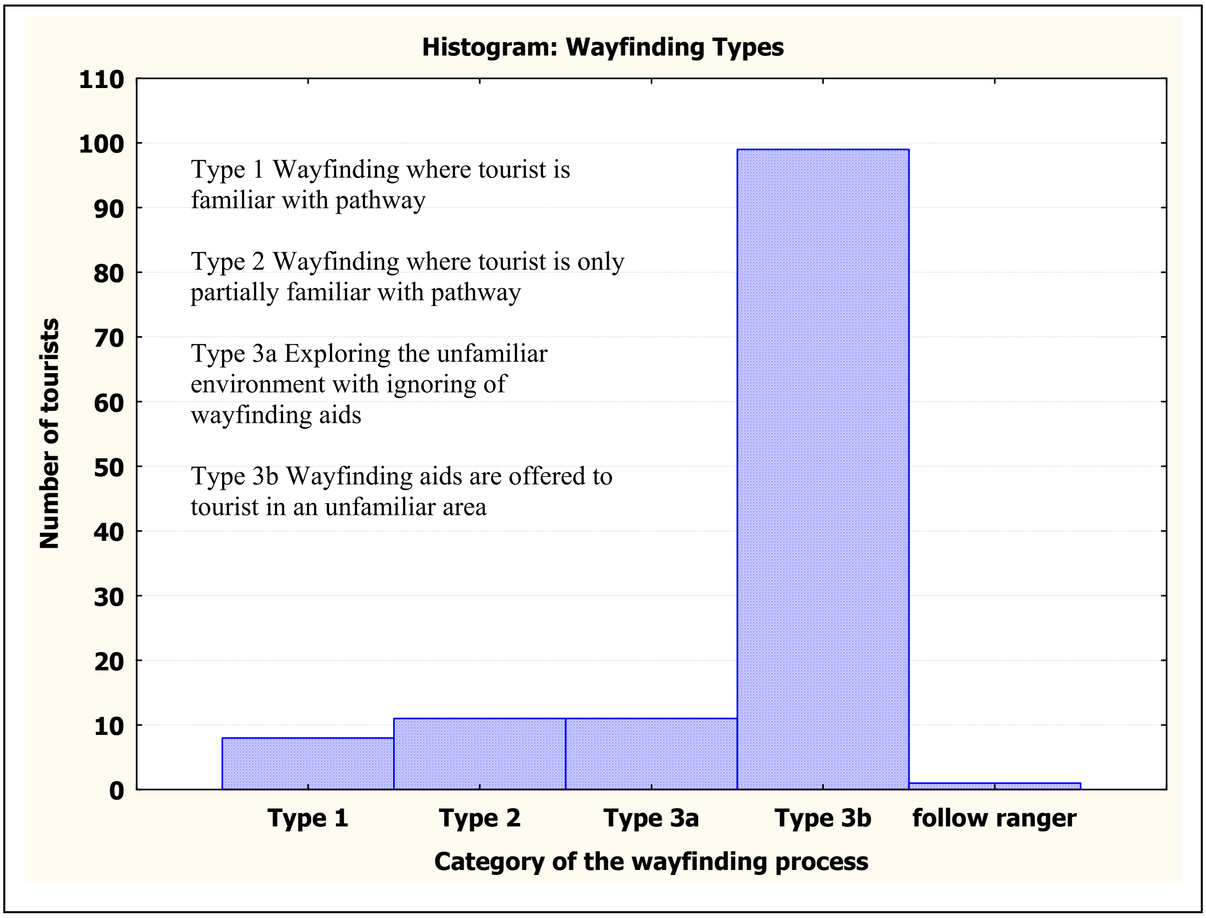

Figure 7.16 Distribution of tourists among different wayfinding types

Landmarks used by tourists to the KCC included a signboard, signposts, track surfaces, vegetation types and visible clusters of other tourists. The signboard at the entrance to the KCC has a general map of tracks and background information (see figure 7.17). Signposts are used to direct people to the various attractions (see figure 7.18). They are usually put at the entrance, intersections, or at the exit of an attraction. Track surfaces were also considered as landmarks for tourists as they provide pathways to walk along giving subconscious direction. Vegetation can be an important landmark particularly where large trees or unusual vegetation species can be discerned. However, due to little variation in vegetation in the KCC, few people identified vegetation as a means for wayfinding. Crowding was seen as an important landmark, particularly in the Koala Woodland area. Respondents were attracted to a crowd because it indicated possible koala sightings.

Figure 7.17 A track map and introduction of the KCC

Figure 7.18 A decision point and a signpost

The signboard and signposts were seen as the major landmarks for wayfinding in the KCC irrespective of familiarity with the centre. It is interesting to find that only two types of visitors used track surface as a landmark. They are first-visit tourists and frequent-visit tourists/tour guide/rangers. More than 41% of tourists who visited the KCC for the first time and nearly 95% tour guides and rangers chose track surface as their principle landmark.

- **Wayfinding Type one**

Tourists belonging to this wayfinding type are familiar with the environment. In this survey, the six tour guides and two rangers who had previously visited the KCC numerous times fell into this type. Of the remaining 126 survey participants, five tourists regarded themselves as being familiar with the KCC.

Because of their familiarity with the KCC, the tour guides and rangers had already built up a comprehensive cognitive map of the centre. Familiar routes used were extracted from their cognitive maps and transformed into actual wayfinding. Landmarks were used merely to facilitate directional change and primarily consisted of pathways along which they were traversing. Minimal, if any, use was made of artificial landmarks such as signposts. Surprisingly, 70 percent of tourists who experience this wayfinding process are male. As previously mentioned, males are more likely to use cardinal directions (Schmitz 1999). Therefore, it is easier for them remember the route and build up a cognitive map.

All participants familiar with the KCC, except for one, visited the Koala Boardwalk. Of these, half walked around the Woodland Walk. Most tourists who visited the Woodland Walk used road I first and walked in an anti-clockwise direction (see figure 7.19). Some of the participants reasoned from previous experience that there was more chance of sighting koalas along road I. Other participants in this category also believed that this route was selected as it was the first one sighted and was considered the shortest route.

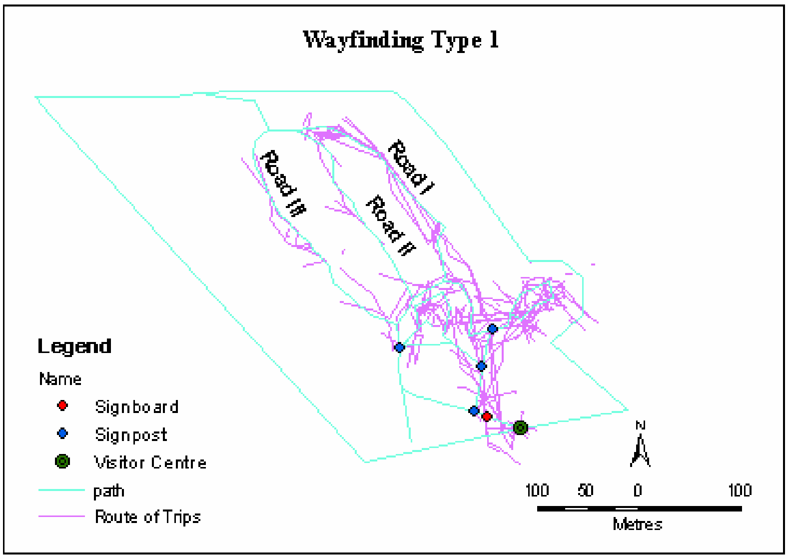

Figure 7.19 Wayfinding type 1

- **Wayfinding Type two**

Tourists in this type are partially familiar with the physical environment through which they are traversing. Eleven of the participants (8%) regarded themselves as being somewhat familiar with the KCC.

All of the tourists in this type visited the Koala Boardwalk, the Woodland Boardwalk and the Visitor Centre. Seven out of eleven tourists walked around Woodland Walk (see figure 7.20). Eight tourists in this type had previously visited the KCC more than twice. In contrast to the first wayfinding type, this type of the tourist used road II and III more often than road I. They walked predominantly in a clockwise direction. Their strategies for wayfinding were based primarily on selection of roads that appeared different from previous ones used. Four out of eleven respondents decided to use these roads based on first sighting.

These tourists, according to the interviews conducted, had previously visited the centre, but had largely forgotten detailed information regarding navigation through the centre. Ten out of the 11 respondents in this type regarded landmarks such as the signposts and signboard as important. Track surface subconsciously assisted navigation and enabled more comprehensive cognitive maps to be developed. However, few respondents answered that the track itself was used as a landmark. In addition, this group was often goal-oriented, wanting to visit specific locations and was therefore conscious of point landmarks (such as signposts) rather than linear landmarks such as pathways.

In contrast to the first type, females tended to be more represented. This confirms Lawton and Kallai (2002) observations that women are more likely to utilise landmark-based route information than men. However, this is based on the condition that these tourists have a low level of familiarity with the location.

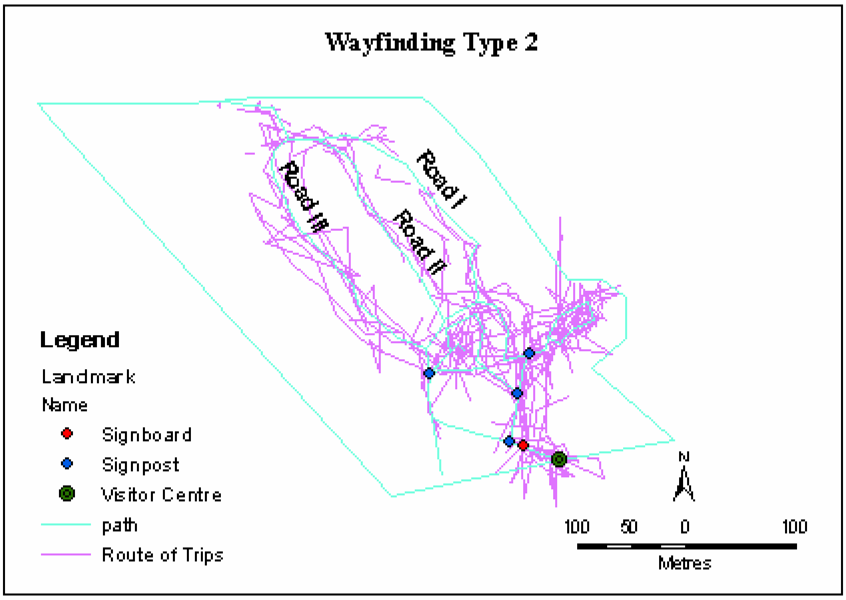

Figure 7.20 Wayfinding type 2

- **Wayfinding Type three**

Of the original 132 participants, 112 participants had not previously visited the KCC and could be classified into the third type. This type can then be further subdivided by the level of use of provided navigational signage.

(1) Without navigational aids (3a)

Eleven out of 111 tourists who traversed around the KCC for the first time ignored the signs and just moved towards areas that looked interesting. During the exploration process they walked randomly and tried to see as much as possible at the KCC. All of these tourists visited the Koala Boardwalk, and Visitor Centre. Ten of the 11 tourists also visited the Woodland Boardwalk and the Woodland Walk (see figure 7.21).

Only one of the 11 respondents used road I and stated they believed there was more chance of sighting a koala in their natural habitat (rather than along a boardwalk). Seven out of the 11 respondents visited the Woodland Walk first and commencing their trips along road III. They walked predominantly in a clockwise direction.

Eight of 11 participants were international tourists. They indicated the main reason for visiting the KCC was to view koalas. They also indicated their desire to experience the natural

Australian environment. In contrast, domestic tourists went there to relax or socialise with family or friends. More than 70% of them in this wayfinding type were younger than 35 years old. More than 90% of them in this type travelled with their partner, friends or just by themselves. Seven out of eleven (64%) travelled with their partners.

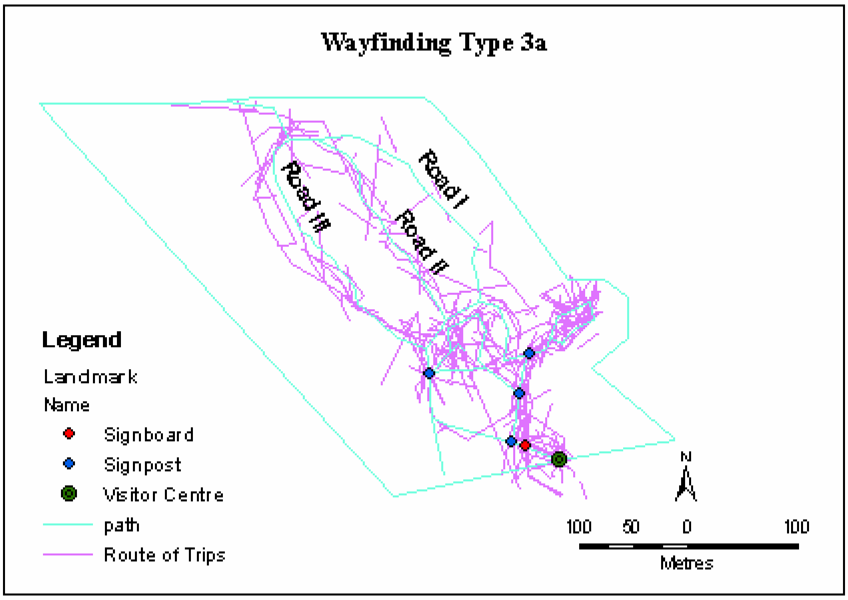

Figure 7.21 Wayfinding type 3a

(2) Using navigational aids (3b)

This was the most popular category for those tourists visiting the KCC for the first time with a total of 99 visitors. These visitors were also unfamiliar with the physical environment but considered landmarks and navigational aids as important. However it should also be noted that apart from the main signboard at the entrance to the KCC there were no maps available to visitors. Therefore these tourists utilised as many landmarks as possible including signboards (81), signposts (78), track surfaces (94), or followed others (24). Their main motivation for visiting the KCC was to view koalas, experience the natural environment, and socialise with other people. More than 45% of them travelled with family (children) and 25.2% travelled with their partners. They expected landmarks to make their wayfinding task easier. Some tourists in this group suggested that park management could employ mobile signposts (that is, each day, rangers could indicate to tourists the location of koalas in the park). More than half of this group were domestic tourists.

Of the 99 participants in this group, 85 visited the visitor centre, 96 the Koala Boardwalk, 90 the Woodland Boardwalk and 76 the Woodland Walk. Slightly more tourists used road III than road II and I (see figure 7.22).

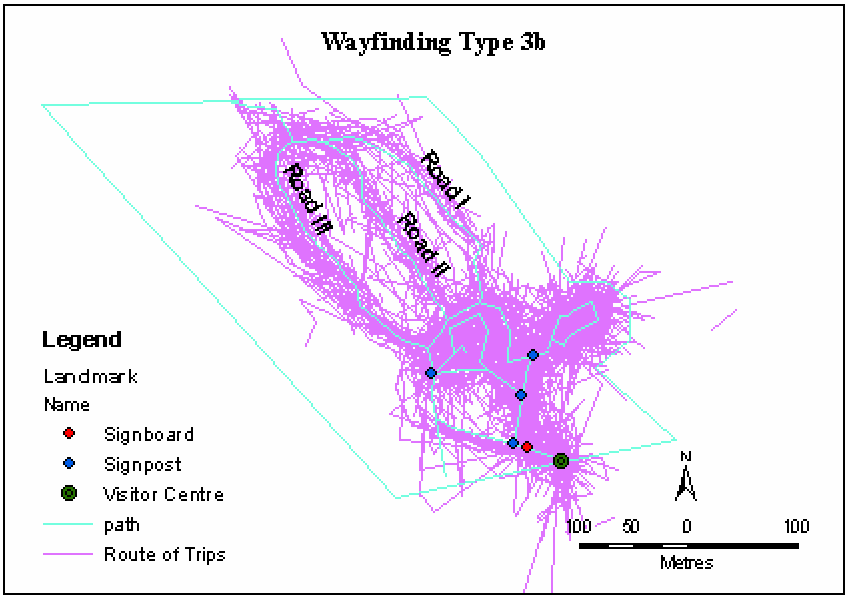

Figure 7.22 Wayfinding type 3b

7.4 FINDINGS AND DISCUSSION OF THE CASE STUDY

Phillip Island provided a local study area in which to develop, validate and calibrate the modelling methodology. It is one of the most popular tourist destinations in Australia. As stated, almost 1.5 million people visit Phillip Island each year. The most important reason to choose Phillip Island as a research area is that it is easier to collect tourist movement data on Phillip Island, because more than 90% of the tourists visiting the island will visit the Penguin Parade at night. Furthermore, the Penguin Parade is usually the last attraction visited by tourists during a one-day trip since the penguins arrive on shore between 7 pm and 10 pm. Thus, many tourists are left with more than an hour waiting for the penguins to come ashore and are therefore happy to fill in questionnaires. The diverse itineraries of tourist trips on Phillip Island are another reason for the determination of research area, because a variety of landscapes (natural, cultural, historic, and urban) are accessible to tourists on Phillip Island.

The review of tracking techniques in chapter 3 found that a combination of several tracking techniques strengthened the overall tracking process. This idea was tested in this case study based on Phillip Island. The study applied the self-administered questionnaire at the macro and micro levels, and applied GPS and interview tracking techniques at the micro level. At the macro level, it was found that the results from the study supported the review findings that there is a high association between the levels of familiarity with the environment and the accuracy of information offered by tourists. Ninety nine percent of participants answered the question about which attractions they visited. However, only 65% of them drew the route of the trip on the map. The finding confirmed the statement by Schmitz (1999) that males are more likely to use cardinal directions, because 71% of tourists who drew the routes are male. In addition to this, results revealed that visitors travelling by car provide a greater accuracy of movement information than visitors travelling by bus (70%:32%). At a micro level, the instability of GPS signals became obvious. This limitation was also summarised in the review. In conclusion, more research needs to be completed in identifying key factors of tourist movements and finding ways in which to improve the method of quantifying and validating wayfinding decision-making processes.

Scale plays an important role in modelling the spatio-temporal movement of tourists. In this case study, the transition of a tourist movement on Phillip Island between the macro and micro levels was visualised based on the spatio-temporal zooming theory. Views of the spatio-temporal movement of tourists at the macro level showed the itinerary of an entire trip. While at the micro level, lifelines illustrated a part of the trip in a detail. This tourist movement transition visualisation technique will enable more flexible ways for displaying tourist movements. This technique not only visualises the transition between the real-time movement of tourists (movement at a time point) and historical movement (movement at a time period), which is called temporal zooming, but also visualises the transitions of tourist movement at different spatial scales such as the macro and micro levels, which is called spatial zooming. The new generation product of mobile mapping, location-based service or security management could be developed based on this technique.

The MC models were applied in modelling the spatio-temporal movement of tourists at the macro level on Phillip Island. The probabilities of movement patterns on this island were calculated. The results showed that in the majority of cases, the MC distributions provided a good fit to data. However, when n is larger the stationary assumption breaks down and the more general equation should be used in such cases.

Log-linear models were applied to test the significance of the movement patterns of tourists at the macro level based on the survey conducted on Phillip Island. SPSS software package was used to implement log-linear models to discover the relationships between movement variables and to test the strength of values of movement variables using *p*-value at the level of 0.05. One limitation of log-linear models is that when the sample size is small, the accuracy of the residual and component chi-square statistics will be affected adversely (Kennedy 1992). Goodman (1984) suggests adding 0.5 to the observed frequencies of movement patterns of tourists, which is adopted by the package SPSS. The outcome from the log-linear models shows that the Goodman's method can effectively overcome the limitation of the log-linear models. A significant outcome of this case study is that the counts or frequencies of significant movement patterns in the sample data are usually around eight to twelve.

Based on the results from the log-linear models, the EM clustering algorithm was implemented to identify tourist characteristics associated with their movement patterns. Tourism market segments for the nine statistically significant movement patterns were identified. The results show that the tourism markets are different for the various movement patterns. Some movement patterns have some unique market segments. For example, for movement pattern BFG, one interesting market segment is First-time domestic tourists who are old couple without children at home travelling with their partner only and spending 1-3 days on Phillip Island.

The tourism market segment with the heaviest users was regarded as a target market for a movement pattern. There are three target markets for Phillip Island:

(1) Repeat domestic tourists from the middle family group travelling with a spouse or partner and children,
(2) First-time international young singles travelling by tour bus or coach with their friends and relatives or alone with an organised group, and
(3) First-time international tourists who are young couples without children or old couples without children at home travelled by car.

Based on the results from the MC models, log-linear models and EM algorithm, nine tour packages were designed for Phillip Island Nature Park. Each tour package includes recommended attractions, a possible schedule for visiting these attractions and a target market for promotion.

This case study also evaluated the models of the wayfinding process. Four wayfinding situations are summarised based on tourist levels of familiarity with the physical environment, whether the trip is pre-planned or unplanned, and differing spatial and temporal scales in chapter 6. All the wayfinding situations are identified in this case study.

In the first model, it was found that those tourists who had previously visited the KCC had already constructed a well developed cognitive map. Seventy percent of tourists who fitted the patterns associated with this model were found to be male. This supports Lawton and Kallai (2002) where they found that males are more likely to use cardinal directions for wayfinding. This type of wayfinding helps people to recall previously travelled routes and add these to their existing cognitive maps. Decision making at the site was found to be unnecessary and the use of landmarks were only employed to facilitate directional change.

The second model exhibits visitors still in the process of developing local cognitive maps. Interaction still exists between decision-making and landmark utility. The role of landmarks is to facilitate wayfinding and path memory. The majority of respondents in this model regarded landmarks such as the signposts and signboard as important. Based on the survey, most tourists in this category were local or domestic visitors and travelled with their family. In contrast to the first category, females dominate numbers in this group and were more likely to utilise landmark-based route information than men. This seems to confirm the findings of Schmitz (1999) who found that women preferred the use of landmarks in wayfinding.

The third and fourth models are based on wayfinding processes where visitation to the tourist location has not been previously undertaken and no cognitive map has been developed before the visitation. In the third model, where navigational aids were not used walking direction became a random process and any change in direction occurred purely by chance, whim or serendipity. Visitors tried to see as much as possible during their exploration process given their time constraints. Landmarks were mainly used to identify the different natural environments and direct the way. No cognitive map was generated (with no pre-planned itinerary prior to the trip). International couples were found to be the most common group of tourist in this category.

Those visitors exhibiting characteristics in the fourth model, where no prior visitation had taken place but nevertheless used offered wayfinding navigational aids was the most popular category encountered in the case study. Wayfinding decisions were based primarily on using landmarks such as direction signs, track surfaces, vegetation types, or clusters of other people. Direction signs were thought to be important for assisting in tourist wayfinding. New navigation technologies such as PDA's, mobile location based services have been recently introduced to facilitate wayfinding. Domestic families were found to be the most common group of tourists in this category.

The application of GPS techniques to record the wayfinding processes of tourists improved the accuracy for data acquisition. Comparisons can be made between assumptions developed in this paper and observed tourist behaviours. This study confirmed findings by Lawton and Kallai (2002) regarding gender differences and techniques for wayfinding. We also found that the type of landmark used was related to the level of familiarity the tourist had with the site. Linear landmarks such as pathways were used more often by those tourists that were either totally familiar or had never visited the site before. It is not clear at this stage what the reasons are for this, however it could be surmised that track surfaces enabled more comprehensive cognitive maps to be developed and that frequent visit tourists had developed more completed cognitive maps of the environment using linear pathways. Based on this assumption, it can be concluded that different landmarks are used to develop cognitive maps for visitors with different levels of familiarity with a site.

The outcome of this case study will assist tourists in scheduling their trips and park managers in promoting tourism or improving park service. For example, signposts can be placed at an attraction to inform tourists about highly related attractions. The estimated MC model could be used to simulate movements process, by incorporating it within a multiagent modelling system, such as RBSim3 (Itami 2003), thereby assisting park managers to simulate sequence of visits using expert knowledge. In addition, understanding of the tourist wayfinding process will help park managers to plan for methods and locations to assist tourists in the wayfinding process.

7.5 CONCLUSIONS

Phillip Island was chosen as the research area. Six steps regarding movement data collecting, visualising, analysing and modelling were included in the case study. The first step was about tourist movement data sampling and acquisition. The aim of this step was to test the assumption that a combination of several tracking techniques can reinforce the overall tracking process, which was derived from the review of tracking techniques in chapter 4. The self-administered questionnaire was applied to track tourists at the macro level. Four hundred and sixty four questionnaires were obtained in two weeks. Interview, self-administered questionnaire and GPS were used to acquire tourist movement data at the micro level. The wayfinding process of 124 tourists, six group tour guides and two rangers were tracked. The results showed that these techniques could obtain tourist movement information efficiently.

The second step of the case study was designed to apply spatio-temporal zooming theory discussed in chapter 3 to visualise the tourist movement and the transition of the spatio-temporal movement of tourists at the macro and micro levels. The spatio-temporal movement of tourists at the macro level aimed to present the general travel patterns for tourist marketing or facility management. However, tourist movements at the micro level emphasised on real-time tracking, location-based service.

The stationary discrete MC theory was applied to model the spatio-temporal movements of tourists at the macro level on Phillip Island in the third step of the case study. The MC theory and model design were described in chapter 5. The probabilities of each movement pattern were calculated and the model was validated using the same data set by the Chi-Square Goodness Fit Test. The results showed that the MC model provided a good fit to data when the number of attractions visited was not too large. However, when the number of attractions visited in a sequence of movements gets larger, the stationary discrete MC is broken down.

Log-linear models were applied to identify the major spatio-temporal movement patterns and hidden patterns in the fourth step of the case study. A statistic package, SPSS was used to implement models. The *p*-value derived from the models indicated the significance of patterns in the data set. The method of using log-linear models to test statistical significant movement patterns was established in chapter 5.

Based on the results from step four, tourists on Phillip Island travelling with statistically significant movement pattern were grouped into different types or segments using clustering methods, i.e., the EM algorithm. This method was discussed in chapter 5. For each significant movement pattern, at least two groups of tourists were identified. The tourist types for the various significant movement patterns were different. Some movement patterns, with which the tourists travelled, created unique market segments. Compared to the other segments, the tourist segment with the highest number of tourists was selected as a target market for a significant movement pattern. Then a tour package was designed based on the results of step three, four and five. Nine tour packages were designed to assist tourists on Phillip Island in developing itinerary of their trips and the park mangers in promoting to the markets.

The last step of the case study was conducted to evaluate models of the tourist wayfinding process at the KCC on Phillip Island. This was established in chapter 6. All types of wayfinding situations; in terms of the levels of familiarity with the physical environment, whether the trips were pre-planned or unplanned, spatial and temporal constrains, were identified from the case study. Relationships between wayfinding decision-making and roles of landmarks, cognitive map generation, the tracks of the trips, tourist profiles and their travel behaviours in these four wayfinding situations were known to be different.

In conclusion, this case study is used to apply and evaluate the theories and methods related to modelling the spatio-temporal movement of tourists. Generally the results from the case study proved that the methods used in this thesis are suitable for modelling the spatio-temporal movement of tourists. The next chapter is the last chapter of this thesis. It will summarise the outcomes of this research along with a discussion on the limitation of the developed models and future research directions

CHAPTER 8 EVALUATION AND CONCLUSIONS

8.1 INTRODUCTION

The previous chapter presented a case study that incorporated the application and evaluation of the models and theories discussed in chapters 3 to 6. This chapter summarises the major findings of this research, discusses the limitation of the theories and methods and applications of modelling the spatio-temporal movement of tourists. This chapter also addresses future directions. The research objectives and research questions set out for this thesis are reiterated to show how these were achieved.

8.2 SUMMARY OF RESEARCH FINDINGS

This section highlights the major findings of the research on modelling the spatio-temporal movement of tourists. These findings include definitions of the spatio-temporal movement of tourists, an application of spatial and temporal zooming theory and significant outcomes of tourist movement models developed in this thesis at the macro and micro levels.

One of the significant outcomes of this research was the definition of the spatio-temporal movement of tourists in terms of spatial and temporal scale. The spatio-temporal movement of tourists was defined at two levels: the macro level and micro level. The macro-level of tourist movement was defined in terms of spatial scale, where movements were determined from one regional location to another some distance away. Tourist movement at the micro level was defined from one spatial point (x, y) to another rather than from one area to another. Sequence of movement can be represented as a collection of spatial points in a coordinate system. Temporal movement of tourists at the macro level was considered in terms of hours, days, weeks or years measured with low resolution. Temporal movement of tourists at the micro level had a high level of resolution to the nearest minute.

The switching between the micro and the macro level of movement was illustrated using spatio-temporal zooming theory. Spatio-temporal movements of tourists at the macro level aimed to represent the general travel patterns (sequence of tourist attractions) for the purposes of tourism marketing or facility management. However, movements of tourists at the micro level emphasised real-time tracking for location-based services.

The application of tracking technologies for tourist movements depends on the research objectives. The results from the data collection step of the case study showed that a combination of several tracking techniques strengthened the overall tracking process. The movement tracking technique of the self-administered questionnaire proved to be a suitable method for obtaining tourist movement data at the macro level. For the movement of tourists at the micro level, GPS, self-administered questionnaire and semi-structured interview were applicable.

The probabilities of movement patterns of tourists were estimated using MC models. One significant outcome from MC models was that it could assist park managers in designing new tour packages for marketing promotion. In addition, the results could also be used as input into agent-based simulations, such as RBSim3, which was designed to evaluate visitor behaviours under differing management scenarios (Itami 2003).

Log-linear models were used to test the significance of spatio-temporal movement patterns of tourists at the macro level. A p-value at the level of *0.05* indicated statistical significance of tourist movement patterns. Discovery of significant spatio-temporal movement patterns of tourists would enable park managers to better understand which attractions are most frequently visited by tourists, and how tourists develop an itinerary for the trip. Therefore, signposts could be put up in attractions to inform tourists about significantly related attractions. Identification of significant temporal movement patterns of tourists could assist park managers in deciding how long to open an attraction and what time activities should be arranged for an attraction.

Nine tour packages were designed for Phillip Island Nature Park. Each tour package included a target market, a sequence of attractions and a possible schedule to visit these attractions by tourists. Two significant outcomes of this case study were firstly, increasing assistance to tourists to arrange their trips and secondly, to assist park managers to promote tourist markets.

Four wayfinding situations were summarised based on tourist levels of familiarity with the physical environment, whether a trip is pre-planned or unplanned and different spatial and temporal constraints. All the situations were identified from the case study. Some other findings from this study are that a cognitive map can be generated by tourist prior to or during the trip. Decision-making was unnecessary for some wayfinding situations. Landmarks are used to facilitate directional change, recognise roads, identify the differences in the natural environment and memorise paths. In addition, tourists of various ages, residency and gender and in different stages of the lifecycle can have different wayfinding behaviours.

People can benefit from the wayfinding models developed in this thesis in two ways. Academic people such as psychologists can obtain demographic information and determine if there are any individual differences associated with wayfinding. Park managers can understand different types of wayfinding behaviours and provide complementary materials to assist tourist wayfinding.

8.3 LIMITATIONS OF THE RESEARCH

This section looks into the limitations of the methods for modelling the spatio-temporal movement of tourists. Limitations regarding survey design and implementation are also discussed.

8.3.1 Limitations of the modelling methods

The MC theory is used extensively in statistical modelling to link a sequence of events together under the assumption of first-order dependence (that is, the future evolution of events is only dependent on its present state). In this thesis, MC methodology was utilised to analyse the outcomes and trends of events associated with tourist spatio-temporal movement patterns.

It was a novel method for modelling the spatio-temporal movement of tourists at the macro level. From the output of the model, it was found that as the number of attractions visited in a sequence of movement gets larger the MC model breaks down and therefore, does not fit the data well. In this case study, the performance of the MC model is still good because there are only seven destinations for tourists on the daily trip. However, if there is a longer sequence of movement higher-order Markov Chains should be considered.

One interesting result from the case study is that the Markov property is not reliable in explaining tourist movement behaviours under certain circumstances. For example, tourists who visited the KCC will probably not visit it again on a single day trip. The MC models cannot accommodate this situation. A suitable model should assign zero or small probabilities to tourist returning to attractions that have already been visited.

One important issue for utilisation of Log-linear models is sample size. When the sample size is small, the accuracy of the residual and component chi-square statistics will be affected adversely (Kennedy 1992). In particular, when the frequencies of movement patterns are zero, the log of zero will be $-\infty$. Consequently, the likelihood ratio Chi-square G^2 becomes meaningless. Goodman (1984) suggests adding 0.5 to the observed frequencies of movement patterns of tourists. The package SPSS adopts this method. Agresti (1990) recommends that an extremely small constant (such as 10^{-8}) can be added to the cell frequencies. Both methods can overcome the difficulties with the chi-square. But if zero is recorded too often as the frequency of movement patterns, the expected frequencies of movement patterns will converge to zero during iterative fitting. Therefore, a big sample size is necessary (Kennedy 1992).

The EM algorithm implements a statistical model to identify tourism market segments for each significant movement pattern of tourists. If appropriate, an optimal result will be achieved from the algorithm. However, the lack of explanation of tourism market segments is one of the limitations of the EM algorithm. Sometimes, expert experience or knowledge is needed to identify the characteristics of tourism market segments. Witten and Frank (2000) suggest that a supervised model, namely, the classification method, could be used to analyse the results outputted from the EM algorithm.

In this thesis, variables such as tourist spatial and social abilities, their knowledge of the region they are visiting, their levels of familiarity with the environment, their individual motivation, their spatial and temporal constraints and the configuration of the physical environment were used to build the wayfinding decision-making models. However, there could be other variables, such as physical limitations of tourists, which this thesis did not consider. Therefore, inclusion of more variables in the cognitive model can optimise the model, which is another direction for the future research.

8.3.2 Limitations of the survey design and implementation

Two surveys were conducted from 6-8 March 2004 and from 17-20 January 2005 on Phillip Island. The survey included nine attractions as tourist destinations on this island. Four attractions: the Penguin Parade, the KCC, Churchill Island, and the Phillip Island Information Centre were chosen as sampling locations. As mentioned in section 7.3.1, most questionnaires were collected from the Penguin Parade. Therefore, nearly 5% of tourists who did not visit these four attractions could have been missed by the surveys. (Particularly, domestic tourists who preferred to stay elsewhere or to surf or swim at beaches during their visit).

Another limitation of the case study is the sampling time. Both surveys were conducted in the high season. Therefore, low seasonal tourist behaviour was not tracked. During the low season, especially winter, 30-50% fewer tourists visit Phillip Island and the number of attractions that the tourists visit during their daily trip could be smaller (Phillip Island Nature Park 2001-02). Comparison of movement behaviour between the high and low seasons could be the subject of further research in the future.

Finally the sample size is questionable. Different types of data analysis need different sample sizes. For example, 464 self-administered questionnaires for tracking movement at the macro level, and 132 movement records tracked by GPS along with questionnaires at the micro level were collected from Phillip Island. The sample sizes at both levels are suitable for most analyses conducted in this thesis. However, for data mining methods, especially for classification, which is used to identify the differences between tourist groups, a larger sample size is required (Witten and Frank 2000). Therefore, in this thesis, the classification method was not adopted.

8.4 FUTURE RESEARCH DIRECTIONS

Modelling the spatio-temporal movement of tourists is a new research area. This thesis established a theoretical framework and developed a methodology for this research area. At the macro level, the physical movement of tourists was modelled, while at the micro level, the wayfinding decision-making process was concentrated. In the future, further research on physical movement modelling at the micro level, especially real-time movement tracking, simulation and modelling should be undertaken. The methods used to explore interactions between spatial and temporal movement would be another interesting direction for future study. The wayfinding models established in this thesis are conceptual models. The next stage should consider whether other factors affect the wayfinding decision-making process. A computational model should be developed based on these factors. In addition, new navigation technologies could change wayfinding behaviour in a dramatic way. The next research stage should apply mobile technologies to support the wayfinding decision-making process in unfamiliar settings.

8.4.1 Modelling of the spatio-temporal movement of tourists using non-stationary Markov Chains

The assumption of a stationary MC is that the probability of moving from one state to another is invariant of the time at which the jump takes place. However, when the number of attractions visited in a sequence of movement gets larger, for example, when movement sequences are up to six or seven, the MC models prove unable to predict the probabilities of movement patterns accurately. This is very likely caused by the *stationary assumption*. Transition probability from one attraction to another will be higher if it is in the early stage of movement. Therefore, the *non-stationary* MC models approach should be adopted to model spatio-temporal movements of tourists, and the results from these two approaches should be compared.

8.4.2 Application of mobile technologies to support the wayfinding decision-making process in unfamiliar settings

One significant finding of this research is that the roles of landmarks in tourist wayfinding navigation are different in the four wayfinding situations. However, new navigation technologies such as PDA and mobile location-based services could change people's wayfinding behaviours in a dramatic way. It is not necessary to built cognitive maps before travelling, the PDA will track and navigate tourist's movement and help tourists navigate around attractions. Landmarks, therefore, will be used by tourists to match the real world with the map provided by the PDA. Future research should focus on trying to understand the effect of mobile technologies on tourist wayfinding decision-making in unfamiliar settings.

8.4.3 Transition between the different levels of tourist movements

Scale plays an important role in modelling the spatio-temporal movement of tourists. In this thesis, scale issues are reviewed and analysed in terms of definition of movement, movement tracking techniques, data mode, and data analysis. Scale is discussed as part of a hierarchical structure. The number of levels of hierarchy (scale) is dependent on the application. Transition between two levels of movement is illustrated based on the spatio-temporal zooming theory. In the next stage, a study will customise either the tracking analysis package of ArcGIS software (ESRI 2004) or a space-time information system (STIS) developed by TerraSeer, Inc (Jacquez 2004) to simulate the simultaneous dynamic movement at the macro and micro levels.

8.4.4 Interaction between tourist spatial and temporal movements

Establishing a method to identify interactions between spatial and temporal movement of tourists is another subject for future research. For example, how will the variation of start time on Phillip Island affect the spatial movement sequence of tourists? Is there any association between the type of tourist attraction and arrival time of the tourists? Are there any associations between arrival time at an attraction and duration of visits? What is the variance in the duration for each attraction? How will the time spent at the first attraction influence the number of attractions visited by tourists during a single day trip? Some statistical methods, such as interaction plots, cross-tabulation, and logistic regression should be used to answer these questions.

8.4.5 Data mining methods on tourist transaction data

The EM algorithm has been used in this thesis for tourism market segmentation based on the significant movement patterns of tourists and tour package design. In future, tourist transaction data should be applied because there are a large number of transactions in the Phillip Island Natural Park every day. The tourist transaction data can record the tourist ID numbers, the ID numbers of attractions that tourists visited, dates of the transaction, and in-store tourist information such as tourist profiles. Therefore, based on these transaction records, tourist movement patterns can be identified and market segments can be discovered. However, this method is only suitable for developed attractions, which means that the attractions should have their own information centre and EFTPOS (Electronic Funds Transfer at the Point Of Sale) machines. Tourists would purchase something like entrance tickets or tourist souvenirs with their card. In addition, the privacy issues regarding the use of transaction data should also be of concern.

8.4.6 Tourism management issues related to tourist movement modelling

There are many issues relating to tourist movement modelling, for example, tourism facility management, tourism marketing management, tourism service management. This thesis addressed the link between tourism marketing management and tourist movement modelling. However, more interesting tourist movement modelling research could be conducted to facilitate in tourism management. For example, by understanding the spatio-temporal movement of tourists could assist park managers in deciding how long to open an attraction, what time activities should be arranged for an attraction, where to put up signposts to inform tourists about significantly related attractions, whether peak tourist flows over the transport infrastructure capacity or accommodation facilities and whether a better models can be designed to examine alternate transportation scenarios to minimise tourist conflict issues.

8.5 DID THE STUDY MEET ITS OBJECTIVES?

The main objective of this research was to develop a methodology for modelling the spatio-temporal movement of tourists at the macro and micro levels. A number of questions have arisen while attempting to achieve this objective.

The first research question dealt with spatial and temporal scale issues relating to modelling the spatio-temporal movement of tourists. Chapter 3 defined the spatio-temporal movement of tourists at two levels: the macro and micro levels. The spatial and temporal zooming theory was used to examine the transition between the spatio-temporal movement of tourists at the macro and micro levels. The second research question concerned the characteristics of the spatio-temporal movement of tourists. Also in chapter 3, the definition, database design and representation of the spatio-temporal movement of tourists at the both levels were discussed and compared.

The next research question was answered in chapter 4. In this chapter, the techniques of counting and tracking tourist movements were reviewed and compared. The advantages and disadvantages of the techniques were discussed and suitable applications for the techniques were presented. In addition, the appropriate techniques for counting and tracking the spatio-temporal movement of tourists at the micro and micro levels were investigated. The data collection step of the case study in chapter 7 applied the tracking techniques of the self-administered questionnaire to acquire the tourist movement data at the macro level, and of the self-administered questionnaire, interview and GPS to track tourists at the micro level.

Chapter 2 reviewed tourist movement models extensively used in different disciplines and determined the methods for modelling the spatio-temporal movement of tourist at the macro level and for modelling the tourist wayfinding processes at the micro level, which answered the fourth and part of eighth research questions.

The fifth, sixth and seventh research questions regarding the modelling of tourist movement at the macro level were answered in chapter 5. The fourth research question was answered by modelling the process of tourist movement and estimating the probabilities of tourist movement patterns at the macro level using MC models in section 5.2. A method to test the significance of movement patterns of tourists using log-linear model was discussed in section 5.3, which answered the fifth research question. The sixth research question deals with tourism market segmentation. Section 5.4 outlined the procedure of tourism market segmentation based on significant movement patterns of tourists. The EM algorithm was used to segment tourist markets. The methods developed in chapter 5 were evaluated and validated in steps 3 to 5 of the case study in chapter 7.

The eighth, ninth and tenth research questions focused on modelling the tourist wayfinding process at the micro level. Factors that could affect the tourist wayfinding decision-making process were reviewed and analysed in section 3.4. These included motivation of trip, configuration of physical environment, spatial and temporal constraints, spatial ability, social ability and levels of familiarity with environment. This answered research question 8. The ninth research question was answered in chapter 6. Four cognitive wayfinding models were developed based on the reviews of wayfinding factors in this chapter. Chapter 6 also answered the tenth research question, which was to clarify the relationship between the roles of landmarks and tourist wayfinding decision-making. Step 6 of the case study in chapter 7 evaluated these four models using the micro level movement data of tourists collected from the KCC on Phillip Island.

Through addressing all of the research questions, a comprehensive method enabling tourist agencies, park managers and tourist organisations to model the spatial and temporal movement patterns of visitors to tourist locations has been developed in this thesis. These spatial and temporal movements can be geographically wide (macro level) or localised (micro level) or for an extended period (macro level) or for a short time interval (micro level). In developing this methodology, the objective of modelling the spatio-temporal movement of tourists has been achieved.

8.6 CONCLUSIONS

In conclusion, this thesis has established a methodology for modelling the spatio-temporal movement of tourists at the macro and micro levels. A case study undertaken on Phillip Island was used to apply and evaluate models and theories related to the spatio-temporal movement of tourists. The methodology developed in this thesis combined mathematical modelling methods, cognitive modelling methods and GIS and GPS techniques. Geographic information System is the platform for visualising the movement data of tourists collected from GPS recordings. The cognitive modelling methods examined tourist decision-making during the wayfinding process, the factors that could affect tourist wayfinding decision-making at the micro level and in particular the roles of landmarks for wayfinding decision-making. Wayfinding behaviours can be predicted by cognitive models. The cognitive wayfinding models in this thesis were established from literature reviews and commonly shared understanding of tourist wayfinding behaviours. On the other hand, mathematical models, such as MC and log-linear models predicted attraction choices of tourists and represent the uncertainty sequence of attraction choice (movement patterns) as probabilities. Both cognitive models and mathematical models can assist park managers better understand tourist movement behaviours. Mathematical models were used at the macro level of movement to present probabilities of sequence of attractions visited by tourists. Cognitive wayfinding models focused on the micro level movement of tourists to explain why particular behaviours of tourists could occur.

Tourism is one of the most rapidly developing industries in the world. The methodology developed in this thesis can assist tourists, tourist agencies and tour operators in designing tour itinerates and packages and help tourist organisations improve facility management. This methodology can also be used to further clarify and develop the knowledge of tourist movements. One of the significant outcomes of this thesis is to clarify the scale issues in modelling the spatio-temporal movement of tourists. At the micro level, tourist movements are specified within a facility (such as the KCC), while the macro level movement focus on tourist movements from one area to another such as an attraction, a country or even around the world. Therefore, researchers from different disciplines can share their knowledge in this area. People working outside the tourism industry can also benefit from this research. For example, the Markov Chain models developed in this thesis can be applied to city transportation planning of future infrastructure in anticipation of increasing volumes of traffic. The review of tracking and counting techniques can provide guidance in the other research projects that aim to model people or vehicle movement, for example, the international movement of freight.

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APPENDIX 1: QUESTIONNAIRE AT THE MACRO LEVEL

RMIT UNIVERSITY

Department of
Geospatial Science
and the
Geospatial Science Initiative

Excellence in:
- GIS & Remote Sensing
- Measurement Science
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3 March 2004

Project title: Developing Agent Rules for International Tourists

Dear Participants:

My name is Jianhong (Cecilia) Xia and I am a Doctor of Philosophy student at RMIT University in the Department of Geospatial Information. My Supervisor is Dr Colin Arrowsmith who is a Senior Lecturer in the same department. We are currently undertaking a joint project with the Phillip Island Nature Park that aims to understand how visitors use parks, what their needs are and how their satisfaction could be enhanced. The title of project is ***'Developing Agent Rules for International Tourists'***. This project has been approved by the RMIT University Human Research Ethics Committee.

Your participation in this research will involve filling in a questionnaire designed to ascertain basic visiting patterns and socio-demographic data. The questionnaire will take no longer than 10 minutes of your time. The questionnaire is designed to find out more about how you use Phillip Island, what you would like to see and how your satisfaction could be enhanced whilst at Phillip Island. The collected data will make it possible to quantify and classify current park visitors based their upon socio-demographic background, group type and motivation for visit. This will allow park managers to develop more effective and efficient strategies for managing natural and recreation resource in parks. Participation in this research is voluntary and you may withdraw at anytime. We welcome you to examine the study materials before deciding whether you wish to participate.

The data collected will be analysed and aggregated for publishing in professional journals. Because the data will be generalised individual responses will not be identified and your anonymity will be protected. All individual responses will be destroyed at the end of the research.

If you have any queries regarding this project please contact Cecilia Xia on (03) 9925 3277, Email X02250@ems.rimt.edu.au or Colin Arrowsmith (BSurv, MSurvSc, MEnvS (Melb), GradDipEd (HIE), PhD (RMIT)) on (03) 9925 2042, email colin.arrowsmith@rmit.edu.au.

Yours faithfully

Cecilia Xia and Colin Arrowsmith

Any complaints about your participation in this project may be directed to the Secretary, RMIT Human Research Ethics Committee, University Secretariat, RMIT, GPO Box 2476V, Melbourne, 3001. The telephone number is (03) 9925 1745.

Phillip Island Nature Park

This letter is to confirm that we are working with Jianhong (Cecilia) Xia to conduct a tourism survey to gain information about tourist and visitor travel patterns and their expectations of Phillip Island Nature Park.

This research forms part of Jianhong Xia Doctor of Philosophy studies and Phillip Island Nature Park fully supports the research study that is being conducted throughout the park and on Phillip Island.

Kind regards,

Garry Burns
Director of Marketing - International

Churchill Island Koalas The Nobbies Penguin Parade Rhyll Inlet Woolamai

P.O. BOX 97, COWES, PHILLIP ISLAND 3922 PH: 03 5951 2800 FAX: 03 5956 8394 WEBSITE: www.penguins.org.au

PRE-VISITOR SURVEY
PHILLIP ISLAND NATURE PARK

Dear Sir/Madam,

In order to promote Phillip Island as tourist attraction we are conducting a survey to gain information about tourists and visitors travel patterns and their expectations of Phillip Island and how well their expectation was met.

We thank you for your time and assistance.

Date:______________ Location of survey:___________

Time:_________________________

Weather (Please tick one box only):

Sunny ☐ Fine ☐ Partly cloudy ☐ Overcast ☐ Raining ☐ Other ____________

Q.1 How did you originally hear about Phillip Island (Please tick all that apply)?

Holiday brochure/travel shop ☐ Word of mouth ☐ Tourist information centre ☐ Local radio or TV ☐
Newspaper/magazine ☐ Website ☐ Other (Please specific) ____________

Q.2 Is this your first visit to Phillip Island? Yes ☐ No ☐

If no, please go to question 3

If yes, please go to question 4

Q.3 Including today's visit, how many times would you have visited Phillip Island (Please tick one box only)?

Once ☐ Twice ☐ Three times ☐ More than three times ☐

Q.4 Why are you visiting Phillip Island today (Please tick all that apply)?

As a part of holidays, leisure and recreation ☐ For educational purposes ☐ For business purposes ☐
To accompany friends or relatives ☐ Group tour ☐
Other (Please specific) ____________________

Q. 5 Including yourself, how many people are in your party on this trip to the Island? Write in: ___________

Q. 6 Which best describes the type of group you are travelling in (Please tick one box only)?

Travelling alone ☐
Travelling with spouse/partner only ☐
Travelling with spouse/partner and children ☐
Travelling with friends/relatives ☐
Travelling in organised group/club ☐

Q.7 How long do you expect your visit to Phillip Island will last (Please tick one box only)?

Less than 1 hour ☐ Half a day ☐ All day ☐ 1-3 days ☐ 1 week ☐ More than 1 week ☐

Q. 8 If you are staying on Phillip Island, where will you stay (Please tick one box only)?

Hotel/motel ☐ Bed & Breakfast/Guest House/Homestead ☐ Caravan/Camping ☐
Beachside Apartments ☐ Self-contained Cottages ☐ Other ____________

Q. 9 Which lifecycle category best describes you (Please tick one box only)?

Young single ☐ Mature family (Children older than 15 years) ☐
Young couple/no children ☐ Older couple/no children at home ☐
Young family (Youngest child younger than 6 years) ☐ Mature single ☐
Middle family (Children 6-15 years) ☐

Q.10 How did you rate your expectation of the following tourist facilities and services prior to your visit today?

Questions	Very Low	Low	Average	Above average	High
A Car parking will be adequate, safe and secure					
B Tracks and paths will be well maintained					
C Directional road signs will be clear and helpful					
D Pre-visit information (brochures, website, etc.) will be timely and helpful					
E BBQs, picnic area will be adequate, accessible and clean					
F Kiosks/cafes/food outlets will be sufficient and accessible					
G The quality and range of food will be good and sufficient					
H Toilets will be sufficient, accessible and clean					
I The site will not be over crowded					
J Staff will be friendly					
K Staff will be knowledgeable					
L Information will be provided at the site					

Q. 11 Are you:

Male ☐ Female ☐

Q.12 Place of residence (Please tick one box only)

1. Australia Postcode ☐

2. Overseas Country ☐ (Please go to Q14)

Q.13 Were you born in Australia? Yes ☐ No ☐

If no, where were you born? ____________________

Q.14 How long have you been in Australia?

Days ☐ Months ☐ Years ☐

Q.15 Which best describes the highest level of education you have reached (Please tick one box only)?

Primary ☐ Some secondary ☐ Completed secondary ☐
Tertiary ☐

Q.16 Which age group are you in (Please tick one box only)?

18-29 YEARS ☐ 30-39 YEARS ☐ 40-49 YEARS ☐
50-59 YEARS ☐ 60 + YEARS ☐

Congratulations! You have finished pre-survey now. If you have time could you fill in post-survey in the following page during or after your trip please? Thank you very much

POST-VISITOR SURVEY
PHILLIP ISLAND NATURE PARK

Q. 1 What form of transport did you use to get and travel around Phillip Island? (Please tick one box only)

1. Walk	
2. Passenger (2WD) vehicle	
3. 4WD vehicle	
4. Campervan/motorhome	
5. Motorcycle	
6. Tour bus/coach	

7. Other (Please specify)____________________________

Q.2 Which activities have you participated in during this visit to Phillip Island? (Tick all those that are applicable)

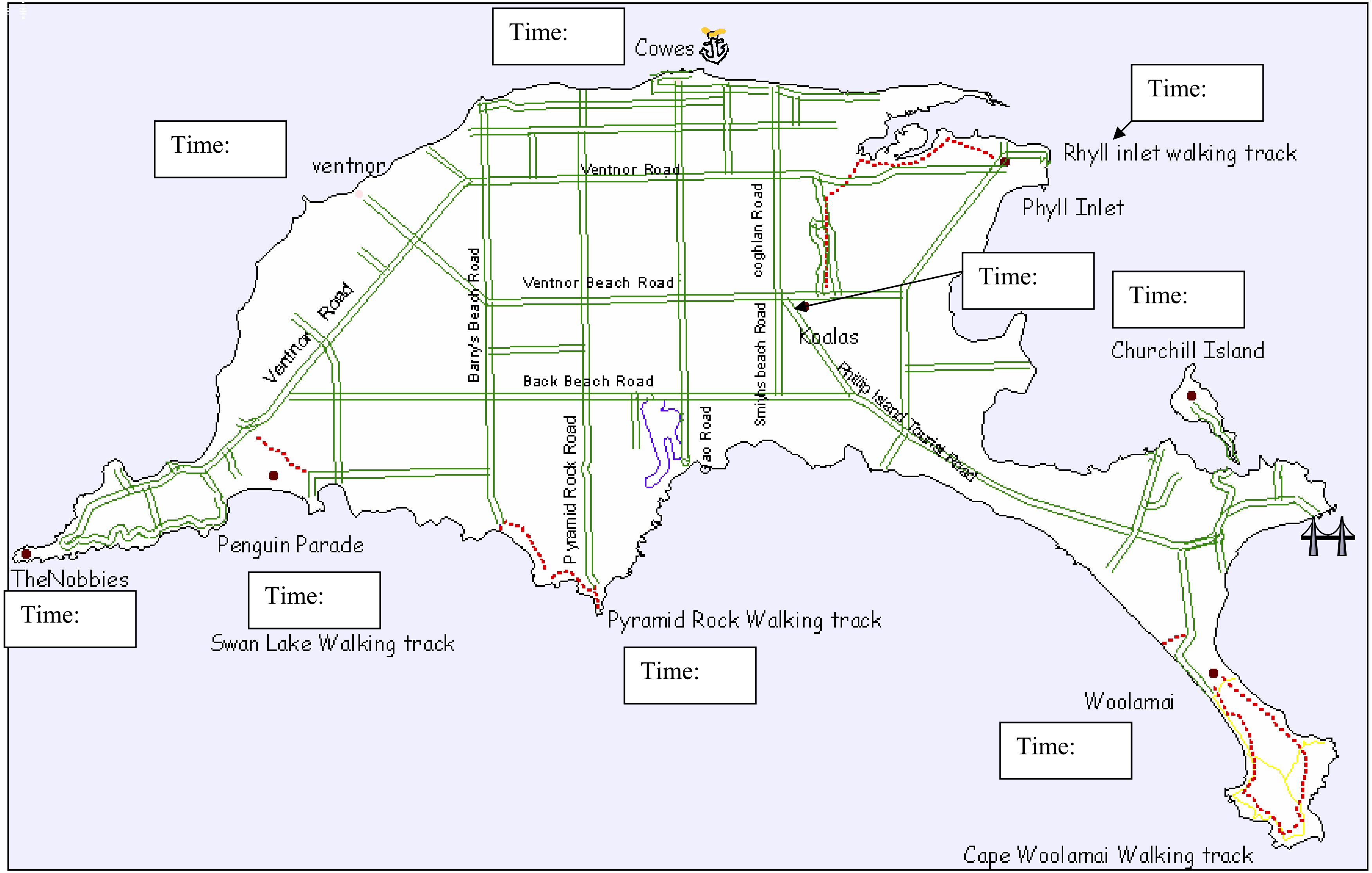
1. Wildlife viewing	
2. Sightseeing/scenic driving	
3. Photography	
4. Picnic/barbeque	
5. Cycling	
6. Surfing	
7. Sailing	
8. Walking	
9. Swimming or snorkelling	
10. Camping or caravanning	
11. Commercial tour	
12. Self guide tour	

13. Other (Please specify) ____________________________

Q.3 During this visit, could you write down the amount of time you have spent at each site , and give an indication of whether you felt you would have liked to have spent more (or less) time at each site on Phillip Island?

Sites	Hours	More	Less	Just Right
1. Penguin Parade				
2. Koala Conservation Centre				
3. Churchill Island				
4. Rhyll Inlet				
5. Cape Woolamai				
6. The Nobbies/Seal Rock				
7. Cowes				
8. Walking Track (e.g. Cape Woolamai, Rhyll Inlet, Oswin Roberts, Swan Lake, Pyramid Roke)				
9. Other (Please specify)				

Q.4 Could you please draw an outline of the route you took and write down the approximate time you arrived at each destination?



Q. 5 Could you please rank how important each sites was to you on Phillip Island?

Q. 6 In term of attractiveness, interest, facilities, provision, and service, how well was your expectation of Phillip Island you visited today met? (Tick one box only for each item)

Questions	Not at all	Slightly	Met expectation	Slightly exceeded	Well Exceeded
A Car parking should be adequate, safe and secure					
B Tracks and paths should be well maintained					
C Directional road signs should be clear and helpful					
D Pre-visit information (brochures, website, etc.) should be timely and helpful					
E BBQs, picnic area should be adequate, accessible and clean					
F Kiosks/cafes/food outlets should be sufficient and accessible					
G The quality and range of food should be good and sufficient					
H Toilets should be sufficient, accessible and clean					
I The site should not over crowded					
J Staff should be friendly					
K Staff should be knowledgeable					
L Information should be provided at the site					

Q.7 How long did your visit to Phillip Island last today (Please tick one box only)?

Less than 1 hour ☐ Half a day ☐ All day ☐ 1-3 day ☐ 1 week ☐ More than 1 week ☐

Congratulations! You have finished the whole survey now. Could you please return the questionnaires to the collection box in the general information centre or Penguin Parade information centre?

Thank you for your time.

APPENDIX 2: QUESTIONNAIRE AT THE MICRO LEVEL

RMIT UNIVERSITY

Department of
Geospatial Science
and the
Geospatial Science Initiative

Excellence in:
- GIS & Remote Sensing
- Measurement Science
- Multimedia & Visualisation
- Risk & Community Safety
- Sustainable Development

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Jan 2005

Project title: Developing Agent-base Simulation for Querying Tourist Spatio-temporal Movement Pattern on Phillip Island

Dear Participant

My name is Jianhong (Cecilia) Xia and I am a Doctor of Philosophy student at RMIT University in the Department of Geospatial Information. My Supervisor is Dr Colin Arrowsmith who is a Senior Lecturer in the same department. We are currently undertaking a joint project with the Phillip Island Nature Park that part of aims to understand how visitors find their way in Koala Conservation Centre. The title of project is **'*Developing Agent-base Simulation for Querying Tourist Spatio-temporal Movement Pattern on Phillip Island* '**. This project has been approved by the RMIT University Human Research Ethics Committee.

Your participation in this research will involve three components in the survey: filling in a questionnaire designed to ascertain basic visiting patterns and socio-demographic data before your visit, tracking your movement using GPS (Global Positioning System) during your visit, Answering few questions designed to identify which landmarks and how landmarks help you find your way or how you find your way after your visit. The questionnaire and interview will take no longer than 15 minutes of your time. The collected data allow park managers to better understand your behaviour and offer more customised services and develop more effective and efficient strategies for managing natural and recreation resource in parks. Participation in this research is voluntary and you may withdraw at anytime. We welcome you to examine the study materials before deciding whether you wish to participate.

The data collected will be analysed and aggregated for publishing in professional journals. Because the data will be generalised individual responses will not be identified and your anonymity will be protected. All individual responses will be destroyed at the end of the research.

If you have any queries regarding this project please contact Cecilia Xia on (03) 9925 3277, Email X02250@ems.rimt.edu.au or Colin Arrowsmith (BSurv, MSurvSc, MEnvS (Melb), GradDipEd (HIE), PhD (RMIT)) on (03) 9925 2042, email colin.arrowsmith@rmit.edu.au.

Yours faithfully

Cecilia Xia and Colin Arrowsmith

Any complaints about your participation in this project may be directed to the Secretary, RMIT Human Research Ethics Committee, University Secretariat, RMIT, GPO Box 2476V, Melbourne, 3001. The telephone number is (03) 9925 1745.

Phillip Island Nature Park

This letter is to confirm that we are working with Jianhong (Cecilia) Xia to conduct a tourism survey to gain information about tourist and visitor travel patterns and their expectations of Phillip Island Nature Park.

This research forms part of Jianhong Xia Doctor of Philosophy studies and Phillip Island Nature Park fully supports the research study that is being conducted throughout the park and on Phillip Island.

Kind regards,

Garry Burns
Director of Marketing - International

P.O. Box 97, Cowes, Phillip Island 3922 **Ph:** 03 5951 2800 **Fax:** 03 5956 8394 **Website:** www.penguins.org.au

PRE-VISITOR SURVEY
PHILLIP ISLAND NATURE PARK

Date:______________ Time:________________________

Weather (Please tick one box only):

Sunny ☐ Fine ☐ Partly cloudy ☐ Overcast ☐ Raining ☐

Q. 1 Including this visit, how many times have you visited Koala Conservation Centre? Write in: ___________
If your answer to Q1 is 1 → GO TO QUESTION 3

Q. 2 If you have visited Koala Conservation Centre more than once, when approximately was the last time? (Tick one box only)

1 Less than 1 month ago ☐
2 More than 1 month, but less than 1 year ago ☐
3 Between 1 year and 5 years ago ☐
4 More than 5 years ago ☐

Q. 3 What time did you commence your touring today? Write in: ___________

Q. 4 Why are you visiting the Koala Conservation Centre today? (Please tick all that apply)

To rest and relax ☐	To socialise with family/friends ☐	To view Koalas in their natural environment ☐
To experience a natural environment ☐	To escape the everyday routine ☐	To work as a tour guide ☐

Other (Please specify) : ________________

Q. 5 Which best describes the type of group you are travelling in (Please tick one box only)?

1 Individual
2 A couple
3 Family
4 Friends
5 Family and friends
6 Club/organisation
7 Commercial tour group
8 Special interest group
9 School group
10 Other (please specify): ______________________

Q. 6 In question 5, if you answered No. 7 (Commercial tour group) then what is the maximum time limit for you to visit the Koala Conservation Centre? Write in: ___________ mins

If you answered No. 1-6 or 8-10 what is the estimated time for you to visit the Koala Conservation Centre? Write in: ___________ mins

Q. 7 Are you:

Male ☐ Female ☐

Q. 8 Place of residence (Please tick one box only)

1. Australia Postcode ☐

2. Overseas Country ☐

Q.9 Which best describes the highest level of education you have reached (Please tick one box only)?

Secondary school education ☐ Technical/TAFE education ☐ Tertiary (university) education ☐
Post tertiary (post-graduated) education ☐

Q.10 Which age group are you in (Please tick one box only)?

18-24 YEARS ☐ 25-34 YEARS ☐ 25-34 YEARS ☐
45-54 YEARS ☐ 55-64 YEARS ☐ 65+ YEARS ☐

POST-VISITOR SURVEY
PHILLIP ISLAND NATURE PARK

Q.1 Which of the sites did you visit in the Koala Conservation Centre today (Please tick all that apply)?

Visitor Centre ☐ Koala Boardwalk ☐ Woodland Boardwalk ☐
Woodland (bush) walk ☐ Don't know ☐ Other (Please specify:) ________________

Q.2 Do you use landmarks (such as signposts, other people) to find your ways around the koala Conservation Centre? Yes ☐ No ☐

If no, How did you find your way around Koala Conservation Centre? → Please go to question 4

____

____

If yes, please go to question 3

Q. 3 Which of the following landmarks that influenced or helped you navigate around the Koala Conservation Centre (Please tick all that apply)?

1. Sign board ☐ 2. Signpost ☐ 3. Track surface ☐ 4. Vegetation type ☐
5. Saw other people there and decided to go there ☐ 6. Saw other people there and decided not to go there ☐
7. Others (Please specify):________________________

Q. 4 What were the strategies that you used to find your way in the Koala Conservation Centre (Please tick all that apply)?

Shortest path ☐ Least time ☐ Fewest turns ☐ Most scenic or aesthetic ☐
First noticed ☐ Different from previous route taken ☐

Q. 5Which type of tourists do you think you belong to when you navigated around the Koala Conservation Centre (Please tick one box only)?

☐ I am very familiar with the Koala Conservation Centre, I need not make decision to find my way here, I walk around the centre according to my memory

☐ I have been the Koala Conservation Centre several times, I know what attractions are in the centre, but I am not very sure where it is, so I still need to follow the signs to find my way here (partially familiar with the centre)

☐ It is my first time to visit the Koala Conservation Centre, I follow my interest to walk around (exploration in an unfamiliar situation)

☐ It is my first time to visit the Koala Conservation Centre, I follow signs (or landmarks) to walk around

Thank you for your time.