CHAPTER ONE
Introduction

Wayfinding is a fundamental spatial activity that people experience in their daily lives. It can be described as purposive and motivated movement by an individual to a specific and distant destination that cannot be seen directly (Heft, 1983; Garling *et al*., 1984; Blades 1991; Golledge, 1992). Wayfinding is also an interactive behaviour between people and their environments. The environment is a dynamic source of information used by people in their wayfinding decision-making processes. Lynch (1960), in his seminal work, suggests that during wayfinding "there is a consistent use and organization of definite sensory cues from the external environment". Furthermore, wayfinding is a form of spatial problem solving. Thus, during wayfinding activities, people undertake a sequential process of decision making in which the purpose is to match internal with external information as it is obtained (Stern and Portugali, 1999). There is a clear consensus, in wayfinding research, that differences exist between the environments that people perceive subjectively, and in the way people acquire, develop and use spatial information for their wayfinding activities (Golledge, 1999). Since wayfinding is purposive behaviour involving people and environments, another important aspect of wayfinding is the individual's spatial ability for carrying out such activities. Individual differences in spatial ability will have an effect upon spatial knowledge acquisition during wayfinding and hence the success of wayfinding activities. In general, the characteristics of people and the attributes of environments influence whether and how well wayfinding is achieved (Allen, 1999b). The acquisition of spatial knowledge and performance of spatial tasks such as wayfinding involves interactions between people and their environments. Although many models have been developed to conceptualise these interaction processes, and their impacts upon spatial behaviour, most emphasis has been upon human cognition and the impacts of prior knowledge upon behaviour. For reasons that are explored in this thesis, there has been rather less focus upon study of overt behaviour during the actual process of wayfinding.

Human wayfinding is often assisted by external aids such as maps, written instructions and devices (e.g. compass). Over the last decade, there has been rapid development of mobile information and communication technologies. The increasing storage capacities of mobile devices, the increasing bandwidth and availability of broadband wireless communication, and the growing volumes of location specific information are all inevitably leading to demand for services that can deliver location specific information to the individual on the move. Such services are generally known as Location-Based Services (LBS). Thus wireless mobile devices,

such as mobile phones and wireless-enabled personal digital assistants (PDA), are providing new ways to deliver spatial information to the individual. Much of this information can be used to assist wayfinding. Consequently, a number of questions and challenges are being raised for wayfinding research. The means by which people acquire spatial information is inevitably changed when mediated by technologies - spatial information can usually be acquired in real-time, at any location. Spatial information can be accessed using mobile devices, in multiple communication modes, and in ways that are tailored towards individual needs. The acquisition of the information can be interactive and the content dynamically refreshed with updates. It seems axiomatic that these new ways of accessing spatial information are affecting the nature of human wayfinding, but we as yet understand rather little about these developments. Specifically, how can these technologies assist our understanding of the process by which spatial knowledge is acquired, valued, communicated and applied for completing wayfinding activities? From a different perspective, these technologies are also poised to impact the methods of spatial cognition research (Montello, 2001). Many of these issues are also at the core of geographical information science (Longley *et al.* 2005). Yet to date, the role of new technologies has not been assimilated into wayfinding research. Moreover, the pivotal role of mobile devices as sources of spatial information has not been considered in studies of interactions between people and their environments.

This research aims to investigate the real-time interactions and information transactions between individuals, their mobile devices and urban environments during pedestrian wayfinding activities. The technology element in the form of mobile devices is seen as a new and important element in the interaction between people and their environments. Thus, a conceptual model is proposed here which explicitly focuses on the interaction and spatial information transactions that occur (Chapter 5). Individuals, as one of the elements of the model, can access and acquire spatial information through a mobile device whilst acting and moving within the environment. They can also gain information directly from the environment. Mobile devices, as the technological element, act as interactive information sources. Spatial information delivered through the mobile device is derived from the environment. The wayfinding performance and the way by which spatial information is acquired by individuals can be influenced by their spatial abilities, prior knowledge and their social and cultural backgrounds. Such performance and spatial information acquisition are also likely to be influenced by the specific environments and contexts in which the wayfinding is taking place. In this research, individual spatial information transactions through the mobile device and the overt wayfinding behaviour are studied within the framework of this conceptual model.

A further strand to the novel methodological approach of this research concerns the ways in which real time interactions and spatial information transactions are captured through monitoring of individuals, mobile devices and environments. The approach consists of: a set of virtual reality (VR) environments, designed and implemented specifically for this research; a series of specially constructed wayfinding experiments; self-assessments of individual spatial abilities; and post-experiment evaluations of the test environment and the user interactions that it fosters. The VR-based test environment provides simulated real world urban wayfinding scenarios in an immersive virtual reality that allows individuals to 'walk around' at street level. The test environment was created using the following components: VR urban models; a simulated location-based service application using a mobile device as an information source; and software for recording participant actions and reactions within the test environment. The multi-source data collection includes movement tracking, recording of spatial information accessed through the mobile device, and detailed recording of participant actions. Crucially, the VR-based test environment is used to provide a stable and consistent setting for all participants during the wayfinding experiments. Furthermore, by using this approach, the overt interaction behaviour and real-time spatial information transactions can be recorded in a clearly controlled manner, and a rich data set is created.

A series of detailed empirical wayfinding experiments concerning geographically extensive areas have been carried out using this controlled setting and research design. The activities studied in this research centre upon urban pedestrian wayfinding using mobile device as information sources for assistance. The test environments seek to present distinctive contrasts between settings in terms of their mix of built features and street layout. They thus present tasks that highlight differences in participant wayfinding abilities, and differences in the nature of spatial information that is required to complete the specified tasks. This study makes no attempt to consider wayfinding in rural areas, and the mode of individual movement is restricted to pedestrian. The wayfinding experiments are task-based and involve travelling to a novel destination in an unfamiliar setting.

The attributes of the environment can have an important influence on wayfinding behaviour, and the VR-based approach allows such influences to be investigated in a systematic manner. This has entailed the creation of two contrasting urban models with their own distinctive layouts and mix of architectures: one of them is characterised by grid-like street patterns and modern low-rise housing; and the other is characterised by a more irregular layout with the features of a traditional market town. Both are based on real UK towns.

The empirical data on interactions and information transactions that have been generated by the wayfinding experiments have allowed a number of aspects of spatial information usage and wayfinding behaviour to be investigated. To begin with, the data make possible the investigation of wayfinding behaviour as expressed in route choice, distance travelled and time taken to complete wayfinding tasks in the two spatial settings. The spatial information usage via a mobile device during wayfinding has been measured and coded into a set of variables. One key focus has been on establishing patterns of spatial information usage preferences in terms of types of information, frequency of access, and time spent in consulting the information. The data have also allowed a classification of usage groups to be developed. This is further investigated in relation to the self-assessed measures of individual spatial ability. This is explored at both individual and group levels. Furthermore, all these aspects have been further explored in the two different urban settings in order to investigate the influence of urban morphology. In this way, original insights are developed into wayfinding using wireless mobile devices.

The arrangement of this thesis is as follows:

- In Chapter 2, the technological setting to the research is examined. A review is developed using a number of technological threads, including mobile telecommunication networks, mobile devices, positioning technologies and applications of Location-Based Services (LBS). The implications for research questions and challenges raised from the development of technologies are examined from the perspectives of LBS applications, human-devices interaction, wayfinding research, and GIScience and spatial information.
- Chapter 3 reviews some important aspects of human wayfinding and its constituent aspects of spatial acuity, spatial knowledge, spatial knowledge acquisition, methods of measuring spatial ability and human-environment interaction. The literature reviewed in this Chapter is derived from a range of different research disciplines, principally psychology, geography and GIScience. This review is organised thematically rather than from any traditional disciplinary perspective.
- Issues pertinent to using Virtual Reality (VR) as a part of the experimental test environment are reviewed in Chapter 4. This includes a review of the components and technical specifications of VR environments, and discusses previous research on issues of realism and presence. Important research on acquiring and learning spatial knowledge through VR environments is also reviewed and discussed.
- In Chapter 5, a conceptual model is proposed which brings into focus the interaction and spatial information transactions between three main elements: individuals, mobile

devices and environments. Challenges in implementing the conceptual model for studying interactions and transactions between these elements are discussed. A novel methodological approach is developed in this research and presented.

- Chapter 6 presents the design and set up of the wayfinding experiments. These consist of: compiling a pre-experiment questionnaire; creating a test environment with two VR urban models; simulating wayfinding assistance using a PDA and monitoring the ways in which it is used; and setting up a two-part post-experiment questionnaire. The design of the task-based wayfinding experiment is also described and explained. Finally, the implementation of a prototype for testing prior to conduct of the main experiments is presented.
- Chapter 7 describes the conduct of the wayfinding experiments including: a brief account of the preparatory work undertaken; description of the participants, the site at which the experiments were implemented and the equipment used; description of the two sets of task-based wayfinding experiments carried out in the VR test environments; and the design of the pre-experiment questionnaire and two-part post-experiment questionnaire. The procedure of data collection during the experiments is also explained.
- Chapter 8 describes the processes of data integration, data exploration and analysis. The research findings and discussion are also presented. The chapter begins with a description of the process of integrating the empirical data to create new data sets for analysis. Next, a classification resulting from the analysis of the pre-experiment questionnaire responses is presented and evaluated. Then follows an analysis of the responses to a post-experiment questionnaire designed to verify the sense of presence experienced in the VR environments. Also verified is the correspondence of the wayfinding strategies used by the participants in the VR environments as compared with their strategies in the real world. Next is an analysis of the spatial distribution of movement tracks and the derived variables of distance and time, and an analysis of the spatial information usage via the mobile device. A classification of individual spatial information usage is also presented. Finally, a number of case studies and qualitative discussions are presented at group and individual levels in respect of spatial layout and spatial information usage. The approach taken in this Chapter is to present results and findings in Sections immediately followed by discussions of the research findings.
- In Chapter 9, the conclusions arising from this research are drawn together and critically discussed. Based on these findings, a number of strands for future research are identified.