SPRINGER BRIEFS IN COMPUTER SCIENCE

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D. Glenn Geers

Transportation and Information

Trends in Technology and Policy

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To the memory of our fathers
Bhabesh Chandra Thakuriah
Donald Leslie Geers

Preface

In this book, we review recent developments at the intersection (no pun intended) of Information and Communications Technology (ICT) and surface transportation, and the technical, social and institutional challenges stimulated by these trends. Developments in pervasive sensing and widespread proliferation of vast numbers of mobile and static sensors promise to bring a sea-change in the way transportation information can be designed and used, particularly with Machine-to-Machine communications and by information generated by people-centric sensors. Methods to manage and analyze such data have led to novel mobility services which may have the potential to lead to sustainable and socially interesting travel. The use of such information stimulates numerous social, institutional, ethical, and legal challenges, some of which we have attempted to bring together in this book.

The book is aimed at researchers, graduate students, industry professionals, and decision-makers considering problems in surface transportation and approaches and limitations of ICT in understanding and addressing these problems. The use of the word transportation throughout the book refers to surface transportation, unless explicitly noted otherwise. Contributions from a number of academic disciplines have made these myriad developments possible. We take a broad-based view of policy and the underlying organizing theme is one of economic, environmental, and social sustainability. It is our hope that we have been able to bring together this broad spectrum of knowledge in this brief volume, albeit in a limited way. Our eventual goal is awareness-building about a wide range of problems in ICT and transportation, thereby stimulating research approaches that address multiple concerns and perspectives. The book is broad and non-technical in nature, with an emphasis on being a survey as opposed to an exhaustive treatment of a small set of topics. It may be read as part of an introduction to a graduate course on transportation and technology offered in transportation planning, transportation engineering, computer science, geography, or public administration.

The book begins, in Chap. 1, with an overview of the many facets of ICT in transportation, including Intelligent Transportation Systems (ITS), Location-Based Services (LBS), relevant aspects of smart and connected cities, dynamic resource management, mobile health, and assistive technologies. We also discuss environmental, economic, and social sustainability outcomes which an information-centered mobility environment can potentially address. In Chap. 2 we present an

overview of the major existing and emerging sensor and communications technologies and describe the types of information they generate. Chapter 3 follows with a range of systems and services that utilize these sources of information. Chapter 4 addresses institutional, legal, and coordination issues as well as issues of behavioral effects and societal preparedness to handle the information-centered mobility environment. Conclusions and possible future directions are given in Chap. 5.

Whereas ITS and LBS have been very active research areas in transportation, the contributions of ICT have been greater than solutions and services developed under such banner. Examples include strategies for mobility-on-demand, mobility assistance for persons with disabilities, smart cities and ubiquitous information environment, community and urban informatics, resource management and asset condition monitoring. Although we try to devote space to many different types of ICT examples in transportation, we had to be selective, thereby making greater discussions of certain concepts than others and the book is far from an exhaustive survey of all that has been done on this vast topic. By a survey, we also mean that we do not go into detailed discussion of any one topic and attempt to merely provide an overview of what has been done in an area. Moreover, the emphasis is on the transportation system and service aspects and not on the details of the technology and methodological aspects.

The book was stimulated by our involvement in many research projects that are too numerous to list. However, virtually each of these projects gave us the ability to explore and appreciate the technical, social, and management challenges associated with the emerging information-centered mobility environment.

The book would not have been possible without the strong support of our spouses, Claude Hanhart and Nicole Geers, and Glenn's daughter, Céline. We would like to acknowledge the contribution of Dr. Caitlin Cottrill, University of Aberdeen, UK and John Laird, NICTA and University of New South Wales, who helped with reading through and editing the book. The book was written while the first author worked in Chicago and we would also like to thank ICT for making the 9,300-mile collaboration possible.

Glasgow and Sydney
January 2013

Piyushimita (Vonu) Thakuriah
D. Glenn Geers

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Chapter 1
Introduction

1.1 Trends in ICT-Based Surface Transportation

This book is concerned with the use of Information and Communications Technology (ICT) in the field of surface transportation. ICT is a major driver of both economic growth and improved quality of life in the new global economy. ICT has evolved over centuries and innovations in ICT have occurred throughout history. This book is concerned with digital ICT, which has its basis in computer software, hardware and communications systems, and the explosive development of which spans the last fifty or so years of human history.

Surface transportation has historically been a fundamental backbone of economies and societies, by contributing significantly to the Gross Domestic Product (GDP), employment and overall support of trade and commerce. Surface transportation is also a critical ingredient in the quality of life by enabling travel to jobs, educational, social and recreational activities. Surface transportation systems can also lead to poor economic and social outcomes because of traffic congestion, road fatalities, air pollution, Green House Gas (GHG) emissions and continued dependence on fossil fuels. Transportation technology, like ICT, has greatly evolved over time from primarily muscle (human or animal) powered systems to current-day motorized mobility for passengers and freight.

ICT has the potential to contribute to environmentally sustainable and safe travel and mobility management. Some examples of how such outcomes can result include:
Environmental Sustainability: On-board diagnostics of environmental pollution in cars, road traffic signals and motorway ramp meters which lead to shorter vehicle idling time, vehicle engines that turn off automatically when the vehicle is stationary and automatic eco-feedback to inform drivers about the environmental impacts of their driving behavior may enable eco-friendly travel;
Safety: Sensors which remotely telemonitor the health of a driver, anticipatory weather information to help drivers avoid hazardous driving conditions, cars that brake without driver intervention when sensing an obstruction ahead or warn drivers when they are overly fatigued or distracted may enable safer travel;

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Shared Mobility and Social Transportation Systems: Social media that allow people to find a real-time walking buddy from an unsafe train station in real-time, volunteer to be a driver for seniors in the neighborhood, or to share interesting location-based information to others nearby may lead to new models of co-production of shared transportation and mobility services;
Assistive Travel: Robotic assistive technologies for persons with disabilities, scooters that follow a senior person back home with the shopping load, and augmented real-world environments in which wayfinding and navigation are made easier may assist the mobility of those with special mobility needs;
Asset and Resource Management: Bridges that autonomously report their own structural health conditions to engineers and systems that monitor and adjust the charging load of electric vehicles in accord with location-specific load on the electricity grid may enable efficient ways of managing resources.

The above examples demonstrate that ICT may be used for transportation and mobility services in diverse ways and in different application areas. In the following chapters the focus is on growing ICT-based mobility strategies and a discussion of the technical, social, policy and user-related questions in the emerging information-centered mobility environment.

As in many other ICT-rich sectors such as health, energy, defense and finance, the use of ICT in transport enables knowledge discovery and service development that would otherwise not be possible. In each of the above examples, there are questions of coupling together sensors and communications systems; methods to extract, analyze and distribute information; and issues relating to user acceptance, legal implications and management. Yet, research, development and practice at the different stages of the technology lifecycle traditionally lie with professionals from different disciplines, and feedback and learning from experiences at each stage is not automatic (for example, professionals who are involved with the evaluation of the impact of such technologies on the behavior of travelers are often not involved at the design stage, or, technology designers may not be interested in the broader societal or economic impacts of a particular sensor, communication system or mobile application). In fact, it may be quite difficult to estimate what the broader impacts would be. By focusing on the "technology and policy" aspects of transportation and ICT together, we discuss the trends relating to these complex questions and directions towards which they are headed.

1.2 Overview of the State of Information-Based Mobility Environment

The convergence of several heterogeneous technologies has made the current state of information-centered mobility a possibility. The most relevant developments are in the fields of: (1) sensors; (2) location and positioning systems; (3) information extraction technologies; (4) sensor fusion technologies; (5) communication

methods; (6) information and data management systems; (7) methods for information analysis; and (8) methods to understand user dynamics and impacts associated with the use of mobility information and services.

Sensor systems collect operational details on transportation conditions and provide real-time data on current conditions for immediate service delivery and informed decision-making. The transportation sector has a vast range of specialized infrastructure-based sensors for the detection and surveillance of mobility patterns and infrastructure conditions. In-vehicle sensors in the powertrain, chassis and the body of vehicles allow myriad automated tasks ranging from monitoring energy use to vehicle handling and safety as well as situational awareness regarding hazardous conditions on the road around the driver. People-centric sensors such as the microblogs, question-and-answer databases and mobile connected devices such as cell phones with location-aware technologies promise to allow large-scale, pervasive and distributed sensing system. Wearable biometric and other person-based sensors may have applications in mobile health and wellness informatics. In virtually all of the technologies discussed in this book the ability to more-or-less precisely locate a user or an asset, is a central ingredient. Satellite-based positioning systems such as the Global Positioning System (GPS) have been transformational in strengthening the role that mobile sensors can play.

Developments in spatial data management, geographic information retrieval, information extraction to retrieve intelligence from raw data (for example, data from digital images, text, audio data) and traffic and transportation engineering and planning have increased the overall utility of raw, sensor-based information. Mobility analytics generate knowledge for functions as diverse as automatic incident detection on roads (due to vehicle collisions or lane closures due to a hazardous material spill), prediction of bus arrival times at specific locations, future traffic conditions, location-based information-sharing among members of a social network, real-time management of vehicle fleets, or information on when people should travel. Such intelligence is necessary in order to support broader economic, environmental and societal outcomes as well as for high quality personal travel and freight movements.

Currently, different entities collect data on different aspects of the transportation system in a region. Mobility analytics based on such heterogeneous data sources will be critical components of intelligent cities of the future. We see future mobility intelligence giving rise to a *Digital Mobility Information Infrastructure* (DMII), which will comprise three tiers of information sources.

Primary Tier: The primary tier will consist of a myriad of infrastructure-based, vehicle-based, mobile, portable and wearable sensors, communications and information processing elements that are briefly discussed above, and which are the main subjects of this book. Some of these sensors may not be traditionally used in the transportation sector, e.g., weather sensors, but the information they offer may be critical for quality mobility information. This tier defines a continuum of information on transportation.

Secondary Tier: The second tier of information is comprised of information that is not directly generated by the primary tier but which may support its use in various ways. Examples include maps and Points of Interest (POI) databases which are critical for