

Implementation of Advanced Transit Traveler Information Systems in the United States and Canada: Practice and Prospects

by

Anthony Charles Rizos

Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degrees of

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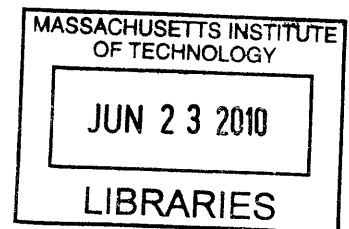
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ABSTRACT

Over the past few years, public transit agencies across the United States and Canada have increasingly implemented methods for passengers to access traveler information using new media and personal mobile communications devices. The most advanced examples of these devices, commonly known as “smartphones,” combine telephone, Internet browsing, and personal digital assistant (PDA) functionality into a single, portable unit. Mobile data applications are literally exploding on the scene every day, and transit agencies are under tremendous social and political pressure to deploy more related information systems as rapidly as possible. These applications are popular with technology-savvy riders who enjoy easy and real-time access to information and updates about their transit routes and services of choice, anywhere they happen to be.

A review of the literature, as well as interviews with managers at thirteen transit authorities across the spectrum of size and technical sophistication, provides a portrayal of the states of the practice and art, and paints a clear picture of the challenges facing implementation of these advanced systems in the field. The research confirms the initial hypothesis that while transit agencies are indeed devoting energy to pursuing advanced traveler information systems, the approaches to implementing them could be improved.

Based on the findings, I recommend that transit agencies: conduct necessary market research; develop more explicit and comprehensive traveler information system strategies; clarify the role and business case for social media; secure sufficient financial and technology resources; ensure sufficient operating as well as capital funding; eliminate constraints on use of data from commercial software; and, adopt and embrace open-source software development using an “open government” model.

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Table of Contents

ACKNOWLEDGMENTS	3
CHAPTER I: INTRODUCTION	6
<i>Hypothesis and Research Questions</i>	<i>10</i>
<i>Methodology and Interview Process.....</i>	<i>11</i>
<i>Summary of Chapters.....</i>	<i>14</i>
CHAPTER II: STATE OF THE PRACTICE IN TRANSIT TRAVELER INFORMATION	15
TRADITIONAL MEANS OF TRANSIT TRAVELER INFORMATION	16
<i>Static Information Materials and Print Media,</i> <i>such as Schedules, Maps, Brochures, Bulletins, and Advisories.....</i>	<i>16</i>
<i>Customer Service Call Centers</i>	<i>18</i>
<i>Automated Interactive Voice-Response (IVR) Telephone Systems.....</i>	<i>19</i>
INTELLIGENT TRANSPORTATION SYSTEMS (ITS) AND REAL-TIME INFORMATION SYSTEMS.....	21
INTERNET-BASED AND REMOTE INFORMATION DELIVERY.....	26
<i>Web Sites/Web Applications.....</i>	<i>26</i>
<i>“Web 2.0” & Asynchronous JavaScript and XML (Ajax) Web Applications</i>	<i>27</i>
<i>511 and Transit.....</i>	<i>28</i>
<i>Transit Agency Trip Planning Systems</i>	<i>29</i>
<i>Google Transit Trip Planning.....</i>	<i>30</i>
E-ALERTS.....	32
TRAVELER INFORMATION ON MOBILE DEVICES	34
<i>WAP and Web Sites Intended for Use with Mobile Communications Devices</i>	<i>34</i>
<i>Social Media</i>	<i>35</i>
<i>Custom Applications for Smartphones and Other Advanced Mobile Communications Devices</i>	<i>37</i>
CHAPTER III: STATE OF THE ART IN TRANSIT TRAVELER INFORMATION	39
<i>Real-Time Information.....</i>	<i>40</i>
<i>Official Transit Agency Sponsorship of Open-Source Traveler Information Software Development</i>	<i>41</i>
<i>“Augmented Reality” and Implementation in Custom Smartphone Applications.....</i>	<i>42</i>
<i>Peer-to-Peer, On-Line, Real-Time Exchange By and Between Transit Passengers</i>	<i>44</i>
CHAPTER IV: INTERVIEW FINDINGS AND INTERPRETATION	49
RESOURCE CONSTRAINTS.....	50
<i>Overall Financial Constraints / General Lack of Financial Resources.....</i>	<i>50</i>
<i>Difficulty in Securing Operating (as opposed to Capital) Funding.....</i>	<i>52</i>
<i>Lack of Board/Management Recognition of IT as a Strategic Resource for Transit</i>	<i>53</i>
<i>General Lack of IT Resources.....</i>	<i>54</i>
ISSUES RELATED TO TTIS STRATEGY DEVELOPMENT	57
<i>Lack of Focus on Market Research, and Lack of Surveys to Inform Strategy</i>	<i>57</i>
<i>Sensitivity to the Digital Divide</i>	<i>57</i>
<i>Use of Social Media and Strategy.....</i>	<i>59</i>
<i>The Debate about Controlled versus Open Data</i>	<i>59</i>
DATA AVAILABILITY AND TECHNICAL CHALLENGES.....	62
<i>Implications of Being Locked Into Commercial, Proprietary Systems and Contracts.....</i>	<i>62</i>
<i>Lack of Use of Open Standards for Intelligent Transportation Systems /</i> <i>Transit Traveler Information Systems.....</i>	<i>64</i>
<i>Difficulty in Adapting Legacy Systems to New Uses –</i> <i>for example, Transit Traveler Information Systems.....</i>	<i>66</i>

CHALLENGES RELATED TO SPECIFIC INFORMATION DELIVERY MECHANISMS	68
<i>Labor-Intensiveness of E-Alerts Composition and Maintenance</i>	68
<i>Concerns about the Cost of SMS Message Transmission</i>	69
<i>Targeted Deployment Trends for Real-Time Information Displays</i>	70
CHAPTER V: CONCLUSIONS, RECOMMENDATIONS, AND FUTURE RESEARCH	72
RECOMMENDATIONS	73
<i>Develop an Informed TTIS Strategy</i>	74
Conduct Necessary Market Research on Transit Traveler Information Systems (TTIS)	74
Develop a Multi-Format TTIS Strategy	75
Clarify Role/Structure for Social Media and E-Alerts as part of Overall TTIS Strategy.....	77
<i>Acquire Sufficient Resources (Financial and IT)</i>	79
Build and Support Sufficient IT Resources.....	79
Ensure Sufficient Operating as well as Capital Funding for TTIS Initiatives	80
<i>Develop a Data Strategy: Interoperability, Open Source, and Open Government</i>	82
Eliminate Constraints on Use of Data and Interfaces of Commercial Software	82
Adopt Open-Source and Intelligent Transportation Systems (ITS) Standards	83
Adopt and Benefit from “Open Government” Approach to Public Data.....	83
FUTURE RESEARCH	87
<i>Exploring the Impact of Transit-Specific Information Using Mobile Device Technologies</i> <i>on Travel Behavior</i>	87
<i>Exploring Methods to Educate Digitally Disadvantaged Users about the Use of</i> <i>More Advanced (and Less Costly) Means of Traveler Information</i>	88
<i>Issues Concerning Multimodal Trip Planners</i>	89
<i>Exploring Incorporation of Real-Time Passenger Information into Systems</i> <i>which Currently Only Support Static Information</i>	90
CHAPTER VI: SCENARIO FOR SUCCESS	92
APPENDIX A: DISCUSSION OF THE DIGITAL DIVIDE	93
APPENDIX B: LIST OF INTERVIEWS	96
APPENDIX C: INTERVIEW TOPICS AND RECRUITMENT METHOD	99
BIBLIOGRAPHY	101

Chapter I: Introduction

Over the past decade, public transit agencies across the United States and Canada have increasingly implemented methods for passengers to access traveler information using new media and personal mobile communications devices. The most advanced examples of these devices, commonly known as “smartphones,” combine telephone, Internet browsing, and personal digital assistant (PDA) functionality into a single, portable unit. As of 2010, even the most basic cellular telephones allow users to send and receive Short Message Service (SMS) messages, and many major transit agencies have partnered with service providers to make wireless connectivity available in their vehicles and at their stations. Furthermore, high-speed cellular and local area wireless data connectivity blankets nearly every city where significant transit operations are present, raising the ceiling for the types of digital interactions possible while on the go. Perhaps the most important implication of this connectivity for transit is that passengers are now able to make dynamic trip planning decisions quickly and without the aid of transit agency personnel – whether before, during, or after the trip.

In a world of ubiquitous Internet access to information at one’s fingertips, technologically savvy passengers often express a preference for digital versions of publications, such as timetables and route maps, over traditional print counterparts. Users are able to both shed the heft of physical documents and achieve a higher level of efficiency using computerized reference tools. A corresponding benefit of this format for transit operators is the ease and low cost of maintaining information when updates become available. Traveler information in paper form has long been widely distributed aboard buses and

trains, in stations, and at information booths, requiring significant human and reprographic resources to replace when updates are made. Publishing static information on the Internet is nothing new, but the development of applications tailored to mobile devices that intelligently manipulate this information is rapidly broadening the scope of traveler engagement. While traditional Internet trip planning facilities often restrict passengers to utilizing a fixed terminal with a full Web browser, applications intended for mobile consumption optimize the user experience for the reduced form factor of portable displays.

Continuously updated sources of real-time service information, such as feeds from automatic vehicle location (AVL) systems, can be used to create mobile applications that inform passengers of the precise location of the transit vehicle they hope to board, or estimate the arrival time of the next vehicle at a given stop. In response to emerging trends in the information technology (IT) community to produce dedicated applications for specific smartphone operating systems, these feeds are starting to be published on pioneer transit agencies' Web sites for consumption, adaptation and further development by public third parties. While some agencies develop their own applications and do not publish the data feeds, others feel that the public developer community is best suited to serve the myriad populations in the transit service area, each of which may have different needs and abilities to consume traveler information. These applications, especially when created by third parties, tend to add significant, unusual value to the travel experience by combining transit data with other relevant features. Programs that ascertain a user's current location by employing a smartphone's built-in Global Positioning System (GPS) receiver, for instance,

can suggest the nearest transit stop, the estimated arrival time of the next transit vehicle at that stop, and available restaurants along the route. The trip enrichment possibilities made available by such combinations of travel-related information sources far exceed the capability of any single traditional medium, calling into question the utility and value of retaining less efficient media formats in the future.

While these advanced applications bring considerable potential for a revolution of the way citizens use transit and interact with the city around them, there are some important implications that have not yet been settled. Some of these implications pertain to the agencies themselves – challenges of a financial, strategic, organizational, or technical nature. Others pertain to the user experience for passengers, whether they happen to be technologically savvy or not, or able to afford the most sophisticated devices and related data plans.

Initially, the scope of this research was geared much more heavily toward potential traveler information issues surrounding the “digital divide.” The “digital divide” is a phrase used to describe the gap in knowledge and access between users who do, and do not have the means or ability to utilize the emerging technologies of the Internet age. (For a more extensive discussion of the digital divide, refer to Appendix A.) These two groups of users often, but do not always, correspond with two respective categories of transit riders: “choice” riders, who have access to other mode choices of transportation and are consciously deciding to use transit; and, “captive” riders, who for one or more reasons, do not have access to other modes and are dependent upon transit alone to get where they are going. I initially hypothesized that a trend toward reliance

on increasingly sophisticated mobile connectivity would not necessarily correspond to or reflect the demographics of transit users, many of whom are socioeconomically disadvantaged, often do not have access to the latest (and still expensive) mobile devices, and who are also without other transportation options. This would be especially true outside of dense metropolitan areas, where the vast majority of transit (e.g. bus) riders are captive and have no other affordable means of transportation available. I also hypothesized that digitally disadvantaged riders would find transit to be increasingly more difficult to use as these new technologies emerge. In the longer term, as a result of potential replacement of traditional forms of traveler information with advanced digital media, I hypothesized that these same users would experience societal discrimination or disenfranchisement in their local contexts, owing to their resulting ineffective (or disparate ability to make) use of transit.

While it may appear easy or even obvious to a technical crowd how to operate a smartphone and access new forms of traveler information, a significant segment of the population struggles to acquire these skills and must resort to alternative formats of the information they seek. Moreover, in the case of cellular data services, access to the network is relatively expensive – and for the most advanced devices that support the most intriguing applications, a strong consumer credit rating and subscription contract commitment is usually required. Prepaid cellular services in the U.S. and Canada typically exclude the most capable smartphones from their device lineup as an incentive to subscribe to more profitable postpaid plans, and only offer a more limited data network footprint in some cases. Mobile devices that support wireless local-area

networking, such as free connectivity to ubiquitous wireless access points around the city, are typically the most expensive of all. While the cost of the traveler information applications themselves may be nominal or free (and thus, seemingly as “accessible” as traditional forms of information), the burden of device and access costs, education required to make the most of the device, and financial instruments required to gain an access subscription are not inconsequential considerations for many transit users.

My initial research quickly revealed that there was insufficient existing information available about the transit digital divide for me to test that hypothesis. The exercises necessary to attempt to reliably and comprehensively gather that information, such as controlled focus groups and extensive fieldwork, would have been too great in scope for this master’s thesis. Instead, I expanded my research and analyses such that the digital divide was only one of several issues to explore. This study aims to highlight and discuss implementation practices, challenges, and recommendations for advanced transit traveler information systems, with a special emphasis on the benefits and limitations of the emerging media formats travelers use to interact with them.

Hypothesis and Research Questions

Advanced transit traveler information systems are becoming increasingly important to transit agencies as they attempt to conduct their mission of serving passengers in the face of evolving technology. I hypothesize that while agencies

are indeed devoting energy to this pursuit, the approaches are, in practice, not very effective – for a number of organizational, technical, and other reasons.

Are transit agencies effectively using information technology to serve the traveler information needs of their clients? Do the approaches these agencies use to apply technology to the dissemination of traveler information represent best practices and ideal implementation, or are there potential areas for improvement? If so, what are they?

Methodology and Interview Process

This research was conducted by following an explicit four-part methodology for gathering and reporting on pertinent information. First, I conducted a review of the literature in the fields of transit technology, transit demographics, and the digital divide. Second, I conducted a broad review of official Internet information published by transit agencies about their advanced traveler information offerings. Third, I reviewed a range of secondary Internet sources, such as news reports, “blogs,” and opinion articles, in order to gauge the technology community’s perceptions of various emerging digital information formats that relate to the transit context.

Fourth, I conducted interviews with managers from a range of transit agencies. The objectives of the interviews were to develop a better understanding of strategy and implementation related to the use of technology for delivering traveler information, as well as some of the related challenges and prospects.

The specific questions were:

- What recent initiatives has your agency undertaken, or is planning to undertake, with respect to transit traveler information systems (TTIS)?
- What is your agency's current and evolving strategy with respect to TTIS, and what are your perspectives on how these new tools/initiatives relate to more traditional tools to provide information to different categories of customers?
- Could you send me any statistics or results that you may have collected from focus groups, surveys, or analyses of passengers with respect to demographics, travel behavior, increases in ridership, use of wireless devices, and/or engagement with traveler information systems?
- What is your opinion on the level to which existing passengers can/will embrace these new information tools, vis-à-vis the potential use of these tools in attracting new riders (especially "choice" riders)?
- In your opinion, are there any issues or obstacles in your agency's context that may be affecting the pursuit of TTIS?

I selected, in consultation with staff from the Intelligent Transportation Society of America (ITS America), a representative range of transit agencies in the United States and Canada with respect to various criteria: fleet size, geographic location, demographics of ridership, deployment of vehicle location

systems which enable real-time information, technological sophistication with respect to traveler information, etc. Interviewees were managers at these agencies who play a material role in the strategy and development for traveler information technology, and all had a keen interest in these issues. ITS America staff assisted in establishing an initial introduction, and I then followed up and arranged telephone or in-person interviews with each manager or staff member (see Appendix B for a list), and posed the questions above.

After the conclusion of all interviews, I arrived at an understanding of key themes, insights, and challenges regarding traveler information in the industry, informed by numerous recurring topics raised across the range of agencies and conversations. I then synthesized my findings in this thesis.

Summary of Chapters

Following this **Introduction**, I first present the **State of the Practice in Transit Traveler Information**. This chapter serves as a typology of the most common transit traveler information media, channels, and systems deployed today in the United States and Canada. Second, I present the **State of the Art in Transit Traveler Information**. This chapter serves as a discussion of advanced or conceptual transit traveler information media, channels, systems, and trends that hold promise for the field in the future. Third, I discuss my **Interview Findings and Interpretation** of the information synthesized from my interviews with transit agency personnel. Fourth, I present my resulting recommendations to transit agencies, as well as a discussion of future research in the field of advanced traveler information, in the chapter entitled **Conclusions, Recommendations, and Future Research**. Finally, I propose a model **Scenario for Success** that transit agencies can employ to begin realizing the benefits of this research.

Chapter II: State of the Practice in Transit Traveler Information

- **Traditional Means of Transit Traveler Information**
 - Static Information Materials and Print Media, such as Schedules, Maps, Brochures, Bulletins, and Advisories
 - Customer Service Call Centers
 - Automated Interactive Voice-Response (IVR) Telephone Systems
- **Intelligent Transportation Systems (ITS) and Real-Time Information Systems**
- **Internet-Based and Remote Information Delivery**
 - Web Sites/Web Applications
 - “Web 2.0” and Asynchronous JavaScript and XML (Ajax) Web Applications
 - 511 and Transit
 - Transit Agency Trip Planning Systems
 - Google Transit Trip Planning
- **E-Alerts**
- **Traveler Information on Mobile Devices**
 - WAP and Web Sites Intended for Use with Mobile Communications Devices
 - Social Media
 - Custom Applications for Smartphones and Other Advanced Mobile Communications Devices

Traditional Means of Transit Traveler Information

Static Information Materials and Print Media, such as Schedules, Maps, Brochures, Bulletins, and Advisories

The traditional format for physical distribution of traveler information in the public transit setting has long been printed media. Passengers commonly seek a printed reference of routes, schedules, or other services that is generally free, readily available and easily portable¹. These materials are typically published by transit agencies and offered at no cost within stations, at platforms, and on transit vehicles. In the present day, these media are especially convenient for passengers without technological fluency, as interpretation only requires the common and usual literacy that nearly everyone enjoys. The lack of any access cost to these materials also makes them popular among the financially disadvantaged. However, as a result of financial constraints, an increasing number of transit agencies are charging a fee for transit maps, comprehensive schedule booklets, or other information media, in order to defray costs and discourage waste.²

Despite the essential facts conveyed by printed traveler information materials, there are inherent shortcomings in the medium³ which have sparked efforts to investigate and develop new, replacement media. Publication of printed materials requires costly and labor-intensive reprographic resources, and

¹ Texas Transportation Institute, et al., TCRP Report 45, 1999

² Hemily (personal interview)

³ Texas Transportation Institute, et al., TCRP Report 45, 1999

for agencies with frequent updates to schedules or services, it becomes a logistical challenge to ensure old information is removed and replaced throughout the network. The consumption of paper in producing printed materials has, in recent years, become unpopular for its perceived deleterious environmental effect – a detriment to the social good which runs counter to the overall philosophy of publicly-funded transit service. Printed materials are also only useful when in a person’s physical possession, which is inconvenient for users attempting pre-trip planning⁴ in an unfamiliar city or for tourism purposes. Finally, propagation of urgent or timely information, such as news about emergency detours and service disruptions, is difficult when relying solely on printed materials. The best an agency could do is to position these printed bulletins at high-traffic locations on transit property, and hope that passengers will see them – or, rely on external information channels such as commercial radio and television news broadcasting.

As most printed traveler information materials are now created using desktop publishing software applications or similar digital means, it is simple to distribute a facsimile of the material in digital form (typically in Portable Document Format) on the Internet. This distribution practice is extremely common within transit agencies across the continent, as it requires no further manipulation or presentation of the content.

⁴ Texas Transportation Institute, et al., TCRP Report 45, 1999

Customer Service Call Centers

As an alternative to requiring physical access to printed information, transit agencies have historically provided free telephone-based support to passengers. Originally, this medium was supported by a dedicated staff of customer service specialists who were tasked with answering transit-related queries. Ostensibly apprised of all route and schedule information, as well as any prevailing bulletins or advisories that may be in effect, these transit employees provided a vital service to riders who cannot otherwise travel to a transit service location to retrieve information at that moment. Call centers were one of the first means of remote access to real-time service information (at least with respect to major disruptions), as employees answering the phones are often within physical proximity of transit operations, and, presumably, can provide up-to-the-minute data by direct voice reference to callers.

However, staffing call centers is expensive⁵ – not only because of telephone lines and switches, but also because it is very labor-intensive, and dedicating human resources to answering the phones is exceptionally costly. All transit agencies have call centers, though hours of operation vary widely. Increasingly, transit agencies organize themselves as much as possible so that live staff focus on more complex customer service tasks, passing along simple static information requests to automated systems (see below). In other cases, metropolitan planning organizations (MPOs) with regional oversight for transportation will create a centralized system, or even absorb individual transit

⁵ Battelle, et al., TCRP Report 134, 2009

call center resources into a single, consolidated call center that provides assistance for other transport modes.⁶ The U.S. Department of Transportation, in recent years, has promoted and subsidized the establishment of statewide “511” telephone services for highway traveler information – and in some jurisdictions, these services also provide assistance for transit users.⁷

Automated Interactive Voice-Response (IVR) Telephone Systems

As financial situations have become more constrained, agencies looking to continue providing telephonic customer support have availed themselves of automated IVR systems to augment or supplant more costly and dear human resources. These systems allow customers to retrieve static and real-time traveler information on a self-service basis, navigating voice prompts with spoken commands or dual-tone multi-frequency (DTMF) input on the telephone keypad. With the advent of real-time information in various markets, call centers were finding a shift toward customer telephone requests for vehicle arrival estimates and other basic queries⁸. IVR systems allow passengers to retrieve these simple results themselves, freeing up staff resources for more specialized customer service activity (or removing the need for telephone staff entirely).

IVR systems often raise the ire of individuals who find their prompts and data structures to be non-intuitive, or who experience poor luck with having their

⁶ Battelle, et al., TCRP Report 134, 2009

⁷ Battelle, et al., TCRP Report 134, 2009

⁸ White (personal interview)

requests for information understood correctly by the automated recognition system.⁹ Nevertheless, IVR systems remain an important traveler information access means, as telephones with simple voice call capability are ubiquitous, and users need not wait for a live staff member to become available (in queue) in order to retrieve a specific result. Telephone-based information systems are especially helpful for the socioeconomically disadvantaged, due to the universal availability of traveler information at the low cost of a local (or toll-free) call. They are also convenient for users with cellular telephones, who can access information via the IVR while on the go.

⁹ Call Centre Helper, *How to right the wrongs of IVR*

Intelligent Transportation Systems (ITS) and Real-Time Information Systems

A review of the literature identified important features and functions of Intelligent Transportation Systems needed to support a successful, next-generation transit operation. In the Transport Canada publication entitled *Transit Intelligent Transportation Systems (ITS) and IntelliDriveSM: A Preliminary Investigation of Developments, Opportunities, and Challenges for Urban Public Transportation in Canada*, key functionalities listed include: voice and data communications; computer-assisted dispatch (CAD); automatic vehicle location (AVL); security (such as emergency alarms and public address systems); schedule adherence monitoring; traveler information (both pre-trip and *en route*); automatic vehicle mechanical monitoring; automatic passenger counting; management reporting (such as incident reports and on-time performance statistics); transit signal priority; and, advanced fare collection (such as smart cards and/or stored-value payment systems).¹⁰

CAD/AVL systems are well-established in subway and light rail transit networks, because the routes are fixed, stops are always the same, and the infrastructure is under total control of the agency. Vehicle location tracking is a more recent feature for bus systems, where Global Positioning System (GPS) receivers are employed in tandem with mobile data transceivers to report exact positions at regular intervals. Computer-aided dispatching (CAD) and automatic vehicle location (AVL) systems promote a higher level of service quality by

¹⁰ Hemily for Transport Canada, July 2009

providing operational monitoring for dispatchers, which in turn allows for better-informed operational decisions.

Of these core functionalities, some naturally enable or support the operation of others. For example, effective provision of real-time traveler information relies on reliable data communications and robust CAD/AVL systems, which in turn enable an ideal set of real-time data and delivery features.¹¹ In particular, this publication describes essential traveler information functions as: passenger-facing information that assists with itinerary and trip planning in anticipation of making the trip, real-time information provided pre-trip to customer concerning real-time departure times at desired stops (delivered using various information media, such as the Internet or the telephone); information made available en-route at stations or stops that provides next arrival or departure times; and, audiovisual next-stop or other informational announcements made on transit vehicles themselves.¹²

Real-time information collected by CAD/AVL systems is of particular pertinence to traveler information systems. For example, automatic updates of the exact positions of transit vehicles add a rich layer of context to mere static schedule information, whereby passengers can be apprised of an estimated arrival time for the next vehicle on their transit route *as well as* the scheduled arrivals that follow it.

Originally, real-time information was primarily delivered at transit stations or stops. Common hardware for these displays is the analog cathode ray

¹¹ MultiSystems Inc., TCRP Report 92, 2003

¹² Hemily for Transport Canada, July 2009

tube (CRT) or digital liquid crystal display (LCD). These displays act in a passive capacity to broadcast either static or real-time information at no cost to the passenger, as all capital and maintenance costs are borne by the agency¹³. These displays afford a direct cost savings to passengers, as traveler information is readily available to any sighted individual without the need for any sort of auxiliary device. Additionally, displays can often be outfitted with audible broadcast components to serve blind passengers, which is important given transit agencies' mandates to provide equitable transit access to everyone in their jurisdictions. With screens or displays, the burden does not fall on the user to carry a device necessary to obtain available information.¹⁴

Physical displays can be improved with touchscreens, human interface devices, or other interactive interfaces, to allow passengers to manipulate the types of information displayed on demand.¹⁵ Common settings for these interactions are navigational displays (with interactive maps), or in consolidated transit information kiosks – often complete with ticketing abilities. In some cities, displays also convey commercial news, advertising, or video content as means to defray hardware capital and upkeep costs.

In recent years, transit agencies have been displaying on their Web sites the same real-time departure information found at stations/stops, and most recently, a few transit agencies have developed the means to distribute real-time information to mobile communications devices.¹⁶ A popular commercial product for this purpose is NextBus Inc.'s NextBus, which combines a customer-

¹³ Schweiger, TCRP Synthesis 68, 2006

¹⁴ Schweiger, TCRP Synthesis 68, 2006

¹⁵ Schweiger, TCRP Synthesis 68, 2006

¹⁶ Schweiger, TCRP Synthesis 68, 2006

accessible, mobile-friendly interface with back-end, wireless data-based hardware to continually transmit vehicle locations to the Internet and compute estimated arrival times.¹⁷ Some agencies with existing back-end vehicle location tracking hardware simply use the NextBus front-end application in concert with that hardware to avoid the need for new software development and updates.

Transit scheduling and dispatching software is highly specialized and sophisticated, and all transit agencies, except for the very smallest, contract with one of a limited number of third-party vendors to acquire scheduling or dispatching software packages. While this may produce a serviceable result for the benefit of the agency's operations and customers, the practice also raises some questions for the industry at large.

Due to the specialized nature of transit technology, especially on the scheduling, dispatching and vehicle operations levels, the number of qualified software vendors with commercially successful products is small. In many instances, contracts for these systems were negotiated years ago, before the industry fully understood the value of information or could envision the uses of the data for other purposes. As a result, contracts with vendors often placed limitations on the ability to interface these proprietary systems with other systems, or on the ability to export the data for purposes beyond those explicitly included in the original procurement.¹⁸ Any desired changes invariably lead to the renegotiation of license agreements and/or to the need to pursue projects to

¹⁷ NextBus, *How NextBus Works*

¹⁸ Standard Trapeze Software License and Maintenance Agreement – Transit

develop new interfaces.¹⁹ All this, in turn, creates delays and additional costs for traveler information development, which has been particularly true for deploying mobile device applications – either internally, or through other third-party developers.

¹⁹ Standard Trapeze Software License and Maintenance Agreement – Transit

Internet-Based and Remote Information Delivery

Web Sites/Web Applications

Web sites have become essential means of delivering traveler information for transit agencies. Every transit agency has a Web site where customers can retrieve basic, static information, including route schedules, system maps, fare tables, and information on fare media. The level of sophistication of transit agency Web sites varies widely.²⁰

Web applications, very broadly, refer to software that is accessed and executed over the Internet to generate dynamic Web content. Web applications also can interact with other systems to exchange data and facilitate communication. In the format most applicable to transit traveler information, Web applications receive direct input from the user via the user's Web browser, and then query databases or other sources of information to provide a custom result.

Other Web applications that one finds on transit agency Web sites include e-commerce systems that allow users to purchase monthly passes, or human resources systems that accept electronic applications for employment. Web applications are an essential framework for conveying any type of dynamic Internet content for which user input can aid in presentation.

²⁰ Schweiger, TCRP Synthesis 68, 2006

“Web 2.0” & Asynchronous JavaScript and XML (Ajax) Web Applications

As Web applications continued to evolve throughout the 2000s, advancements in client-side Web browser technology improved the user interface experience, applying dynamic markup elements to quickly retrieve and display server-side data within the browser view itself. While original Web applications required a full data submission to the server (and therefore a Web page reload) in order to display result content, Ajax applications allow users to dynamically interact with content on the screen in order to achieve a desired goal. This technique is perhaps most notably implemented on Google Inc.’s Google Maps Web site, where users can drag a computer mouse from side to side, and watch cartographic tiles update automatically in response to panning or zooming cursor movements. Before the onset of the so-called “Web 2.0” movement and the advances in client-side Ajax technology it inspired, a user would have to click an on-screen button and allow the page to fully reload for each new map tile to display, one directional movement at a time.

These user experience enhancements have great potential to transform the online pursuit of transit traveler information in the same way they have enriched Internet information delivery for other purposes.²¹ For example, the Google Maps Application Programming Interface (API) allows developers to “mashup,” or overlay and combine, data from different sources and have them appear atop an interactive map.²² In practice, these data typically are represented as either

²¹ MashTrans.org (UC Berkeley)

²² MashTrans.org (UC Berkeley)

points, such as a restaurant or a transit stop, or lines, such as roads or transit routes. The capability to merge transit source data can lead to particularly helpful visualizations, when attempting to put transit service in context with the overall geographical surroundings, or even for monitoring real-time updates. A Google Maps view can be outfitted with icons representing transit vehicles, for instance, and with no action by the user, these icons can automatically move along the map to represent up-to-the-minute transit vehicle locations.²³ The end user result is an unlimited number of possibilities and combinations for both information interaction and information delivery.

511 and Transit

A 2009 Transit Cooperative Research Program (TCRP) report entitled *Transit, Call Centers, and 511: A Guide for Decision Makers* tells us that most 511 telephone systems are administered and operated by state departments of transportation. 511 systems were initially intended for highway or vehicular traffic information, and this pedigree is evident in the promotion and accessibility of transit information within these systems – even where such transit-specific information is considered to be fully included. Only two 511 systems (as of early 2009) featured transit as the first choice in their phone

²³ Google Transit

menus.²⁴ Furthermore, only 20 of the 42 total 511 systems (as of March 2009) had any transit content at all.²⁵

Of these 20 systems, three (pertaining to San Francisco, San Diego, and the state of Maine) had any kind of real-time transit information available.²⁶ It is rare for a 511 system to be operated at a scale smaller than regional or statewide, but heavily-populated areas such as San Francisco (which contain a host of individual transit agencies) may have their own, administered at the MPO level.

Transit Agency Trip Planning Systems

A popular and successful type of transit Web application is the trip planner. Trip planners provide a customized itinerary between specified transit stops, usually also providing estimated trip durations and scheduled arrival and departure times. Trip planners are especially useful for complex itineraries with multiple transfers, as they compute optimal connections and help to minimize potential transfer wait times. Web-based trip planning systems have been prevalent in transit agencies' traveler information offerings for nearly a decade; as early as 2002, there were already 30 Web transit trip planners deployed in the U.S.²⁷ Trip planners began primarily as sources of information from single agencies, but have since evolved in some cases to applications with multi-agency

²⁴ Battelle, et al., TCRP Report 134, 2009

²⁵ Battelle, et al., TCRP Report 134, 2009

²⁶ Battelle, et al., TCRP Report 134, 2009

²⁷ Volpe Center for U.S. DOT, *Trip Planning State of the Practice*, July 2002

or regional scopes. Most trip planning applications have traditionally been developed by third-party vendors.²⁸

Trip planning information is generally sought by passengers for new itineraries more than for “usual or familiar trips,” and typically, users new to transit desire this information more than habitual riders.²⁹ While passengers appreciate trip planners on the Web, there are sometimes reservations about the veracity and accuracy of itineraries generated (due to a computer’s representation and interpretation of the route network not always concurring with plausible and efficient human behavior).

Google Transit Trip Planning

Google Inc.’s Google Transit Web application is a “mashup” of Google Maps cartographical depictions with static transit schedule data. For inclusion in Google Transit results, schedule data must be translated to the Google Transit Feed Specification (GTFS) file format and provided to Google.³⁰ Upon acceptance by Google, GTFS-formatted schedule data is incorporated into the application to facilitate trip routing.³¹ Just as Google Maps provides traditional driving, walking, and bicycling directions between user-entered origin and destination addresses, Google Transit suggests transit itineraries that can take advantage of multiple modes. Routes selected as part of the automatically-generated itinerary are graphically depicted on a map view in the Web browser.

²⁸ Volpe Center for U.S. DOT, *Trip Planning State of the Practice*, July 2002

²⁹ Battelle, et al., for FTA, *Customer Preferences for Transit ATIS : Research Report*, August 2003

³⁰ Google Transit Partner Program

³¹ Google Transit Partner Program

The presence of schedule data allows Google Transit to compute estimated trip duration, accounting for headways and transfers.

Passenger information modules of transit agencies' commercial scheduling software enable schedule information to be reformatted for the benefit of call center use or for trip planning design; the most recent versions typically also enable export of schedule data into GTFS format.³² As a result, many agencies also use commercial solutions from these same vendors for deploying trip planning Web applications, and for deploying the export into GTFS and Google Transit.

³² Google Code – Google Transit Data Feed – “OtherGTFS Tools”

E-Alerts

“E-Alerts” (or rider alerts) is a name given to a category of service that allows passengers to subscribe to real-time traveler information updates in a broadcast fashion. Typically, E-Alerts are sent in batch form via the Internet and electronic mail, or via the Short Message Service (SMS) to individuals’ cellular telephones, or both. SMS is a standard for the transmission and reception of limited-length text messages that is interoperable across and between commercial cellular telephone networks. E-Alerts typically contain timely service advisories, bulletins, detour information, or details on transit emergencies.³³ They are meant to be a low-volume channel for short, limited-length text content. E-Alerts are often one of the first “advanced” traveler information systems agencies deploy, as they take advantage of emerging technology and communications trends while keeping costs and agency requirements low. Text content is readily created and consumes little bandwidth to transmit over data services, compared with rich media or output from systems with more frequent output.

Passengers typically subscribe to E-Alerts services via the transit agency’s Web site, or via SMS message to a central registration processor. Passengers are usually given a choice as to the types of messages desired – whether specific to a favorite route, service, or topic.³⁴

³³ MultiSystems Inc., TCRP Report 92, 2003

³⁴ MultiSystems Inc., TCRP Report 92, 2003

Because of inherent costs in this interoperability and, more generally, in cellular system maintenance and development, telephone carriers typically levy a small per-message charge to transit agencies and other companies wishing to utilize SMS. Cellular telephone users typically incur per-message charges for transmission and reception, unless the user subscribes to a flat-rate messaging plan with their carrier.

Traveler Information on Mobile Devices

WAP and Web Sites Intended for Use with Mobile Communications Devices

The prevalence of cellular telephones at the popular onset of the World Wide Web prompted exploration and development of wireless data delivery services, much like alphanumeric pagers provided to the masses in the 1980s and 1990s. Web sites specifically designed and tailored for diminutive displays and less capable processors soon became available using the Wireless Application Protocol (WAP).³⁵ WAP content is not generally rich in multimedia, but its simple focus on delivery of text material makes it an ideal medium for efficient dissemination of small bursts of traveler information. The basic design of WAP pages lends itself to low data usage costs when such costs are billed by the kilobyte or megabyte.

With the advent of more advanced wireless devices that connect to high-speed data networks, it has become possible to supply higher volumes of traveler information in new and emerging formats. These devices include enhanced cellular telephones running commercial operating systems by Apple Inc., Google Inc., or Microsoft Corp., as well as personal digital assistants (PDAs) with IEEE 802.11 wireless standards support.³⁶ As these devices are more robust than their basic, WAP-enabled counterparts, they are able to parse and interpret traditional

³⁵ Open Mobile Alliance – wapforum.org

³⁶ IXD Studio, *Mobile Web Evolution*, 2010

Web content³⁷ – reducing the burden on transit agencies to develop Internet materials in parallel formats for mobile and traditional clients. However, the heavier bandwidth requirements for modern Web content causes users to incur higher data transfer costs, which is undesirable for the equitable service of financially disadvantaged or transit-captive customers. Furthermore, advanced mobile Web client devices typically carry a significant upfront equipment cost, or require a lengthy contract term and good consumer credit for data service provision – factors to be discussed later.

Social Media

Social media systems comprise an emerging platform for dissemination of timely, brief messages pertaining to transit service.³⁸ While these systems, such as Facebook Inc.'s Facebook and Twitter Inc.'s Twitter, are primarily used by individuals to stay in touch with each other, transit and other government agencies have increasingly signed up in order to connect with the constituent public – many of whom are avid users of these systems. Users can subscribe to updates from official agency user accounts with these services, and when the agency publishes a text posting, it is syndicated to the news feeds of subscribers in line with, and in the same format as, updates from their friends. This personal aggregation display of news from all subscribed accounts provides a common portal for a user to frequent when general updates about his or her social network

³⁷ IXD Studio, *Mobile Web Evolution*, 2010

³⁸ Planning Pool, *Using Social Media to Make Transit Fun!*, 2010

are desired. Transit agencies are therefore able to more quickly distribute service advisories or other news to interested users who are already using social media systems to stay in touch with their friends and associates, anyway.

Social networking, as a category of Internet information exchange, has evolved from somewhat humble beginnings to the current and popular social media “live update” format. Internet users have long communicated with others via computer, dating back to a time when wide adoption of bulletin board systems (BBS), Usenet newsgroup services, and Internet Relay Chat (IRC) servers facilitated real-time, or near real-time, text-based interaction. However, the current trend of limited-length messaging in social media is inspired by the 160-character limit of SMS messages³⁹, providing a familiar format and context for existing SMS and mobile communications device users. The character limit of these messages often requires that users condense or abbreviate lengthy text content in order for it to fit within the constraint.

Transit agencies which have already implemented E-Alerts or other SMS-based advisory systems can easily link their existing updates and other content to emerging social media platforms, as the nature and length of the text messages are compatible and interchangeable. A potential pitfall arises when integrating text updates from feeds or systems that were not designed for such character constraints, since advisory messages can be inadvertently truncated upon receipt by social media users.⁴⁰

³⁹ *Twitter 101 for Business: A Special Guide*

⁴⁰ GovFresh, Interview with John Lisle of DDOT, Washington, DC

*Custom Applications for Smartphones and Other Advanced Mobile
Communications Devices*

Taking advantage of the enhanced, personal computer-like processing capabilities of smartphones and PDAs, operating system manufacturers have begun widely offering software development kits (SDKs) to the general public, which includes the general Internet community of amateur and freelance developers.⁴¹ Traditionally, applications offered on mobile device platforms were limited to programs commercially produced by approved partners, which heavily restricted the utility of such devices. With the introduction of Apple Inc.'s "App Store" for the Apple iPhone device, thousands upon thousands of individual applications were made available by developers to all iPhone users, either for free or at a very nominal upfront cost. Other smartphone platforms followed with their own developer marketplace constructs, although it appears from personal investigation that none has yet reached the sheer application inventory of the Apple App Store.

The significance of these community-based application marketplace initiatives is that they empower transit riders to create programs and systems that serve their, and their fellow riders' traveler information needs when such needs are perceived to remain unmet.⁴² Where developers choose to set a price for installation of their programs, a significant commission is typically collected by the marketplace operator (typically the operating system manufacturer) to

⁴¹ Android Developers – Android SDK (as example)

⁴² The Wall Street Journal, *How Geeks Get Us Around Town*, May 7, 2010

cover overall transaction overhead. Transit agencies also can benefit from the marketplace approach, in that they can stimulate development activity by technologically-savvy customers and, in turn, defray internal IT development expenses.⁴³

Custom applications developed for these advanced hardware devices can take advantage of built-in functions such as magnetic compasses, GPS receivers, accelerometers, and unfettered access to the devices' own high-speed Internet data connectivity. Developers are able to make their applications' functionality available cheaply because the upfront device costs, and ongoing network access and bandwidth costs, are already borne by individual customers. Most custom traveler information-oriented smartphone applications contain little to no meaningful data stored internally; instead, they make use of transit operators' own static and real-time feeds, published in standardized formats such as Google Transit Feed Specification (GTFS) or Extensible Markup Language (XML), and accessed on-the-fly using the wireless data connection.⁴⁴ This means that such applications are typically non-operational when and where wireless data coverage is unavailable – which is very often the case within the transit system itself, or when no data service subscription is in effect for a user. As a result of these factors, the appearance of inexpensive availability of custom mobile information applications can be misleading, as many other costs must be borne and maintained by the user to gain access to them.

⁴³ MassDOT Developers Page

⁴⁴ MassDOT Developers Page

Chapter III: State of the Art in Transit Traveler Information

1. Real-Time Information
2. Official Transit Agency Sponsorship of Open-Source Traveler Information Software Development
3. “Augmented Reality” and Implementation in Custom Smartphone Applications
4. Peer-to-Peer, On-Line, Real-Time Exchange By and Between Transit Passengers

Real-Time Information

Expanding upon the emerging industry trend of releasing feeds of static schedules and other service data in computer-readable formats, these feeds (where available) are increasingly being supplemented for provision of real-time information, such as geographical vehicle positions or delay notifications. Real-time feeds are made available to the public for incorporation in unofficial Web sites and applications by third-party developers, in addition to use in official agency user-facing systems. Application Programming Interfaces (APIs) for ITS systems are typically leveraged to deliver this real-time information in an automated and direct fashion, such that humans need not be tasked with manually updating the feeds as new data become available.

While the notion of real-time information itself is not especially new⁴⁵, the ways in which third parties are manipulating and presenting such data on the Internet are contributing materially to the state of the art. Developers are continually inventing new representations of real-time updates about transit service that combine other pertinent, contextual information about the physical environment to produce systems that significantly add value to the travel experience. For example, these representations are finding their way into custom smartphone applications, which traditionally only contained static information.

As new media and delivery mechanisms emerge, the evolution of real-time information will play an important role in the overall development of TTIS, as it

⁴⁵ Schweiger, TCRP Synthesis 48, 2003

empowers travelers to make dynamic trip planning decisions based on ever-changing network and service conditions.

Official Transit Agency Sponsorship of Open-Source Traveler Information Software Development

A promising trend in the advancement of traveler information systems is transit agency sponsorship of open-source software. Contrary to proprietary solutions by third-party commercial vendors, open-source software allows free use by anyone as long as the terms of the free license are followed.⁴⁶ Extensions to the software can be developed by anyone who sees fit, as long as those extensions are then made available to other developers and users of the software.⁴⁷ Investment in open-source software allows the entire transit industry to benefit from, and evolve with, a vision of technical collaboration that will enhance the state of the practice, as well as the quality of service, for passengers.

OpenTripPlanner, an open-source multimodal trip planner Web application, was created by a team of software developers led by Oregon's Tri-Met, and OpenPlans, an urban planning nonprofit which focuses on open-source Internet development. This application is released to the public under the GNU Lesser General Public License (LGPL), which allows free distribution and use as mentioned above.⁴⁸ OpenTripPlanner has the potential to save agencies the significant upfront capital outlay required for proprietary trip planner

⁴⁶ Open Source Initiative (OpenSource.org)

⁴⁷ Open Source Initiative (OpenSource.org)

⁴⁸ OpenTripPlanner.org

development, and it supports data imports from GTFS, shapefiles, and the U.S. Geological Survey's National Elevation Dataset (NED).⁴⁹ This cross-format compatibility reduces the burden on agencies to conform existing scheduling and dispatching software to a new platform, as GTFS exporters are common extensions to these proprietary systems, and shapefiles are often already maintained by agencies or their governmental affiliates, for example.

“Augmented Reality” and Implementation in Custom Smartphone Applications

“Augmented reality” is a term given to the user experience of a mobile device that utilizes hardware and software functionality to enrich one’s visual and mental perception of his or her surroundings.⁵⁰ Recent smartphones and other advanced mobile communications devices have been manufactured with components such as built-in magnetic compasses, still and video cameras, photodetectors (light sensors), Global Positioning System (GPS) receivers, accelerometers, and cellular and wireless data antennas, all of which are utilized by custom applications to provide rich information delivery. These “augmented reality” applications stand to significantly enhance the state of traveler information for transit passengers, especially those who are visiting unfamiliar areas of the city and seek specific destinations or services upon arrival.

A typical “augmented reality” user session involves viewing one’s surroundings through a virtual, on-screen viewfinder of a smartphone’s built-in

⁴⁹ OpenTripPlanner.org

⁵⁰ The Observer, *Augmented reality: it’s like real life, but better*, March 21, 2010

camera.⁵¹ As the user pans the smartphone from side to side, the image pans in the viewfinder display in response to that movement. With the aid of the compass, GPS, and wireless data services, information is overlaid on the live image to add positional context – for example, pointing the device in a certain direction while standing on a sidewalk could prompt a display of a list of businesses that lie within walking distance in that direction, or better yet, identify specific buildings seen through the lens (and provide that identification instantly, on the same display).

For a few years now, applications have existed to utilize a mobile device’s built-in camera as a scanner, mostly for use with barcodes or two-dimensional “QR Codes.”⁵² Barcodes can be used in the transit context by affixing them to signs or other physical surfaces, so that passengers can “scan” them with a Web-enabled mobile device, submit the image to a server using a custom application, and receive a translation of that barcode into human-readable information. For example, a barcode can be printed on a sign at a bus stop, allowing riders to scan the barcode with their phone, and then wirelessly download a schedule for service to that stop – without tedious navigation of a mobile Web page to mine for the information traditionally.

While optical character recognition (OCR) software has long been able to turn scanned images of printed material into editable text, advances in image recognition technology, in concert with increased resolution of cameras built into today’s mobile devices, allow for intelligent recognition of artwork and objects as

⁵¹ The Observer, *Augmented reality: it’s like real life, but better*, March 21, 2010

⁵² Fast Company, *What Business Card? Just Scan My QR Code*, March 16, 2010

well. Google Inc.'s "Google Goggles" application, recently released on the Android mobile operating system, allows a user to capture a photograph of any object, and then submit that photograph for instant identification of its subject.⁵³ It is foreseeable that such a tool could be invaluable in the pursuit of traveler information during a trip, as a passenger need only aim a device at a curious landmark or waypoint, capture its image, query a central server for positive identification, and then receive contextually-appropriate information in return. Furthermore, as GPS receivers have difficulty operating underground, this visual, virtual identification of one's surroundings could be a primary navigation aid as long as access to a wireless data network is available. Future advances in mobile hardware – specifically, sensors and peripherals that interact with and interpret the physical world – will only serve to further empower the technologically-savvy traveler in this field.

Peer-to-Peer, On-Line, Real-Time Exchange By and Between Transit Passengers

The availability of wireless data network access within transit systems, particularly within previously disconnected underground infrastructure, has created new means of sociable information exchange for passengers. Recent research conducted in a collaboration between MIT's Mobile Experience Laboratory and Régie Autonome des Transports Parisiens (RATP) has highlighted potential for interpersonal interaction between passengers – not only

⁵³ Google Mobile Labs, *Google Goggles for Android*

in the pursuit of traveler information, but also to beneficially harness the knowledge and economic power of the collective ridership.

“Metro 2.0,” a research workshop held during the Spring 2007 academic semester at MIT, explored the potential for radically leveraging the collective ability of the transit-riding crowd, given advancements in mobile communications device technology and wireless data network accessibility.⁵⁴ The focus of the workshop was to develop design proposals for futuristic hardware or software technological enhancements to the passenger experience, and the suggestions developed by students ranged from the whimsical to the practical.

On the lighter side, “social gaming” proposals aim to catalyze spontaneous and enjoyable passenger interactions during itinerary transfers, between service headways, or simply as mechanisms to displace boredom during transit vehicle dwell time. Ideas included such activities as playing virtual ping-pong across subway tracks, or conducting a mobile device-enabled “scavenger hunt” with fellow passengers throughout the transit system.⁵⁵ More relevant to this study, a proposal for an online information exchange envisioned that passengers could use their mobile devices to pose questions to, and answer questions from, fellow riders in real time. The basis for the idea is that other riders in the same vehicle (or train) possess knowledge that someone may seek – for example, information about transit service, or about the surrounding city – but in practice, the threshold for starting a conversation with a stranger is too high for such knowledge to be unlocked and shared. With an impartial third party (the transit

⁵⁴ MIT Mobile Experience Lab, *Metro 2.0 Report*

⁵⁵ MIT Mobile Experience Lab, *Metro 2.0 Report*

agency) acting as a virtual facilitator, it is thought to be possible that fellow passengers can spark dialogue, learn from each other, or simply assist in the common goal of a better commute.⁵⁶

“Smart Urban Mobility Systems,” a follow-up research workshop held at MIT’s Mobile Experience Laboratory in Fall 2008, again partnered with the RATP to more closely examine the relationship between mobile communications technology and the built environment (i.e., transit spaces). The primary proposal that resulted from this effort was a “social freight” scheme, whereby riders could connect with each other to personally deliver small packages throughout Paris’ subway, bus, and tram network for a predetermined fee or reward.⁵⁷ This system would depend upon a strong IT backbone administered by the transit agency (or an affiliate), which would be utilized as a proxy for these personal courier transactions. While this is not strictly a traveler information medium, it has the potential to further acquaint users with the transit network as they perform deliveries to unfamiliar stations or areas of the city, as well as create an incentive for users to take transit over taxicabs or other modes, due to the potential of making money from one’s unrealized personal carrying capacity.⁵⁸

As a model of the state of the art meeting the emerging information systems practice, BART in the San Francisco Bay Area has recently partnered with “Foursquare.com,” a location-based, mobile Web-enabled, competitive social networking game.⁵⁹ Foursquare mirrors representations of physical businesses, landmarks, and locations in an online political and social

⁵⁶ MIT Mobile Experience Lab, *Metro 2.0 Report*

⁵⁷ MIT Mobile Experience Lab, *Smart Urban Mobility Systems Report*

⁵⁸ MIT Mobile Experience Lab, *Smart Urban Mobility Systems Report*

⁵⁹ ZDNet, *How mass transit integrates with Foursquare*, May 5, 2010

environment, in which users can be nominated and serve as “mayors,” or virtual ambassadors, of the locations they frequent in real life.⁶⁰ In the BART system, passengers are claiming virtual “mayor” positions for the transit stations they use most regularly⁶¹, and this “political” activity – along with each physical visit – is syndicated to the users’ social media feeds on services such as Twitter. The result of this engagement of transit service, as well as of fellow passengers, through an offering like Foursquare is that customers can actively promote transit use to their friends via social media, while passively adding amusement and personal value to their own time spent in transit.

Google Inc.’s “Google Latitude” service replicates Foursquare’s location-reporting functionality on a more practical level. Working in conjunction with official Google Maps smartphone applications and built-in GPS receivers, Google Latitude broadcasts your exact location (or nearest triangulated location inferred from cellular tower sites) to others you allow in your social network. Fellow Latitude users can view your Google avatar (and that of other friends) superimposed on a Google Maps display for geographical reference, and if desired, your location history can be saved privately for later review of routes taken.⁶² This service has the potential to greatly enhance navigation for a transit user who is attempting to meet up with friends or associates at the conclusion of a trip, as the friends’ exact, real-time geographic coordinates would be at his or her disposal while on foot. Google Maps (or similar applications) could then

⁶⁰ Foursquare.com

⁶¹ ZDNet, *How mass transit integrates with Foursquare*, May 5, 2010

⁶² Google Latitude

provide handheld, door-to-door walking directions from the transit station to that final destination.

Chapter IV: Interview Findings and Interpretation

Resource Constraints

- Overall Financial Constraints / General Lack of Financial Resources
- Difficulty in Securing Operating (as opposed to Capital) Funding
- Lack of Board/Management Recognition of IT as a Strategic Resource for Transit
- General Lack of IT Resources

Issues Related to TTIS Strategy Development

- Lack of Focus on Market Research, and Lack of Surveys to Inform Strategy
- Sensitivity to the Digital Divide
- Use of Social Media and Strategy
- The Debate about Controlled versus Open Data

Data Availability and Technical Challenges

- Implications of Being Locked Into Commercial, Proprietary Systems and Contracts
- Lack of Use of Open Standards for Intelligent Transportation Systems / Transit Traveler Information Systems
- Difficulty in Adapting Legacy Systems to New Uses – for example, Transit Traveler Information Systems

Challenges Related to Specific Information Delivery Mechanisms

- Labor-Intensiveness of E-Alerts Composition and Maintenance
- Concerns about the Cost of SMS Message Transmission
- Targeted Deployment Trends for Real-Time Information Displays

Resource Constraints

Overall Financial Constraints / General Lack of Financial Resources

Based on the responses from interviewees, it is clear that transit agencies across the United States and Canada are suffering from the prevailing economic situation that has ravaged the coffers of countless state and municipal governments. Discretionary research and development funding for projects deemed nonessential to everyday operations is often among the first line items to be cut when budgets must tightly balance. Moreover, even in progressive systems where funding has historically been available for the pursuit of passenger information, projects have recently been placed on hold, curtailed, or postponed indefinitely for lack of financial resources.

Respondents indicated that in many markets, availability of real-time passenger information is a widespread expectation among the public for a number of reasons: increased knowledge and expectations in society in general with respect to technology; expectations of a technologically-savvy rider base which is fluent in emerging applications and covets information offerings seen in other cities (typically abroad in Europe or Asia); or, historical customer frustration over the lack of information in the face of infrequent and often unreliable service. In some cases, this expectation is fed by technology advances for other transportation modes: for example, live traffic cameras and Web updates have been used for years in many jurisdictions to enhance the commuting experience for motorists. Transit operators are subjected to social

and political pressure to embrace these trends, and to position themselves as more attractive options for both the daily commute and leisure travel. Therefore, respondents report that they increasingly have to do more with less on the technology front – in addition to bearing the usual, traditional expenses inherent in providing safe and efficient transit service.

This dismal state of financial affairs has had an unexpected, beneficial impact on the advancement of transit traveler information applications, as it has forced operators to become more creative in how to meet the needs and expectations of the public. In some cities, interviewees confirmed that the need to conserve resources has prompted investigation of low- or no-cost methods of disseminating information (where available) which leverage the software development abilities of the local community. This is particularly prevalent where real-time information is already captured by computer-aided dispatch and automatic vehicle location (CAD/AVL) systems that can easily be configured to publish a live data feed to the public. In other cities, operators have chosen to partner with commercial information systems providers for the express purpose of passenger information delivery, but funding constraints often limit the scope of these partnerships (and therefore, the public benefit). As another example, two agencies interviewed – in Ann Arbor and Montreal – enjoy close relationships with local universities, which have provided student resources for research and development of trip planning and real-time information applications.

The endemic funding constraints in many transit agencies have been a chief driver of the emerging trend of making traveler information available to

third parties, in the spirit of the open-source software movement. Software developers with no previous connection to the transit industry are discovering motivation from the free market to develop applications that present and manipulate this information in new and compelling ways. This is reportedly attractive to transit operators as it allows for innovation and better customer service with little to no financial outlay on the part of the agency.

Difficulty in Securing Operating (as opposed to Capital) Funding

A key trend evidenced by the comments of several interviewees is the ongoing challenge of convincing transit agencies' senior management to provide for perpetual maintenance and upkeep of passenger information systems. Where resources are available, it is apparently straightforward to make the business case for capital funding to establish new projects, systems, and initiatives. But when *operating* money is requested on a perpetual basis to continue supporting and extending these systems, management is not always so forthcoming with support.

One example provided is that commercial real-time bus arrival systems, for example, typically require agencies to pay annual license fees (beyond the initial capital cost) to continue syndicating updates to passengers. Additional costs are also incurred if an agency decides to expand its service area to include more routes or vehicles. And even in cases where traveler information is fed by in-house sources, therefore obviating the need for external licensing fees, incremental costs are reportedly incurred in enabling new features or keeping up with emerging trends in the industry.

Lack of Board/Management Recognition of IT as a Strategic Resource for Transit

The agencies interviewed represented a broad spectrum of management styles, each with its own organizational structure and varying levels of in-house information technology support. A recurring theme reiterated by multiple interviewees is the importance of a high-level philosophy regarding IT as a strategic, specific resource for transit.

The agencies that have been most prolific with the release of advanced traveler information applications enjoy an IT staff whose work is wholly dedicated to transit. While this may seem elementary, there are many operators which, as departments of municipal governments (particularly in Canada), share technology resources with other city agencies. Respondents hypothesized that this may be because of an overarching belief of officials that the IT needs of a transit agency are identical to that of any other government organization, and therefore, that the capabilities of a shared IT staff are sufficient to fulfill them.

Respondents were quick to debunk this notion. In cases where agencies are forced to share IT resources with other groups, transit projects receive less concerted effort by a diluted staff which is somewhat unfamiliar with the systems and challenges unique to a transit operation. The technology issues that face public works or police departments understandably differ from that of public transit, and it is suboptimal to assume that a “jack of all trades” strategy can prove effective. Project innovation is reportedly stifled and potential customer

service impact is diminished when the IT staff must answer to numerous allegiances.

In one instance, it was not resources of a human nature that were in danger of dilution, but rather communications and technology infrastructure. It was reported that in one Canadian city, the transit agency has its own radio communications equipment and towers situated along its bus routes for dispatching and other operations purposes. The administration of this infrastructure falls squarely under the purview of the transit agency itself, which enjoys a dedicated IT staff. However, in a municipal effort to consolidate resources, the police and fire radio antennas are slated to be piggybacked on the transit towers. Even though this would not create an undue, direct burden for innovation going forward, it reportedly places a support responsibility on the transit agency to at least maintain the towers according to the specific standards of emergency services. It is felt that this sort of consolidation only serves to take away from the primary mission of serving transit passengers' best interests, even when any competition for resources can be said to provide other public benefit.

General Lack of IT Resources

As previously discussed, it is no secret that transit agencies are facing increasingly constrained financial contexts. Respondents noted that this reality makes it difficult for sufficient monetary and labor resources to be devoted solely to information technology, even when a clear strategy and vision exist within the organization.

Historically, systems such as BART in the San Francisco Bay Area have been leaders in IT systems, specifically those relating to real-time passenger information. For example, BART trains have long enjoyed a communications and technology infrastructure that enables accurate reporting of train arrival times to the public. Interviewees felt that this highly detailed level of available information has fueled a trend of innovation in the types of applications that consume and display real-time information, creating an interest and expectation of innovation on the part of the public. For years, BART supported in-house versions of smartphone applications for numerous handheld operating systems, such as PalmOS. Due to funding constraints, it was apparently recently necessary to not only discontinue support of these standalone tools, but also cease new development of future official applications like them. While the public release of a real-time information feed to third-party developers has arguably increased accessibility to such tools in the marketplace, it is understood by managers that more could be done to support and encourage development with a heftier IT budget.

In transit systems where overall funding is not so tight, the administrative budget allocation to IT projects is reportedly often too meager to support the state of the practice in transit technology. Passenger expectations have grown to include sufficient end-user technology *in addition to* simply a timely arrival, and it was noted that this trend is often borne of experiences with cutting-edge IT applications in other industries. One manager felt that if transit agencies have any hope of attracting new choice riders to their systems, thereby alleviating traffic and environmental consequences of single-occupancy vehicle use,

significant IT investment is an important incentive that often makes a positive and tangible passenger impact.

A common sentiment echoed by many interviewees is the notion that transit passengers care more about up-to-date, real-time trip information than they do about schedule adherence – especially for services with short headways. A bus can be running an hour behind schedule, but if its exact geographic position and arrival estimate are able to be mapped on a patron’s smartphone display, he/she can make dynamic trip planning decisions to maximize the use of her time. This sort of public passenger empowerment is said to resonate strongly with higher-income demographics which tend to place a higher value on their time – reportedly indicative of choice riders who may subscribe to traditionally unfavorable perceptions of public transit service. Better information, made possible by IT investment, changes the ways people value and interact with their transit commute. This is thought to lead to increased revenue and ridership, potentially offsetting some of the upfront cost of making that information available.

Issues Related to TTIS Strategy Development

Lack of Focus on Market Research, and Lack of Surveys to Inform Strategy

Even in the most advanced transit agencies studied, results gleaned from surveys or other research (where conducted) typically lack information about passenger technology use and preferences. Where surveys are common, they tend to be focused on assessment of customer satisfaction of the transit service in general, and may include basic questions about the agency's Web site or other marketing materials. However, they are seldom specific enough to assess penetration rates of mobile devices among transit patrons, or to gauge users' ability to comprehend and interact with mobile devices, application interfaces, or other emerging platforms for information delivery.

As a separate issue, due to limited resources, some agencies utilized Internet survey applications which allow users to answer questions on their own computers and at their own pace. Interviewees noted that while such applications can reach a wider audience than a traditional intercept or telephone survey, access to them is inherently limited to the "Internet savvy," creating a potential bias in the results toward the digitally capable.

Sensitivity to the Digital Divide

As discussed previously, passengers who are on the disadvantaged side of the digital divide are typically also most dependent upon transit for their

commuting or other mobility needs, and face unique challenges consuming traveler information when it is made available using new media and technologies. Many of the interviewees recognized this issue, and felt that traditional traveler information media will likely remain in distribution until the digitally disadvantaged “catch up.”

This high-level realization by interviewees that advanced information systems cannot equally serve all demographics is important, but absent from the prevailing dialogue is any cohesive strategy on what to do about it in the long term. Some offer that interactive voice-response (IVR) systems and dynamic platform information signs are immune to the digital divide, as no specialized education or unusual outlay of capital is required to benefit from these devices. Others suggest that old-fashioned printed schedules and other media will always remain, and that the new Web and smartphone applications are merely optional gadgetry that only builds upon the existing baseline of available information for the sake of convenience.

In the case of public call centers staffed by agency personnel, it is reported that the advent of real-time vehicle arrival prediction technology has markedly shifted call patterns toward questions about information from these systems. In many cases, passengers will simply call the transit operator and ask “when is the next bus arriving at my station?” Interviewees stated that questions like these are more efficiently served by automated sources, given that the operator is just retrieving the answer from his or her computer terminal, anyway. Some agencies have attempted to adapt their call centers (a traditional information medium) to

the new technology, by shifting delivery of these simple answers to IVR systems and the Internet.

Use of Social Media and Strategy

As can be expected with an emerging communication format, there is a general lack of understanding and lack of strategy in transit agencies' approach to these services. It is generally accepted by respondents that to meet public expectations by being technologically savvy and connected to the new Internet information trends, transportation companies feel the need to have an official marketing presence on social media services. However, it is less clear where the real value lies in the expenditure of resources in such a forum. What is the business case for having a social media presence? Are agencies trying to enhance the availability of service information for existing users, or is the goal to attract and connect with new, tech-savvy choice riders? These questions and themes were largely left unaddressed in the interviews, and the lack of a cohesive strategy for leveraging social media was apparent in most cases.

The Debate about Controlled versus Open Data

In order to bring a transit system to a level of service that enables real-time vehicle location tracking, it is reported that the agency must invest a significant amount of capital into infrastructure and information technology. While this investment is said to significantly improve both the efficacy of

dispatching as well as the perception of service quality by the customer, agencies are experiencing general financial constraints that often make such investment difficult. Initially, as a result of these pressures and the overall cost of supporting real-time as well as static passenger information, some larger transit agencies did attempt to capture the perceived value of the information they were providing, in particular if exported to third-party developers. However, as a result of some high-profile conflicts in the public/political realm, this is no longer the case; the agencies interviewed for this research do not generally look for ways to monetize these resources as they are published in new and emerging media.

However, providing information carries costs to the transit agency, either because license fees with existing system vendors need to be renegotiated, and/or because staff time is required to develop and maintain these external feeds; interviewees emphasized that these costs are a significant obstacle in the highly financially constrained environment faced by transit agencies, and often result in a lower priority given to such initiatives and delays. Nonetheless, despite these financial constraints, agencies which provide data access to third-party developers do not generally charge for it, nor do they impose a royalty on licensure of applications which make use of this data. Indemnity disclaimers are standard among the agencies, such that the veracity of data accessed from the feed and repackaged elsewhere will not be guaranteed by the agency. Concern by transit agencies that they will be held responsible for errors by third party developers reportedly leads some respondents to distance themselves from these applications, and even to expressly remove themselves from providing support for the feed or for any of the information gained from it.

Agencies which possess real-time information, but do not make it available to outside developers in a standard format, are sometimes concerned about data integrity and the potential for customers to be misinformed by unapproved sources. More frequently, however, these agencies have partnered with a vendor to provide public next-stop announcements or arrival estimates through proprietary interfaces and Web sites, and would be forced to pay a license fee or other consideration for a real-time public feed.

Managers at agencies which do not possess real-time service data, but which make their static schedules available on the Internet, report that they often provide these schedules to Google Transit in the Google Transit Feed Specification (GTFS) format. When schedule and other data are prepared in GTFS, agencies do not always release the data files to anyone else but Google. This decision is said to make it much more difficult for third-party developers to attempt to incorporate schedule or other service information in private applications or sources, and transit agencies concerned with issues such as data integrity will often make this choice. That said, some interviewees at agencies which provide their data in GTFS format to Google simultaneously make these files available to the public on their Web sites, usually in a “developers” section.

Data Availability and Technical Challenges

Implications of Being Locked Into Commercial, Proprietary Systems and Contracts

Respondents from a number of transit agencies indicated that they utilize proprietary traveler information systems to disseminate both static and real-time data to customers. These systems span the range of applications from trip planners fed by static schedules, to real-time arrival predictors and GPS-enabled mapping tools. Instead of attempting to develop and support such systems in-house with an internal IT staff, these agencies will instead contract with commercial vendors who offer turnkey solutions to suit these needs.

This practice conceivably offers some benefits to transit agencies without the necessary manpower to build information applications from scratch can benefit from industry innovation at, potentially, a fraction of the aggregate cost. However, several interviewees who enjoy the privilege of in-house IT developers warned that these proprietary vendors often include heavily restrictive terms in their contracts regarding information use. For example, these terms often restrain agencies from using real-time vehicle location data obtained using the vendor's equipment for any unsanctioned purpose, meaning that any new applications built upon the real-time data feed must be licensed through the vendor. For a transit system with numerous bus routes, it was posed that a license fee could be demanded under the contract for each route with data the agency wishes to make available to the public. In other cases, if an agency wishes

to extend or benefit from new uses of proprietary scheduling software, it must work with that sole vendor to produce those extensions if data integrity and interoperability is to be assured. Of course, this software development takes place at that vendor's rate, which may be higher than that of an unaffiliated firm with a standalone product or feature.

One interviewee suggested that transit agencies in the U.S. and Canada which have not already committed to a traveler information technology may be in the best shape of all. This is because they have not committed themselves to any specific vendor, and are potentially in the best shape to evaluate all available options in a rapidly changing technological environment – including in-house development or open-source technologies – on their own merits.

It was suggested by this respondent that agencies which locked themselves into agreements with service providers years ago may have the least leverage in applying existing data feeds to emerging applications and concepts. Before today's traveler information applications were widespread, it was apparently hard to foresee emerging uses for real-time location data, and contract terms governing its use may not have been negotiated to a transit agency's best advantage. The best time to negotiate future use of real-time data captured by a vendor's equipment is reportedly in the tendering phase, meaning agencies in that position today are best prepared to demand free and open access. A similar issue exists with respect to any static data stored in proprietary formats.

*Lack of Use of Open Standards for Intelligent Transportation Systems / Transit
Traveler Information Systems*

Some interviewees argue that always adopting proprietary solutions to solve transit technology challenges reinforces the practical oligopoly in the industry, working to stifle innovation and other improvements that usually result from competitive forces. Instead, it is argued, transit agencies should invest in open standards and platform development to enrich the state of the practice and enhance the transit user experience in other cities, as well. As a community effort, these open standards and software platforms would come with flexible usage terms that do not preclude the sharing of data with third parties, or impose license fees on new applications and media. Oregon's Tri-Met is a pioneer in this area, as a key sponsor of the Google Transit initiative and GTFS format, and more recently, of the OpenTripPlanner project. Transit agencies that are geographically separated are, by nature, not competitors for the same passenger base – so interviewees feel they have much to gain from collaborating with each other.

Agencies which rely on a software suite from a specific vendor for the majority of their scheduling and service information often find themselves relying upon that vendor for future technology. The public relies on smooth and successful transit operations every day, and technology managers reported that they often do not want to risk incorporating new applications that are not guaranteed to be 100% interoperable with their existing platform, for fear of system disruptions or dissemination of faulty information. While this cautious

approach may be operationally prudent given the circumstances, one reported downside is that it forces the agency to wait until the funding is available to get the vendor to supply a proprietary solution for every emerging passenger information trend.

In one specific instance, an agency interviewed chose not to offer real-time E-Alerts to their customers over two years ago, despite there being several solutions for this function available in the marketplace. The reason cited for the non-implementation was that their vendor of choice (one of the eminent developers of transit scheduling and operations software) didn't yet have such a product on offer, and it would be too much of a support headache for the agency to both plug in a third-party alert system and ensure its scalability in the future. The end result is that this agency's riders still lack access to an E-Alerts system, while the agency's IT division continues to work with the preferred vendor on developing a solution, with no definite release date in sight. Custom software extensions such as this are often apparently only developed on demand, at a high individual cost to the requesting agency and to any subsequent agencies who wish to license the new product from the vendor. The inherent delays in the "closed" systems approach end up negatively impacting customers who can benefit from better access to traveler information immediately.

Finally, the use of proprietary systems which do not adhere to open information standards also is said to make aggregation of traveler information difficult. One interviewee noted that metropolitan planning organizations (MPOs), and other regional transportation oversight bodies which are in charge of representing and aggregating data from all of the agencies in their jurisdiction,

often experience difficulties when multiple agencies provide static or real-time data in conflicting formats. The need to reconcile these data often results in extensive delays while conversion processes are put into place by either the MPO or individual agency; this, in turn, delays passenger consumption of information through centralized Web or telephone resources, such as “511” services, he said.

Difficulty in Adapting Legacy Systems to New Uses – for example, Transit Traveler Information Systems

As advanced traveler information technologies are relatively new entrants to the world of public transportation, transit agencies that have historically embraced static passenger information systems are reportedly finding themselves at a crossroads. Traditional trip planning Web applications, for instance, were designed to generate itineraries based on fixed schedule data that is loaded periodically when changes to the schedules are made by the agency. Providing real-time information is said to introduce several magnitudes of complexity, since it requires a CAD/AVL system that continuously monitors the location of each and every transit vehicle, continuously compares the actual location of each vehicle to its scheduled location, calculates the variance from schedule, and then creates a continuously updated database of real-time schedules. This CAD/AVL system can then be used, in combination with historical data, to predict the arrival times at downstream stop locations.

Approximately two-thirds of transit agencies have deployed some form of CAD/AVL. However, most of these legacy CAD/AVL systems were designed

based on an architecture that minimizes communications with the vehicles, often with updates only every two to four minutes (and more frequently in cases of emergencies). While this is an adequate architecture for purposes of regular communications, incident management (e.g., replacing broken vehicles, managing deviations, etc.), and responding to the occasional emergency, the responses from the interviews highlighted that it becomes particularly difficult to adapt these legacy systems to support the precise location tracking and continuous, accurate communications required to provide minute-by-minute real-time information to patrons. It is felt that the lack of location precision provided by these legacy systems will seriously affect the performance of traveler information, and in some cases, result in early arrivals and missed trips. Inaccurate arrival predictions would then lead to patron frustration, and lack of trust in the system.

Respondents felt that moving from the current private radio architecture, which uses a limited number of radio channels, to a cellular-based wireless communications system would improve accuracy, but would likely result in a large increase in operating costs because of the large amount of continuous data transmission. As previously mentioned, it has been noted by interviewees that securing operating funding is typically more difficult than new capital funding. Real-time information systems are more costly to maintain because of the need for constant data transmission and reception, so it could be difficult for cash-strapped agencies to make the case for an increased maintenance budget unless it is part of a necessary, total replacement of the entire CAD/AVL system.

Challenges Related to Specific Information Delivery Mechanisms

Labor-Intensiveness of E-Alerts Composition and Maintenance

E-Alerts are reportedly one of the very first types of mobile device-based traveler information applications enabled by an agency in their IT development timeline. Therefore, respondents were generally more familiar with E-Alerts than some other traveler information systems.

Respondents highlighted some operational drawbacks inherent in E-Alerts. For one, they typically require a human operator to generate and submit the text content intended for broadcasting. This is a highly labor-intensive process that requires an agency employee's dedicated effort to learn of the disruption and concisely transcribe it in less than 140 to 160 characters. In this age of constrained financial contexts, human resources are dear, and agencies indicated that their allocation always requires careful consideration.

Interviewees felt that ideally, E-Alerts would be automatically created and distributed when advisory conditions are recognized by CAD/AVL systems or other sources of information. This would remove the need for an employee to manually compose an E-Alert. However, the architecture of CAD/AVL systems has been in place for many years, and was not designed to produce natural language responses for public consumption; in the few cases where respondents indicated written service advisories are linked to dispatching, a human operator must still write the advisory for operational use, at which time the message is automatically relayed to E-Alerts or social media platforms. Due to character

limitations of these broadcasts, messages not expressly written with social media in mind are often truncated and rendered unintelligible to the public.

Respondents also noted that trip planning systems, whether on an agency's Web site or built into mobile phone applications, suffer from a lack of interoperability with these manual service alerts. In general, itineraries generated by online trip planners do not recognize temporary disruptions manually entered by an operator – especially when such a trip planner normally relies solely on static schedule and route information to perform its calculations. As mentioned previously, commercially-developed trip planning applications are costly to extend when new communications media emerge, as they incur additional third-party development expense.

Concerns about the Cost of SMS Message Transmission

The per-message costs of SMS, while small and easily absorbed on an individual scale by riders, reportedly become prohibitively expensive when examined on a transit agency level. For example, E-Alerts systems may have tens of thousands of subscribers, some or all of which are sent a copy of an alert message whenever one is produced. Other traveler information systems, such as vehicle arrival estimate predictors, often employ SMS in a two-way capacity – allowing users to request information via text message, and receive an answer to the query using the same medium – and therefore are reported to incur a double message cost for the agency.

If SMS messages are to become an integral part of any new traveler information application, respondents felt that an adequate operating budget must be developed to support the ongoing messaging charges the agency will be sure to incur. Even at two or three cents per transmission, the costs quickly add up for large agencies.

Targeted Deployment Trends for Real-Time Information Displays

Interviewees reported that there are significant capital expenses involved in procuring and installing physical displays, as well as ongoing operating costs to support data transmission and supply power to these devices.

In general, information displays are said to be most useful when conveying real-time information updates, such as vehicle arrival estimates or service disruption alerts, due to the deficiencies of traditional (such as print) media in displaying dynamic content. The reported tradeoff in forgoing physical displays for less expensive (or no) hardware is that fewer passengers will be able to benefit from available content, particularly where user finances do not provide for personal device ownership. While respondents felt this was regrettable, it was also noted that it is clearly impractical to outfit each and every bus stop in a transit route network with advanced technology hardware. Transit agency personnel interviewed for this study generally believe that fixed displays are a positive investment, but for budgetary reasons, should be targeted for deployment at only the largest or busiest hubs in the system.

Interviewees representing the most progressive of transit systems, which promote a “bring-your-own-access” model for traveler information that shifts technology development to third parties, feel that such physical displays are unnecessary, as users can simply access available content using ubiquitous cellular phones. Where recognition of the “digital divide” is present in such progressive agencies, the general feeling is that cellular phone penetration and available information technology will develop to the point that nobody will be dependent upon a physical display for their information needs. The lack of market research data about penetration of smartphones, and their potential use by transit patrons, again makes it difficult to evaluate the pros and cons of different information deployment strategies (for example, stop-level displays versus wireless device-based information delivery).

Chapter V: Conclusions, Recommendations, and Future Research

This study supports the hypothesis that the general industry approach to the pursuit of advanced transit traveler information systems is, in most cases, less than adequate. Transit agencies in the United States and Canada are eager to embrace these new technologies, but could do so more effectively by adopting a number of best practices.

The areas for potential improvement identified through this research are summarized in the recommendations that follow.

Recommendations

1. Develop an Informed TTIS Strategy

- Conduct Necessary Market Research on Transit Traveler Information Systems (TTIS)
- Develop a Multi-Format TTIS Strategy
- Clarify Role/Structure for Social Media and E-Alerts as part of Overall TTIS Strategy

2. Acquire Sufficient Resources (Financial and IT)

- Build and Support Sufficient Information Technology (IT) Resources
- Ensure Sufficient Operating as well as Capital Funding for TTIS Initiatives

3. Develop a Data Strategy: Interoperability, Open Source, and Open Government

- Eliminate Constraints on Use of Data and Interfaces of Commercial Software
- Adopt Open-Source and Intelligent Transportation Systems (ITS) Standards
- Adopt and Benefit from “Open Government” Approach to Public Data

Develop an Informed TTIS Strategy

Conduct Necessary Market Research on Transit Traveler Information Systems (TTIS)

I recommend that transit agencies conduct necessary market research on TTIS in order to develop sufficient knowledge required to build an effective, overall TTIS strategy.

This market research initiative should aim to help identify the information needs of different categories of transit users, especially targeting choice riders who may be convinced to use transit more often if improved traveler information is made available. Additionally, the research should assist in determining passengers' use and access to potential information delivery means (such as personal mobile communications devices), including penetration rates. Over time, reliable results from surveys, focus groups, or other forms of market research will ideally reveal trends in personal technology use and acceptance among the ridership, and help to predict the likely evolution of the same.

Market research should be conducted regularly, and questions posed to the public (as found in surveys) should be revised regularly to reflect emerging trends in information technology, wireless communication, and real-time passenger information. Furthermore, the mode in which the research is advertised and conducted should lend itself to as little demographic bias as possible. For example, Internet-based surveys only reach an already connected,

potentially tech-savvy audience, and will likely insufficiently indicate ability of those on the disadvantaged side of the digital divide.

If possible, agencies should also forge strategic partnerships and connections with local civic groups, community centers, or community research labs at area universities for assistance with carrying out market research to specific underrepresented demographics.

Develop a Multi-Format TTIS Strategy

Next, I recommend that transit agencies develop a strategy for the delivery of TTIS that encompasses multiple information formats. This strategy would account for the requirements of users on both sides of the digital divide, identifying market niche categories of current and potential transit users, and their information needs and expectations. Informed by market research, the strategy would determine TTIS delivery methods that are appropriate to meet the individual needs of each market category.

Publication of traditional traveler information media, such as printed schedule or navigation materials, should (for the near future) be continued at a level of support that permits a user to take full advantage of transit services without the need for, or access to, Internet connectivity or personal mobile communications devices. While technology costs and trends may change in the future, captive riders who lack the skills, funds or physical ability to access that technology must be able to successfully utilize transit service by consulting traditional information media.

That said, of the current personal communications technologies, SMS messaging is perhaps the most widely adopted by users, due to extensive SMS support in even the most inexpensive cellular phones on the market. Individual SMS messages cost, at most, about twenty-five cents to send and receive if the subscriber lacks a flat-rate feature plan. Transit agencies endeavoring to reach out to the largest possible audience using text-based TTIS should strongly consider supporting SMS interaction by and with passengers.

Along these same lines, IVR phone systems enable passengers to access traveler information when only the ability to place voice calls exists. IVR systems allow users to query an information system for specific data via speech recognition or dual-tone multi-frequency (DTMF) keypad input, theoretically obviating the need for information technology fluency among literate, hearing-unimpaired persons. As anyone can call into IVR systems using the most basic of cellular phones, or even pay phones, they should be considered a very accessible alternative to printed media – although cellular signal reception and platform-level noise pollution are potential detractors to their utility. Implementation of free and open-source software packages such as Digium Inc.'s Asterisk can eliminate much of the usual cost incurred by an IVR installation.

Finally, another important medium of traveler information is the physical display. As this type of hardware is expensive to purchase and maintain, the deployment of physical information displays should be targeted at either the busiest stations in the network, or at stations in socioeconomically disadvantaged districts where a minority of riders will have access to the Web, or to mobile device-based TTIS.

If a transit agency makes either a static or real-time information feed available publicly for use by third-party developers, I recommend an explicit partnership with community groups to encourage creation of information applications specifically catered to disadvantaged markets. This partnership could also foster an education and awareness campaign for those less connected to traveler information technology in the community.

Clarify Role/Structure for Social Media and E-Alerts as part of Overall TTIS Strategy

The adoption of social media and E-Alerts services by transit agencies is an important component of the overall TTIS strategy that merits special attention. The business case for dedicating resources to creating and updating social media and E-Alerts content needs to be carefully considered and developed.

With specific respect to social media, what exactly is the intended market? Do transit agencies intend to utilize social media to attract new riders – therefore classifying this format as a marketing resource? Or, are they a customer service tool, aiming to support the needs and desires of existing riders? Can they, or should they, serve both purposes given the expected audience and its demographics? What is the desired benefit or return on investment for the transit business? These questions should be posed, and answered, before committing to either capital or operating funding for social media tools.

E-Alerts applications, while similar to social media systems in function, have a much narrower scope as to types of content and potential usage. Transit agencies should explore methods to consolidate composition of real-time customer service content, such as service advisories or other urgent operational updates, with existing dispatching operations, thereby reducing the labor-intensiveness of E-Alert message composition.

Furthermore, agencies should actively develop cost-effective approaches to address the overall labor costs of these means of information delivery. The very nature of compelling electronic interaction with users requires a large degree of human resources. Successful implementation of emerging social media applications and other tools intended to keep passengers informed with timely, salient content will require effective financial and human resource planning for the long term.

Two areas of exploration deserve further consideration: first, agencies should investigate flat-rate or other advantageous SMS messaging plans with their telephone services providers, as an insurance policy against unexpected usage increases by passengers, or simply to arrive at a static monthly cost figure for the operating budget; and second, agencies should carefully weigh the possibility of designating their SMS product as a “premium service,” whereby some or all of the messaging costs are borne by the user requesting the information. The latter approach, however, raises new dilemmas – since captive riders with limited financial resources may be less likely to have Web-enabled smartphones, and more likely to use SMS to obtain information.

Acquire Sufficient Resources (Financial and IT)

Build and Support Sufficient IT Resources

I recommend that transit agencies commit to building and supporting a dedicated IT staff and resources, to the best extent given available funding and as a key, strategic priority in the organization.

Agencies cannot simply rely on the capital purchase of technology systems provided by third-party vendors for seamless implementation and ongoing operation. Successful execution of TTIS requires sufficient investment in internal IT resources to properly merge and connect new and existing systems and infrastructure.

Some agencies have the budgetary capability to make necessary internal IT investments, but simply choose not to do so, or choose to direct those IT funds toward third-party vendors and other external resources and development efforts. Other agencies have extremely constrained financial capacities, but believe strongly in establishing and fostering a team of in-house technology staff. In my view, the best examples of efficient use of resources can be found in the more financially-constrained organizations which have had to resort to innovation to maximize their public reach.

Agencies which adhere to open technology standards (a topic that will be explained in more detail in a later recommendation) often realize capital cost savings that can be better allocated to IT labor and systems implementation. Open-source software allows an organization to not only benefit from a zero-cost

use license, but also to gain experience with and extensions to that software already developed by peer agencies.

Ensure Sufficient Operating as well as Capital Funding for TTIS Initiatives

It is imperative that a transit agency's senior management is adequately educated and informed about the need for a guaranteed, ongoing operating funding commitment for TTIS – and then acts to meet that need affirmatively. This funding would be in addition to any upfront capital outlay, and is critical to realizing long-term success in any TTIS implementation.

Political (and other ongoing) pressures to keep up with emerging trends may do their part to convince management to quickly allocate funds for establishing forms of TTIS. However, the long-term cost of additional development, support, maintenance and usage charges falls upon the transit agency, unless explicitly passed on to users – and even then, ongoing human resources will be required to manage these systems.

There are perpetual, recurring costs associated with information delivery via TTIS, especially for those modes which transmit and receive data using Internet communications. SMS per-message charges and Internet bandwidth usage fees are typically borne by the entity serving the information, which, in this case, is the transit agency. Although agencies can attempt to charge users for TTIS, it is generally discouraged as such a fee would disproportionately affect low-income, captive riders who are most dependent upon transit service and good access to transit service information.

Some technologically advanced agencies with limited funding have focused their TTIS delivery efforts to focus primarily on engaging third-party developers. While this is a progressive approach that takes great advantage of the willingness of the Internet community to enhance the transit experience, it cannot be the sole TTIS strategy in place for the medium to long term. The development of advanced, user-facing mobile and Web-based information applications is an important, but relatively minor part of a successful, overall TTIS plan. For TTIS to be successfully implemented and accepted by a rider base with constantly emerging technology expectations, a large increase in real-time information via SMS messaging and E-Alerts-style services will likely be required. As previously discussed, information delivery through these text-based media has both a recurring operating cost, as well as a (currently) labor-intensive content update scheme.

Agencies should be prepared for the future and ongoing costs of TTIS which extend beyond initial capital outlays, and establish operating funding for that purpose.

Develop a Data Strategy:

Interoperability, Open Source, and Open Government

Eliminate Constraints on Use of Data and Interfaces of Commercial Software

I recommend that transit agencies work actively to remove limitations on use of real-time service data, and on developing new or extended interfaces to those data, for successful implementation and propagation of their current and future TTIS. Agencies should carefully evaluate contracts of commercial third-party TTIS vendors for policies on information use, sharing and interoperability with other software and information platforms. The goal is to remove all barriers to free and open use of TTIS information about an agency's service, even when a third-party application is generating, storing, and displaying it.

If an existing contract governing TTIS information is in place, agencies should review it for restrictive language, and attempt to revise or negotiate the contract mid-term if such language is present. If this is not feasible for financial or other reasons, the language should be stricken at the time of renewal. If a contract has not yet been executed, agencies should demand free and open use of any TTIS information for other purposes, such as inclusion in other internal or public-facing content or applications, and publishing in live, raw data feeds to third parties and the public. The bottom line here is that the ownership of data generated by virtue of a transit agency's own operations should lie solely with the agency itself.

Adopt Open-Source and Intelligent Transportation Systems (ITS) Standards

I propose that agencies adopt and embrace open-source software and data standards, as well as established ITS industry standards, as part of their overall TTIS development strategy.

Adhering to open-source software platforms makes adoption of and interoperability with current and future TTIS platforms easy, as there are no license fees to pay and no single required vendor with which to contract. Separately, committing to ITS industry standards enhances data quality and improves compatibility with data portals and aggregation systems, whether present or future.

Ideally, an open-source and open standards approach is most easily implemented at the beginning of an agency's technology plan, as all future systems will be based upon that foundation, and interoperability is assured from the start. It is more difficult to introduce a new set of standards once a comprehensive software strategy is committed, especially if that software is proprietary and sourced from a single vendor.

Adopt and Benefit from "Open Government" Approach to Public Data

I advise transit agencies to embrace the "open government" philosophy of making static and real-time traveler information available in source form, for consumption by third-party developers. This will stimulate creativity, achieve cost-effectiveness, and add value where sufficient IT resources have already been

committed, developed and deployed. Examples of agencies that have structured their IT strategies in favor of “open government” are Oregon’s Tri-Met, and the Massachusetts Department of Transportation, which has oversight of the greater Boston area’s Massachusetts Bay Transportation Authority. Static source data include digital representations of routes, stations/stops, and schedules formatted in standard, machine-readable files for easy inclusion in applications by external developers. Real-time data, such as geographical vehicle positions, bus arrival time estimates, and service operation status, enrich third-party development possibilities when incorporated within new applications in tandem with static data.

In general, there are some guiding principles that such an “open” policy should contain. First of all, the published source feed for TTIS data should not be viewed as a possible means of revenue generation for the agency. It can be compelling to attempt to monetize the output of systems that originally required a large capital outlay, and which continue to require ongoing operating funding for maintenance and support. However, this has not been cited as a successful or meritorious strategy by the agencies interviewed. Monetization should be left to the open marketplace of developers, as an incentive for producing innovative applications that manipulate and present transit data (especially from real-time sources). This practice reduces development cost borne by the agency for public applications that incorporate data of great utility to transit customers, all the while building significant goodwill among the rider base for having published the data in the first place.

Second, agencies should not fear that information integrity or veracity will become compromised with unofficial sources presenting and manipulating data gleaned from traveler information feeds. While it is possible that a passenger who relies on a third-party service or application could be misled by incorrect information, I believe that such poorly designed applications will be quickly revealed for their inaccuracy in the marketplace, just as low-quality products in other industries are shunned at retail. Especially with respect to emerging mobile devices and platforms, applications are often assigned an aggregate rating and reputation value by users within the online marketplace construct. These ratings include written reviews, which can augment the numerical score with specific details of the application's strengths and shortcomings. These reviews and scores appear before new users commit to a download or purchase, and presumably, an application with a low score and unfavorable reviews would cause a user to be deterred.

Third, in addition to providing public feeds of raw data, agencies should promote and foster the desired types of development activity within the passenger community. This can be accomplished with the coordination of events such as developer conferences, competitions, and similar outreach events that prompt technologically-inclined citizens to focus development energy on transit-related projects. Best practices in this space include strong partnerships with local universities, leveraging the talent and enthusiasm of students and recent alumni who have a penchant for emerging technologies.

Future Research

1. Exploring the Impact of Transit-Specific Information Using Mobile Device Technologies on Travel Behavior
2. Exploring Methods to Educate Digitally Disadvantaged Users about the Use of More Advanced (and Less Costly) Means of Traveler Information
3. Issues Concerning Multimodal Trip Planners
4. Exploring Incorporation of Real-Time Passenger Information into Systems which Currently Only Support Static Information

Future Research

Exploring the Impact of Transit-Specific Information Using Mobile Device Technologies on Travel Behavior

Generally speaking about all types of transit traveler information systems, more research is needed to determine whether or not the provision of TTIS indeed encourages modal shift by so-called “choice” riders – those who have other travel modes available to them, and who choose to use transit instead of those modes. Do TTIS help to justify their inherent upfront cost, human resource allocation, and ongoing maintenance by encouraging new use of transit as a result of better information? It is a very acceptable use of TTIS to enhance the navigation and user experience of existing riders – whether choice or captive – but further investigation is warranted as to how else TTIS can serve to impact travel behavior across the city, and across modes.

Expanding on this, does the provision of TTIS indeed stimulate more transit use by current transit riders? For example, do individuals who use transit to commute to and from work end up using transit more extensively for personal trips, or particularly to reach unfamiliar or more distant destinations than usual, in the presence of advanced TTIS? Do real-time TTIS make existing riders feel more comfortable with using transit, whether for the added security of knowing the status and predicted positions of transit vehicles, or for the added pre-trip and on-the-go navigation benefits?

Finally, and as a subset of the above, research is needed to determine whether passenger utilization of real-time TTIS can stimulate more ridership on poorly-serviced transit routes. Specifically, and for example, bus routes with lengthy headways (hourly or half-hourly) are often overlooked as viable transport options by users who place a high value on their time, because of perceived uncertainty in bus arrival times and a lack of flexibility if a bus is missed. Will choice riders gain confidence from – and begin utilizing these lesser serviced routes as a result of – real-time bus arrival estimates sent to their mobile communications device via Web or SMS? Or are these emerging information delivery methods not enough to overcome practical service deficiencies and poor public perception?

Exploring Methods to Educate Digitally Disadvantaged Users about the Use of More Advanced (and Less Costly) Means of Traveler Information

Better and more extensive research is needed to specifically determine how users on the disadvantaged end of the digital divide can best benefit from emerging forms of TTIS. In particular, these users are often financially constrained and may lack traditional access to offline trip planning resources, or the skills and training to make use of Internet-enabled technologies. Advanced TTIS have the great potential to assist this demographic group, but it remains to be determined how best to poise these individuals to benefit from them. As suggested previously, transit agencies can begin with outreach to civic organizations and community centers that represent the needs of these users, and

gain their assistance in arranging focus groups to evaluate adoption of and fluency in TTIS as they emerge.

Issues Concerning Multimodal Trip Planners

Multimodal functionality appears to be the next logical development in the Web-based trip planner applications found at many transit agencies. Google Maps has been a recent leader in providing distinct trip routing for multiple modes, but the emerging trend in this technology is to engage a combination of multiple modes in a single itinerary. The emerging question is: will enhancing existing trip planners with the ability to calculate a door-to-door route across several modes encourage modal shift from the unsustainable to the more sustainable?

First, is this a relevant enhancement to make in the first place? It is unclear whether people indeed transfer from private auto to transit (outside of park-and-ride situations), or from private auto to bicycle, or from and between other unrelated modes, at frequencies that makes such an enhancement worthwhile and broadly applicable. Will this new ability really convince passengers to drive less, and if so, is that result compatible with other types of cities which host more, or less, extensive and integrated transit service? A general business case needs to be developed for this technology extension to determine whether it is worth the effort, and if so, who should undertake it.

Furthermore, will data aggregation challenges among sources pertaining to multiple modes preclude timely coordination and updates of multimodal

information in a single trip planner system? When various sources do not publish data in the same standards and formats, it becomes difficult to merge them, and to expect data sets to be interoperable for purposes of calculating a common itinerary without inefficient or laborious conversion. Some of these challenges have already become evident in MPO-level efforts to collect data from constituent transit agencies and present them in a unified way, such as in the context of “511”-style portals.

Exploring Incorporation of Real-Time Passenger Information into Systems which Currently Only Support Static Information

Further research is needed to adequately discover how existing traveler information systems, which were designed and deployed before the recent push of increasingly available real-time information, can be adapted in order to augment current static information delivery with real-time updates. In many cases, these systems were produced by commercial vendors, who would conceivably command further capital funding allocations to provide upgraded, real-time data functionality.

Web-based trip planning applications comprise a particularly salient topic in this area of research, as they stand to gain significant benefit from the addition of real-time information – specifically, active updates on service disruptions, detours or delays. An itinerary computed by a trip planner that relies solely on static schedule and route information is only fully accurate when service is, in fact, adhering tightly to schedule. As this is often not the case under real-world

conditions, real-time data would significantly enhance the accuracy and pertinence of trip planner itineraries for pre-trip planning by passengers. Do these systems need to be completely retooled to, for example, dynamically reroute the user in the face of a service disruption? Moreover, can this system retrofitting process be conducted in a cost-effective fashion, both for the agency (in terms of monetary cost), and for the users (in terms of learning the new interface, as well as potentially forgoing access to the system or enduring glitches during the upgrade)?

Chapter VI: Scenario for Success

There are four keys to success in the implementation of advanced transit traveler information systems (TTIS) as considered in this study.

First, sufficient financial and IT resources need to be identified, developed, and secured.

Second, a strategy for TTIS (and the use of technology therein) needs to be defined based on market research data.

Third, this strategy should use information delivery mechanisms that are appropriate to the transit agency's specific ridership profile and customer needs. This will likely mean that traditional means of delivery will be retained in the short- to medium-term, along with increased development and use of low-cost, accessible technologies, such as SMS messaging for E-Alerts and real-time information.

Fourth, pursuit of the most advanced technologies should be started or continued, based on open-source standards and the "open government" approach, and in cooperation with the third-party developer community. It is important that this effort not lead to the detriment of more traditional means of information delivery that may currently be in place.

Appendix A: Discussion of the Digital Divide

Literature specific to the digital divide, as applied to the transit context, is sparse. However, there are many articles and books on the subject as it more widely pertains to the Internet and access to digital information. Some focus more on the Internet and Internet connectivity, and others provide a broader look at communication technologies and are not restricted to computing or data transfer. One such book is Technology and Social Inclusion by Mark Warschauer (MIT Press, Cambridge, Mass.). Warschauer discusses the digital divide across a spread of media, considering models of access and factors of physical, digital, human and social resources. Questions of literacy and education are raised. As the digital divide has only been realized in the past ten to fifteen years, the bulk of the volumes on the subject deal squarely with Internet access. This is pertinent to our study as mobile connectivity is an evolutionary development of ubiquitous Internet access. Digital Divide: Civic Engagement, Information Poverty and the Internet Worldwide by Pippa Norris (Cambridge Univ. Press, Cambridge, UK) focuses on social inequalities in the civic society as they relate to maintaining democracy and political participation – but this is perhaps less relevant here.

Several pertinent articles on the digital divide and information and communication technologies (ICTs) were included in recent issues of the journal *New Media and Society*. Neil Selwyn writes in his article entitled *Reconsidering Political and Popular Understandings of the Digital Divide* that “inequalities in terms of access to ICT [are] strongly patterned along the lines of socioeconomic status, income, gender, level of education, age, geography, and ethnicity,” even

within developed countries such as the United States and Canada.⁶³ These same variables tend to affect transportation mode choice, to the extent that individuals with lower socioeconomic status tend to be more transit-dependent. On a related note, Maria Sourbati offers a perspective of Internet access adoption among the elderly in *“It could be useful, but not for me at the moment”: Older People, Internet Access and E-Public Service Provision*, which is comparable to other demographics experiencing the effects of the digital divide (and particularly in the public transit context). Sourbati notes that a “user-centered perspective [...] requires an understanding of the socially shaped and locally situated nature of media use”,⁶⁴ which tells us that transit agencies need to develop a sound understanding of their ridership (ideally, through market research) when planning the release of new customer-facing information technology, as well as before the discontinuation of any existing information media. And in another issue of this journal, Jack Linchuan Qiu details an optimistic view of ICT potential for adaptation to disadvantaged socioeconomic groups in *The accidental accomplishment of Little Smart: Understanding the Emergence of a Working-Class ICT*. Qiu writes that technology entrepreneurs in the developing world have, in recent years, effectively reached out to groups of citizens with wireless and mobile communications devices and media – the capabilities of which are only accessible via more expensive services in countries such as the U.S. Qiu’s example is “Little Smart,” a so-called low-end wireless technology in

⁶³ Selwyn, *New Media and Society*, Vol. 6(3), 2004

⁶⁴ Sourbati, *New Media and Society*, Vol. 11(7), 2009

China that is used by over 90 million Chinese.⁶⁵ “Little Smart” is a best-effort wireless communication technology for which service reliability is not guaranteed; presumably, cost-conscious consumers are willing to accept the chance of service disruption for the inherent cost savings.

Chen and Wellman, in their chapter of Transforming Enterprise: The Economic and Social Implications of Information Technology, offer the view that the “digital divide is narrowing” with respect to gender, age, and geography, at least in the United States (and ostensibly Canada) – while the “sociodemographic” manifestation continues to persist.⁶⁶ This suggests that methods employed by transit agencies to sustain or increase availability of traveler information among digitally divided passengers are likely widely applicable across jurisdictions with similar socioeconomic profiles.

⁶⁵ Qiu, *New Media and Society*, Vol. 9(6), 2007

⁶⁶ Chen and Wellman, *Charting Digital Divides*, Transforming Enterprise, 2005

Appendix B: List of Interviews

Massachusetts Department of Transportation (MassDOT)

March 12, 2010 (in person)

Christopher Dempsey
Director of Innovation (Information Technology)

Joshua Robin
Manager of Performance Reporting

Ann Arbor (Michigan) Transportation Authority

March 15, 2010 (telephonic)

Christopher White
Manager of Service Development

Alameda-Contra Costa (California) Transit District (AC Transit)

March 15, 2010 (telephonic)

Linda Morris
Transportation Planner

Central Florida Regional Transportation Authority (LYNX)

March 18, 2010 (telephonic)

Doug Jamison
ITS Program Manager

Winnipeg Transit

March 19, 2010 (telephonic)

Bill Menzies
Manager of Service Development

Société de transport de Montréal (STM)

March 19, 2010 (telephonic)

Michel Thérér
Conseiller corporatif

Metropolitan Transportation Commission (San Francisco Bay Area)
March 19, 2010 (telephonic)

Jim Macrae
511 Senior Program Coordinator

Metropolitan Transportation Authority – New York City Transit
March 19, 2010 (telephonic)

Andrew Bata
Chief, Strategic Improvements and Best Practices, Capital Program Management

Potomac and Rappahannock Transportation Commission (Virginia)
March 19, 2010 (telephonic)

Eric Marx
Director of Planning and Operations

Capital Metropolitan Transportation Authority (Austin, Texas)
March 29, 2010 (telephonic)

Todd Hemingson, AICP
Vice President of Strategic Planning and Development

York Region Transit (Ontario, Canada)
March 30, 2010 (in person)

Christine Terin
Marketing Supervisor

Igor Zaslavsky
ITS Developer

Tri-County Metropolitan Transportation District of Oregon (Tri-Met)
March 31, 2010 (telephonic)

Bibiana McHugh
IT Manager, GIS & Location-Based Services

San Francisco Bay Area Rapid Transit District (BART)
April 6, 2010 (telephonic)

Timothy Moore
Website Manager

Appendix C: Interview Topics and Recruitment Method

Interviewees were recruited by e-mail, and where a reply was received, interviews were either conducted in person or by telephone. A sample of the text of the e-mail message used to recruit interviewees is as follows:

For my master's thesis, I am conducting a study of advanced traveler information systems in the urban transit context, with a specific focus on new media and wireless applications. As you know, this is an emerging field with many exciting new developments in terms of how traveler information can be assembled and delivered to customers, by the transit agency itself or through third parties. These developments are opening up new horizons, and are likely to have many implications including: methods by which customers receive and interact with traveler information on the go, changing relationships between transit agencies and their customers and between agencies and new third-party providers, as well as implications concerning financial and human resources required to deliver these services, etc.

I am wondering if you might have some time for a phone call interview in the next week or two, to answer a couple of questions about the strategies and directions your agency is taking in this field.

Specifically, I am interested in the following issues related to Transit Traveler Information Systems (TTIS):

- Recent initiatives that your agency has undertaken, or is planning, with respect to TTIS (e.g. agency trip planning system, Google Transit, e-alerts, next bus arrival information via texting, social marketing tools, Web 2.0 applications, etc.)
- Your agency's current and evolving strategy with respect to TTIS, and your perspectives on how these new tools/initiatives relate to more traditional tools to provide information to different categories of customers

- Statistics or results you may have collected from focus groups, surveys, or analyses of passengers with respect to demographics, travel behavior, increases in ridership, use of wireless devices, and/or engagement with traveler information systems
- Your opinion on the level to which existing passengers can/will embrace these new information tools, vis-à-vis the potential use of these tools in attracting new riders (especially choice riders)
- Any issues or obstacles that may be affecting the pursuit of TTIS

I would be pleased to provide you with a summary of the results from my research after it is completed. Thank you in advance for your consideration in participating in this research.

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