DESIGNING A MULTI-MODAL TRAVELER INFORMATION
PLATFORM FOR URBAN TRANSPORTATION

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Siddharth Doshi

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DESIGNING A MULTI-MODAL TRAVELER INFORMATION PLATFORM FOR URBAN TRANSPORTATION

Approved by:

Dr. Bert Bras, Advisor
School of Mechanical Engineering
Georgia Institute of Technology

Dr. Roger Jiao
School of Mechanical Engineering
Georgia Institute of Technology

Dr. Steven French
School of City and Regional Planning
Georgia Institute of Technology

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NOMENCLATURE

Abbreviations:

API: Application Programming Interface

ASN.1: Abstract Syntax Notation One

ATIS: Advanced Traveler Information Systems

BRTS: Bus Rapid Transit System

GHG: Greenhouse Gases

GTFS: General Transit Feed Specification

HTTP: HyperText Transfer Protocol

ITS: Intelligent Transportation Systems

JSON: JavaScipt Object Notation

MARTA: Metropolitan Atlanta Rapid Transit Authority

NaPTAN: National Public Transport Access Node

SIRI: Service Interface for Real Time Information

UTF-8: 8-bit Unicode Transformation Format

VMT: Vehicle Miles Travelled

XML: eXtensible Markup Language

XSD: XML Schema Definition

SUMMARY

Urban transportation networks are inefficient due to sub-optimal use by travelers. One approach to counter the increase in urban transportation demand is to provide better information to travelers, which would allow them to make better use of the network, thus increasing network efficiency.

Existing traveler information systems do this to a certain extent, but are limited by the data available and the scope of their implementation. These systems are vertically integrated and closed, such that using any external elements for analysis, user interfacing etc. is difficult.

The effects of such traveler information systems are reviewed via a comparative analysis of case studies available in the literature. It is found that while information availability has a definite positive effect, the social and environmental benefits are difficult to quantify. It is also seen that combining data by integrating systems can lead to additional uses for the same data and result on better quality of service and information.

In this thesis, a regional platform for multi-modal traveler information is proposed that would support the development of traveler information systems. The architecture incorporates a central processing and storage module, which acts as an information clearinghouse and supports receiving, managing and sending data to and from multiple sources and interfaces. This setup allows sharing of data for analysis or application development, but with access control where required.

The components are loosely coupled to minimize inter-dependencies. Due to this, the source, analysis, user interface and storage components can be developed

independently of each other. Such an infrastructure will give the traveler better access to service operators and vice versa.

To better develop the requirements and understand the challenges of the proposed concept, a limited implementation of the system is designed for the midtown Atlanta region, incorporating multiple data sources and user interfaces. The individual elements of the system are described in detail as is the testing and evaluation of the system.

CHAPTER 1

INTRODUCTION

1.1 Motivation

In 2009, the urban population of the world surpassed the rural population. This trend is expected to continue such that percentage of urban population will cross 60% by 2030 and 70% by 2050 [1]. With that pace of urbanization, the population density of cities will increase.
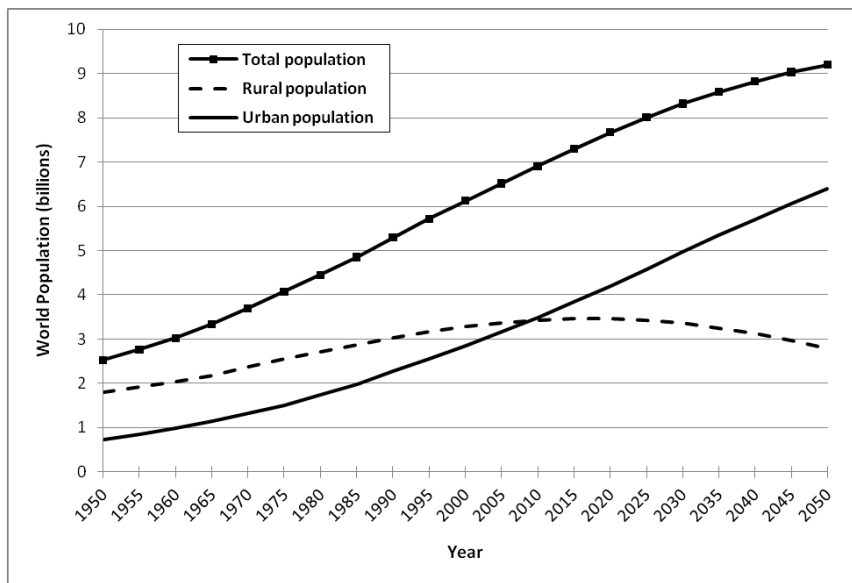
Figure 1-1: World Urbanization Trend [1], [2]

With the increase in urban population, the demand for urban transport will also increase. Comparing urban U.S. population to U.S. urban vehicle miles travelled (VMT) (Figure 1-2), a correlation can be seen between increase in urban population and increase in travel demand over the period of 20 years from 1990-2010. If the U.S. VMT figures

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are adjusted to reflect equivalent VMT including non-road urban travel, the rise in demand is likely to be more pronounced. If this pattern holds, we can expect the demand for urban transportation to keep increasing at least up to 2050, when the world population is expected to stabilize [3].
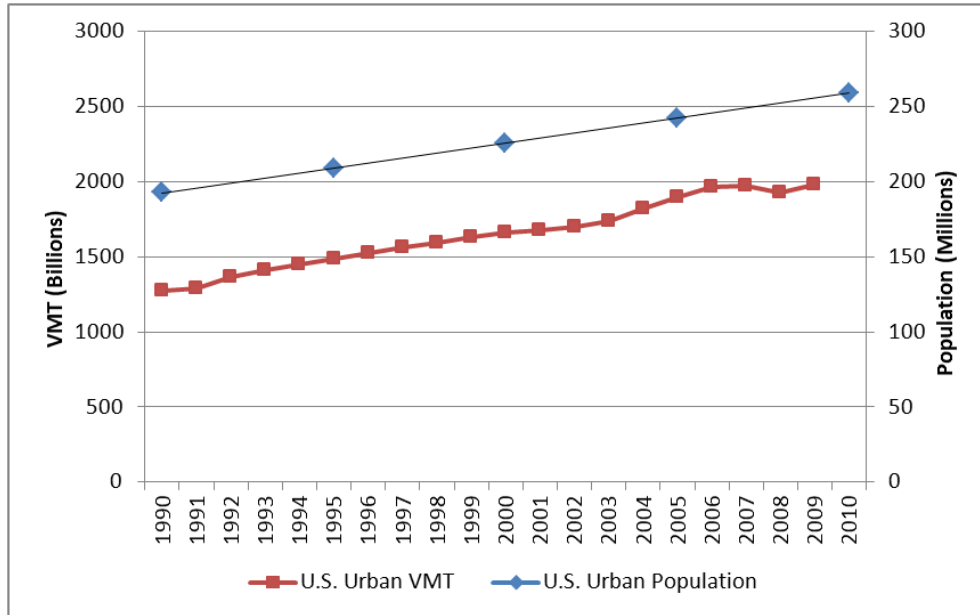
Figure 1-2: U.S. Urban Population and VMT [1], [4]

Urban transportation or the lack thereof is already a problem around the world. In part, some of these issues arise from inefficient utilization of the available resources. The complex nature of transportation networks as a whole, involving multiple stakeholders, makes them difficult to co-ordinate and inefficient. Energy use, environmental, accessibility and quality of life concerns can be alleviated to some degree by making sure that existing transport services are used at maximum possible levels with minimal waste of resources.

1.2 The Problem

A large part of the inefficiencies in urban mobility can be attributed to the lack of information. Availability of this information can help with reducing excess capacity, higher utilization and future planning, thus using resources to their full extent. This can lead to reductions in total travel times, increased customer satisfaction, reductions in pollution levels etc.

Without access to accurate mobility information – such as traffic, public transportation, taxi and shuttle service, and ride-share information – it is difficult for commuters to make the best transportation decisions. A traveler's access to information can be limited in two ways: either because no data is being generated, or because the generated data is not accessible to the traveler.

Hence, providing information to travelers requires the addition of infrastructure to handle data. This information infrastructure does not require any major reconfiguration of physical infrastructure and can be built and maintained in parallel to it. This means that providing travelers with information can be one of the least resource intensive additions with high visibility and gains for a transport service.

Due to this fact, information systems and the use of information in the transportation sector have developed to a great extent over the last decade. However, the participation of transport operators and hence, the data generated, still remains low. Another issue is that systems in use are not geared towards making data accessible publicly, and the traveler is limited to accessing data that is available via interfaces provided by the service operator.

The problem is, therefore, the unavailability of accurate transportation information and a lack of options to access the information that is available.

1.3   Information Systems for Transportation

'Intelligent transportation systems' or 'ITS' is the phrase used to describe information systems deployed in the transportation field.   The basic architecture for most of these systems can be described as shown in Figure 1-3. They consist of source, storage, analysis and application layers with transmission elements connecting them. In fact, this architecture can be used to describe most information systems in general.
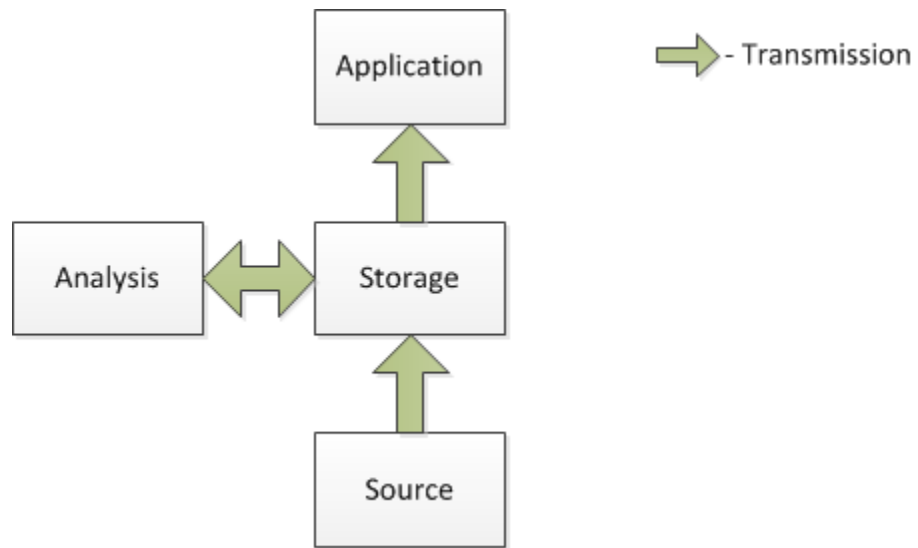
Figure 1-3: General flow of Information in an Intelligent Transportation System

The advantages of information systems become more apparent when they are used across all of a transport network's modes & services and this information is available all together to the end-user in intuitive ways, be it to plan trips, or analyze movement in cities for planning purposes.

In such a case, information can be used to inter-connect different modes of transport closely. Such an integration of modes using information, however, is difficult to achieve within the present ITS scenario, where every transport service has its own closed system information network.
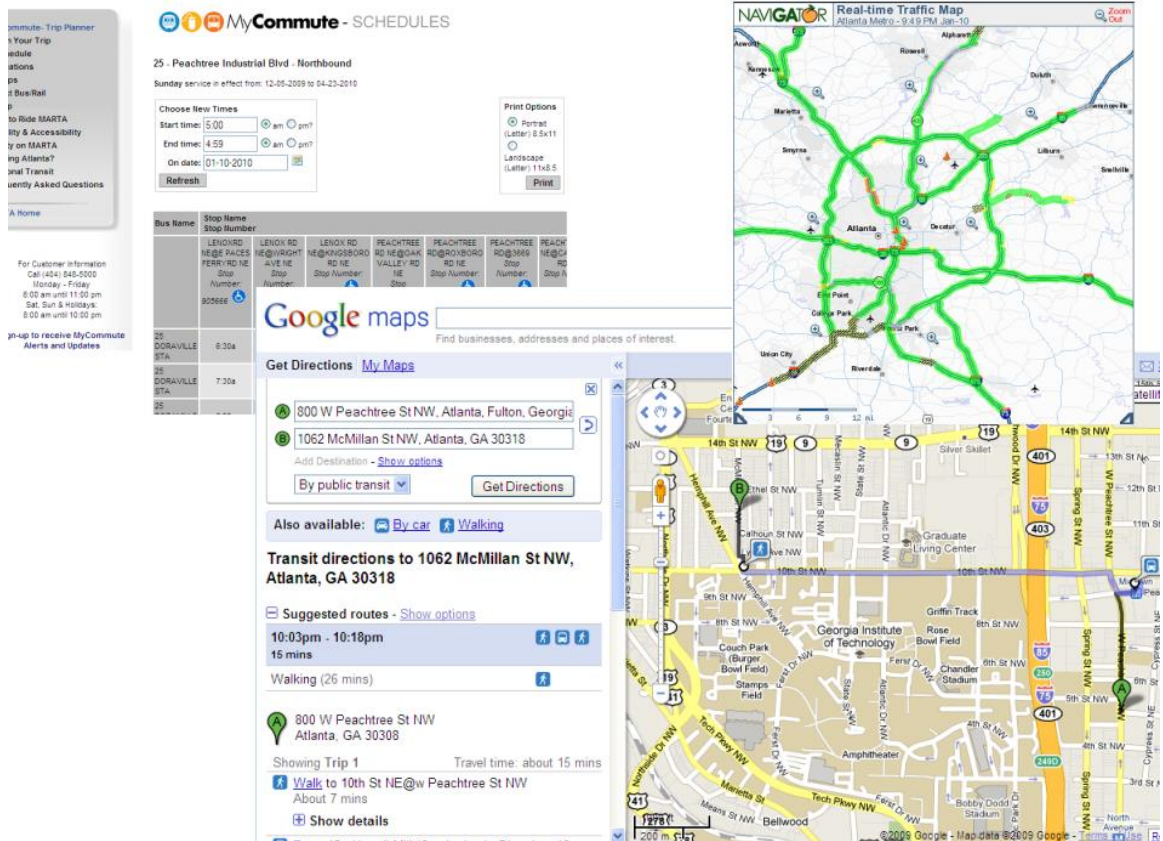
Figure 1-4: Examples of information applications [5-7]

To build a multi-modal information application under the current circumstances, any developer or business would have to get the information individually from various transport operators, if the information is being generated at all.

This is a big barrier to how much information is available and how useful it is to the end-user, because the responsibility of developing user-facing applications rests with

the transport service operator, and application development and maintenance is not their core competency.

1.4   The Solution

The proposed solution is to use the available technologies to build an information sharing platform for traveler information. This platform, a sort of an information clearinghouse, can facilitate the collection and distribution different data to and from multiple sources in the regional transportation mechanism.

While this model still follows the same basic model described before (source, storage, analysis and application layers), the difference is that the layers are loosely coupled and systems are set-up to share information using standard formats (Figure 1-5).
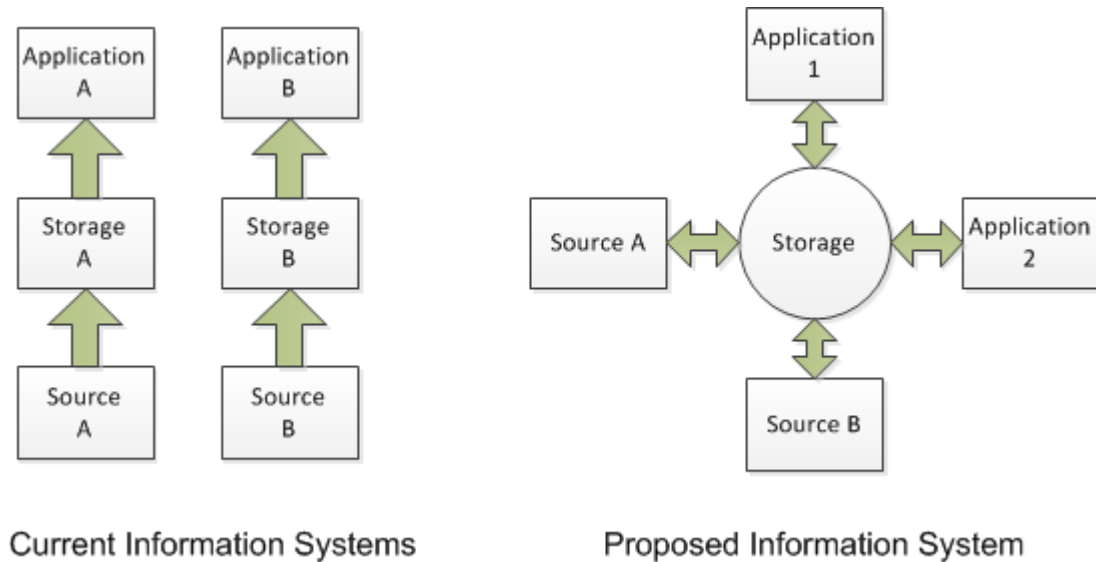
Figure 1-5: Current and proposed flow of transportation information

This model leaves the transport operator with only the responsibility of operating the service, whereas storage, analysis, display and if necessary, even generation of data, can be left to other entities. Thus, the task of interface development can be left to device manufacturers and application developers, analysis can be done by data-mining firms etc.

In this way, applications can be developed without concern for the generation and sourcing of information, with all the data being sourced from a single point-of-access, which could possibly provide city-wide, regional or national information.

This brings benefits in the form of standardization, reduced duplication of efforts, stricter security and access control measures, and the leveraging of the respective competencies of transport service operators, software developers and device manufacturers etc.

This also provides incentive for more complete generation of information (such as real-time data etc.), because the impact can potentially be manifold and immediate, while the investment and maintenance on the transport operators part is reduced.

1.5 Scope

Transportation information covers a wide range, from route planning to toll collection. For this thesis, the focus is on transportation information that can be used to inform the traveler, such as real-time location, timetables, road conditions and transportation options. This collection of information, which is a subset of all transportation information, is called 'traveler information' in this thesis.

Along with public facing systems, certain systems transportation management systems (such as fleet management) also use a lot of the same data, and these might be included in the discussion where required.

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While comparison to freight transport will be made where required, unless specifically mentioned, urban transport, in the context of this thesis, refers to moving people.

Lastly, urban and rural transport networks tend to differ widely due to variations in population densities and infrastructure investments. The mobility requirements and solutions for rural transportation are a different subject matter which pose significantly different challenges and are not considered in the discussion here.

1.6 Project History

In the early stages of the project, research was focused around the idea of 'Hub Networks' for urban transportation. The concept presented the view that all urban transportation can be arranged around 'hubs'. These hubs would be places where multiple transportation modes exist, along with many other facilities, not unlike large transit stations that combine taxi, bus, bicycle and train transport.

The idea was to look into the possibilities and challenges of an urban transport network built specifically with the goal of multi-modal transport using these hubs, followed by a high-level design process. The initial locations used for study included the cities of Chennai, India, Cape Town, South Africa, and Salvador, Brazil due to an identified need and the presence of the project sponsor in these areas.

The importance of information systems for effective multi-modal systems became apparent during the development the 'hub network' concept and it was observed that the existing information systems did not address multi-modal transport, even in developed countries. The imprint of the initial hub-network planning for developing countries can

be seen in this thesis, such as the selection of a kiosk-based interface over a mobile interface, the early emphasis on solar-powered hardware etc.

1.7   Research Goals and Methodology

The discussion above brings up a few interesting questions with regard to ITS systems and urban transportation in general. These are the questions that this thesis aims to answer. Each question is followed by a description of the approach taken towards answering it.

Question 1 – What work has already been done in the field of multi-modal transportation information and what technologies are available?

The use of information technology in transportation has only increased since the 1970's, when the field of intelligent transportation systems first started emerging. With the growth of the internet and information access playing a larger role in people's lives, it has grown even faster. The existing technologies used and the standards and formats being developed will be researched in the literature review.

Question 2 – How effective has accessible traveler information been in real-world scenarios to make an impact on urban transportation?

The effect of traveler information on the urban transport network, the traveler as well as the service operator can be determined by aggregating and analyzing the data available from different case studies and results published for other projects around the world. While the situation in every case is different, an overall view of the situation should provide a better understanding of the answer to this question.

The approach taken here uses case-studies for various deployments of the same information systems and performing a comparative analysis. This is done for two different types of information systems, which have been well-defined, and for which data is available. The possible effects of integrating these and other information systems to share data and infrastructure are also considered based on existing projects.

Question 3 – What are the requirements for building a multi-modal traveler information platform and what are the challenges?

This question will be answered by creating a web-based infrastructure based on the proposed concept of a multi-modal traveler information platform for the midtown Atlanta region. The design process will reveal the requirements for such a project as well the challenges towards building it, albeit at a much smaller scale. These findings can then be applied to large scale projects with appropriate adjustments.

1.8 Organization of Work

In the following chapters, an attempt is made to answer the questions raised. The second chapter contains background on sustainable transportation, intelligent transportation systems, technologies related to or used in transportation, and an overview of some existing traveler information systems. Chapter 3 makes an assessment of the impact of traveler information using data available in the literature for two specific kinds of information systems as well as integrated systems. Chapter 4 describes the architecture of the proposed traveler information platform and provides an overview of the system developed based on it. Chapter 5 gives a detailed description of all the individual components of the designed system. Chapter 6 details the testing and evaluation of the

system. Finally, the last chapter discusses the results, future work and summarizes the answers to the questions put forth.

CHAPTER 2
RESEARCH BACKGROUND

2.1 Urban transportation

Urban transportation systems are encumbered with problems ranging from inefficient or insufficient public transport, to overcrowded urban highways, to limited accessibility of transport options. The large and agglomerative nature of the system as a whole, where coordinating efforts efficiently between many different stakeholders and entities is difficult, only adds to the complexity.

2.1.1 Modal Considerations

The existing modes of urban transport today mainly include car, bus, rail, ferry, three-wheeler (auto-rickshaws), motorcycle, bicycle and walking. While there are many different non-road modes of transport, the number of road-dependent transport offerings means that road and highway development remains important.

Table 2-1: Travel Modes by Vehicle-type

Car	Bus	Rail	Ferry	Motorcycle	Bicycle / Rickshaws	Walking
Private Car sharing Ride sharing Car pooling Taxi Rental car Shared-Taxi	Transit BRTS Shuttle	Transit	Transit	Private	Private Bike-sharing Rickshaw taxi	Private

The modal split for urban transport trips is skewed towards private vehicles in developed countries such as the U.S. and Western Europe (Figure 2-1). In the U.S, 88% of private vehicle trips are single occupancy vehicles [8]. On the other hand, the

infrastructure to support these private vehicles has not kept up with the rise in vehicle miles travelled (VMT). For the U.S., from 1980 to 2007, there has been a 97% increase in VMT [4], but only a 7% increase in lane miles [9].
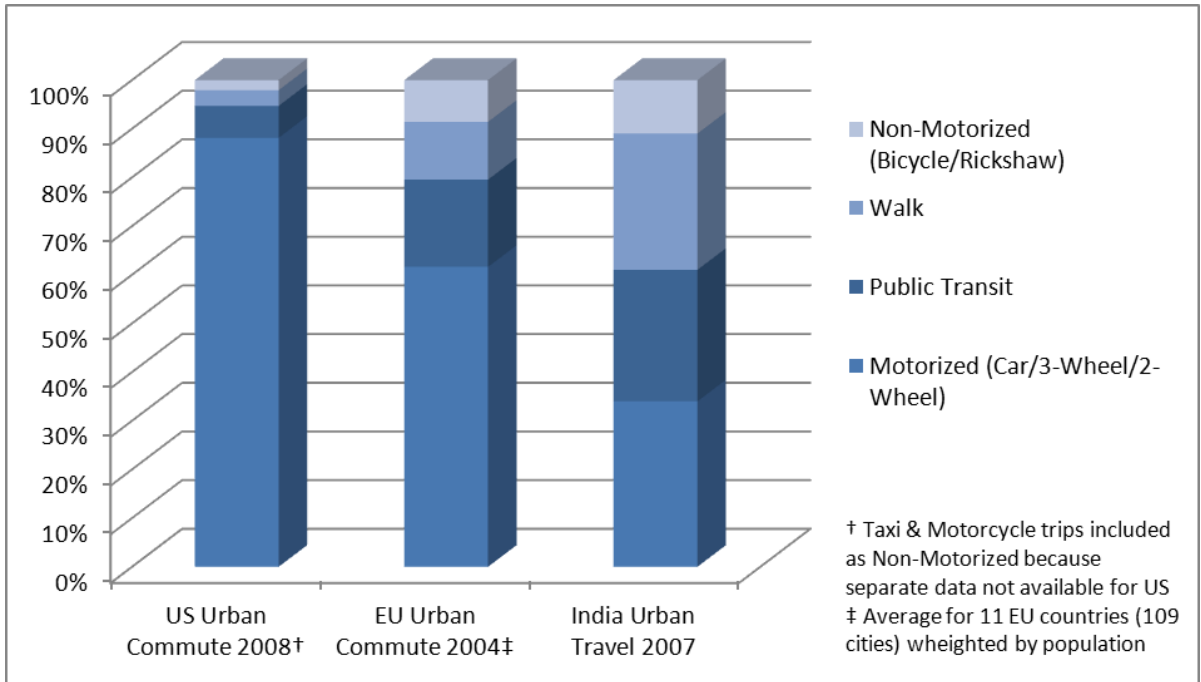
Figure 2-1: Modal Splits for Urban Trips [8], [10], [11]

While growing economies like China and India are more inclined to use non-motorized transport options, the main reasons for this are reduced availability and affordability of vehicles in these countries. It has been seen that as the financial resources become available and motorized vehicles become more accessible, urban areas in developing countries also start moving towards private vehicles, starting with motorcycles, and then cars. This is reflected in motorized vehicle ownership growth rates in developing countries, which range between 15-20% annually [12].

2.1.2 Energy and Environmental Issues

In 2004, the transportation sector accounted for 14% of the World's annual greenhouse gas emissions not including lifecycle emissions for vehicles or fuel production. Within that share, 72 % was contributed by road transport [13].

There is a large disparity in the energy use and emissions per capita of third world, developing and first world countries [13], [14]. As the developing parts of the world, which are starting to emerge as the largest market for motorized vehicles, start bridging this gap, the problem has the potential to become unmanageable.

There is a need for reduction in use of resources in developed countries combined with the early introduction and adoption of sustainable transport strategies in developing and third world countries.

2.1.3 Economic Issues

Transportation is one of the larger categories of expenditure at a city level as well as at an individual household level. Cities in developing countries can spend from 15 to 25% of their annual expenditure on transportation. Similarly, urban households worldwide spend an average of 8 to 16% of their income on transportation costs, though this can be as high as 25% in extreme cases [12].

An unsustainable urban transportation system causes a drain on financial resources and a more efficient network can lead to lower spending on transportation.

2.1.4 Social Issues

Unsustainable urban transportation leads to services with low accessibility, causes social segregation and thus exacerbates social exclusion. The paradox of urban transport

is that the growth of cities which comes with economic development also leads to increased cost of motorization and land [12]. This in turn leads to the lower socioeconomic classes having to move to the outskirts and leaves them unable to afford motorized transport. Both of these factors together create a polarizing effect of further impoverishment of these classes by cutting off their accessibility.

2.1.5   Congestion

Congestion, which is an effect of growth in cities without corresponding planning initiatives, has been estimated to increase the fuel consumption of vehicles by an average of 13% and increase vehicle emissions by as much as 25% [15]. This effect extends to an increase in the cost of public transport as well [12]. This is besides the quality of life issues that are raised by longer commute times, health issues due to pollution etc. Congestion is thus an important factor which contributes negatively to the environmental, economic and social bottom lines.

2.2 Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) cover the wide range of solutions that combine high technology from the fields of information systems, communications, electronics and automation with analytical methods and conventional transport infrastructure [16].

While ITS started out with surface transport, and more specifically, highway systems, it has evolved to encompass technology applications for all modes of transport. The innovation in ITS is usually the integration of existing technologies to create new services.

2.2.1 History

The U.S. first started working on intelligent systems for highways, such as the Electronic Route Guidance System (ERGS), around 1965, but due to a variety of reasons, including technological ones, none of the programs made it past the initial stages. In general, through the 70's and 80's, ITS development in the U.S. was limited, with Europe and Japan pursuing more aggressive research agendas [17].

By 1991, congestion was a recognized problem in major US cities, and a renewed interest in intelligent systems led to the formation of IVHS America (Intelligent Vehicle/Highway Systems), which developed a strategic vision for further development of the field which is now known as ITS.

Through the nineties, there was a shift in the way we use information as technology became cheap and pervasive and infrastructure to exchange information was developed. Owing to this fact, in the past few years, development in the ITS field has exploded, with increasing investment from industry as well as developing countries.

2.2.2 Classification

ITS systems can be broadly classified based on their functions. A general classification scheme used is described here [16], [18].

2.2.2.1 Advanced Traveler Information Systems (ATIS)

Traveler information systems are those that disseminate information to travelers before, during and after a trip. This could include information about weather conditions, road conditions, congestion, timeliness of transport, routing etc.

These systems are the major component that would be supported by the platform proposed in this thesis.

2.2.2.2 Advanced Transportation Management Systems (ATMS)

These systems deal with the management of transportation services such as incident management, routing, signaling etc. ATMS and ATIS systems often have similar source data requirements, such as real-time vehicle locations. However, ATMS use this data for planning and decision support while ATIS use it for informing travelers.
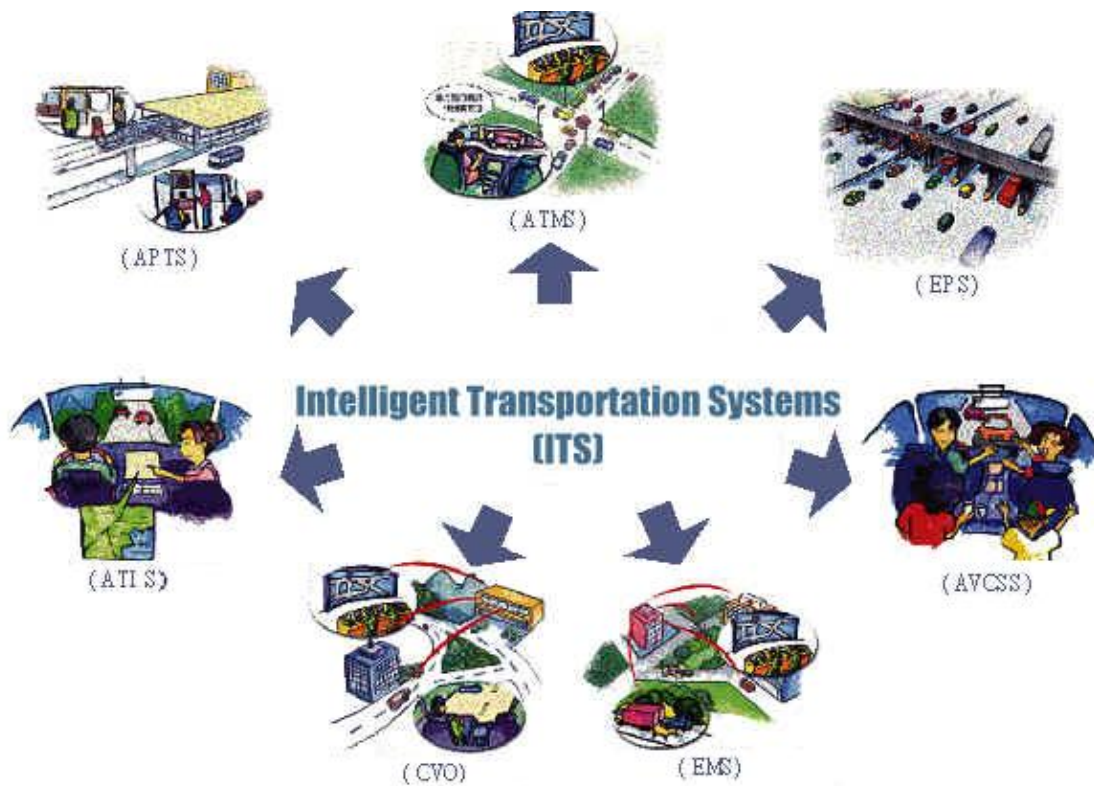
Figure 2-2: Classification of ITS Systems [19]

2.2.2.3 Commercial Vehicle Operations (CVO)

Fleet operations involving corporate vehicles fall under this category. ITS technologies applied towards better management and utilization of fleets are widely used,

though there is little standardization, most of the technology is proprietary and functionality varies across the board.

2.2.2.4 Advanced Public Transportation Systems (APTS)

The suite of ITS technologies described above, when developed for and applied to public transportation, falls under the APTS category. Public transport systems often have different requirements, such as conformance to national standards etc.

2.2.2.5 Advanced Vehicle Control Systems (AVCS)

AVCS systems enhance the driver's control of the vehicle. These systems are important from a safety and efficiency perspective, but are on a longer term development pathway. Examples include collision detection, automatic braking etc.

2.2.2.6 Electronic Payment Systems (EPS)

Payment systems can be classified under ATMS or APTS, but are generally given their own category because they have been widely implemented. This is due to the fact that they make ticketing and charging for services easy and accountable. The direct impact on the bottom-line makes the cost of payment systems easily justifiable.

2.2.3   ITS Application Categories

The above classifications are broad in nature, and contain some amount of overlap with regards to the actual systems they describe. The United Stated Department of Transportation defines 16 ITS application categories which provide a narrower classification.

		Arterial Management Systems
		Collision Notification Systems
		Collision Avoidance Systems
		Commercial Vehicle Operations
		Crash Prevention and Safety
		Driver Assistance Systems
		Electronic Payment and Pricing
		Emergency Management Systems
		Freeway Management Systems
		Incident Management Systems
		Information Management
		Intermodal Freight
		Roadway Operations and Maintenance
		Road Weather Management
		Transit Management Systems
		Traveler Information

Figure 2-3: ITS Sub-Systems according to US DOT [20]

2.2.4   ITS in an urban context

As discussed in section 2.1, urban regions are likely to develop mobility problems, due to higher population density, congestion etc.

In this scenario, ITS technologies are seen as the network that links multiple systems, vehicle and infrastructure together to provide gains in safety, productivity and operational efficiency etc. The overarching, and overly simplified view of ITS, is as a mechanism to develop and support the regional transport infrastructure [16].

In fact, in certain situations, besides serving as an information link, ITS can also play a big part in political, social, environmental and economic contexts, owing to the nature of many ITS systems, which require large investments, wide-ranging partnerships, and public approval.

2.3 Underlying Technologies in Transportation

This section describes the underlying technologies that make intelligent transportation systems possible. These technologies are mostly well-developed and used extensively in various fields besides transportation and generally constitute an entire field of study on their own. This section only contains an overview of the broad technology areas and some examples, without going into too much detail for every individual technology area.

2.3.1   Telecommunications

Communications technologies play a large and probably the most important role in the development of intelligent transportation systems. A lot of these technologies were

developed or received wide use only in the last decade, but they are generally proven technologies and have wide applications in fields other than ITS.

In fact, early efforts by the US government in route guidance required the development of special communications networks to support the system [17] and this may have proven too expensive. The development of the internet, and networking hardware and software to support it, let transportation systems use existing networks at a lower cost and make a lot of intelligent transportation systems possible.
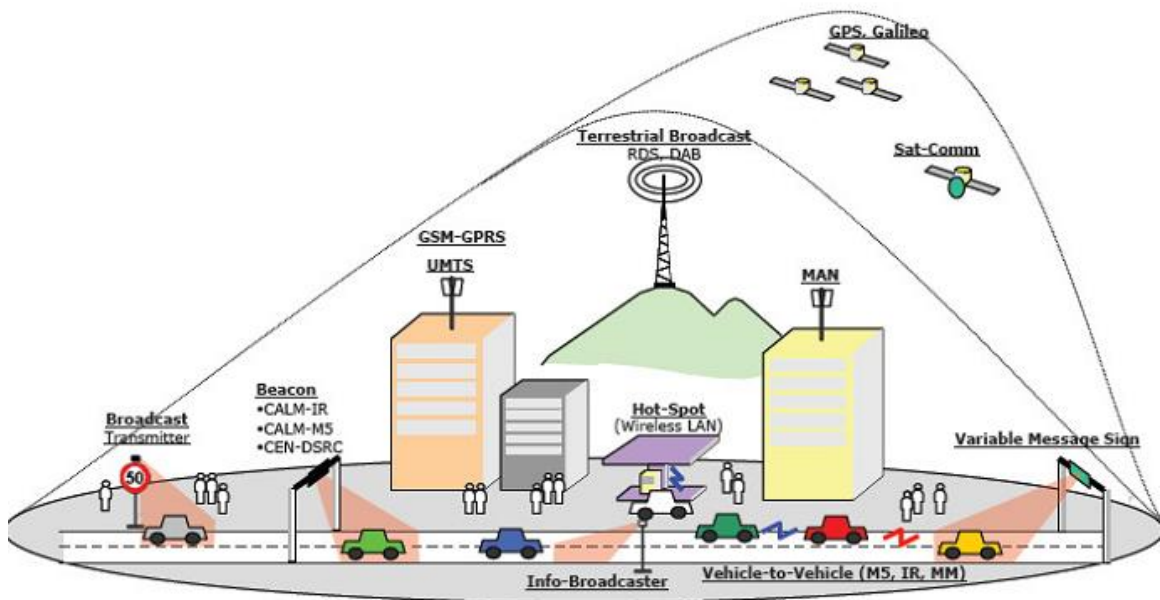
Figure 2-4: Communication Technologies in Urban Transportation [21]

A whole range of technologies have been developed for different purposes, ranging from last mile access to network backbones (Figure 2-4). These include both, wireless and wireline technologies. Due to the fact that wireline technologies are more mature than wireless and provide more bandwidth, instances where use of wire is possible do not generally cause a communications bottleneck.

Wireline technologies include a range of physical options (fiber, coaxial, twisted pair) and protocol options (DSL, ISDN, Ethernet). Given the many alternatives available, the capacity and/or throughput of wireline systems can be made to meet the systems requirements while also satisfying cost criterions [22].

Wireless technologies include many different alternatives also, but most of these have been developed fairly recently. These can be categorized into wide-area systems and short-range systems. Short-range communications can be further classified into: (i) Vehicle-to-Vehicle communications and (ii) Vehicle-to-Roadside communications [23].

Wide-area systems include cellular technologies such as CDMA, GSM/GPRS, UMTS, and more recently, WiMax and LTE, which have been providing increasing rates of data transfer as well as coverage. Some examples of short-range radio systems include IEEE 802.11p, WiFi, infrared and RFID. The 802.11p standard uses the 5.9 GHz frequency band, and is designed specifically for ITS [24]. WiFi, which is the collective name for IEEE 802.11a/b/g/n standards, is used to create local area networks. Infrared systems are for directed communications and other systems, like RFID (Radio Frequency IDentification), are used for identification purposes.

2.3.2   Location Sensing

Location sensing technologies are a set of techniques used to determine the position of a vehicle or device with respect to its surroundings.

2.3.2.1 GPS

GPS is a satellite based system that provides reliable location and time information, maintained by the United States Government. It works in all weather and at all times and anywhere on or near the Earth where there is an unobstructed line of sight to

four or more GPS satellites [25]. Other Satellite based navigation systems exist, but many are regional (e.g. China's Beidou), or are planned global systems in various stages of preparation (e.g. EU's Galileo, Russia's GLONASS).

2.3.2.2 Signpost Positioning

Signpost positioning is a system of locating vehicles using fixed beacons along specific routes, which along with an odometer reading, allows the vehicle to determine its location between two beacons. This system was used extensively on the 'Transport for London' bus service. [26]

2.3.2.3 Authentication/Identification

Identification technologies make it possible to verify an account or an account holder. Various technologies are currently used in transportation for different systems, especially in access control and payment systems.

2.3.2.4 RFID

Radio frequency identification (RFID), is widely used not only in transportation, but also in healthcare, supply chain, construction etc. It works on a system of tags and readers that can decode the tags. In transportation, it is used for electronic payment cards, automated toll collection, vehicle location [27].

2.3.2.5 Automatic number plate recognition

Automatic number plate recognition (ANPR) is an image processing based identification system which works by scanning and analyzing the license plate of a vehicle. These are used for toll collection, enforcing congestion charges, traffic analysis

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such as travel time measurements, origin-destination choices etc. While this kind of system does not require special tags to be installed for identification, it can only be used for vehicular identification [28].

2.3.2.6 Magnetic Stripe Cards

Magnetic stripe cards store data on a band of magnetic tape. They are used extensively as financial cards (credit, ATM etc.), but also as identification like driver's licenses and membership cards. There are various ISO standards that govern the design of the cards and card readers.

2.3.2.7 Online Authentication

There are a number of different ways with different levels of security to verify someone's identity online. In computer science terms, authentication and authorization are separate processes, though mostly performed together. Authentication is the verification of identity, whereas authorization is concerned with whether that identity is allowed to access the required information.

An example setup might use OpenID for authentication and OAuth for authorization. OpenID allows a user to be authenticated by an identity provider of his/her choice [29]. OAuth allows users to be authorized without sharing their identity once they have been authenticated [30].

2.3.3   Dissemination of data:

There are many different systems that distribute transportation information to the end user or traveler. In all of these systems, the last element is always the interface with the user or traveler.

The commonly used distribution media are the internet, mobile phones (voice, data and SMS), dynamic signage (LCD, LED etc.), and kiosks. With the proliferation of mobile devices, there is literally a screen in every pocket that can be leveraged to display transportation data. However, dedicated media such as LED signs, announcements etc. are still important in most cases.

Figure 2-5 shows the usage of different distribution methods by various public transport agencies for real-time arrival systems, a type of intelligent transportation system that almost always requires the use on public display signs.
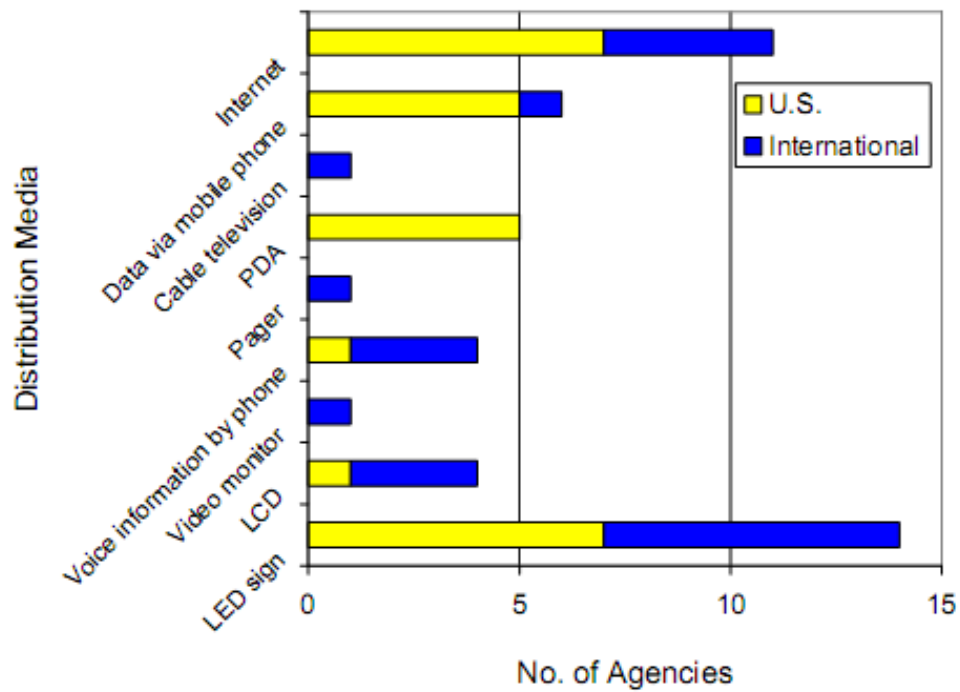
Figure 2-5: Distribution Media used for Real-time Arrival Information [26]

2.4 Multimodal transportation

Multimodal transportation, also called intermodal transportation, occurs when more than one mode of transport is used to complete a single trip, as opposed to 'unimodal' transport, where the entire trip is made by one mode of transport.

Walking can be considered a special case as it is inherently part of almost every trip at the beginning and end. However, in certain cases, depending on the distance, walking might be considered a separate mode also.
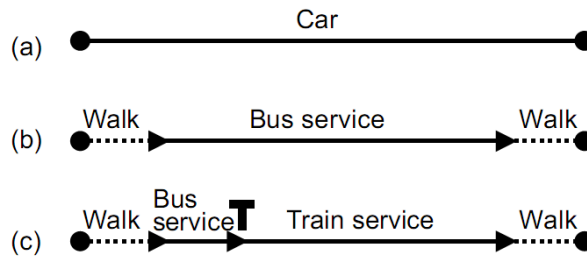
Figure 2-6: Unimodal (a,b) and Multimodal (c) trips [31]

A multi-modal network is formed of a hierarchy of smaller networks. Some networks act as feeders and are suitable for travelling short distances. On the other hand, there are certain modes that can cover longer distances faster, but do not offer door to door connectivity.

Connecting transport networks to make multimodal transport easier is one of the solutions being used to solve urban transportation problems. Intelligent transportation systems have an important role to play in this integration.
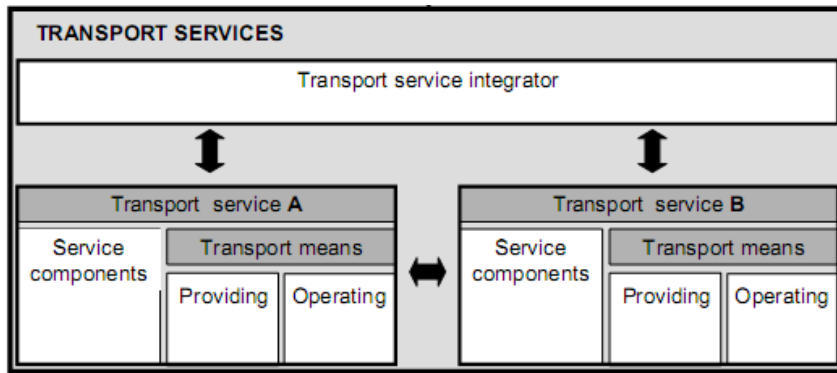
Figure 2-7: Multi-modal Transport Services [31]

Multi-modal networks inherently offer some redundancy and flexibility by offering multiple choices and routes. At the same time, they also help by distributing congestion and adjusting to varying demands

The main elements of multimodal transport are (i) Modes of Transport and (ii) Transfers between the different services. Transfers carry a certain overhead in terms of waiting time and convenience and are sometimes a key factor in the decision to make a multi-modal trip.

The objective of multi-modal network planning is not to reduce transfers, which would lead to a unimodal network, but to reduce the transfer overhead. This is achieved by coordinating different services in order to reduce the waiting times at transfer points and otherwise make transfers as painless as possible.

Multimodal transport is more conducive to trips with certain properties. It is difficult to justify the transfer overhead on shorter trips, whereas on longer trips, the transfer time accounts for a shorter percentage of the total trip time. Trips that have a preset route and time, such as a commute to work, are suited for multimodal trips as they are easier to plan and have less transfer uncertainty. Regional characteristics, such as

27

densely populated urban centers, also create a suitable environment for multimodal transportation, as the higher demand for transportation supports multiple modes.

2.5 Frameworks, Standards and Specifications

2.5.1 National ITS Architecture

The National ITS Architecture is an effort by the US Department of Transportation to provide a common framework for planning, defining, and integrating intelligent transportation systems. It provides federal direction to distributed ITS efforts at the regional, state and city levels.

The architecture defines:

- The functions (e.g., gather traffic information or request a route) that are required for ITS

- The physical entities or subsystems where these functions reside (e.g., the field or the vehicle).

- The information flows and data flows that connect these functions and physical subsystems together into an integrated system.

As such, the national ITS architecture can help transport operators in project development and to understand how an individual project fits into a larger regional transportation management context [32].

The architecture is divided into logical and physical architectures. The logical architecture of the National ITS Architecture defined a set of functions (or processes) and information flows (or data flows). These are represented by data flow diagrams (DFDs), which decompose into several layers of detail.
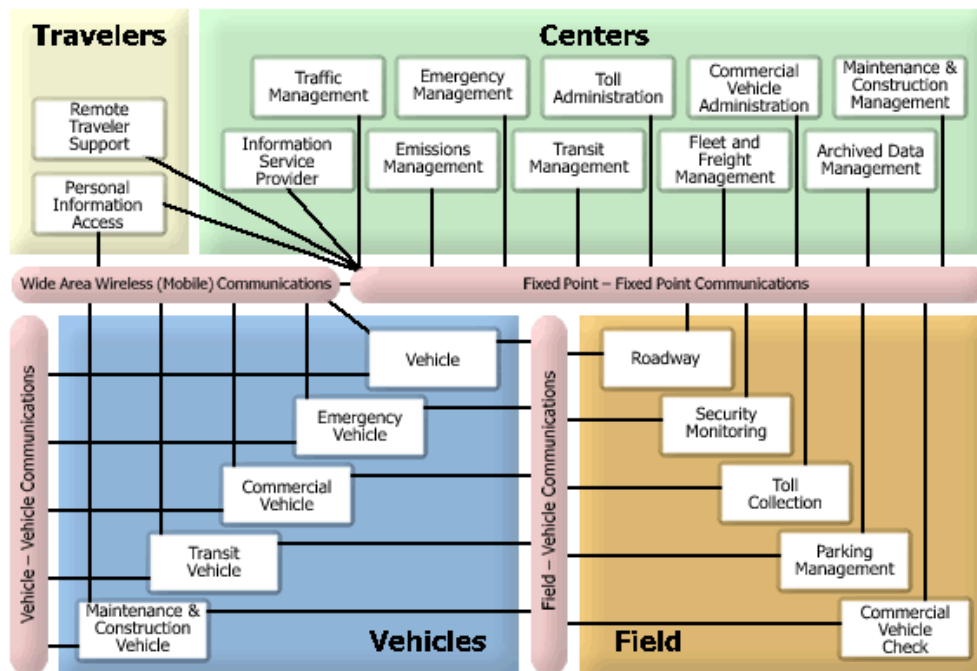
Figure 2-8: The National ITS Architecture – Physical Architecture [32]

The physical architecture is further divided into transportation and communications layers. The physical architecture takes processes defined in the logical architecture and assigns them to physical entities. The transportation layer of the physical architecture shows the relationships among the transportation-management related elements (called subsystems). The communications layer of the physical architecture provides the communications services that connect the transportation layer components.

Figure 2-8 shows the 22 transportation subsystems (white rectangles), as defined by the architecture, and the 4 general communication links (ovals) used to exchange information between subsystems. This figure represents the highest level view of the transportation and communications layers of the physical architecture. The subsystems

roughly correspond to physical elements of transportation management systems and are grouped into 4 classes (larger rectangles): Centers, Field, Vehicles and Travelers

The national ITS architecture also uses the terms 'equipment package' to define a frequent grouping of functions within a subsystem and 'market packages' to refer to a group of 'equipment packages' required to implement a service.

The architecture also serves as a framework for ITS standards development. Some of these will be discussed in the following sections.

2.5.1.1 Adoption and Use

The architecture has been widely adopted in the US by the public sector to varying degrees. This is in part due to a rule that makes compliance with the architecture compulsory for any ITS projects that are funded by the Highway Trust Fund, which is a large source of federal funds since 2001 [33].
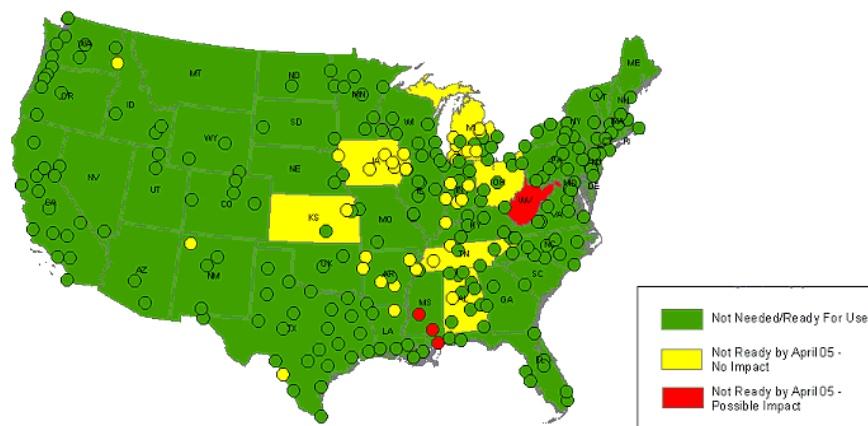
Figure 2-9: Adoption of National ITS Architecture by Region and State [34]

Figure 2-9 shows the compliance of intelligent transportation systems in regions and states across the US in 2005. Generally, every region forms their own implementation following the overall guidelines.

However, participation has been limited to government agencies as they tend to have large operations whereas private service providers tend to use cheaper, independent and smaller intelligent transportation systems.

2.5.2   SAE J2354 – Message Sets for ATIS

This standard defines messages for advanced traveler information systems (ATIS) for general use independent of medium of transmission or bandwidth availabilities. The messages described address all stages of travel, all types of travelers, and all platforms for delivery [35].

A large part of the standard can be traced back to the flows and market packages established by the National ITS Architecture. The messages are defined in the ASN.1 and XSD formats. ASN.1, which stands for Abstract Syntax Notation One, is used to describe data structures for representing, encoding, transmitting, and decoding data [36]. XSD is used to define the structure, content and semantics of XML formats to be used for the messages using XML itself [37].

The messages defined in the standard are made up of one or more data frames, which in turn include one or more data elements. Some of the data elements used come from other ITS standards.

The standard divides the messages into five groups and defines all possible request/reply sequences for them. The five groups are described below [35]:

- Traveler Information – The major portion of the effort, it includes traffic, events, weather, schedules, services etc.

- Trip Guidance – Route planning including selection of mode, dates etc.

- Directory Services – Electronic 'Yellow Pages' along with value-added information

- Parking – Parking lot and space availability

- Settings – Personal preferences

2.5.3 GTFS

GTFS (General Transit Feed Specification) defines a common format for public transportation schedules and associated geographic information [38]. GTFS was originally developed by Google, Inc. as an easy to use format to use for Google Transit, which is a map based trip planner.

The specification defines a set of 12 text files encoded in UTF-8 (8-bit Unicode Transformation Format), which store data as comma-delimited text. The format covers a wide variety of transit schedules; including different fare rules, transfer rules etc.

The format, on account of being easy to use and reproduce, is popular, with official feeds for 118 different transportation agencies available online and even more unofficial ones [39]. GTFS receives support from the developer community, which has developed validation, conversion and web-based maintenance tools [40], [41].

There has been criticism that GTFS, while good for single agency networks, does not capture sufficient data to support rich multimodal, multi-operator journey planning. This is perhaps owing to the fact that it has been developed in the US, where single agency operations are generally the norm [42].

2.5.4   EN 12896 - Transmodel

Transmodel is the European Reference Data Model for Public Transport. It provides an abstract model of common public transport concepts and structures that can be used to build many different kinds of public transport information systems, for timetabling, fares, operations management, real-time data, etc. [43]

Transmodel considers not just public facing data, but also the other back office and operational systems needed to manage, produce and update both reference and real-time data, so that end-to-end electronic systems can be developed.

Transmodel establishes a common vocabulary for transportation terms across the EU. This is especially important for public transport where vernacular uses of terms such as route, journey, and trip, cover many overlapping concepts [44]. A number of national and EU standards are based on the abstract model and the terminology specified in Transmodel, including Trident, TransXChange, and SIRI.

2.5.4.1 TransXChange

TransXChange is the UK nationwide standard for exchanging bus schedules and related data, based on Transmodel.

It is used for the electronic registration of bus routes (EBSR) with the Vehicle and Operator Services Agency, which is required by law. It is also used for the exchange of bus routes with other information systems, such as journey planners and real-time vehicle tracking systems. The standard is part of a family of coherent transport related XML standards [45].

2.5.4.2 SIRI

The Service Interface for Real Time Information (SIRI) is an XML protocol to allow distributed computers to exchange real-time information about public transport services and vehicles [46]. SIRI is primarily based on Transmodel.
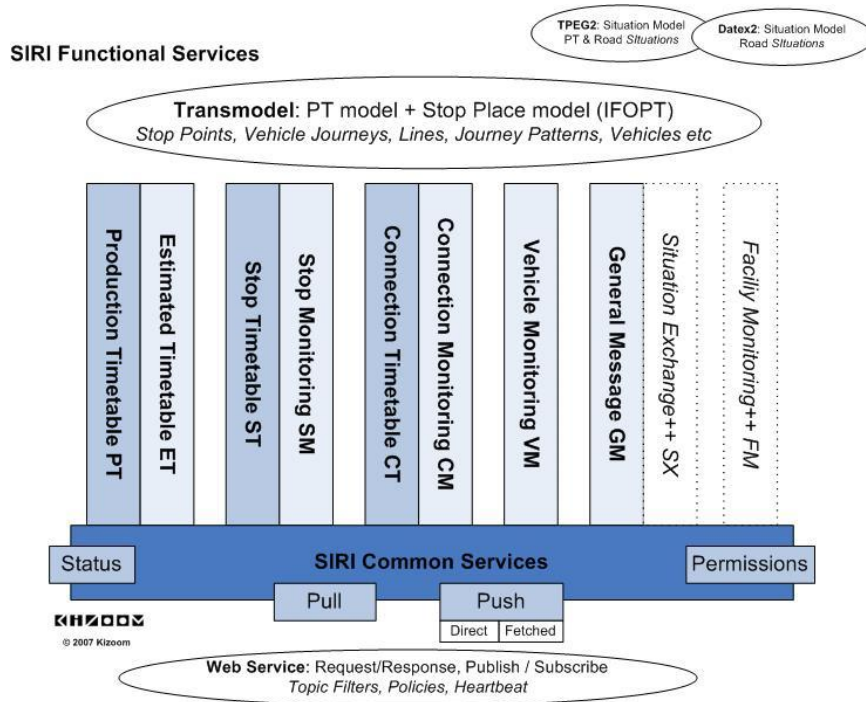
Figure 2-10: SIRI Services Architecture [47]

SIRI uses a client-server architecture that can use either a request-response protocol, where data is sent to the client upon receiving a request, or a subscribe-publish protocol, where data is continually pushed to a client. In either case, the data sent is in the form of XML documents, which follow the SIRI XML Schema [47].

SIRI currently specifies eight different services (Figure 2-10), each consisting of request and delivery message pairs, with more services under consideration.

2.5.5 NMEA 0183

The NMEA 0183 Interface Standard defines electrical signal requirements, data transmission protocol, and specific sentence formats for a serial data bus. Each bus may have only one talker but many listeners. This standard is intended to support one-way serial data transmission, in ASCII form, from a talker to listeners [48].

```
$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W
*6A

Where:
    GP              GPS Receiver
    RMC             Recommended Minimum sentence C
    123519          Fix taken at 12:35:19 UTC
    A               Status A=active or V=Void.
    4807.038,N      Latitude 48 deg 07.038' N
    01131.000,E     Longitude 11 deg 31.000' E
    022.4           Speed over the ground in knots
    084.4           Track angle in degrees True
    230394          Date - 23rd of March 1994
    003.1,W         Magnetic Variation
    *6A             The checksum data, always begins with *
```

Figure 2-11: NMEA v2.0 RMC Sentence [49]

GPS receiver communication is defined within this specification. NMEA defines lines of data called sentences that are totally self contained and independent from other sentences. All of the standard sentences have a two letter prefix that defines the device, which is followed by a three letter sequence that defines the sentence contents [49]. Figure 2-11 shows an example of the RMC sentence (recommended minimum data for GPS) from v2.0 of the standard.

2.6 Traveler Information Projects

Several projects that provide traveler information have been undertaken around the world. This section describes a few projects that differ greatly in scope and implementation.

2.6.1 Transport Direct – UK

Transport Direct was created as a division of the UK Department for Transport to support the development of better and integrated information and retailing systems for passenger transport [50]. The project was started in 2000, and since 2005, it operates the Transport Direct portal at www.transportdirect.info.

Figure 2-12: Transport Direct Information Tools [51]

The transport direct portal provides access to information about trains, flights, roads, buses, parking, cycle routes etc. (Figure 2-12). Transport Direct uses a number of

data sources, which includes government and private transport operators. A lot of public transit data is obtained from the Traveline project.

Traveline is a partnership of transport operators and local authorities, operating since 2000, formed to provide information about public transport. Transport operators prepare the data in electronic formats, which is then brought together into regional databases by 11 Traveline regional organisations. This data is then used by Traveline, Transport Direct and other associated services, which include Google Transit and localized travel planners [52].

While Traveline is limited to collecting data about public transit, Transport Direct also uses other data sources that include private transport operators as well as other government agencies [53].

Some of the data are publicly available, such as the National Public Transport Access Node (NaPTAN) database, which includes all transportation access points across the country (bus stops, ferry terminals etc.). The National Public Transport Data Repository is a snapshot of all Traveline data for one week, which is taken annually. This data, while not freely available, can be used for planning purposes [54].

2.6.2   ENOSIS – Greece

The ENOSIS project concerns the development of an integrated decision support system for passenger transportation in Greece, attempting to supplement and complete the existing reservation systems by giving them these characteristics and capabilities that will provide 'smart' and valid real-time information for multimodal transportation. The information system that will be developed under the framework of this project is directed to travelers and business bodies [55].
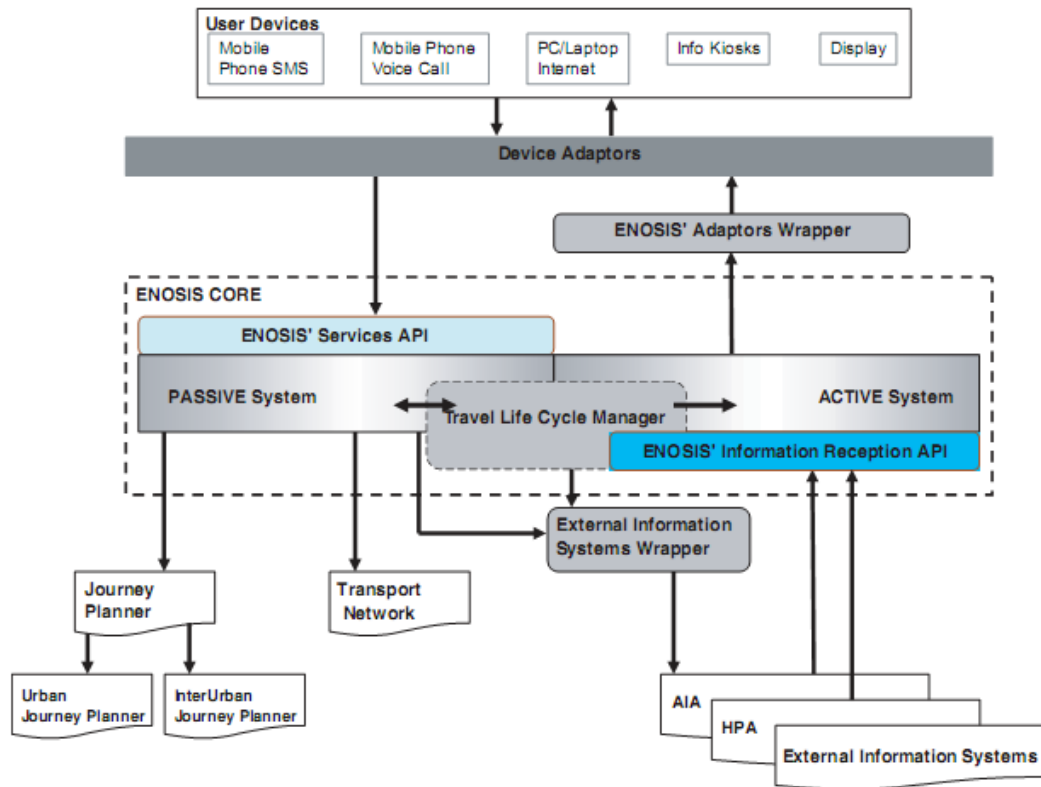
Figure 2-13: Proposed architecture for ENOSIS

The provision of the travel information includes both ordinary information (e.g., departure time reminders) and unscheduled information (e.g., change of departure time) through many alternative channels of communication, including mobile phones (voice message, SMS) and e-mail.

A prototype of the proposed system has been developed for supporting interurban trip planning in Greece and urban trip planning in Athens. The interurban public transportation network covered includes the national ferry and boat lines, coach lines and national flights connecting to Athens. The Athens urban public transport system covered by the prototype includes the city's metro, tram and bus lines. The ENOSIS prototype is

available through the web and at two information kiosks located at Athens Airport and the Port of Heraclion [56].

2.6.3   OneBusAway – Seattle, Washington

OneBusAway is an open source project developed at the University of Washington that provides tools to improve the usability of public transit, using real-time arrival information for Seattle-area buses.
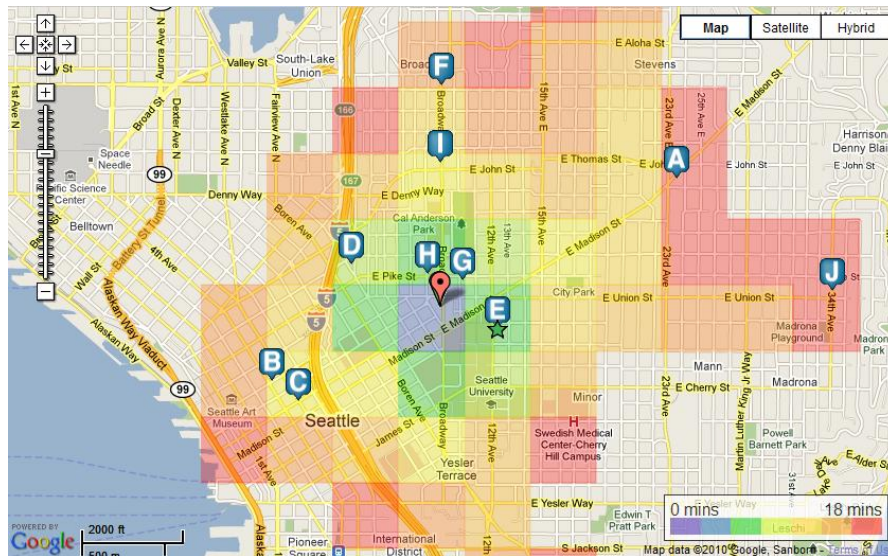
Figure 2-14: The Explore Tool on OneBusAway [57]

The project provides a variety of interfaces, including web (http://onebusaway.org), phone, SMS, and mobile devices to provide services that include real-time arrival information, trip planning, and service alerts [58]. The system relies on static timetable data for the most basic information. The project includes tools that present basic data in innovative ways (Figure 2-14).

2.7   Summary

Urban transportation systems are in constant, if not dire, need of improvement. Intelligent transportation systems can offer a way make urban transportation networks more efficient. Many technologies are available to use in the development of ITS and existing infrastructure, such as data networks, can be leveraged where possible.

Attempts have been made, at different levels, to standardize intelligent transportation systems. However, these solutions are too complicated, expensive to implement, or have not taken into account the requirements of all the relevant stakeholders. For these reasons, standardized ITS have not seen the levels of deployment that would be expected, especially in the private sector.

Specifically for traveler information systems, there haven't been many directed efforts towards information sharing between transport operators to create a multi-modal traveler information system. The 'Transport Direct' system in London is similar to the solution proposed in this thesis, but allowing even partial access to the data for use on outside projects could provide many interesting results.

The requirements for a platform for multi-modal information and the advantages to be gained from it would thus benefit from more research.

CHAPTER 3
EFFECTS OF TRAVELER INFORMATION

3.1 Traveler Information

A traveler's use of information in a transportation network is not optimal. This is due to one of the following reasons:

- A lack of sources

- A lack of awareness of sources

- The effort involved in accessing available sources

- The effort involved in understanding and/or comparing sources

- The perceived quality or accuracy of information

Traveler information systems can mitigate all the issued to some degree. The phrase 'traveler information' is used here to describe any information that allows a traveler or passenger to make better use of a transportation network, which makes it a subset of general transportation information. It follows that the phrase 'traveler information system', is used to describe intelligent transportation systems that provide traveler information. These systems can be loosely categorized as advanced traveler information systems (ATIS), described in 2.2.2.1.

Different traveler information is used during the pre-trip, in-trip and post-trip stages. Real-time information can augment the use of information in all these stages. In the previous chapter, some background on the technology and systems used for intelligent transportation systems was covered. This chapter focuses on the effects, on the network and the traveler, of using traveler information systems.

This is accomplished by reviewing the results from published case studies for different types of traveler information systems. The specific systems used here are real-time arrival information systems and highway information systems. Some examples of integrated systems and the effects of sharing data and infrastructure are also considered.

The reviews includes results from studies that use different techniques, such as stated preference surveys, which are conducted prior to system implementation, reported behavior surveys, which rely on individuals to report their behavior post trip, before and after surveys, which reveal traveler preferences by comparing two surveys, as well as simulations, discrete choice models etc., which rely on data from various sources themselves.

Overall, little quantitative data is available for traveler information systems, and even less is available for integrated systems. Part of the reason might be that it's difficult, in a dynamic system, to attribute changes such as increase in ridership, decrease in traffic etc. to a specific reason with complete confidence. Regardless, an attempt is made to organize the available data to form a clearer picture of the effects and the utility of traveler information.

3.2 Real-time arrival information

Real-time arrival information systems provide information about vehicles operating on a transit route and when they are likely to arrive at a stop, based on their current location and predictive analysis. The information may be presented in different ways to the traveler, including countdown timers, maps, announcements etc.
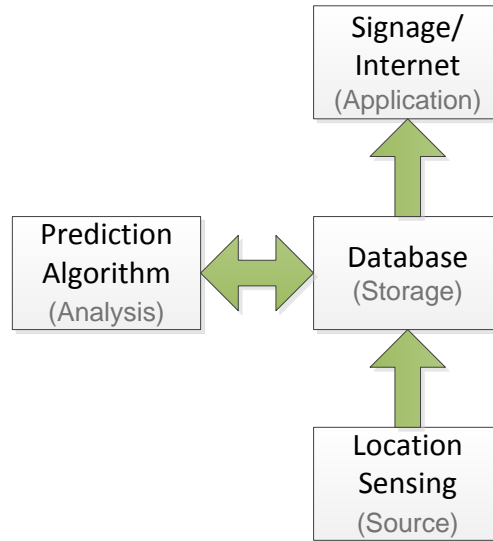
Figure 3-1: General Setup for Arrival Information Systems

The system architecture in most cases follows the general ITS pattern, as shown in Figure 3-1. Location sensing methods are used to record vehicle locations, which are stored in a central database. This data is used in dynamic signage as well as web applications etc. Prediction algorithms, based on historical data are used, especially in the case of road-based transit, where external factors such as traffic can vary the travel time significantly.

An increase in ridership is the most desired benefit from any transit ITS implementation, since it leads to a direct increase in revenues and an increase in the modal share of transit. Increases in ridership due to any one particular improvement are difficult to measure. However, other metrics, such as perceived reduction of wait time, perceived increase in safety etc., are easier to establish, as these are not quantitative metrics.

Figure 3-2 shows the reasons agencies deploy real-time arrival information systems, based on a survey of transit agencies conducted by the Transportation Research Board [26]. The reason most often cited is the general improvement of customer service.
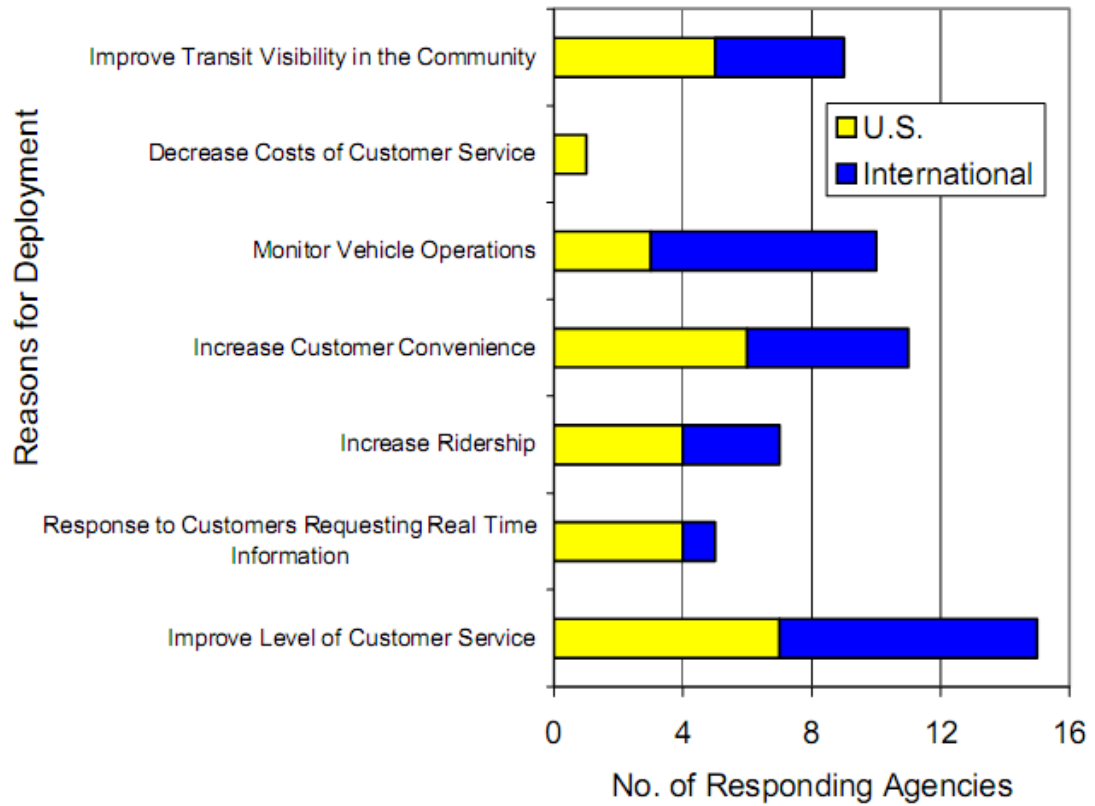
Figure 3-2: Reasons for deployment of Real-Time Arrival Systems [26]

3.2.1 <u>Ridership</u>

A survey carried out in the Seattle area in for the TransitWatch system found weak evidence for retaining new transit riders, which was attributed to the positive effect on comfort and satisfaction due to the system. However, no support for the increase in usage by existing users was found [59]. The TransitWatch survey was performed in 2000. A 2010 survey, also in Seattle, but for a wider deployment, showed that there was a slight but definite increase in ridership, especially for non-commute trips [60].

Similarly, a study in Leicester, UK, found that there was a 20% increase in patronage in some routes, but there were other ongoing improvements at the same time as well, so it is not possible to attribute the increase to just real-time information [61].

On the other hand, a 2008 before and after survey for a system at the University of Maryland showed no increase in ridership [62]. The results from a quantitative analysis, based on fare data, performed in the Thanet region of the UK also show no increase in ridership [63], and agree with the Maryland results.

An interesting point to note here is that studies carried out soon after a small deployment, such as in Maryland and Thanet, do not show an increase in ridership, but those carried out after a full scale deployment has been in use for some time, such as in Seattle (2010) and Leicester, support the increase in ridership, even though weakly.

Another fact is that of all the findings mentioned, most are based on survey data, and not on data from fare collection or passenger counters. Better insight can be obtained by conducting follow-up studies once systems are deployed fully and for a significant amount of time, as well as gathering more substantive data.

Table 3-1: of Real Time Arrival Information Systems [26], [59-66]

System	Area	Benefits							Year	Type of Study
		Increase Use	Get new Riders	Reduced perceived or actual waiting time	Higher Perceived Reliability	Reduced Anxiety / Uncertainty	Higher Perception of Security	Higher Customer Satisfaction		
Countdown	London	--	--	✓	✓	✓	--	✓	1994	Reported Behavior Survey
Transit-Watch	Seattle	✗	✓	✓	--	✓	✓	✗	2000	Reported Behavior Survey
KomFram etc.	Sweden (4 cities)	--	✓	✓	--	--	✓	--	2002	Various
Star Trak	Leicester	✓	--	✓	✓	✓	✓	--	2003	Before and After Survey
Transit Tracker	Portland	--	--	✗	✓	✓	✓	✓	2003	Before and After Survey /Online Survey
RTI for Stagecoach	Thanet, East Kent	✗	--	--	✗	--	--	✓	2004	Operations Data / Before and After Survey
ShuttleTrac	College Park, Maryland	✗	--	--	--	✓	✗	✓	2008	Before and After Survey / Panel Model
OneBus-Away	Seattle	✓	--	✓	--	✓	✓	✓	2010	Reported Behavior Survey
N/A	Chicago	✓	--	✓	✓	--	✓	--	2006	Stated Preference Survey

✓ – Study Agrees   ✗ – Study Disagrees   -- – Not Addressed

3.2.2   Wait time and Reliability

Multiple studies have reported that travelers perceive a reduction in waiting time when they know the arrival time of their service. An early study of the countdown system at London bus-stops found that 65% of travelers felt that their perceived wait time was reduced by an average of 27% [67].

A study of four Swedish systems showed that travelers with real-time information estimated their wait times more accurately, overestimating it by only 9-13% instead of overestimating it by 24-30% in the general case [64].

In the same way, it has also been observed that real-time arrival information increases the perceived reliability and quality of service. The same 1994 London trial found that 64% of the travelers interviewed felt the countdown system increased service reliability, whereas in fact, service reliability had decreased [67]. The same was observed in a 2003 study of a system deployed at Leicester [61].

On the other hand, a before and after survey in Portland showed no decrease in the mean perceived wait time, and only showed an increase in perceived reliability at one out of the three bus stops targeted. A explanation given for these results is that 91% of the respondents were already satisfied with the on-time performance of the buses, which would have left little room for improvement due to real-time information [65].

3.2.3   Anxiety and Uncertainty

Perceived waiting time is generally closely linked to anxiety and uncertainty; however, there are other factors that may also be responsible. So while those two benefits are linked, they are not the same. In general, all the reports that did include the effect on anxiety, found that anxiety was reported to be reduced due to real-time information.

A stated preference survey in Dublin, the results of which were analyzed using a nested logit model, found that 80% of their respondents were caused frustration by not knowing when the next service was due to arrive and 69% were frustrated due to not knowing whether their service had passed [68].

These results point to the fact that providing the traveler with information can lead to a less anxious transit experience.

3.2.4 Security

The reduction in uncertainty due to real-time information can provide an increased sense of security for some travelers. It is however, debatable how much of a difference this makes to most travelers. The results from different studies vary widely as far as the how many people feel more secure. Among the travelers who do feel more secure, there is no measure of how much more.

The 2010 Seattle study, for example, found that only 21% respondents felt more secure but found that women experienced greater increases in perceived security [60]. The University of Maryland study also showed no major difference in feelings of security before or after the installation, but weak support for increased perception of night-time safety [62].

3.2.5 Summary

The above results indicate that the effects of availability of real-time information, while uncertain with respect to increasing ridership, have a definite impact on the traveler's perception of a transit service. As far as ridership is concerned, there are

positive indicators, but without more rigorous data, it is impossible to determine the final effect.

It is however important to note that most of these studies have been conducted on limited deployment and relatively soon after deployment. Better results might be obtained from allowing people time to adjust to the availability of information as well as broader deployments.

The only two sets of data compared from the same area are those for Seattle, which are 10 years apart, and the later survey shows much more confidence in the positive results as well as a definite increase in ridership. However, the two studies used were performed by different organizations for systems that have changed over time, and as such, a direct comparison might not be fair.

As will be discussed in the section on integration of different ITS services, a lot of the same data can also be used for fleet management and improvement of services. An argument can be made that a perception of better service together with actual improvements in service would ultimately lead to increased ridership.

3.3 Highway Information Systems

Real-time incident and traffic information systems provide information about road conditions, speed of traffic, blockages or incidents on highways etc. and may also include estimated trip time or alternative routes, based on analysis of the data. The data is generally delivered using different channels, which include variable message signs (VMS), highway radio and phone-in services such as 511. Variable message signs are also called dynamic or changeable message signs.

The data for these systems can be split up into two major types, traffic or congestion information and incident information. These two are related as it is known that incidents contribute to congestion in a major way, but they require slightly different set-ups, and can have varying levels of integration.
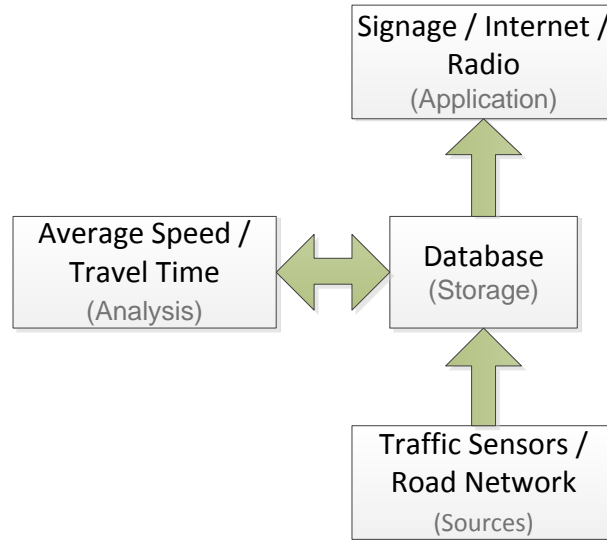
Figure 3-3: General Setup for Highway Information Systems

For data sources, these systems generally use traffic sensors such as loop detectors for data inputs. Incident data comes from submitted incident reports, highway work schedules, and might also come from traffic data analysis. This data is then presented using various methods mentioned before. Analysis is also used to predict the congestion, which may be based on real-time as well as historical data.

An important difference between real-time highway and real-time transit information systems, which were discussed in the previous section, is that highways and hence real-time highway information systems are almost always run by public

institutions, whereas with transit, there can be a mix of public and private service operators.

The expected outcome of these systems is to allow people to make better trip choices, such as route, time, mode etc., by providing better information. This, in turn leads to better distribution of traffic over time and over the network. The effect is thus a two-stage one, the first stage being a change in trip choice, which in turn leads to a reduction in time, cost and uncertainty.

Table 3-2: Benefits of Real Time Highway Information Systems [69-73]

Area	Delivery Method	Benefits					Year (Data)	Type of Study
		Change Trip Route	Change Trip Time (Pre-trip only)	Change Trip Mode	Reduce Travel Time	Reduce Travel Time Uncertainty/Anxiety		
Los Angeles	N/A	--	--	--	✓	✓	2006	Operational Data / Simulation
Chicago	Radio	✓	--	--	✓	--	2008	Reported Behavior Survey / Discrete Choice Model / Macro Traffic Flow Model
Raleigh /Durham	Internet, Radio, VMS etc.	✓	✓	--	--	--	2006	Reported Behavior Survey / Discrete Choice Model
San Francisco	Internet, Radio, VMS etc.	✓	✓	✓	✓	✓	1995-98	Focus groups / Multiple Surveys / Field Data
EU (8 Regions)	VMS	✓	--	✓	✓	--	1994-99	Multiple Surveys / Simulation etc.
✓ – Study Agrees ✗ – Study Disagrees -- – Not Addressed								

The relationship of trip choice changes to time and cost savings is complex. It depends on a number of local factors, such as the route layout, capacity and population demographics etc. This makes it hard to translate the trip choice changes, which are essentially the traveler's reaction to the system, to time and cost savings. A lot of studies thus focus only on the change in route or time, and do not calculate the secondary effects.

3.3.1 Change in trip route, time or mode

Several studies found that changes in trip choices, or travel decisions, are associated with better travel information access. A survey based discrete choice model, applied to the Raleigh-Durham area of North Carolina showed that the travelers who frequently access information are likely to change trip choices. The study estimates that 78.6% of all people who received information made some change to their trip [69].

A series of surveys conducted for the TravInfo system in San Francisco, between 1995 and 1998, provide more in-depth results. The different surveys reported that the number of people who changed trip choices varied from 15-34%. This number was as high as 84% among people surveyed while they were actively seeking out information via telephone or the internet. The study also differentiates between different trip choice changes. It was found that route changes are by far the most common, followed by changes in departure time, with changes in mode being the least common change [70].

A report that compiled results from various surveys across European cities found diversion rates due to variable message signs to be up to 35%. However, results from London and Southampton, which used manually set VMS, also included in the report, are much lower (3-7%) [71]. The results point out the fact that better quality of information (in this case, real-time information) leads to better utilization of the information.

Besides actual quality of information, the perceived quality of information was also found to be important [74], as it leads travelers to trust the information. Trust of information is a major factor in trip-choice decisions.

3.3.2 Travel time and Travel time uncertainty

A simulation based on data from the Los Angeles highway system, that calculated travel time savings based on different levels of real-time information (historic, instantaneous and predictive) found that all of them offered time savings as well as reduction in uncertainty compared to static information, but better results were seen with better information. The time-savings in this particular simulation ranged from 1-14% depending on the type of information [72].

Another simulation, based on a highway traffic flow model called FREEVAL, with behavioral inputs from a survey in downtown Chicago also reports reductions in travel time; and increasing effects with higher access to information [73]. The set of surveys carried out for TravInfo in San Francisco, also found that users perceived benefits in the form of time-savings and reduced anxiety [70].

Network simulation models for Toulouse and Turin in Europe predicted a savings in travel time of 1 to 2% if all drivers made trip choice changes. This shows that if the network doesn't have spare capacity of is already relatively efficient in using existing capacity, redistributing traffic will have limited effect [71].

3.3.3 Other Factors

There are other factors which have not been given much attention, such as the impact on cost of travel, the environment and safety. The initial assumption would be that

the net impact on the cost as well as the environment should be positive, considering that time saved and the consequently reduced congestion would lead to less burning of fuel and more productivity. However, there is not a lot of research to support that assumption.

There have been concerns with regard to safety that stem not from consumption of information, but rather from the distribution methods, which might lead to driver distraction [70]. Additional traffic on arterial routes, which are considered to be less safe than freeways, might also lead to increased accidents [75], as would an increase in average speeds. On the other hand, reduced stress and congestion might lead increased safety too [70], [71]. While these concerns have been mentioned, none of them have been addressed in the studies reviewed, and the overall effect on safety in unclear.

3.3.4 <u>Summary</u>

While more detailed data is available for highway information systems than for arrival information systems, it is still difficult to assess the exact impacts due to the varying nature of the systems. There is a definite gap in the information regarding the secondary effects such as reduction in travel times and even more so for other effects such as environmental impact and safety concerns.

On a macro level, however, it can be seen that the effects of providing highway information are positive and the results get better with better information as well as with increased usage of the system.

3.4 Integrated Systems

Intelligent transportation systems can be separated into many small systems, such as the few described in detail above. Some systems inherently share a lot of

infrastructure, and are very often deployed together, whereas many others have very little to no overlap. In either case, especially when it comes to traveler information systems, it makes a lot of sense to integrate the systems in a planned way.

The integration of the information can overcome two major barriers to information use; the awareness of sources of information for each mode and the effort involved in accessing and comparing these sources [76]. Integrating multiple information systems enables sharing of data between systems. Some common examples are using real-time transit data to improve bus driver effectiveness [77] or service reliability [78].

In some cases, information sharing can lead to more accurate or more useful information reaching the traveler, when the same data is used in a different context. For example, real-time transit data may be used to estimate traffic conditions on highways [79], or information from parking guidance systems can be used to provide more accurate estimates of total travel time and cost.

Integrating traveler information systems has the potential to realize benefits by maximizing the utility of the information gathered by each individual system. However, there is such a thing as systems that are too closely integrated. This brings with it its own set of problems such as maintenance or upgrades on individual systems are difficult to perform without affecting dependent systems.

3.5 Summary

Traveler information can have a decidedly positive impact on a transport network. The data available on a lot of these systems, is not enough to quantify the benefits and more research and development in that area may be required before that is possible.

An interesting point that is brought out in the review is that as the quality of information provided rises, so does the utility of the information and this is reflected in the use of the system and its effect on the network. The 'quality of information' depends on the accuracy & perceived reliability of the information and the amount of data conditioning (additional sources and data analysis) done before presenting it to the traveler.

Additionally, when infrastructure is shared, the potential for using data in different ways increases. This can lead to the development of entirely new kinds of systems, major reductions in cost of deploying systems, and increase the impact of currently deployed systems. In that respect, the potential for a framework that ties in all ITS systems together, such as the National ITS architecture is huge, but those implementations are expensive, and have slow rates of adoption among private transportation operators.

On the other hand, an application-driven architecture, focusing primarily on integrating traveler information, which can possibly tie into the larger, general ITS architecture, can be very useful in increasing the accessibility of transportation data to more travelers, increasing the visibility of transport services, and potentially provide quicker returns.

Another important benefit of such an architecture would be to allow a fine separation of sub-systems, such as separating schedule adherence algorithms from real-time arrival information systems, so that the systems can be developed separately, but continue to share infrastructure.

CHAPTER 4
DESIGN AND DEVELOPMENT

4.1 Concept

With access to data becoming ubiquitous due to the spread of internet access and mobile broadband, more and more application development is web based. It is now possible to have applications rely on remote data streams available over a data network. Such applications are now used for geographic, financial, weather data etc.
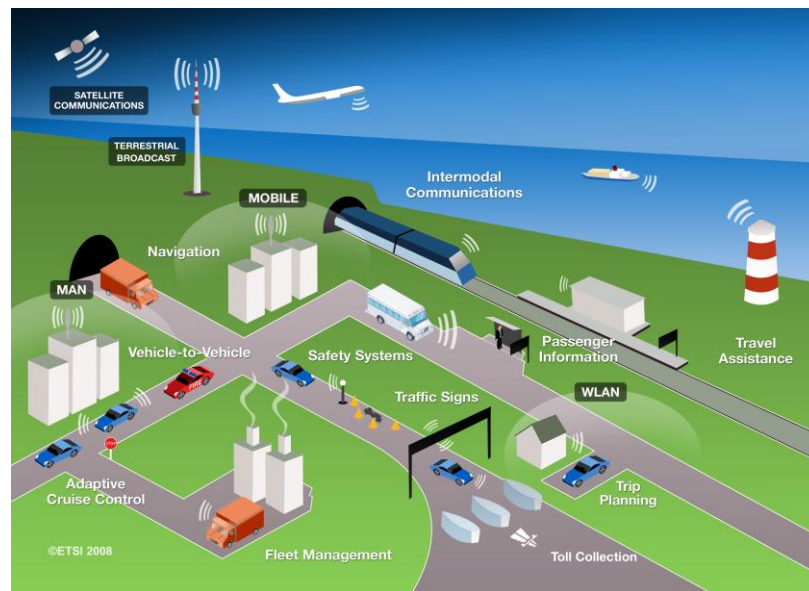
Figure 4-1: Ubiquitous data in an urban transport environment [80]

While similar applications are in use for transportation as part of intelligent transportation systems, the development of such applications would be greatly accelerated if the data is available to developers in a well-defined and easy to use format.

A lot of data is generated in an urban transport environment, but for it to be useful to the traveler; it has to be categorized, analyzed and made accessible.

The information platform being proposed is a portal where information pertaining to transport can be fed and retrieved by all stakeholders in the regional transportation mechanism or a virtual clearinghouse for traveler information. The purpose is to enable more effective use of urban transport data. The setup also provides a way to share data from different sources, which can increase the utility of data. Finally, newly available data can become immediately useful because the platform can provide an established mechanism for dispersion and use of information.

4.2   Architecture

The high level architecture of the proposed platform is discussed in this section. Individual implementations would vary based on the specific methods used to build the system while conforming to the overall architectural concept. One example implementation (called RideVia) and its design and development are discussed in the next section.

Traditionally, ITS architecture consists of vertically integrated tightly coupled systems that start from data generation and go all the way up to application development. Inter-connections between two disparate systems are difficult, and since there is no governing architecture, often haphazard. Newer ITS systems are moving towards looser coupling between elements, which adds some modularity and also makes it easier to provide hooks for external systems.

The proposed architecture incorporates a central processing and storage backend, which supports receiving, managing and sending data to and from multiple sources. The

design can incorporate security measures to control and provide different levels of access. Data entry into or access from the backend is achieved by using pre-defined interfaces and formats. This provides a high degree of modularity as all the different components are loosely coupled; i.e. the inter-dependencies of modules are minimized [81].

The entire transportation network can use one centralized system, or use a decentralized setup where multiple such systems can be deployed and act as nodes in a network, connected via the data interfaces. Existing legacy systems can also be connected with some modifications.
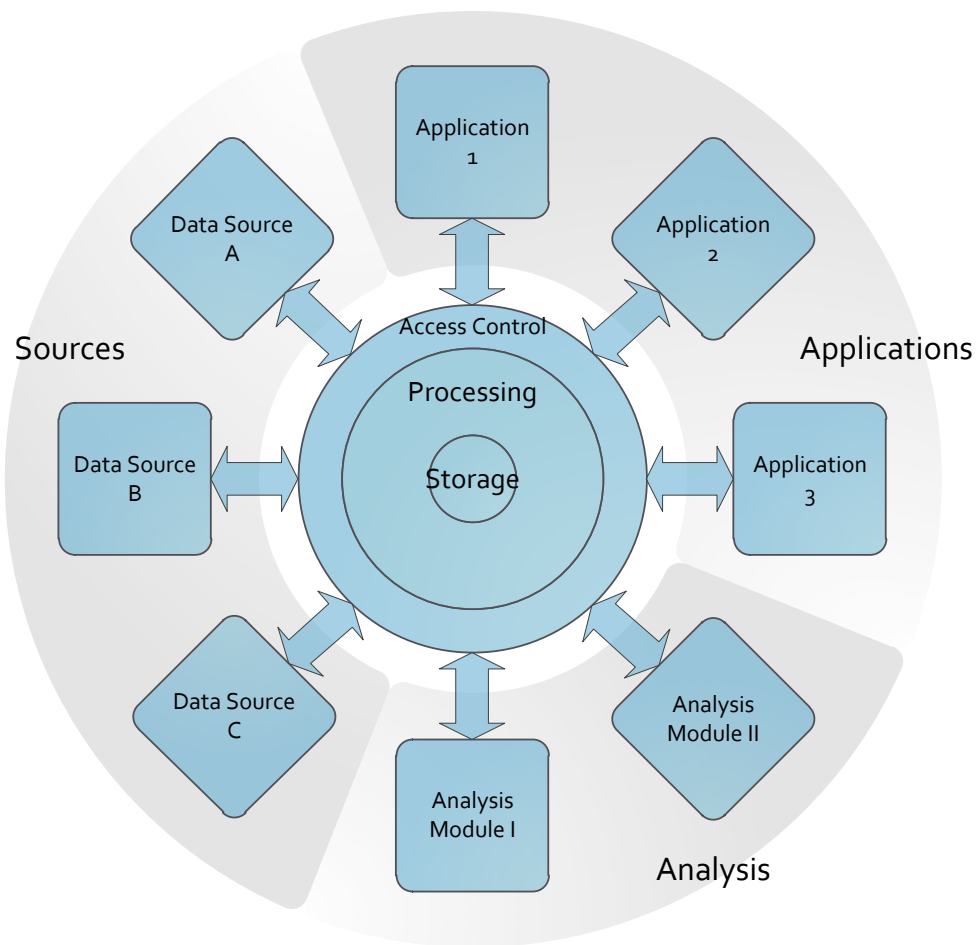
Figure 4-2: General architecture for a traveler information platform

The resulting system is architecturally horizontal, where every stakeholder performs the task they do best. The transport operator can focus on just operations and outsource almost everything else, if so required, and not necessarily use a single vendor or consortium, as is generally the case with current systems, while at the same time maintaining extensibility.

The loose coupling between system modules adds some overhead to the data transactions, processing etc. However, current technology, easily available processing power and high bandwidth data networks reduce the impact of these overheads and the benefits far outweigh the costs.

4.3 Introduction to RideVia

A full-fledged regional or city-wide information platform would require the involvement of almost all transportation sector companies, including public and private sectors. This being difficult to achieve within the constraints of the duration of this thesis, it was decided to focus on midtown Atlanta which includes Georgia Tech and Atlantic Station (Figure 4-3).

The ecosystem of elements that make the information network consists of data sources, a data backend, and multiple user applications. The project is called the 'RideVia', and is hosted at www.ridevia.com.
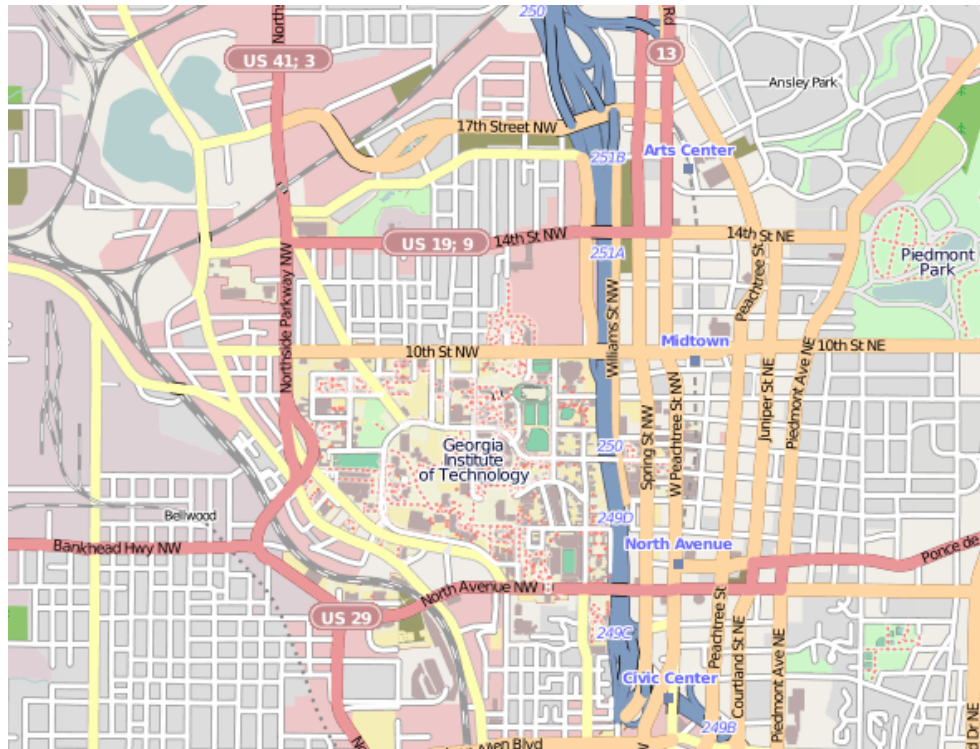
Figure 4-3: Area of focus for RideVia – Midtown Atlanta [82]

The project went through two revisions with incremental development and addition of features. While broadly similar in architecture and function, version 1.0 was more of an exercise in study and prototyping to understand the feasibility of the concept and demonstrate the use. Building on the interest in the first version, version 2.0 was designed as a more complete solution which would be easier to extend and deploy as a finished solution if required.

4.4   RideVia Version 1.0

4.4.1   Requirements and Goals for Version 1.0

The goal for version 1.0 was to build a demonstration project, not meant for use in a production environment. The purpose was to show how the concept could be useful,

and drum up interest in the system among stakeholders in the transportation community, within a limited period of time. The focus was on real-time and multi-modal data.

The development for v1.0 took place in parallel with the development of the general concept of the information. The design requirements thus underwent modification as the concept was developed. The following are the final set of requirements:

- Store real-time transit data

- Store data for multiple modes

- Display real-time and static data

- Drive multiple applications

- Multi-modal trip Planning

4.4.2   Design of Version 1.0

Work on Version 1.0 was started in September 2008. The design stage took around 2 months until November 2008, after which development was started. Most of the major work was completed by March 2009 with incremental work being done up until May 2009.

The architecture of Version 1.0 consists of a database designed to store transportation schedule information and real-time location data, and server processes that allow for selective insertion and removal of this data (Figure 4-4). Almost all the data entry in this version is manual, except for real-time location updates from GPS trackers.
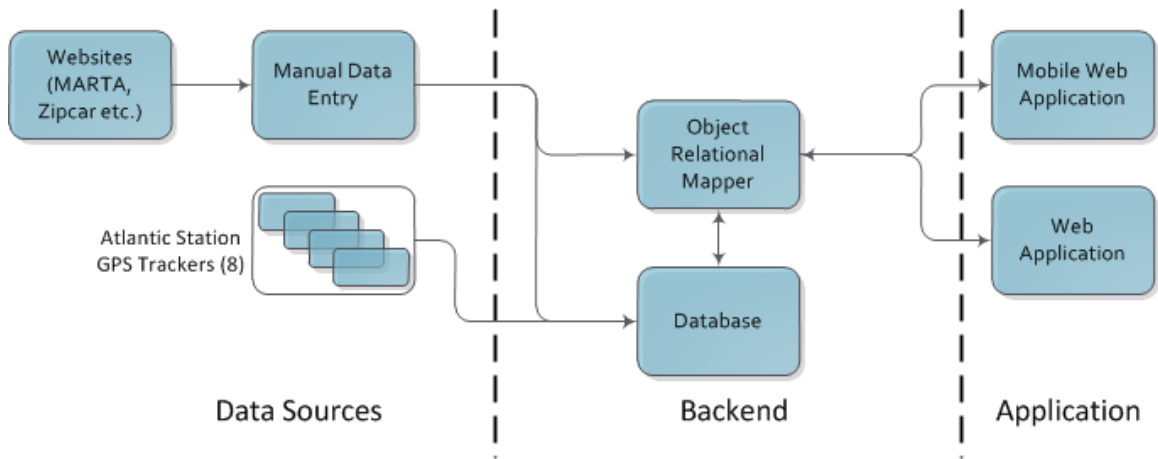
Figure 4-4: RideVia Version 1.0 - System Diagram

The application-database interface is very tightly coupled in this version, meaning that the data calls for the mobile and web applications are specific to those applications.

4.4.3   Version 1.0 Components

4.4.3.1 Data Sources:

1. MARTA Transit Schedule and Route Data from website (manual)

2. Atlantic Station 'Free Ride' Shuttle

    ▪ Location Data from Tracking Modules (8)

    ▪ Route Data from Atlantic Station website (manual)

3. Zipcar Carsharing Locations from website (manual)

4.4.3.2 Backend:

1. PostgreSQL Database

2. Django Object Relational Mapping

4.4.3.3 Applications:

1. Web Interface for Kiosks

2. Web Interface for Mobile Devices

4.5   RideVia Version 2.0

4.5.1   <u>Requirements and Goals for Version 2.0</u>

The goal for version 2.0 was to develop a scalable system that would be capable of running in a production environment with some changes. The focus with version 2.0 was on demonstrating the data backend and loose coupling concepts.

The additional requirements for Version 2.0, besides the requirements for Version 1.0, were set as follows:

- Store real-time data history

- Use of uniform data formats

- Scalability and extensibility

- Maintainability

- Loose coupling between layers

4.5.2   <u>Design of Version 2.0</u>

Work on version 2.0 of the project was started in September 2009, after version 1.0 was used to demonstrate the technology, and get feedback on next steps. While, the overall structure is similar to version 1.0, the version 2.0 database offers easier access with the full use of the capabilities of an object relational mapper (ORM), and an application programming interface (API).
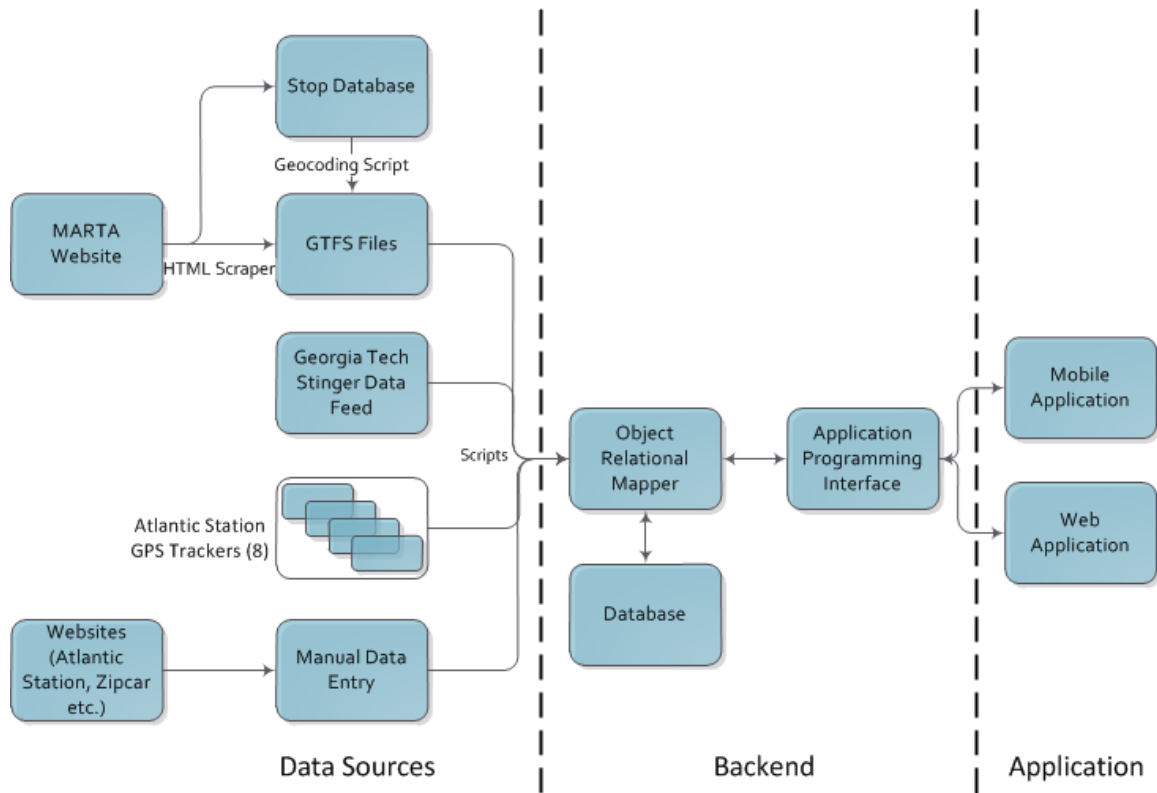
Figure 4-5: RideVia Version 2.0 - System Diagram

These modules are discussed in more detail in later sections. Data input is more automated and uses multiple sources. The application-database interface is loosely coupled, and exchanges data using XML via the API. The database is also more fully featured and capable of storing historical data.

4.5.3   Version 2.0 Components

The individual components together make the current RideVia system can be divided up into sources, backend and applications. At present, there isn't any analysis component, but there are future plans for development in that area.

4.5.3.1 Data Sources:

Data sources for v2.0 include schedule and route data for certain train and bus routes operated by MARTA, the public transit authority in Atlanta, the shuttles operated by Georgia Tech and by Atlantic Station in Midtown, and car-sharing locations operated by Zipcar.

1. MARTA Transit Schedule and Route Data from website

2. Atlantic Station 'Free Ride' Shuttle

   - Location Data from Tracking Modules (8)

   - Route Data from Atlantic Station website (manual)

3. GT Shuttles

   - Location Data from Georgia Tech data stream

   - Route Data from Georgia Tech website (manual)

4. Zipcar Carsharing Locations from website (manual)

4.5.3.2 Backend:

The database, object-relational mapping (ORM), and some utility scripts that run on the server, together form the backend. The ORM consists of the object model itself, as well as the programming interface (API) for database access.

1. PostgreSQL Database

2. Django Object Relational Mapping

3. Application Programming Interface

4. Other utility scripts (Python and PHP)

4.5.3.3 Applications:

1. Web Interface

2. Windows Mobile Native Application

4.6   Summary

The systems described above follow the concepts outlined in the earlier sections of the chapter and the latest version is currently available as a demo. The website application can be accessed at www.ridevia.com. The developed systems contain data generation, processing, storage and application modules, but no access control or analysis modules at this point.

The project demonstrates the use of multiple streams of data from varying sources, including manual entry, real-time location, third-party sources etc., examples of which are GPS trackers, Georgia Tech servers and various locations on the web. Version 2.0 of RideVia also shows how it becomes easier to develop applications for multiple devices using such a platform.

Finally, it can be said that a single source for traveler information can definitely be useful but only if there is consistent availability of data and good applications to present the data. Such a platform can possibly be maintained by a regional transport authority, the city or state government, or even a consortium of transport service operators. Data gathering and multiple formats pose a challenge, but they can be ultimately overcome, and with the industry moving towards adopting more standards, this should become easier in the future.

CHAPTER 5
SYSTEM COMPONENTS OF RIDEVIA

5.1   GPS tracking modules

The GPS tracking module had design requirements of low capital and operating cost, easy operation, and easy installation. The initial GPS tracker design is based on a simple cellular phone equipped with an inbuilt GPS receiver and a cellular modem.

The initial device was designed to be always on constantly sending location information to the server, allowing no control on the operators end. The device, not being designed for continuous transmission, became unresponsive every few days and required a manual reboot.

The second iteration (Figure 5-1 & Figure 5-2) was designed to alleviate these problems by placing the phone and some additional circuitry into a box, so that it can be switched on or off by the vehicle operator, while at the same time, providing an easy way to reboot the phone.

Figure 5-1: Low-cost GPS Tracking Module

However, the additional required interaction with the device, in the form of an on/off switch resulted in the units not being turned on and off when required. This problem persisted even after some attempts in basic operator training.

Figure 5-2: Internals of GPS Tracking Module

The next version of GPS trackers being developed use embedded cellular modems, and offer much more flexibility and stability. Features such as ignition detection and route selection can be built in, and it can be deigned to work with peripherals such as passenger counters etc.

5.1.1 Components

- iDen phone with Java ME application

- 12 volt car-charger for phone

- Auto-start circuit (Timer chip + Other components)

- Plastic ABS Enclosure (5" x 2.5" x 2")

- Double pole single throw (DPST) switch

- LED indicator light

5.1.2 Software

The phone is capable of running custom software written in Java on a Mobile Java Platform (Java ME). The program uses the phones GPS receiver to get updates about the phones location, and then transmits them to a server.

When ready with the location data (every 5-6 seconds after initial fix), the program performs an HTTP request with the data transmitted as POST variables. The request invokes a server script that performs some basic conditioning and stores the data in the database. Basic conditioning involves discarding data that is known to be inaccurate, formatting location and time data etc.

5.1.3 Installation

The GPS trackers are currently installed on 8 buses operated by 'Lanier Parking Solutions' that run on a shuttle route called the 'Atlantic Station FREE RIDE'. The trackers are powered by the vehicle battery via an accessory socket installed specially for the tracker that allows the unit to be fixed to the dashboard.

5.2 Database

Transportation data can be organized for storage purposes on the basis of the type of service, rather than the mode. Table 5-1shows the classification used for RideVia v2.0 with examples of modes each type covers and the status of support for that type of data in the current implementation.

Table 5-1: Data Models for Transportation

Service Type	Description	Modes	Implementation Status
Route based			
– Predetermined route, schedule, stops	Vehicle on fixed route, with fixed stops at fixed times	Bus, Train, BRTS	Full
– Predetermined route and stops	Vehicle stops at predetermined stops	Shuttles	Full
– Predetermined or loosely predetermined route	Vehicle stops where passengers require, might go slightly off-route	Bus, Shared Taxi, Shuttles	Full
Demand based	Transport comes to passenger based on demand	Taxi, Shared Taxi	Full
Shared resource			
– Vehicle (Return)	Vehicle can be rented from specific locations	CarShare, Rental Cars	Partial, No support for real-time, history data
– Vehicle (One-way)	Vehicle can be rented from specific locations and returned to different location	BikeShare	Partial, No support for real-time, history data
Demand/route based hybrid	Vehicle follows route, but route can change for every trip, and it is flexible	RideShare, Shared Taxi	Partial, No support for access control, information updates
Infrastructure			
– Road	Shared resource, publicly owned	N/A	None
– Parking Space	Space that can be rented	N/A	Partial, No support for real-time, history data

The current version of the database uses twenty-one tables to store schedule, route, and location and other data. The UML diagram for the database is shown in Figure 5-3. A more detailed figure is available in the in the appendix.
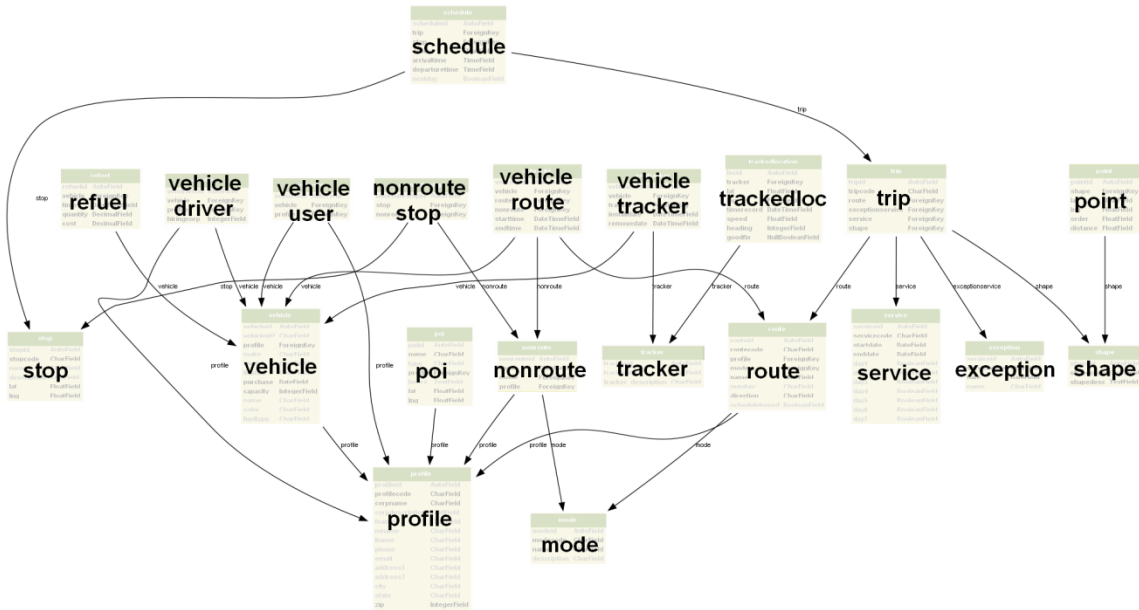
Figure 5-3: Database UML Diagram

The database can link modes of transport with profiles, routes, schedules, stops, vehicles etc. It supports and has been tested with taxi, carshare, rideshare, shuttles and public transport. Due to compatibility with the GTFS feed specification; it is generally easy to import data from public transit agencies.

Table 5-2 shows a detailed description of the 'route' table. The tables used in the database are described below. A table representing a many-to-many relationship between two other tables is denoted by parentheses specifying the two names of those tables:

- Profile

  Profile information for any entity, either individual or corporate is stored here. Other tables link to this table for links to people, such as drivers, passengers etc. and companies, such as service operators.

- Vehicle

  Vehicle information such as license plate number, capacity and other details are stored in this table. Every record represents a distinct vehicle.

- Refuel

  Refueling information for vehicles. Each record represents a refueling operation and stores time, quantity and cost. The quantity is not stored in standard units, and the units can depend on the type of fuel and requirements of the implementation.

- Tracker

  Information about location sensing, or tracking units, which includes identifying codes (for e.g. IMEI number for cellular trackers) and description.

- TrackedLocation

  The information received from location sensing units is stored here, which generally includes location, heading and speed etc. Every group of received information is stored as a separate record, with a tracker id to identify where it came from.

- VehTracker (Vehicle + Tracker)

This table defines the many-to-many relationship between Vehicles and Trackers. It stores other information such as installation date, removal date etc.

- Mode

Mode of transport that defines the type of service. The name and description of each are stored. E.g. Shuttle, Light Rail etc.

- Route

Every record in this table represents a route. Route is used to denote a route-based transport service, which consists of single or multiple trips during the day using the same or slightly varying paths. Information such as the transport operator, mode of transport, and name and/or number of route are stored.

- NonRoute

Every record in this table represents a transport services that is not route based. The mode, name of the service etc. are stored.

- VehRoute (Vehicle + Route)

This table defines the many-to-many relationship between vehicle and route or non-route services. The same vehicle can be assigned to multiple services and vice-versa.

- Stop

Every record corresponds to a physical location that is a stop. A stop is any location where a transport service is available.

- Trip

A trip belongs to a route, and every trip may or may not have a schedule. The trip table is used to store information about the trip, such as links to route, schedule, service and shape tables.

- Schedule (Trip + Stop)

The schedule forms a many-to-many relationship between stops and trips, by assigning stops to trips along with an order field.

- Service

This table is used to define the service schedule of trips, such as weekly repetition, starting and ending dates etc.

- Exception

Exceptions to the weekly service schedule, such as holidays etc. are stored here. Every record represents an exception date. If a trip is for an exception day service, a different service record is used.

- Point

A point is just a simple location stored as latitude and longitude.

- Shape (Trip + Point)

A shape record defines the path a route-based service trip takes. It forms a many-to-many relationship between the trip and the point tables.

- NonRouteStop (NonRoute + Stop)

Relates stops to non-route-based services via a many-to-many relationship.

- VehDriver (Vehicle + Driver Profile)

Relates vehicles to drivers (individual profiles) via a many-to-many relationship.

- VehUser (Vehicle + User Profile)

  Relates vehicles to passengers (individual profiles) via a many-to-many relationship.

- POI

  This table is used to store information about non-transportation related points-of-interest (POI), such as location, description, address etc. This can a business, sightseeing attraction, restaurant etc.

Table 5-2: Example of table in RideVia database

Table Name: route		
Field	**Type**	**Description**
routeid	Auto (Primary Key)	Auto Generated Primary Key
routecode	Character Field	(Optional) GTFS Route Identifier
profile	Foreign Key	Profile of entity that runs this route
mode	Foreign Key	Mode of transport on this route
name	Character Field	Route Name
number	Character Field	(Optional) Route Number/Colour etc.
direction	Character Field	(Optional) Direction descriptor for route (Up/Circular/Northbound etc.)
schedulebased	Boolean	Specifies whether route is schedule based

5.3 Object Map

Object-relational mapping (ORM) in computer software is a programming technique for converting data between incompatible type systems in relational databases and object-oriented programming languages. This creates, in effect, a "virtual object database" that can be used from within the programming language [83].

For the project in question, we are using a specific ORM tool called Django. Django is a high-level Web framework, written in Python, that encourages rapid development and clean, pragmatic design [84]. Python is an open source programming language which is extremely flexible and easy to use. Using Django, the data model can be defined and manipulated using Python classes. Django's object-relational mapping automatically translates between Python objects and the appropriate SQL statements to query and manipulate the database.

The object map acts as a uniform gateway to the database, forming a loose couple between the database and the rest of the system.

5.4 Application Programming Interface

The Application Programming Interface for the backend of the RideVia system allows it to communicate with other systems. The API is based on a request/response setup. Requests for data are made to the server via HTTP (HyperText Transfer Protocol) and data formatted in XML is sent as the response. The XML format is machine as well as human readable, easy to use, and in the development stages, easy to change around. The descriptive tags used can make the file size larger, but the benefits mentioned outweigh the additional cost of data transfer.

5.4.1.1 Functions

The API supports four functions at present:

- stops – Returns list of stops in a specified radius.

- vehicles – Returns list of vehicles in a specified radius.

- stopdetail – Returns details, such as routes, schedules etc. for a particular stop.

- vehicledetail – Returns details, such as route, stops etc. for a particular vehicle.

Each of these are described in detail with examples in the following sections that follow.

5.4.1.2 Stops

The stops function takes initial location and approximate radius around initial location as input parameters, and returns a list of all the stops found within that area, along with relevant data for those stops.

The 'stops' function takes the following input parameters:

- lat - Origin Latitude (decimal degrees)

- lng - Origin Longitude (decimal degrees)

- radius – Radius from origin (meters)

```
<URL>/stops?lat=33.762000&lng=-84.340100&radius=0.05
```

Figure 5-4: HTTP Request for API function: stops

The request is constructed as shown in Figure 5-4, passing the input parameters as HTTP variables. The returned response is in XML and follows the format shown in

Figure 5-5. It contains the sent data for verification followed by a list of stops, ordered by distance from the origin location, and each stop includes a list of services available at that location.

```xml
<?xml version="1.0" encoding="utf-8"?>
<results>
   <resolvedLocation>
     <lat>33.762</lat>
     <lng>-84.3401</lng>
     <radius>0.05</radius>
   </resolvedLocation>
   <stops>
     <stop>
        <id>387179</id>
        <name>EDGEWOOD-CANDLER PARK STATION</name>
        <lat>33.761544</lat>
        <lng>-84.340032</lng>
        <dist>0.0316709483044</dist>
        <services>
          <service>
             <id>R729</id>
             <name>EW-East/West Line-Eastbound</name>
             <mode>Subway/Metro</mode>
          </service>
          <service>
             <id>R736</id>
             <name>PC-Proctor Creek Line - Westbound</name>
             <mode>Subway/Metro</mode>
          </service>
        </services>
     </stop>
     <stop>
        <id>387279</id>
        <name>DEKALB AVE NE@OAKDALE RD NE</name>
        <lat>33.761311</lat>
        <lng>-84.33951</lng>
        <dist>0.0583824148399</dist>
        <services>
          <service>
```

Figure 5-5: HTTP Response for API function: stops

```
            <id>R739</id>
            <name>Atlantic Station/Auburn Avenue -
        Northbound</name>
            <mode>Bus</mode>
          </service>
        </services>
    </stop>
  </stops>
</results>
```

5.4.1.3 Vehicles

The vehicles function takes initial location and approximate radius around initial location as input parameters, and returns a list of all the vehicles found within that area, along with relevant data for those vehicles.

The 'vehicles' function takes the following input parameters:

- lat - Origin Latitude (decimal degrees)

- lng - Origin Longitude (decimal degrees)

- radius – Radius from origin (meters)

```
<URL>/vehicles?lat=33.762000&lng=-84.340100&radius=0.5
```

Figure 5-6: HTTP Request for API function: vehicles

The request is constructed as shown in Figure 5-6. An example response is shown in Figure 5-7. It contains the sent data for verification followed by a list of vehicles, ordered by distance from the origin location, and each vehicle includes details about the location as well as service details such as route (if required) and operator.

```xml
<?xml version="1.0" encoding="utf-8"?>
<results>
    <resolvedLocation>
            <lat>33.762</lat>
            <lng>-84.3401</lng>
            <radius>5.0</radius>
     </resolvedLocation>
     <vehicles>
            <vehicle>
                <id>29</id>
                <mode>Shuttle</mode>
                <name>Stinger433</name>
                <lat>33.77349</lat>
                <lng>-84.39909</lng>
                <heading>119</heading>
                <speed>0.0</speed>
                <time>2010-09-22 15:33:40.486004</time>
                <service>
                    <id>R763</id>
                    <name>GT Red Route</name>
                    <operator>Georgia Tech</operator>
                </service>
            </vehicle>
            <vehicle>
                <id>22</id>
                <mode>Shuttle</mode>
                <name>Stinger404</name>
                <lat>33.7769133333</lat>
                <lng>-84.3941433333</lng>
                <heading>93</heading>
                <speed>16.6287630525</speed>
                <time>2010-09-22 15:33:40.349004</time>
                <service>
                    <id>R765</id>
                    <name>GT Trolley</name>
                    <operator>Georgia Tech</operator>
                </service>
            </vehicle>
     </vehicles>
</results>
```

Figure 5-7: HTTP Response for API function: vehicles

5.4.1.4 Stop detail

This function takes a stop id number as input (obtained from a 'stops' function call) and returns details about the stop,

The 'stopdetail' function takes the following input:

- id – Stop ID in the database

```
<URL>/stopdetail?id=387669
```

Figure 5-8: HTTP Request for API function: stopdetail

The stopdetail function returns an XML file (Figure 5-9) with details of the stop, followed by a list of services at the stop. Each service includes information about the type of service, operator and if it is a route-based service, a list of stops and the route path if available.

```xml
<?xml version="1.0" encoding="utf-8"?>
<results>
    <resolvedStop>
        <id>387669</id>
        <name>Arts Center Station</name>
        <lat>33.789951</lat>
        <lng>-84.387764</lng>
    </resolvedStop>
    <services>
        <service>
            <id>R745</id>
            <name> Atlantic Station Free Ride</name>
            <mode>Shuttle</mode>
            <operator>Lanier Parking</operator>
            <stops>
                <stop>
```

Figure 5-9: HTTP Response for API function: stopdetail

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```
                    <id>387662</id>
                    <name>171 17th St</name>
                    <lat>33.791252</lat>
                    <lng>-84.39418</lng>
                </stop>
                <stop>
                    <id>387663</id>
                    <name>17th/Atlantic</name>
                    <lat>33.79134</lat>
                    <lng>-84.397308</lng>
                </stop>
                .
                .
                <stop>
                    <id>387664</id>
                    <name>17th/State</name>
                    <lat>33.791168</lat>
                    <lng>-84.398796</lng>
                </stop>
            </stops>
            <path>
                <point>
                    <lat>33.789951</lat>
                    <lng>-84.387787</lng>
                </point>
                <point>
                    <lat>33.791889</lat>
                    <lng>-84.387772</lng>
                </point>
                <point>
                    <lat>33.791889</lat>
                    <lng>-84.387772</lng>
                </point>
                .
                .
                <point>
                    <lat>33.791779</lat>
                    <lng>-84.388039</lng>
                </point>
            </path>
        </service>
    </services>
</results>
```

Figure 5-9 continued

5.4.1.5 Vehicle detail

This function takes a vehicle id number as an input (obtained from a 'vehicles' function call), and returns details about the vehicle, such as the route, location, speed, heading etc.

The 'vehicledetail' function takes the following input:

- id – Vehicle ID in the database

- path – Boolean value that specifies if path is required in response

```
<URL>/vehicledetail?id=19&path=1
```

Figure 5-10: HTTP Request for API function: vehicledetail

The request is constructed by passing values for 'id' and 'path' in a HTTP request (Figure 5-10). An example response is shown in Figure 5-11. It contains information about the vehicle, such as the mode, location, speed and heading followed by the service details for that vehicle such as route and operator.

The service information also contains details about the path of the particular service if the path variable is set to '1'. The path information returned contains a list of stops with locations and names and, if available, also a list of location co-ordinates that form the path for that route. The path variable is discarded if the vehicle is not on a route-based service.

```xml
<?xml version="1.0" encoding="utf-8"?>
<results>
    <resolvedVehicle>
        <id>19</id>
        <mode>Shuttle</mode>
        <name>Stinger401</name>
        <lat>33.7771683333</lat>
        <lng>-84.38709</lng>
        <time>2010-09-22 18:05:00.640007</time>
        <heading>0</heading>
        <speed>0.0</speed>
    </resolvedVehicle>
    <service>
        <id>R765</id>
        <name>GT Trolley</name>
        <operator>Georgia Tech</operator>
        <stops>
            <stop>
                <id>388160</id>
                <name>Recreation Center</name>
                <lat>33.775067</lat>
                <lng>-84.402383</lng>
            </stop>
            <stop>
                <id>388176</id>
                <name>Ferst Dr./ Hemphill Ave.</name>
                <lat>33.778417</lat>
                <lng>-84.400933</lng>
            </stop>
                .
                .
            <stop>
                <id>388178</id>
                <name>Ferst Dr./ Atlantic Dr.</name>
                <lat>33.778183</lat>
                <lng>-84.397483</lng>
            </stop>
            <path>
                <point>
                    <lat>33.789951</lat>
                    <lng>-84.387787</lng>
                </point>
                <point>
```

Figure 5-11: HTTP Response for API function: vehicledetail

```
                                 <lat>33.791889</lat>
                                 <lng>-84.387772</lng>
                          </point>
                          .
                          .
                          <point>
                                 <lat>33.791889</lat>
                                 <lng>-84.387772</lng>
                          </point>
                   </path>
            </service>
</results>
```

Figure 5-11 continued

5.5   Other Scripts

5.5.1   MARTA-GTFS Generator

The MARTA GTFS script scrapes and parses the HTML web-pages of the Metropolitan Atlanta Rapid Transit Authority to get the schedules of public transit bus and rail services in Atlanta and convert them into the format defined by the General Transit Feed Specification (GTFS). It also matches the stop numbers against existing stops in a separate database file to get their location, and if the location is not found, enters them in a queue for geocoding.

5.5.2   Geocoder

The geocoder script takes addresses in the stops database and tries to geocode them using web services. It flags unsuccessful and likely inaccurate attempts for manual inspection.

5.5.3   GT Trolley Location

The GT location fetcher script connects to the Georgia Tech servers to retrieve the location of the shuttle buses operated by Georgia Tech, separates them by route, and stores them in the database.

5.6   Applications

The object of designing and developing RideVia is to demonstrate the usefulness of a traveler information platform as a point of access for transportation data. However, this utility is difficult to demonstrate without any user applications.

The user-facing applications have been developed with this purpose in mind. Two interfaces were developed for version 1.0 and version 2.0 of RideVia. They display multi-modal information, both real-time and static, in an intuitive manner.

The following sections describe the development of the applications. Screenshots that show the usage of the applications in more detail are available in the appendix.

5.6.1   Version 1.0 Kiosk Application

The first application (Figure 5-12) is a multi-purpose kiosk/desktop application. Due to this reason, all the controls are touch-screen friendly and finger sized, even though they might be a little awkward for desktop use. The application is based on 'Flex 3', which is a framework to develop rich internet applications [85].

The application accesses data by making a request to the server that returns a snapshot of all the recent data as a response. The application then uses the data it needs for display purposes.
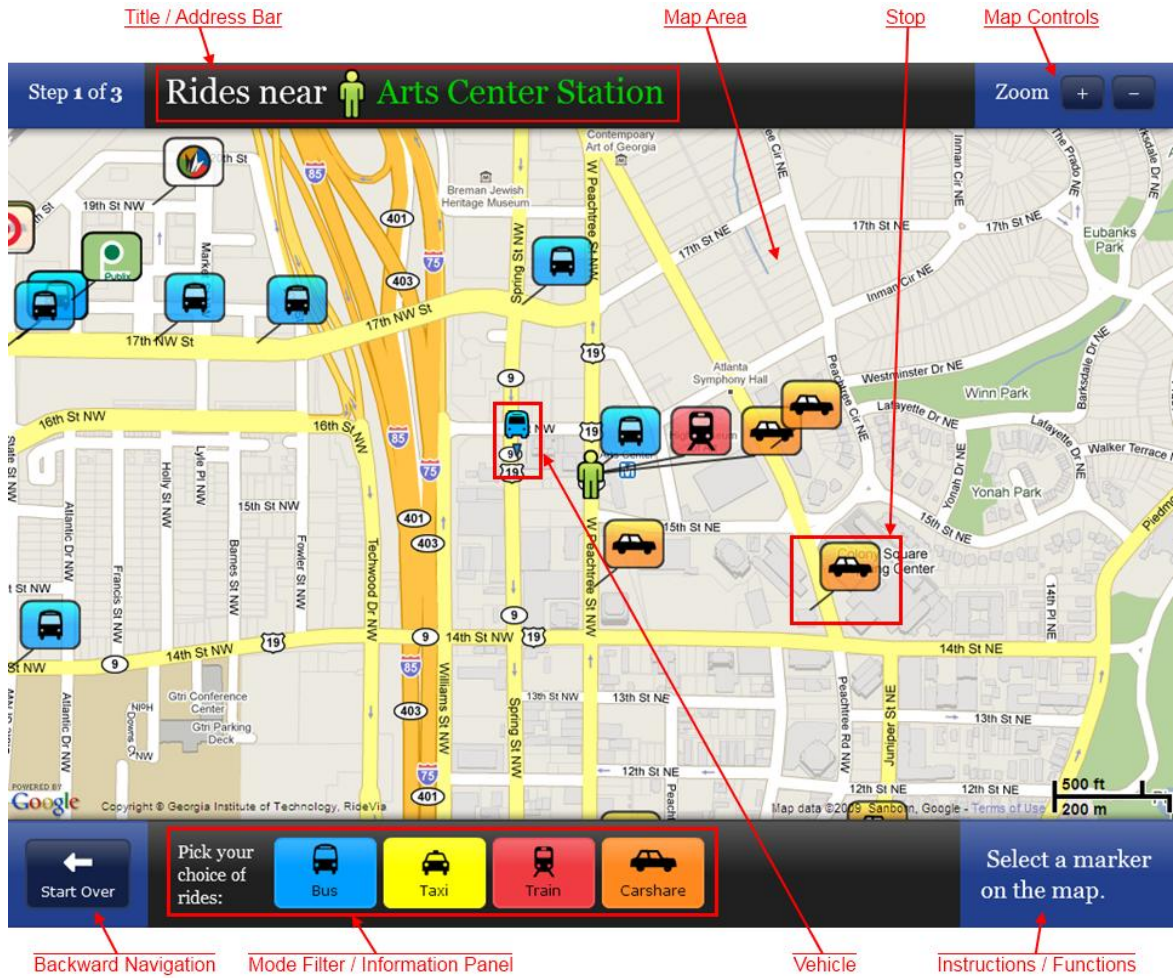
Figure 5-12: Kiosk/Desktop Application for RideVia v1.0

The application allows the user to enter a starting address and then shows all the nearby transport options on a map of the area, color coded by mode. Once a particular mode of transport along with route, stop and such details has been selected, the users have the option of having the information emailed to them or sent to their phone via text message.

5.6.2   Version 1.0 Mobile Application

The second application is for mobile devices and is no longer supported. The application provides similar functionality as the kiosk version, but it is optimized for a mobile experience.
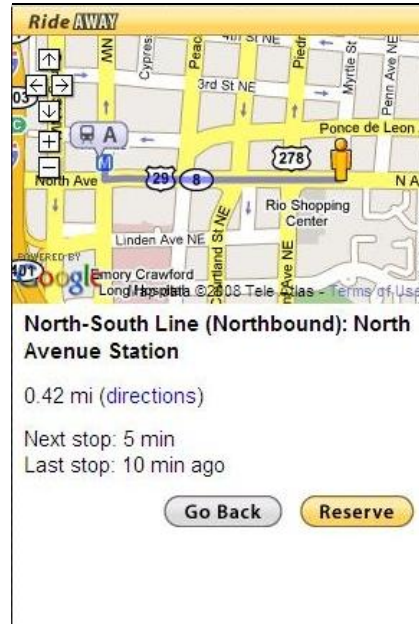
Figure 5-13: Mobile Web Application for RideVia v1.0

This application (Figure 5-13) also uses a map and touch-based controls to let the user input an address and select a transportation option from the map or a list. The same request/response setup is used as for the kiosk application to retrieve data from the server. This application works on fully featured web browsers only as less capable browsers do not support JavaScript maps.

5.6.3   Version 2.0 Web Application

The development of the new web-based application posed an interesting question in terms of whether to go keep developing with 'Flex 3', or switch to a combination of HTML and Javascript, the use of which was now possible due to advances in javascript rendering speeds.

While the Flex framework is open source, the development tools are proprietary and it requires the browser to have a Flash plugin installed. The combination of HTML and Javascript offer similar functionality, but do not require any proprietary software and are rendered natively by web browsers. However, this also means that there are cross-platform development issues and decreased speed.

Ultimately, Flex was chosen due to its previous use and faster rendering speed. Within the application, the event-driven framework for flex, called 'Mate', is being used [86].

The API described in earlier sections is used to obtain data from the server. Polling is used to pull real-time data from the server, as a push data protocol has not been implemented in the API. This interface (Figure 5-14) supports all backend functionality offered and can support future functionality such as multi-modal trip planning, search and ticketing. The current layout devotes more space to the map, uses more user-friendly icons and is more intuitive to use.
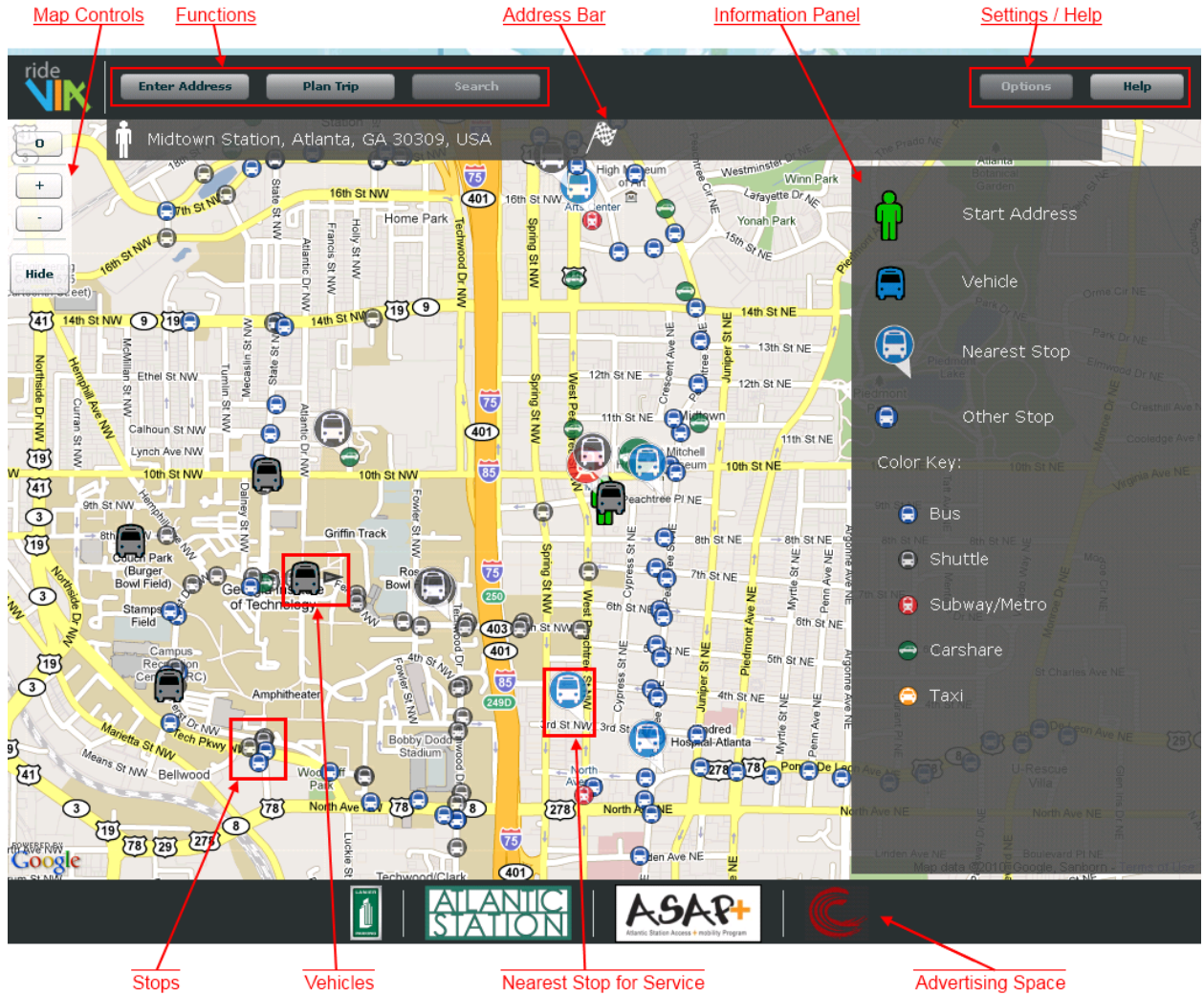
Figure 5-14: Desktop Web Application for RideVia v2.0

5.6.4   Version 2.0 Mobile Application

The mobile interface for v2.0 is a native application for the Windows Mobile platform. The application uses the version 2.0 API to request data from the server. The application can either use the phone's GPS or a user entered address as the starting location, and then shows stops and vehicles around that location. The user can click on a particular icon to get more information.
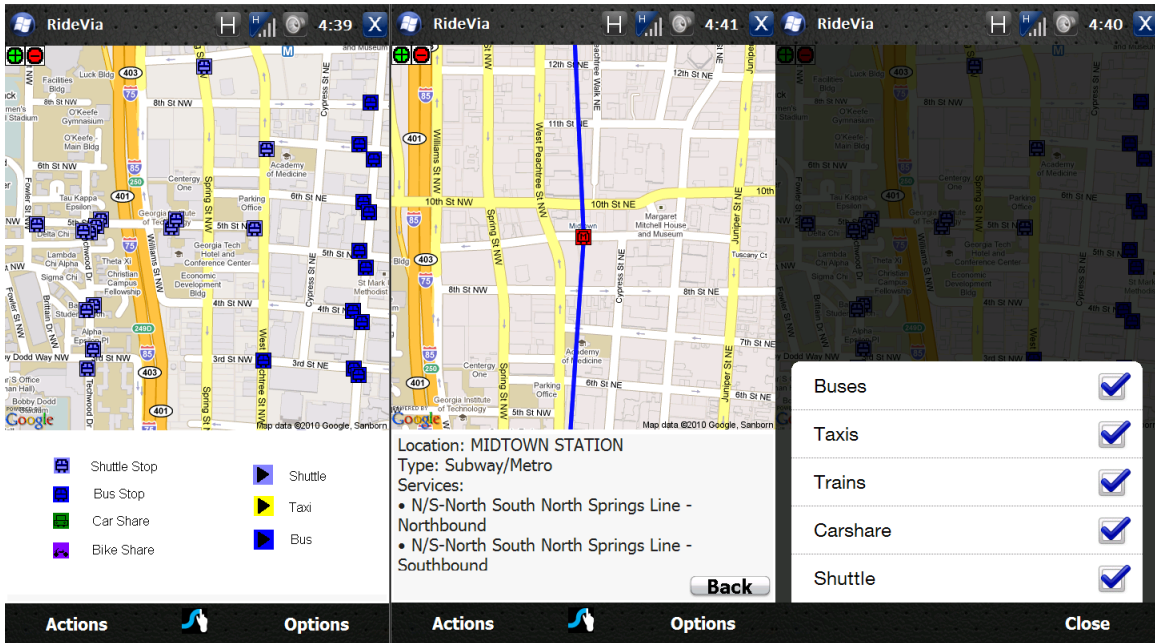
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Figure 5-15: Windows Mobile App for RideVia v2.0

5.7 Kiosks

The kiosks were developed to display the version 1.0 kiosk interface at public locations. They are designed so that they are able to operate without wired connections for power and data, using wireless data connections, and solar panels for power requirements.

Two kiosks were built, one to operate on solar power, and one using outlet power (Figure 5-16). User interaction with the kiosk is accomplished via a touchscreen, and an on-screen keyboard in provided by the application whenever required for text input.

The kiosks were installed at two location in the 'Atlantic Station' area of midtown Atlanta to use for field testing the RideVia v1.0 system and get public feedback. The details are available in section 6.2, which describes the field test.

The kiosks are not in use at present and the focus of the project at this time has shifted towards core functionality of the information platform, rather than hardware development.

Figure 5-16: Kiosk Hardware

5.7.1 Components

The following components were used to build the kiosks:

- Raw Materials (Metal Sheets etc.)

- Barebones Computer (Mini-ITX)

- Flash Memory Hard Drive (CompactFlash)

- LCD Screens with touch panels

- Network Adapter (Wifi/WiMax/CDMA)

Extra components for solar-powered kiosks:

- Solar Panels (12V, 125W)

- Lead Acid Batteries (Deep Cycle, Leakproof)

- Charge Controller

CHAPTER 6
TESTING AND EVALUATION OF RIDEVIA

6.1 Early Testing and Feedback

Early testing was performed in January of 2009, towards the end of the development cycle for Version 1.0 of RideVia. The goal of the test was to get some feedback or user response to the multi-modal information application developed for RideVia. A secondary objective was to test the initial kiosk designs in a real-world environment.

Some changes were incorporated into the design of the application, the kiosks, as well as the entire setup based on the results.

Figure 6-1: Street-side setup for early testing

6.1.1 Setup

The testing was carried out on the street-side near in the 'Tech Square' area of Georgia Tech on two separate days, at nearby but different locations, for around two hours at a time.

The equipment used was an early iteration of the kiosk which consisted of a touch screen panel, computer with a wireless network adapter and a solar panel. A development version of the RideVia v1.0 kiosk application described in section 5.6.1 was used to demonstrate the system to people passing by.

The method used was to ask prospective testers if they would like to test the system. If they showed interest, they were shown the interface without any explanation and observed while they used it. This was in part to gauge the learning curve of the application design and see how intuitive it was to use. Once they were done using the application, they were asked a few questions about the experience.

6.1.2 Results

The results include feedback from 24 individual usage experiences and interviews. The testing group consisted of Georgia Tech faculty and students, professionals and visitors.

One of the realizations of testing was that user testing is always limited to the final experience provided to the user, and while the effectiveness of the interface can be obtained directly from the data, the impact of the delivery system (the backend platform) can only be measured indirectly.

Specific feedback about the application included reducing clutter on the screen by replacing text with imagery, using color or icon repetition to make visual links between

controls and data. Feedback about the kiosk included concerns about visibility in outdoor environments, screen size and positioning.

The general feedback can be summed up as follows [87]:

- The purpose of a kiosk being present has to be made clear using signage in order for users to approach it.

- The reactions to the capabilities and the purpose of the system were generally positive.

- The application was intuitive enough for most users and they had no trouble navigating through it without aid.

- The demand for a mobile application was high. 33% of all testers said they had a smartphone, and 100% of those said they would use a mobile app.

- The question asked the most was about how the system was paid for, reflecting the cost sensitivity of travelers towards transport information

6.2 Field Testing

The field test was conducted between May and June of 2009 at 'Atlantic Station', a mixed use property development, north of Georgia Tech. The goal of the field test was to primarily get an evaluation of the usage patterns of the information made available. Secondary goals were to stress-test the backend systems against real-world demand and also gauge the response to the hardware kiosk and the software application.

A number of issues were encountered early on during the field test that together, ultimately led to the testing period being cut short and the hardware being removed from the test locations.

The issues encountered provided insight into several reliability issues and definitively changed the course of further development of RideVia.

6.2.1   Setup

Two kiosks were used, one solar-powered and built for outdoors use and the second one for indoors use designed to run from a wall outlet. Both kiosks were installed within the Atlantic station area.

The outdoors kiosk was placed in the central square between 18th and 19th Streets. This area is in between restaurants and shops and gets a lot of foot traffic after office hours and on weekends. The indoors kiosk was placed in the lobby of the office building at 171 17th Street, where it could be connected to a wall outlet for power. This kiosk would see the most use towards the end of office hours as there was a bus stop just outside the building.
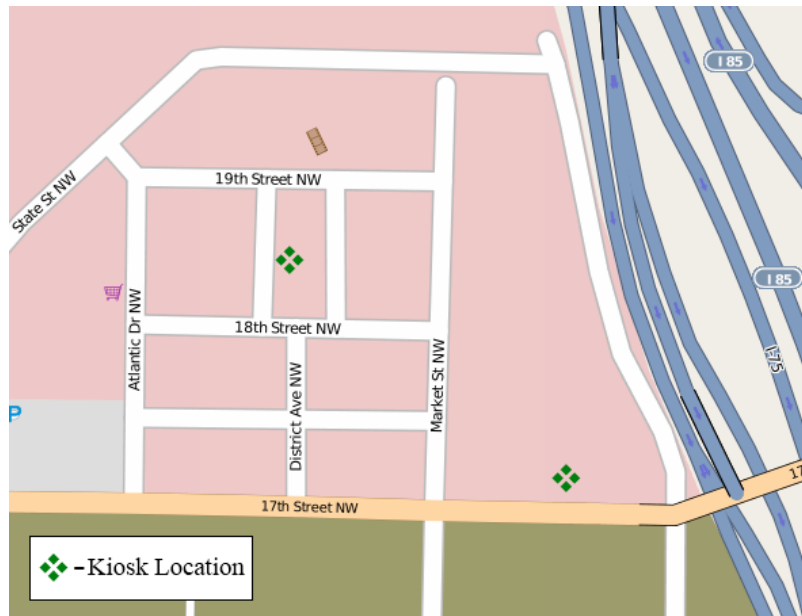
Figure 6-2: Location of RideVia kiosks during field testing [82]

These locations were chosen because they were in close proximity to stops on the 'Atlantic Station Shuttle' route, for which real-time location data was available on the kiosks. Both the kiosks ran similar versions of the RideVia v1.0 kiosk application described in section 5.6.1, the only difference being the default starting locations, which were set to the respective locations of the kiosks. The kiosks were left unattended, and the application was designed to collect usage data that would be accessible remotely.

6.2.2   Issues

There were numerous issues that came up during the field test that were not expected. This was especially true for the outdoor location where the solar powered kiosk was being used.

The outdoor kiosk was sealed to prevent rain-water from entering the internal compartment. However, this weatherproofing led to over-heating when the computer installed inside kept running for a certain amount of time, since the hot air could not be vented. This was eventually fixed by installing vents in the back panel which were angled so that water would not flow in unless forced.

The LCD screen, which had a high brightness ratio specifically for use in bright environments, could not operate under direct sunlight. When exposed to the sun for around half an hour, the screen would start developing black spots, eventually covering the entire area, and would stay black until it was removed from the sun. This was solved by using a shade that was placed under the solar panels, but above the screen.

There were also initial issues with the charge cycle, which resulted in an accidental deep discharge of the batteries and result in the batteries being damaged to the point where they needed to be replaced.

The indoor kiosk proved to be easier to work with, since it did not require charging circuits and weather-proofing. The only issues faced with it were related to the system software and the interface.

6.2.3 Results

The general feedback and response received from users via observation or verbal communication was very positive. However, the reliability issues described above meant that the data collected was far less extensive than what was originally intended. Nevertheless, the data that was collected did provide some results that were useful.

The data, collected via logging the usage on the application, includes 74 separate user interactions after basic sanitization to remove junk data. These interactions together contain 86 requests for stop details and 14 requests for vehicle details. A request for detailed information is recorded when the user clicks on a stop or a vehicle icon. Each interaction may include multiple requests for detailed information.

The length of each interaction varied from 2 seconds to 295 seconds, with the average being 83 seconds (Figure 6-3). This shows the average amount of time travelers would be willing to spend to gather information. If the application is too complicated, or requires too much time, it is likely that the traveler would stick with a more familiar mode of transport.

The number of operations carried out by the user per interaction varies from 2 to 9, with an average of 3.9 operations per interaction. An operation is defined as an individual task within a user session, such clicking on a stop or vehicle, sending directions, resetting the application and starting over etc. The average time per operation

for each interaction is shown in Figure 6-4, along with the overall average time per operation, which is 21 seconds.
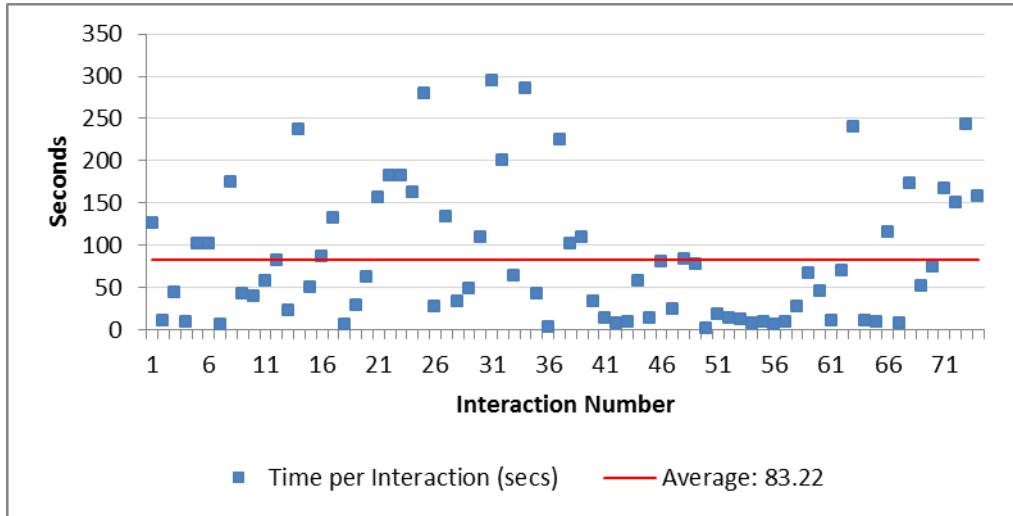

Figure 6-3: Average duration of interaction
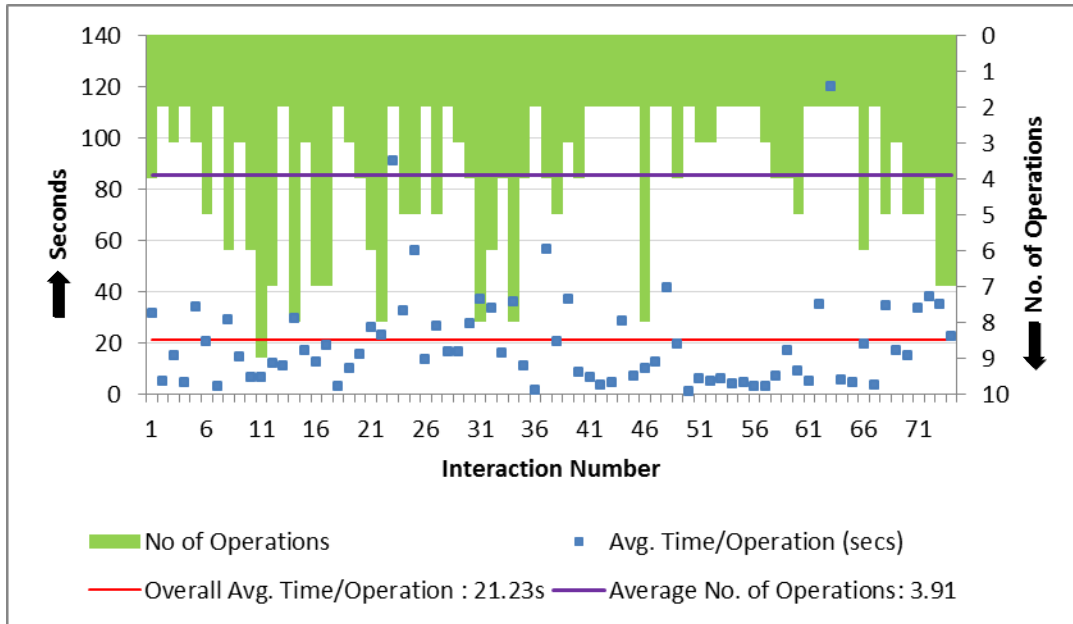
**Figure 6-4: Operations per interaction and average duration**

This time factor is of course, dependent on a lot of other factors which vary, but this data still does provides an interesting observation for these set of conditions. The requests for detailed information can be classified based on the stop and the service they were made for. The distribution of requests is shown in Figure 6-5 and Figure 6-6.
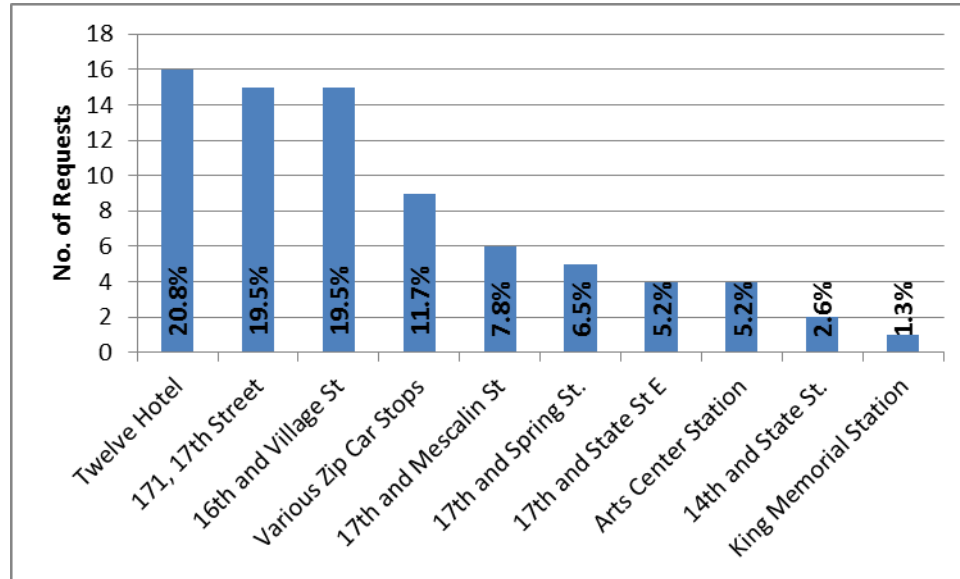
Figure 6-5: Number of information requests by stop

The distribution is slanted towards the stops at 171 17th Street and the Twelve Hotel. These two stops are the nearest to the indoor and outdoor kiosks respectively, and together, they account for 31% of the requests.

Of the remaining requests, most of the stops are on the 'Atlantic Station Shuttle' route, or are stops for other services in the same area, such as 'Bus Route 113', operated by MARTA. The version 1.0 backend did not distinguish between various ZipCar locations, and hence it is not possible to account for them separately.
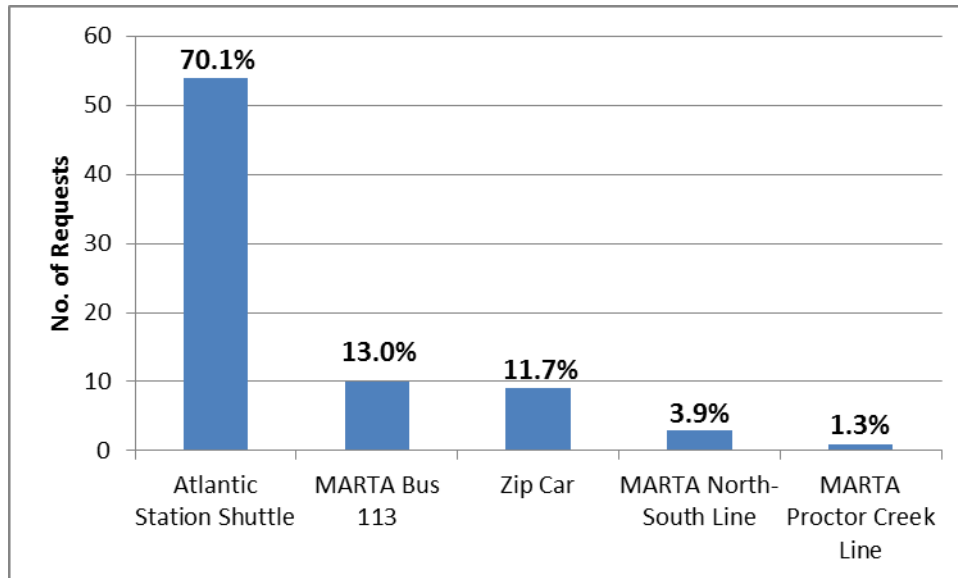
Figure 6-6: Number of information requests by service

The distribution of requests by service shows a bias towards the Atlantic Station Shuttle. The number of requests for information on 'Bus Route 113' service, which runs almost parallel to the shuttle and has stops at similar distances from the kiosks are far fewer than that for the shuttle. This may points to the fact real-time information enjoys greater demand among travelers than static information but may also be due to the fact that the shuttle ride is free and the bus ride is not.

Even though the data traffic was not as high as it might have been in the absence of the interface reliability issues, the backend saw generally higher traffic than during lab testing. During this time, there were no disruptions caused by backend failure and all those services worked without any issues.

The interface reliability issues, especially those relating to the kiosk, led to the decision to shift focus away from peripheral projects such as building the kiosks but instead focus solely on the development of the information platform.

6.3   Setup for Field Test 2

RideVia v2.0 was developed after the May 2009 field test and has not been put through any kind of testing. While a second field test using v2.0 is not within the scope of this thesis, some groundwork for it is presented in this section.

The test should focus on the web and mobile application aspects, doing away with the kiosks and hardware issues. A phased deployment of interfaces by spreading awareness to various user groups, possibly starting with the Georgia Tech campus, is recommended. Three individual sources of data would be useful in such a test:

- Targeted surveys of travelers

  Multiple surveys taken before and after the survey, preferably having a large overlap of respondents, can reveal preferences of the travelers and give information about their changed perceptions of the transport network ad well as changes in traveler behavior.

- Database query statistics based on usage patterns

  Database query statistics can provide information about which data are in high demand besides variations in information requirements over time, area and mode of transport. This can also provide insight for planning purposes besides usability improvements.

- Operations data from service operators

  Data about ridership from ticket sales, vehicle traffic from road sensors etc. is useful to gauge the change due to the new information system and validate the assumptions based on data from other sources.

The end goal is to understand the effect of the system on the transport network and collect data for a report similar to those used for the comparative analysis in Chapter 3. The trend to look for in the data would be the magnitude of changes in traveler behavior due to the availability of information along with the secondary effects on the network, such as savings in time and cost as well as environmental and social benefits.

6.4   Goal Evaluation

6.4.1   <u>Version 1.0</u>

The goals for version 1.0 were to be able to demonstrate the use of multi-modal, real time information and create interest in the project. The project had to be developed within a short time-span, 7 months from conception to first milestone. The version 1.0 interfaces were used regularly as a demonstration tool, most notably for the City of Atlanta Sustainability Office, transportation operators in Atlanta such as Lanier Parking Systems, and various other regional developers and policy makers.

As seen in Table 6-1, most of the set requirements were met, except for multi-modal trip planning, which, while being a useful feature, required too much development time. The version 1.0 system garnered interest for continuing development of RideVia and to secure more data sources for RideVia.

6.4.2   <u>Version 2.0</u>

The goals for version 2.0 were to develop a system more robust than version 1.0, apply the concepts of a traveler information platform more completely for a system which can scale and be extended to accommodate new sources of data easily. For these purposes, it was redesigned from the ground up, incorporating lessons learnt during the

development of version 1.0 in the areas of database design, data exchange, and flexible formats.

RideVIA v2.0 in its current form is highly extensible, and can be used as a platform to base the development of complex intelligent transportation systems. In these respects, it fulfills its stated goals within the scope of this thesis, but there is still room for vast improvement and additions.

Table 6-1: Requirements for RideVia v1.0 and 2.0

Requirement	v 1.0	v 2.0
Store real-time transit data	Yes	Yes
Store data for multiple modes	Yes	Yes
Display real-time and static data	Yes	Yes
Drive multiple applications	Yes	Yes
Multi-modal trip Planning	No	No
Store real-time data history	-	Yes
Use uniform data formats	-	Yes
Scalability and extensibility	-	Yes
Maintainability	-	Yes
Loose coupling between layers	-	Yes

6.5   Summary

While more testing would definitely be beneficial, especially for version 2.0 of RideVia, the initial tests definitely show that a multi-modal traveler information platform would be useful, at a minimum for limited applications, if not as a region-wide one.

A sustained deployment and in-depth testing using directed surveys and observational data would be highly useful, but these are beyond the scope of this thesis.

From a development perspective, the major goals were met but a lot of areas of additional improvement have been identified. These are listed under the future work section in the next chapter.

CHAPTER 7
CONCLUSION

7.1   Relating Research to Questions

7.1.1   Question 1

What work has already been done in the field of multi-modal transportation information and what technologies are available?

While urbanization and the demand for urban transportation have been steadily increasing, so has the proliferation of technology. The first utilizations of information technology in the transportation sector started in the 1970s and have since widened in scope to cover almost every aspect of transportation networks. The current generation of these systems is collectively called 'intelligent transportation systems'.

Intelligent transportation systems are typically mash-ups of many different technologies. These include location sensing, wired and wireless communications, geographic information systems, identification systems, display technologies etc. Their development over the last decade has made information systems more useful and cost-effective.

Multi-modal information systems place an emphasis on shared usage of data. This requires the data to be consistent, uniform and homogeneous. Frameworks, both conceptual and low-level, to support such systems have been developed. These include the National ITS Architecture (US) and Transmodel (EU). However, such frameworks have not seen wide use outside of the public sector, especially in the US.

These frameworks, while they do promote consistency across systems and tend to have a regional perspective, do not necessarily focus on traveler information and specific modes, or distinguish information based on mode.

Ultimately, there are few information systems around the world that use and provide multi-modal information extensively (such as 'Transport Direct' in the UK) and none that are designed to provide open or relatively open access to multi-modal data for a regional or city-wide transport network.

7.1.2   Question 2

How effective has accessible traveler information been in real-world scenarios to make an impact on urban transportation?

Comparative studies of two different types of information systems used in transportation were performed to answer these questions. The systems studied are 'Real-time arrival information systems' and 'Highway information systems'. The focus is on the effects of the systems on the transportation network and the traveler.

Real-time arrival information systems showed that while the magnitude of improvement varies in each case, there is a definite effect, at least in some areas. Increase in usage from new as well as existing riders is one of the desired effects, although data to support that is unreliable. Other improvements are increases in perceived reliability of service, perceived feeling of security and overall customer satisfaction as well as reductions in perceived or actual waiting time and traveler's anxiety or uncertainty.

The same can be said for highway information systems. The data from different studies is not directly comparable and the quantitative results vary, but the results are

generally in agreement. This may be attributed to the fact that highway information systems have been around for a longer period of time and studied in more detail.

The effects of highway information systems can be classified as primary and secondary effects. The primary effect is the change in trip choice decision, such as change in trip route, trip time or trip mode. When travelers have access to information, the effect is reflected in trip choice changes. The secondary effects of these are reduction in travel times and in travel time uncertainty.

However, for both these systems, quantitative results for any particular effect are hard to find in the literature. This is in part due to the complex nature of systems with different variables affecting every individual deployment, which makes direct comparison difficult. In any case, the social and environmental benefits are difficult to express in numerical or monetary terms.

On the other hand, from the data available, the following results can be stated:

- Information availability does lead to a change in traveler behavior, even though the results may vary depending on the location.

- There are definite benefits of information availability, however the cost-benefit ratio depends on how or if the social and economic factors are taken into consideration.

- Higher quality of information, which in this context means reliable or better sources, higher accuracy, rigorous analyses etc., leads to higher utilization of information.

- Integration of data from multiple systems can provide higher quality of information to the traveler by using from the same data in a different

context. This can cause a larger impact than the combined impact of individual systems.

7.1.3   Question 3

What are the requirements for building a multi-modal traveler information platform and what are the challenges?

A traveler information platform will only be useful if service operators and application developers, and ultimately travelers support and use it. Based on the RideVia project and field tests, it can be concluded that certain requirements should be met by such a project.

- Availability of data: Without data, there is not information to store, analyze, share and ultimately provide to the traveler. If data sources do not exist, they have to be established.

- Data access/entry methods: Well defined data access and entry methods provide a stable platform to build on. If the entry and access formats follow an established pattern, then it's easier to use them in other developments, and write translators from other formats.

- Access control and security measures: Effective access control measures encourage service operators to provide more data, which might not be suitable for user consumption but useful for analysis, without worrying about security concerns.

- Reliability of infrastructure: Ensured availability of the platform attracts more application developers as well as service operators to invest more resources. This also ultimately makes user applications more dependable.

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- Accuracy of data: If travelers perceive information as unreliable or inaccurate, they tend to disregard it and its current and future impact on the network is negatively affected.

- Application ecosystem: The way data is presented to the end-user (traveler) is very important because that's the only part of the entire system that the end-user interfaces with. A healthy application ecosystem provides multiple ways for the traveler to interface with the data.

The RideVia project currently does not meet all of these requirements, but RideVia was only meant to be a demonstration project and it can support all of these requirements with further development. The process of setting up and testing RideVia provided the insights with which these requirements were tweaked.

The same process also revealed some challenges, which will also apply to other deployments with appropriate adjustments for environmental variables such as scale, cultural differences, target demographic, available resources, network layout etc. These challenges are described below:

- Stakeholder engagement: The participation of regional stakeholders such as transport operators and regulatory bodies is vital to ensure continued availability of data. This can be difficult to pull off because of the large number of public and private stakeholders; their agendas and viewpoints, which may differ financially and politically.

- Accuracy of data: This is a requirement as well as a challenge. Completely accurate data, especially real-time data, is very difficult to maintain in a large network. The many elements that make a system work require

regular maintenance and oversight, though this can be overcome with proper planning and allocation of resources.

- Institutional aspects: Implementation of an information system from a transport service operator's perspective requires changes at many levels in the organization. This can be difficult when changes in the vehicles operation, maintenance routines etc. might be required, especially in large organizations. Significant resources might be required to bring these changes into effect.

- User awareness and education: The end-user or traveler has to be made aware of the availability of information, but even after that has been achieved, it is necessary to educate the traveler about how to make the best use of the information. This is especially true when new features are introduced.

7.2   Future Work

Further efforts can be directed in many areas. This includes both further research and data collection from existing information systems, as well as further development and testing of the information platform concept.

The data available in the literature about the effects of traveler information and information systems on the network could be better. These studies could provide better results with more rigorous testing and data collection over a longer period of time. A framework, which would allow better comparison of different deployments of similar systems, would also be useful to generate consistent data. The fact that there are benefits

has been established, but more research on the costs of traveler information, financial and otherwise, would be the next step.

The conceptual design and architecture of the traveler information platform can benefit from taking it a step further and standardizing formats and data exchanges, either based on existing standards or new ones. This would ensure that data or analysis modules developed for one region, work with the platforms in other regions. Lessons learnt from the development of the RideVia project would be useful in such work.

The RideVia project itself could use a lot of further improvements in all areas. Adding more sources of data, such as real-time data from public transit, is a vital step towards increasing the utility of RideVia. Every additional source makes the platform more multi-modal and immediately increases the value of all the existing data sources.

The RideVia API currently offers just 4 functions, and one output format. The following additions would make it more conducive to use for application development:

    a. Data storage: Data storage functions would bring the system more in line with the conceptual model, streamlining database access.

    b. Access control: Authentication would allow sensitive data to be made selectively accessible via API functions.

    c. Multiple formats: Support for API output in other formats besides XML to provides more flexibility.

    d. Better methods for real-time data: A subscribe/publish protocol as opposed to the current request/response protocol would allow updating real-time data instantly, providing a better user experience while using fewer resources.

User friendly mobile applications are the next step from a user interface point of view, as evidenced by the results of the early user testing survey. Besides that, applications that offer fleet management functions would be a useful addition, as a value addition for the service operator.

Analysis algorithms are not part of the current RideVia setup, but algorithms such as route guidance, arrival time estimation, and GPS data cleaning are required in order to provide higher quality of data to the application.

Future work in the hardware area for RideVia includes upgrading the GPS trackers to use embedded cellular modules and better GPS receivers instead of the current phones. Finally, longer-term and more rigorous testing of RideVia is required to get a better idea of the benefits and outcomes of implementing an information platform.

7.3   Closure

There are advantages to making transportation information available to the traveler. These apply to the traveler and the network, and result in a more efficient transportation network, leading to savings in time, cost and environmental and social benefits. The effectiveness of information is directly related to the quality of the information.

While intelligent transportation systems are already moving towards an integrated infrastructure based on current frameworks, a dedicated regional platform for traveler information, like the one proposed in this thesis, will give this integration a boost, and encourage the participation of private service operators.

On the other hand, the data in the literature and from the RideVia project is not nearly as conclusive or rigorous as would be required to provide a definite endorsement

from a cost-benefit perspective, but it is conclusive enough to raise further interest and merit further development and testing.

Some conceptual and detail development was performed under the RideVia project and has been described in this thesis, but time and other constraints on the project meant that only a subset of the envisioned functionalities were planned for and implemented. Nevertheless, the project provided useful insight about the real-world requirements and challenges of a multi-modal traveler platform.

APPENDIX A

APPLICATION SCREENSHOTS

A.1   RideVia v1.0 Kiosk Application
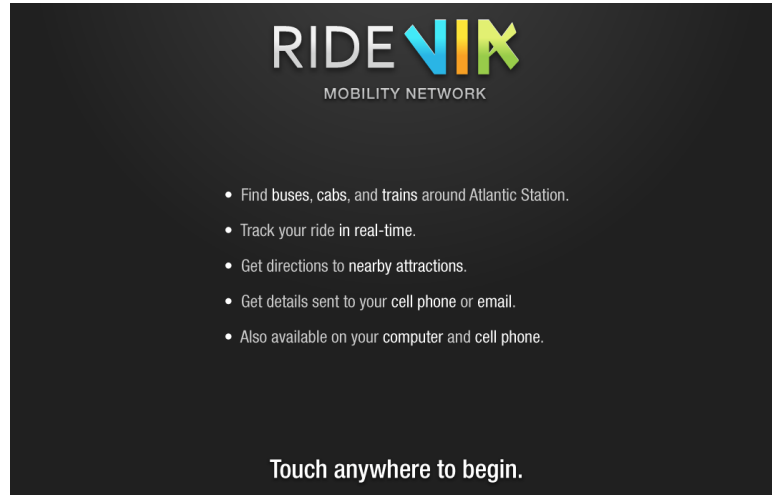
Figure A-1: RideVia v1.0 - Welcome Screen
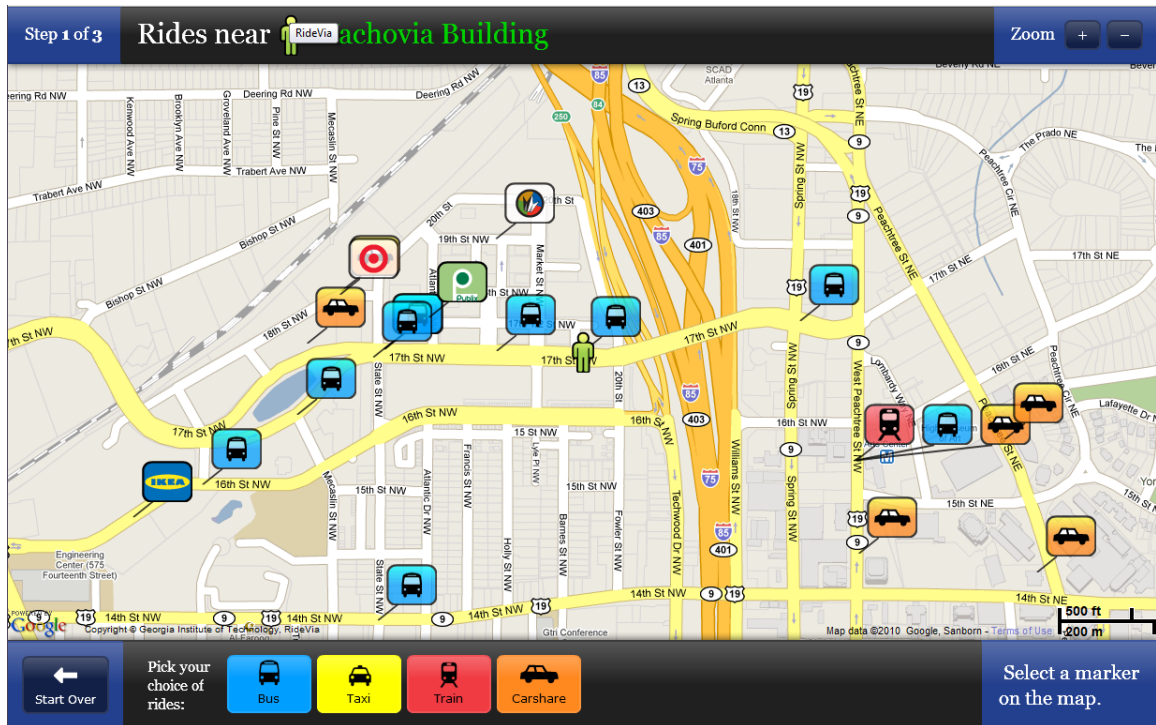
Figure A-2: RideVia v1.0 - Starting View
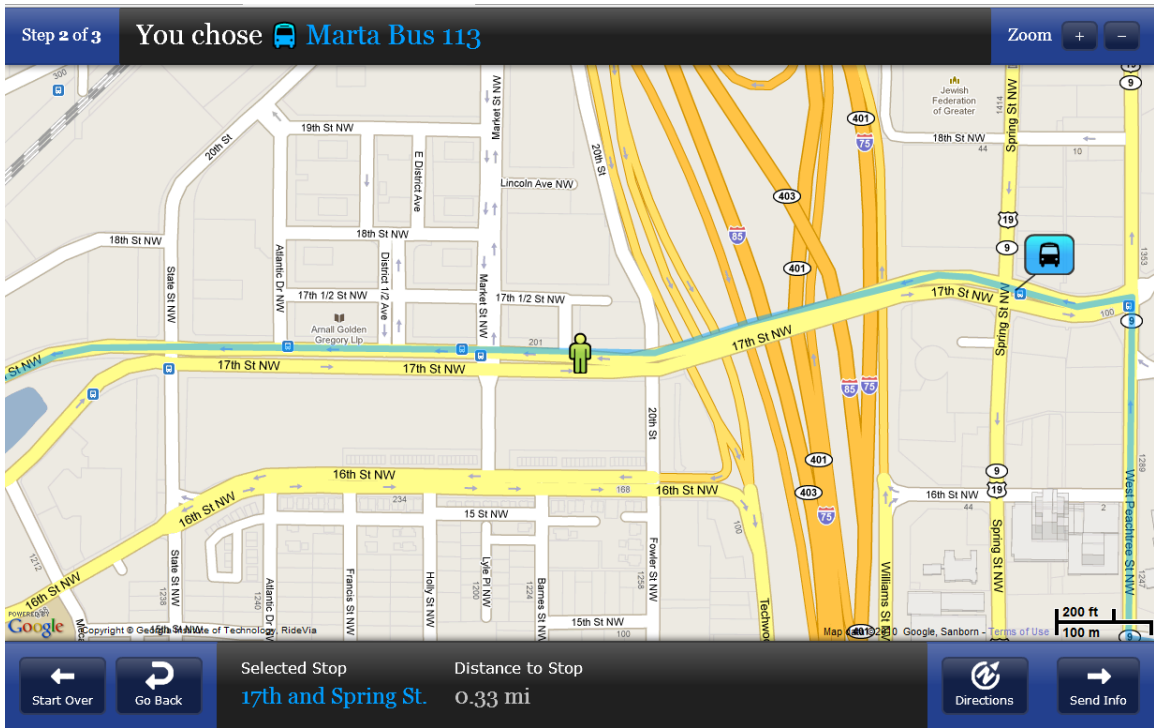
Figure A-3: RideVia v1.0 - Stop Detail View
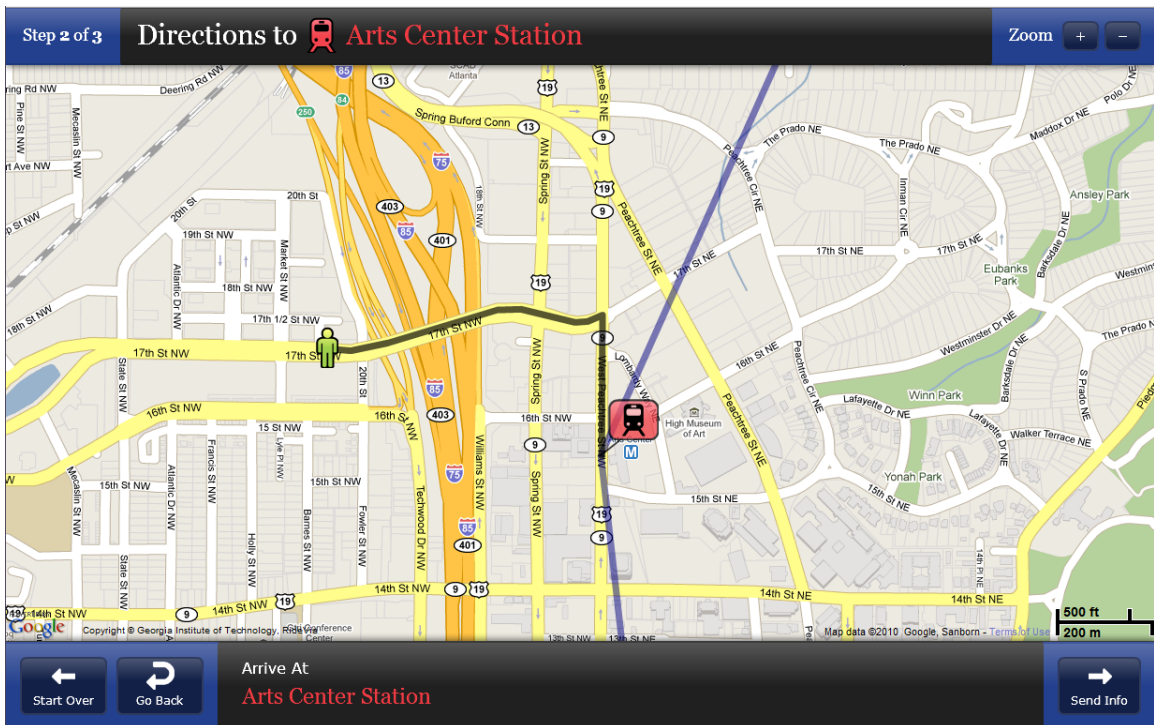
Figure A-4: RideVia v1.0 - Directions to Stop
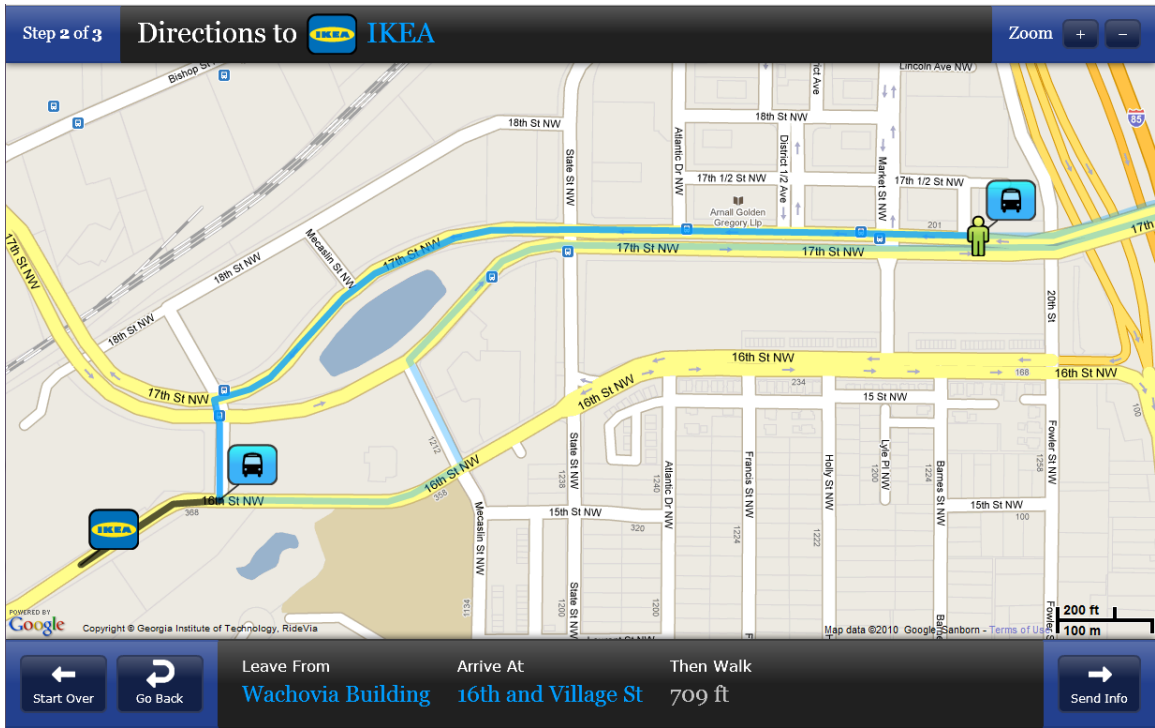
Figure A-5: RideVia v1.0 - Directions to Point-of-Interest
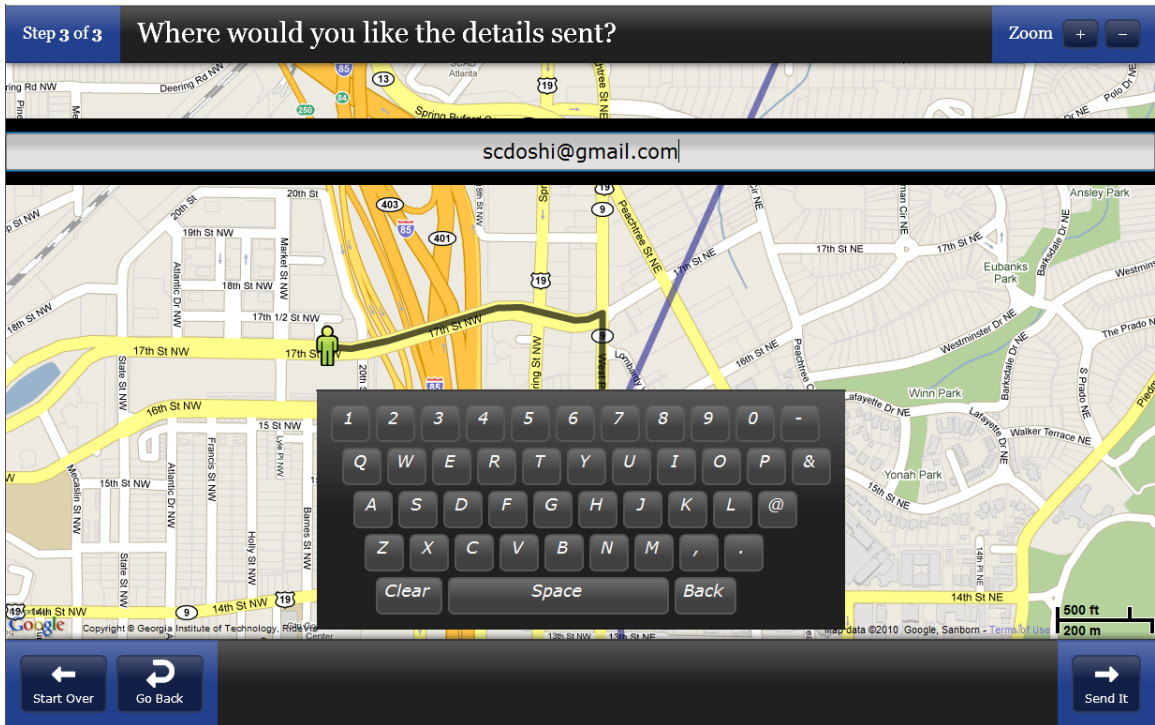
Figure A-6: RideVia v1.0 - Send directions via e-mail or text
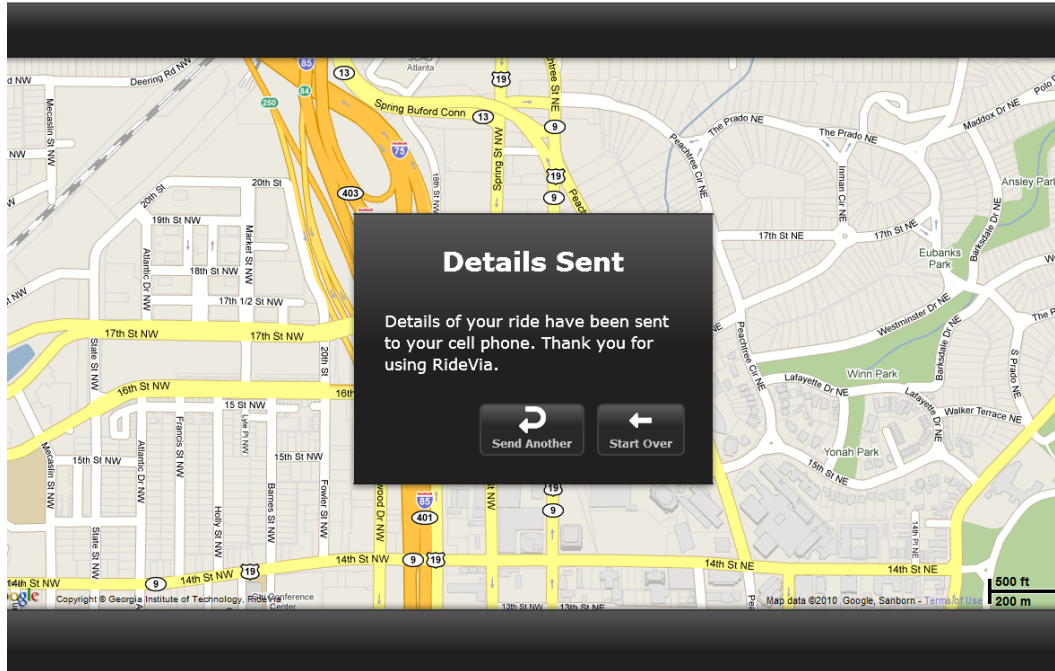
Figure A-7: RideVia v1.0 – Directions confirmation panel

A.2   RideVia v2.0 Web Application
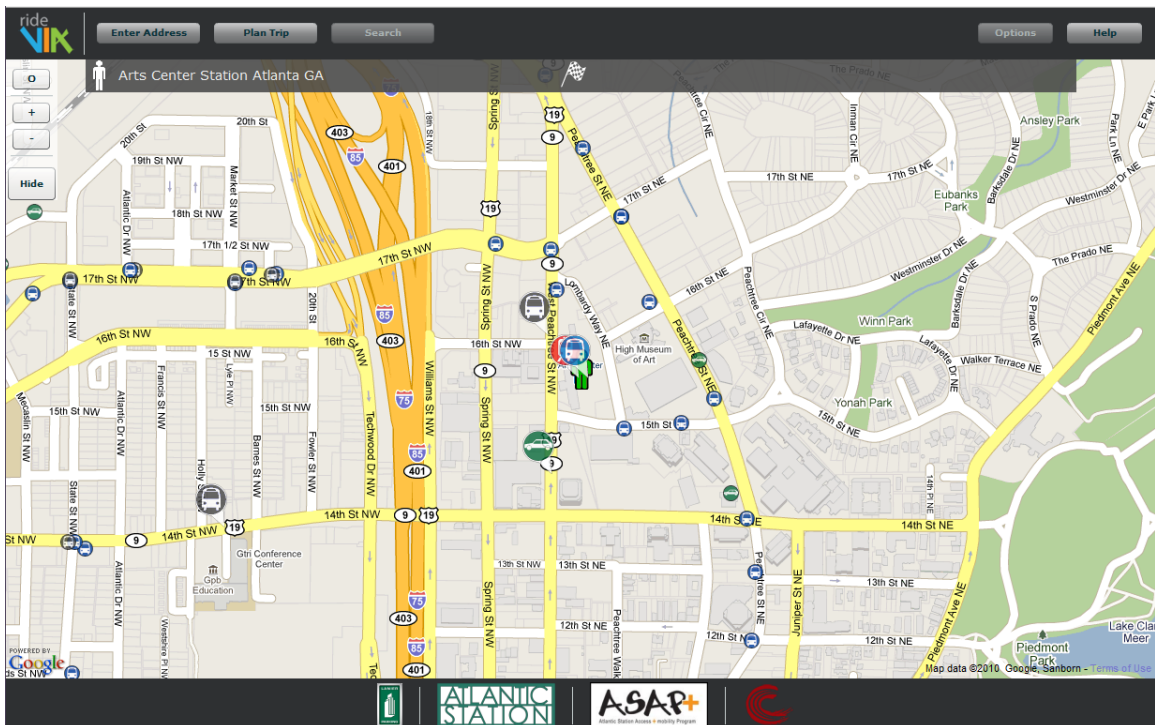
Figure A-8: RideVia v2.0 - Starting Screen
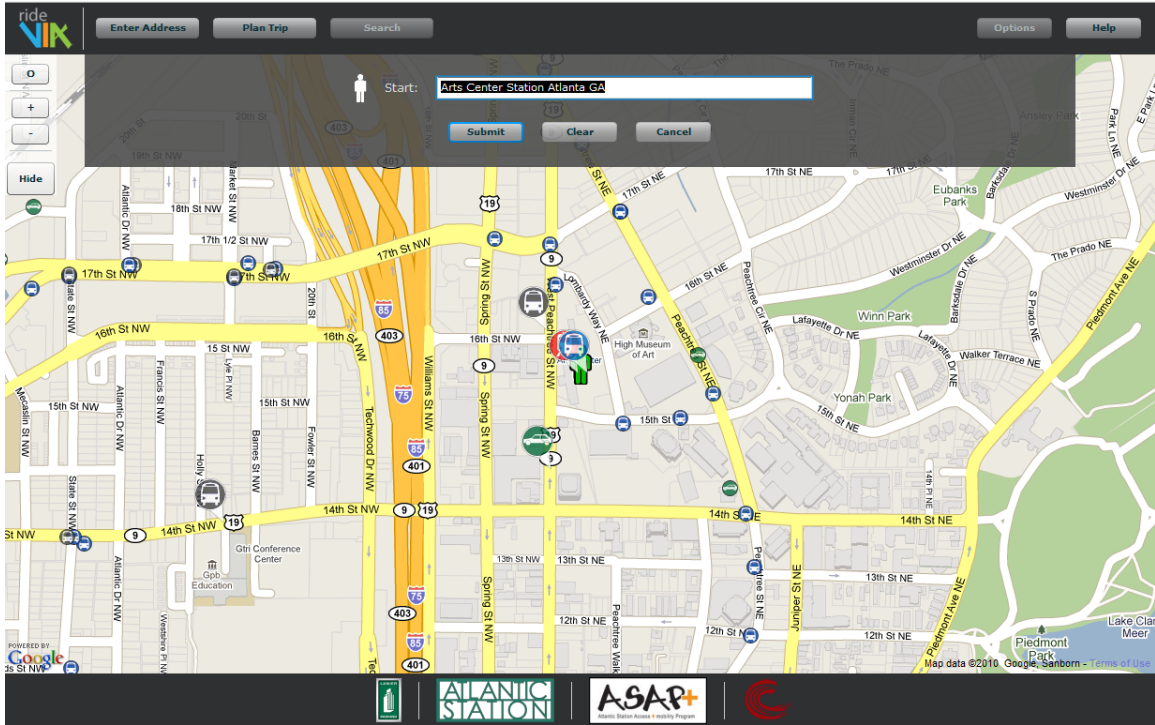
Figure A-9: RideVia v2.0 - Starting Address Entry
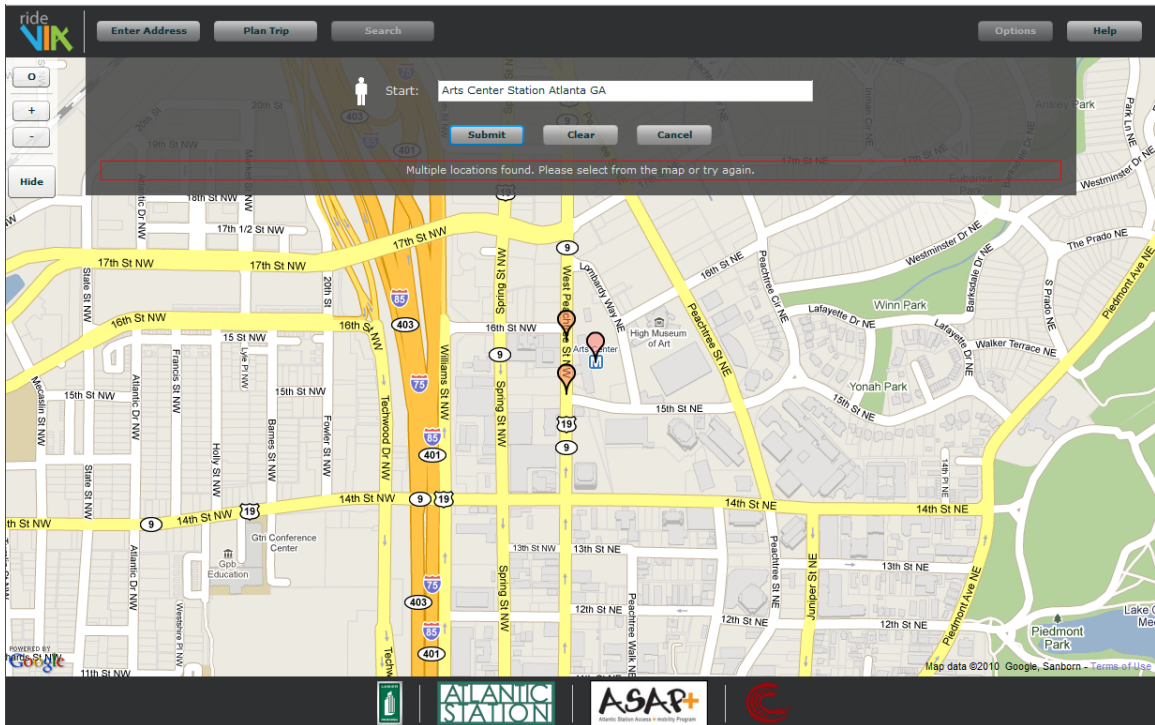
Figure A-10: RideVia v2.0 - Address resolution screen
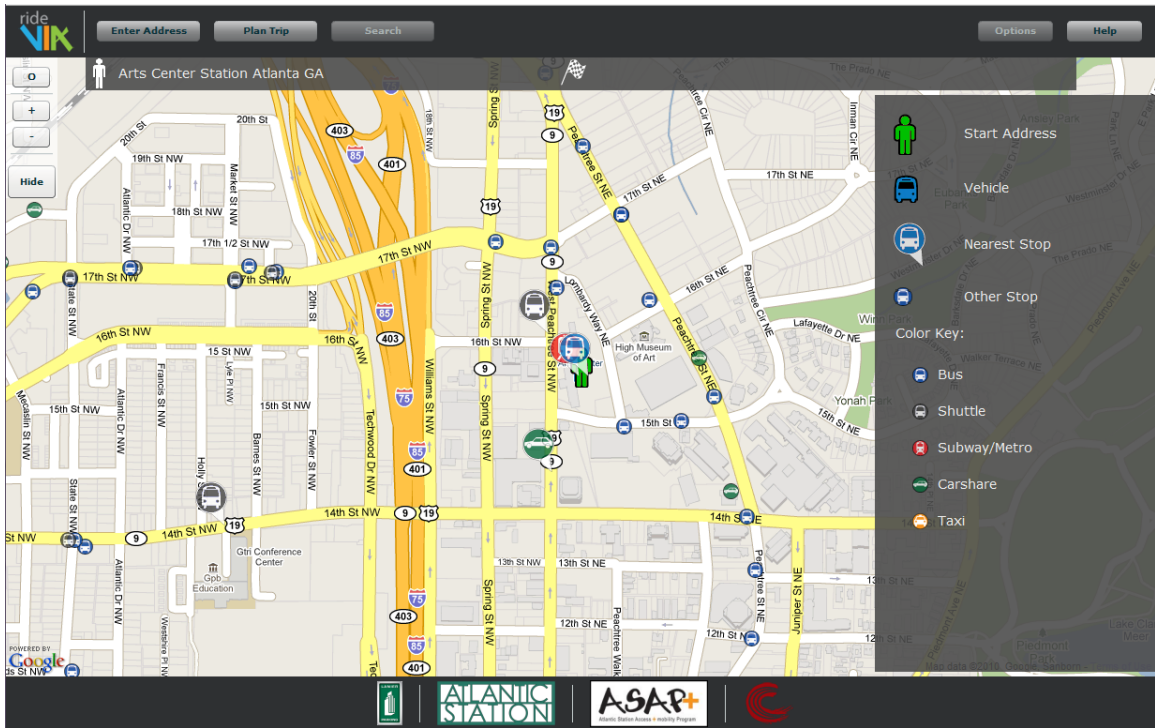
Figure A-11: RideVia v2.0 - Help Screen
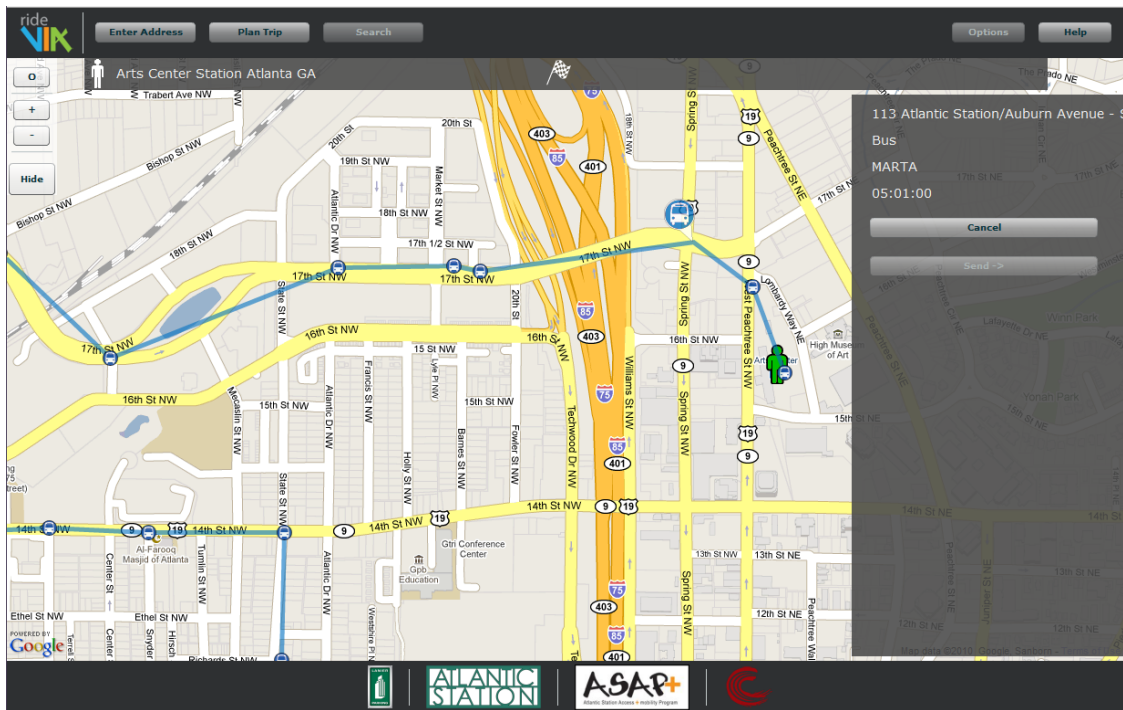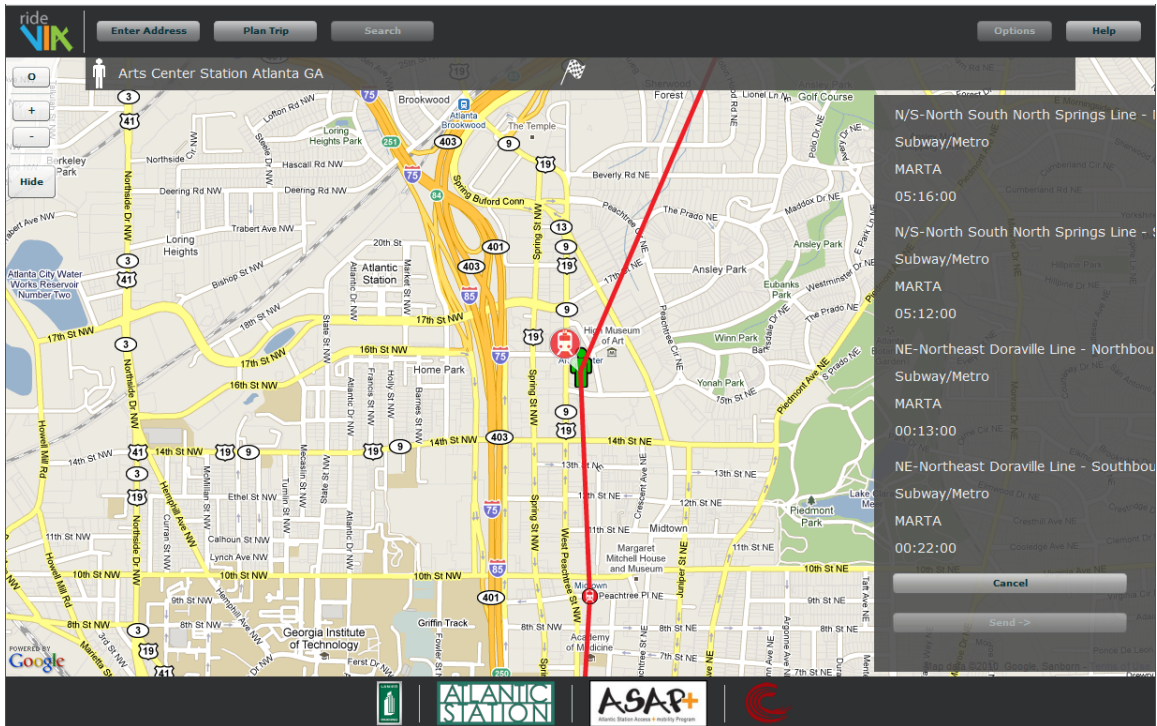

Figure A-12: RideVia v2.0 - Stop Detail

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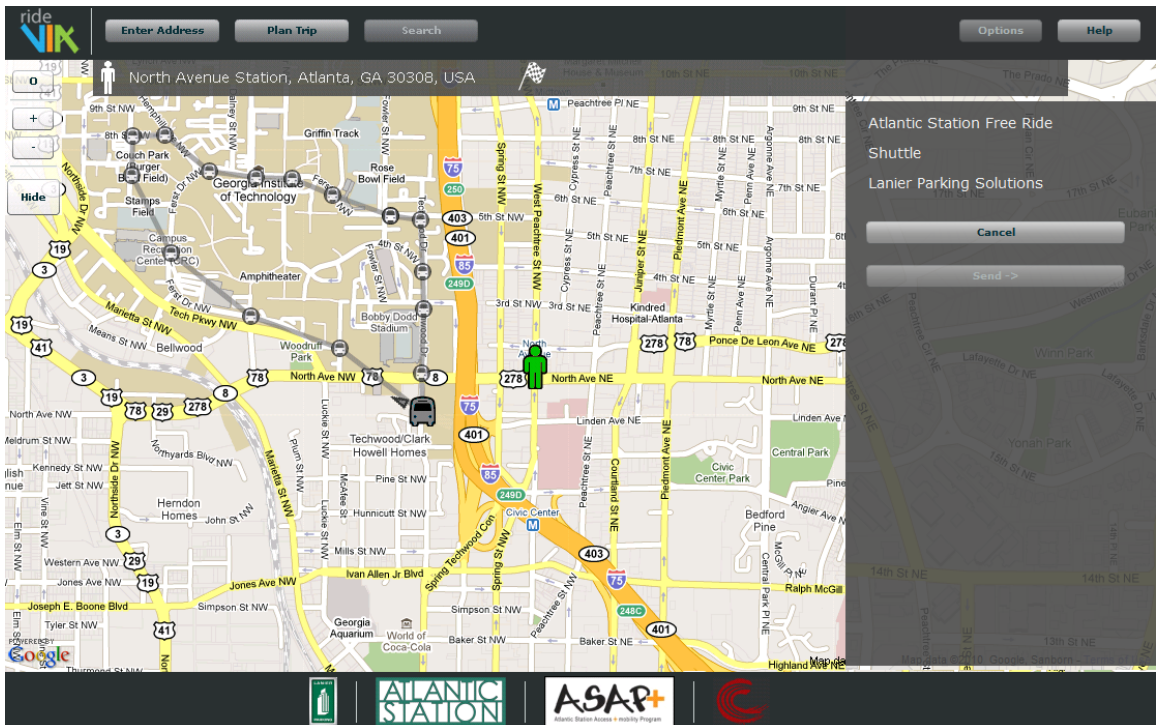**Figure A-13: RideVia v2.0 - Stop Detail (Multiple Routes)**

Figure A-14: RideVia v2.0 – Vehicle Detail
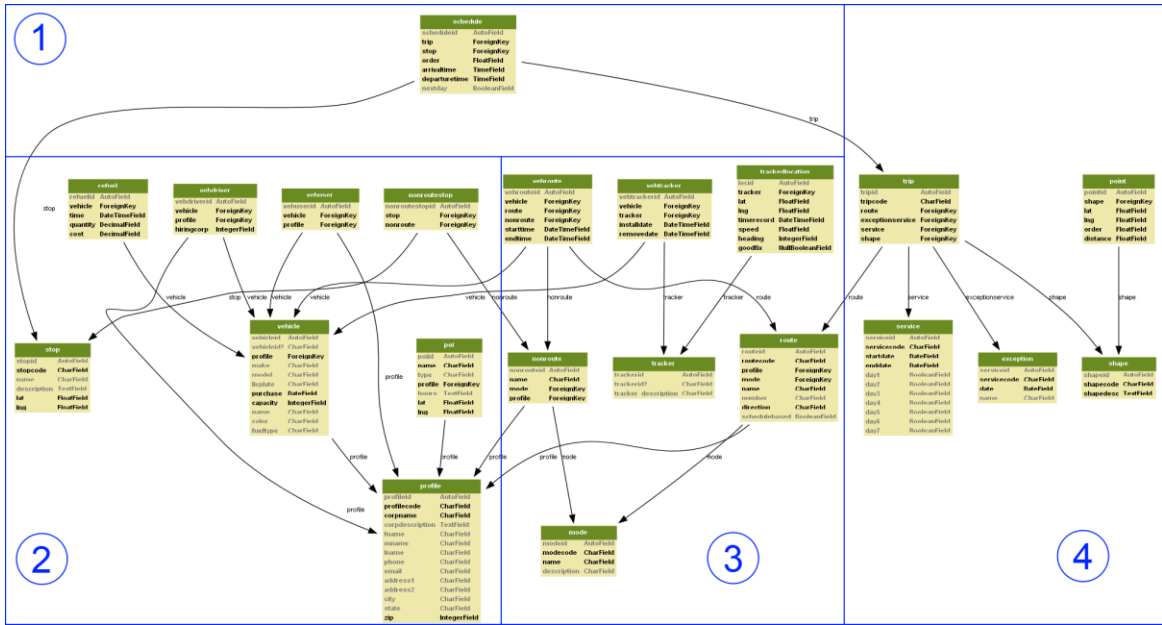
123

APPENDIX B

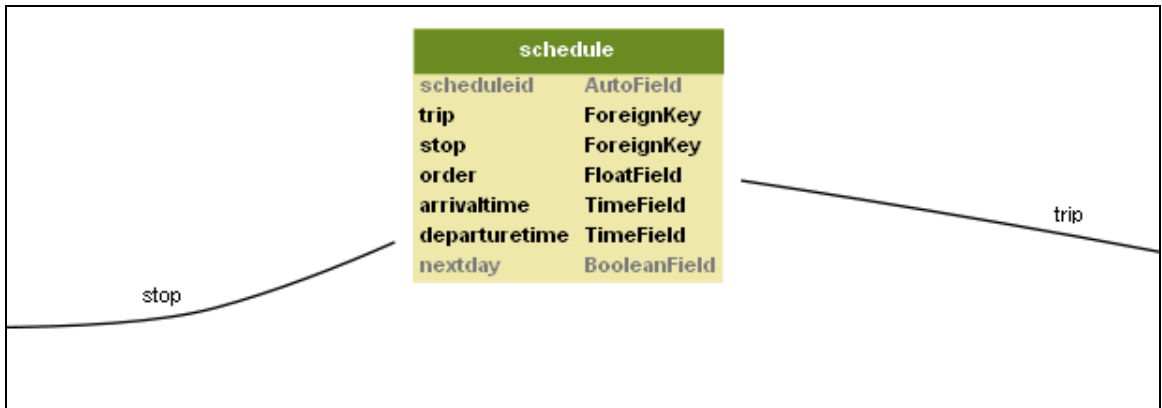# DATABASE UML DIAGRAM

Figure B-1: Database UML Diagram
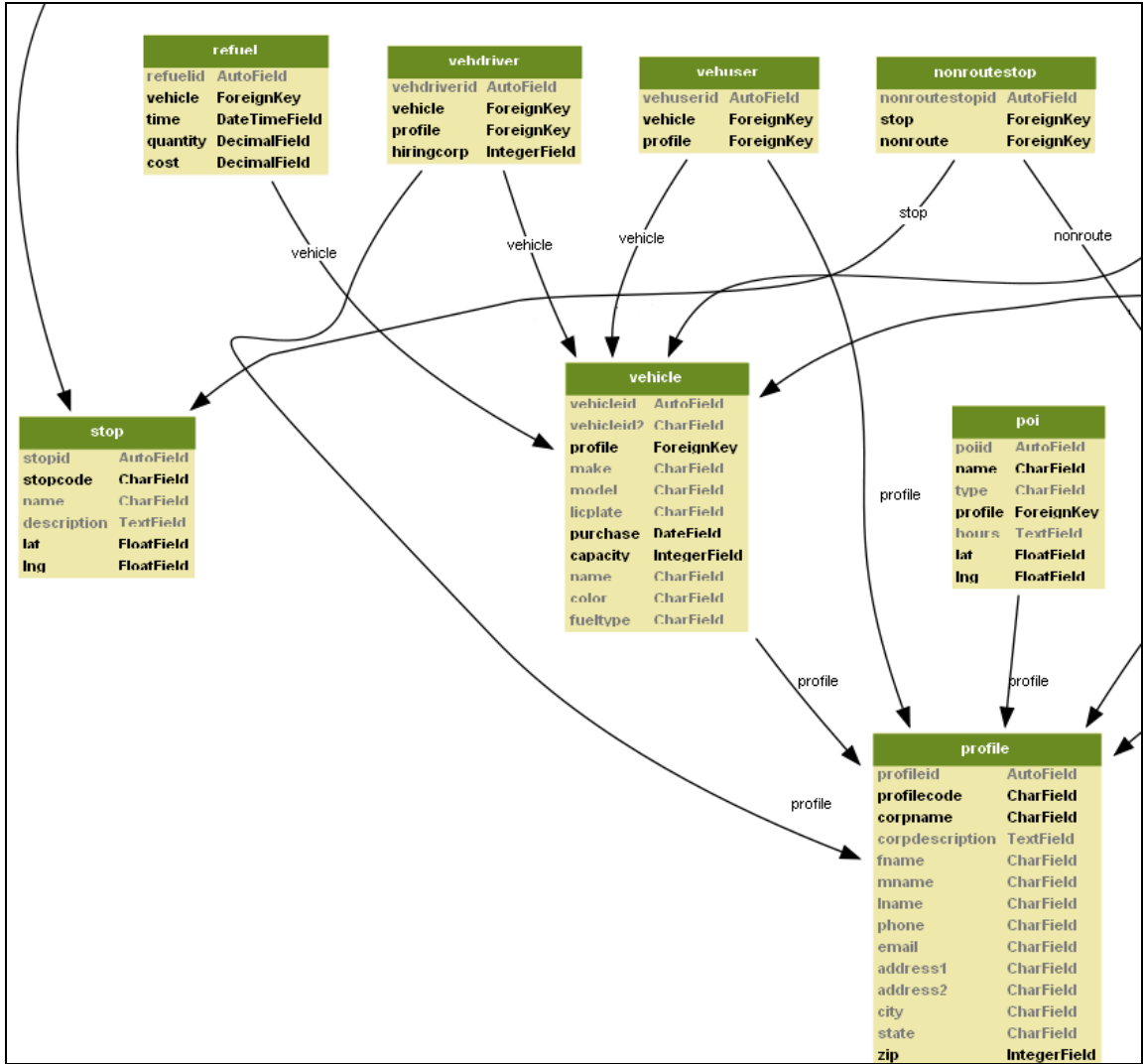

Figure B-2: Database UML Diagram Section 1

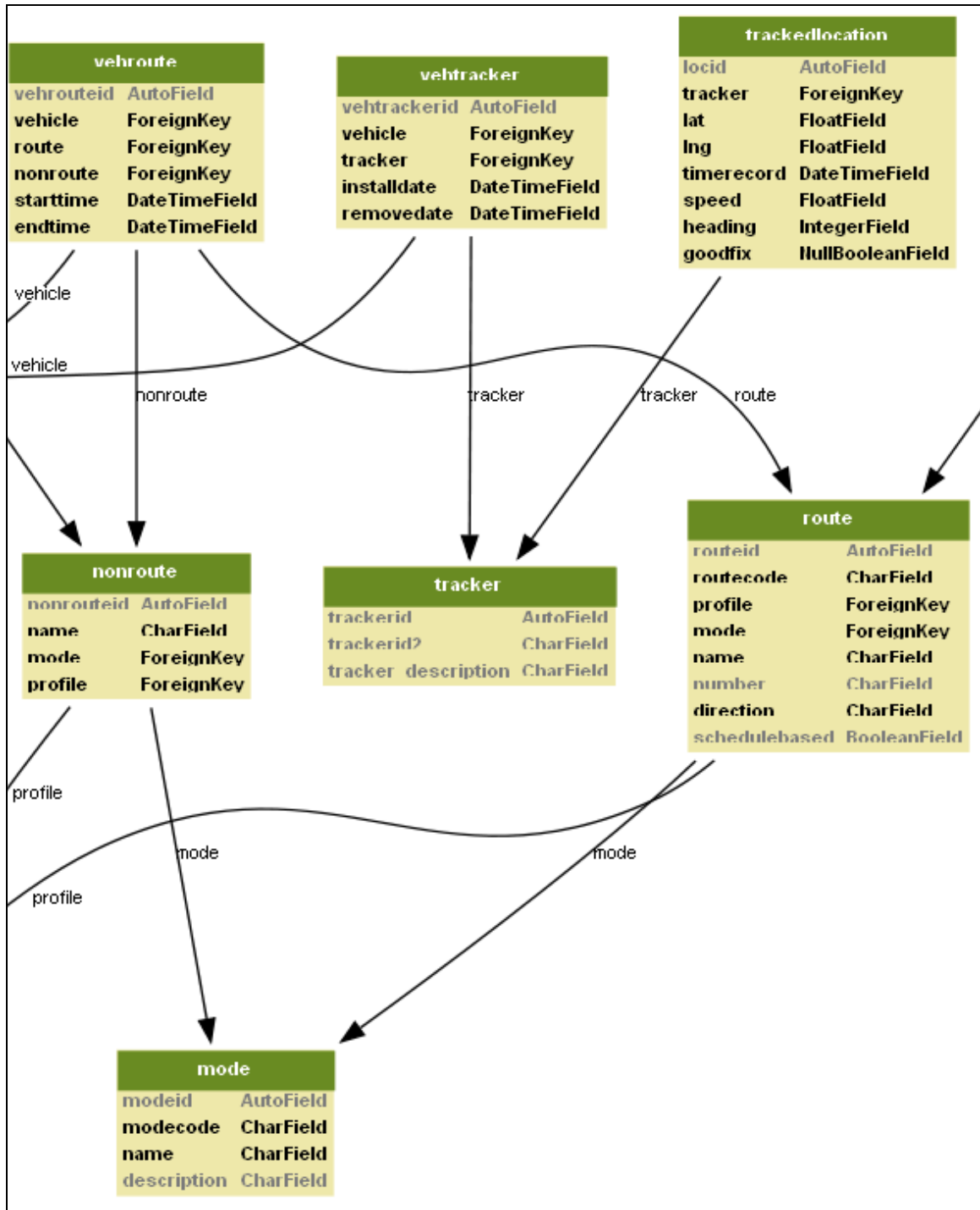**Figure B-3: Database UML Diagram Section 2**
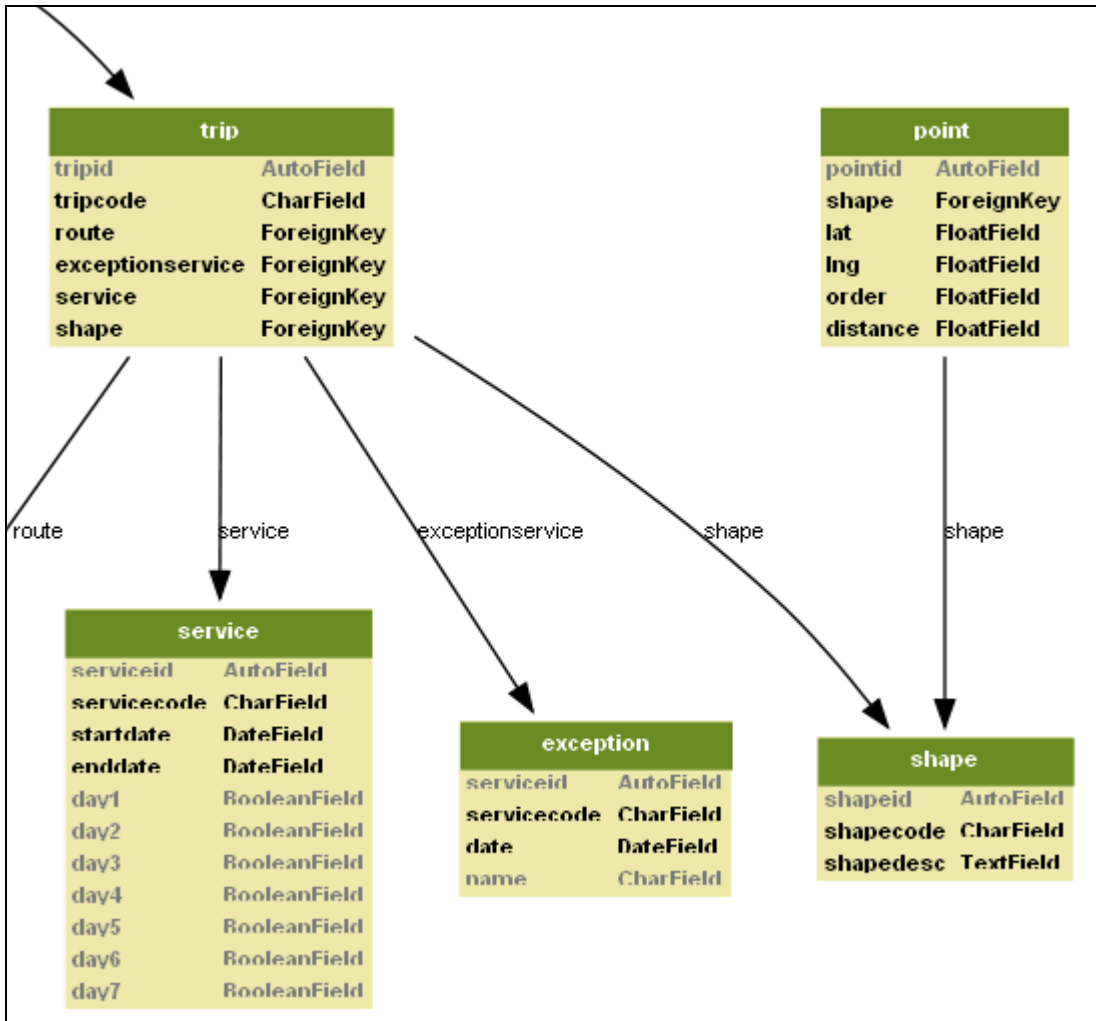
Figure B-4: Database UML Diagram Section 3

Figure B-5: Database UML Diagram Section 4

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