The Use of APTS to Improve Intermodal Passenger Transportation, with Applications to Ground Access to Airports

by

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Abstract

The United States has traditionally paid little attention to the type of intermodal passenger transportation that involves public transportation. The result is continual inefficiency and ineffectiveness in intermodal passenger transportation. The purpose of this thesis is to look at different aspects of Advanced Public Transportation Systems (APTS) by which passenger intermodalism can be facilitated. With this facilitation, the use of public transit can be promoted since travelers can make their plan based on the travelers' information and frustration will thereby be reduced. This thesis will focus on the APTS application to airport ground access. Utilizing the existing APTS technologies, a prototypical intelligent intermodal transportation system for ground access to Logan Airport is designed.

The first half of the thesis analyzes the current status of intermodal passenger transportation in the U.S., by reviewing the existing uses of APTS applications in various transit systems, and by exploring their potential uses. In the second half, the thesis synthesizes both ideas to first investigate how to use APTS as a strategy to promote the efficiency and effectiveness of intermodal passenger transportation, and then to consider whether the strategy can be successful. By limiting the study scope to intermodal transportation related to airport ground access, we are able to study the different needs of a passenger at different points in the entire door-to-door trip in air travel. Since a single air travel trip can involve a number of intermodal connections, the design of an intelligent intermodal system tailored for a single air travel trip can have a significant impact on many intermodal connections.

Efficiency and effectiveness of intermodal passenger transportation can be promoted by Intelligent Transportation Systems (ITS) in three ways: establishing an interconnected network that permits a smooth flow of information among different modes and hubs; providing user-friendly visual and audio interface to deliver intermodal transportation information and other traveler information to the travelers; and allowing transfer of information among different users easily so that dispatchers and operators on different modes can coordinate better among themselves as well as with travelers. The prototypical backbone of the intermodal information structure presented in the thesis can be a model for further development of a large-scale information infrastructure.

Thesis Supervisor: Joseph M. Sussman
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List of Abbreviations

AATA	Ann Arbor Transportation Authority (Michigan)
ADA	Americans with Disabilities Act
APTS	Advanced Public Transportation Systems
APC	Automatic Passenger Counter
ARTS	Advanced Rural Transportation Systems
ATDS	Automatic Taxi Dispatch System
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Transportation Management System
ATM	Automated Teller Machine
AVCS	Advanced Vehicle Control System
AVI	Automatic Vehicle Inventory system
AVL	Automatic Vehicle Location
AVM/C	Automated Vehicle Monitoring/Control
BART	Bay Area Rapid Transit (San Francisco Bay Area, California)
Caltrans	California Department of Transportation
CBD	Central Business District
CCTV	Closed-Circuit Television
CDPD	Cellular Digital Packet Data
CTA	Chicago Transit Authority
CVO	Commercial Vehicle Operations
DGPS	Differential Global Positioning System
EEPROM	Electronically Erasable Programmable Read-Only Memory
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FM	Frequency Module
GIS	Geographic Information Systems
GPS	Global Positioning Systems
HOV	High Occupancy Vehicle
IC	Integrated Circuit
ID	Identification
ITC	Intermodal Transit Connector
ITI	Intelligent Transportation Infrastructure
ITIS	Intermodal Traveler Information Systems
ITS	Intelligent Transportation Systems
KCR	Kowloon-Canton Railway (Hong Kong)
Logan	Boston Logan International Airport
Logan-T	Logan-T Smart System
LOGIC	Logan Growth and Impact Control Study
Loran-C	Long Range Aid to Navigation
MARTA	Metropolitan Atlanta Rapid Transit Authority
Massport	Massachusetts Port Authority
MBTA	Massachusetts Bay Transit Authority

MDT	Mobile Data Terminal
MDTA	Metropolitan Dade County Authority (Miami Area, Florida)
MIT	Massachusetts Institute of Technology
MTA	Metropolitan Transportation Authority (New York City, New York)
MTC	Metropolitan Council of Transit Operations (Minneapolis/St. Paul, Minnesota)
MTR	Mass Transit Railway (Hong Kong)
NII	National Information Infrastructure
NJT	New Jersey Transit
NYCT	New York City Transit
OCTA	Orange County Transit Authority (California)
O-D	Origin-Destination
PACE	
PATH	Port Authority Trans-Hudson (New Jersey/New York City)
PC	Personal Computer
PCD	Personal Communications Device
ROM	Read-Only Memory
Seattle Metro	Metropolitan King County Incorporation
SOV	Single Occupancy Vehicle
T	Equivalent to MBTA. See MBTA.
TCRP	Transit Cooperative Research Program
TDM	Transportation Demand Management
Tri-Met	Tri-County Metropolitan Transportation District of Oregon (Metropoltan Portland Area)
UHF	Ultra High Frequency
USDOT	United State Department of Transportation
VHF	Very High Frequency
VMS	Variable Message Sign
Washington Metro	Washington Metropolitan Area Transit Authority
WWW	World Wide Web

Chapter One

Introduction

1.1 Intermodal Passenger Transportation In the U.S.

Intermodal passenger transportation occurs when two or more modes of transportation are involved in the door-to-door trip. In many European or Asian countries, a passenger trip often involves more than one transportation mode. Bus-train, bus-subway, train-subway, auto-train, and other types of connections are very common. Intermodal passenger transportation is thus a very important element in passenger transportation in these countries. In these countries, a number of transportation centers were built to directly connect different modes to facilitate intermodal transportation connections. In United States, most resources have been devoted to the study for individual transportation modes such as automobile, bus, train and plane. New facilities have been planned, designed and built to facilitate each distinct single mode of transportation. On the other hand, less attention has been paid to passenger intermodalism. When transportation facilities were planned, the element of intermodal connection was often ignored. Even when connection facilities exist, coordination of the modal connection is often poor.

In the U.S., intermodalism often refers to intermodal freight transportation. Intermodalism in freight transportation is heavily considered because efficient, well developed intermodalism can result in great economic savings. Hub systems are usually applied to facilitate the freight transportation. Freight are usually transported in bulk quantity. The transportation schedule of each link is usually pre-arranged and the route does not change once it is fixed.

When we consider passenger transportation, not many people think about intermodalism. Instead, the first thing that comes to the mind of everybody is a single mode of the direct, fast, convenient and reliable automobile. People can drive to any destination at any time without any need to transfer to other modes. The only exception is air travel when everyone has to access the airport by ground transportation and transfer to the plane. To most travelers, problems do not exist in intermodal passenger transportation because the phrase "passenger intermodalism" is not even in their dictionary. Indeed, the real problems exist in the intermodalism that involves public transit. Public transit always has a very low modal share in every part of the country. Indeed, it is an adverse cycle or positive feedback mechanism. Transit does not appeal to most people. Hence, everybody drives and transit usage is low. Policy makers and transportation industries thus do not pay enough attention to improve the passenger intermodalism involving public transportation due to the low demand. As a result, the efficiency of intermodal passenger transportation remains low. Consequently, people avoid switching from a single mode to multi-modal transport because of the low service quality. The cycle repeats itself or even gets worse.

The United States has traditionally paid little attention to the intermodal passenger transportation that involves public transportation. The result is continual inefficiency and ineffectiveness in intermodal passenger transportation. Two common phenomena illustrate the problems clearly. First, connections between different modes of transportation are often indirect. An intermediate link such as shuttle bus, taxi or very commonly long-distance walk is often required to link between two major modes. Transferring between modes is problematic for many travelers.

Examples can be found in many contexts of airport ground access. Like many other U.S. airports, for instance, there is no direct access from the CalTrain to the San Francisco International Airport in Bay Area even at the CalTrain "Airport" station. Travelers need to use taxi to make transfers. Second, information of inter-modal connections usually is not clear or is not even immediately available for the travelers. Even if there are linkages among different modes, signs are usually not clear to indicate where to transfer and which direction to take. A good example can be found in the Massachusetts Bay Transportation

Authority (MBTA) subway, bus, and commuter rail system. At South Station where one can transfer from the subway to the commuter rail, there is no clear indication of how and where to transfer. The ignorance of the importance of passenger information in public transit confuses many travelers and further drives them away from the transit that already has a negative image in U.S.

Transit systems in U.S. have produced a wide variety of passenger information services. However, these services often fall short of providing passengers with information that makes planning their trip easy and effective. Passenger information materials are often not easily available, and are neither user friendly, nor timely. The materials often assume that the passengers have a background with the geographic area and the transportation systems. Information on connections to other bus routes, subway lines, and transit systems is frequently ignored. Since transit riders come from different places with various demographic and socioeconomic backgrounds, it is important to design and prepare information materials that meet the needs of all transit customers.

As part of the Intelligent Transportation Systems(ITS), Advanced Public Transportation Systems (APTS) can help travelers to find their way, to avoid confusion, and most importantly to assure which mode and route to take to get to the destinations through the information kiosk, transit vehicle locator, route guidance system and other APTS components. Also, APTS can improve the service quality of the transit service through increasing reliability of transit service and the intermodal connectivity between transits can be improved. Moreover, APTS can augment transit productivity through better utilization of labor and vehicle fleet, and reduction in the cost of transit operations.

The purpose of this thesis is to look at different aspects of APTS by which passenger intermodalism can be facilitated such that the use of public transit can be promoted as travelers can make their plan based on the travelers' information. This thesis will focus on the APTS application to airport ground access. Utilizing the existing APTS technologies, a prototypical design of a state-of-the-art APTS program of applications will be conducted on Logan 2000 as a case study. Further insights can shape the future direction of the APTS and the concept of real intermodal passenger transportation as a seamless transportation system.

1.2 Intelligent Transportation Systems and Advanced Public Transportation Systems[1]

Intelligent Transportation Systems (ITS) apply advanced computer, communication, sensor and electronic technologies as well as management technologies in an integrated manner to increase the efficiency and safety of the surface transportation system (Humphrey, 1997). ITS consists of mainly six branches: Advanced Transportation Management System(ATMS), Advanced Vehicle Control Systems(AVCS), Advanced Travelers Information System(ATIS), Advanced Public Transportation System(APTS), Advanced Rural Transportation System(ARTS), and Commercial Vehicle Operations(CVO). The name of each system itself is quite descriptive of the functions of each system.

As one of the branches of ITS, Advanced Public Transportation Systems improve the service quality of public transit in several ways: traveler information, electronic fare payment, fleet management and transit/ridesharing demand management technologies.

1.2.1 Traveler Information

Multimodal transportation information is valuable to travelers because the information can affect people's decision on travel. Static information such as bus schedules, routes or train frequency can assist travelers in planning their trips in advance. Reliable

[1] United States Department of Transportation, Federal Transit Administration. *Advanced Public Transportation Systems: The State of the Art - Update '94*. FTA-MA-26-0007-94-1. *The State of the Art - Update '96*. FTA-MA-26-7007-96-1

information adds values to the pre-trip planning process. Inaccurate information, on the other hand, makes the same process meaningless. Use of static information may misrepresent ever-changing information such as traffic conditions or vehicle locations. For example, use of a standard travel time for a particular bus route may seriously underestimate the real travel time when congestion or other unexpected events occur. Dynamic, real-time information can remedy the shortfall of using only static information. For instance, it gives travelers a sense of security by providing arrival, departure time and travel time of next five scheduled buses or trains. Also, Automatic Vehicle Location (AVL) system can inform the travelers of location of the buses so that they can have an expectation of when the next bus will arrive. This application is especially useful for paratransit since there is usually no fixed route for paratransit service and therefore no fixed schedule exists.

Travelers can receive both the static and real-time information via many communication media such as touch-tone phone, pager, cellular phone, voice synthesizer and Internet. World Wide Web makes use of hypermedia to deliver real-time multi-modal transportation information to the travelers through personal computers or information kiosks at the transportation terminals. Automated information can reduce the time and cost of the traveler's request of travel information. It can also reduce the staffing requirement for the customer service to answer these kinds of requests.

At the transit stations, passengers can enjoy schedule updates and intermodal connection information through information kiosks, television screens, and variable electronic signs. Based on the desired origin and destination of the travelers, route guidance system can also help the travelers to plan the trip more efficiently. Besides informing travelers the current road conditions and providing route and mode choice guidance, most importantly, the rod guidance system provides transit information such as recommending certain bus routes, departure times, points and time of connections among bus routes and other modes. It can facilitate the use of public transit and attract travelers to shift modes during peak hours.

Once the passengers are on board, they can enjoy the information such as stops, routes, schedules and connection from the in-vehicle information system. Displays or sound synthesizer facilitate the travelers by providing the simple direction information such as "Next station is Porter Square. Change here to commuter rail" or "Next station is Park Street. The last train of Green 'D' line will arrive at Park Street at 00:45." More complicated information such as the location of all trains can be displayed via a computer screen on the vehicles.

1.2.2 Electronic Fare Payment

One of the barrier to the integration of multi-modes of transportation is the difference in fare media among different modes. Some modes may take coins only. Other modes may take tokens while some may take both. Different modes have different fare structure. Travelers need to keep track of the fare of every single route so that they have enough coin changes for fare payments. If a ticket/token counter is available for purchases, a long queue can be seen during peak hour. Sometimes when transfer time is tight, one can miss a train easily by waiting in line to buy tokens. Automated changes machine may help ease out the problem a bit, but this kind of machines cannot be available at every single bus stop. The only way to fully solve the problem is to use a single fare medium for all the modes. With the smart card technology, a true seamless system can be created to integrate multiple modes together into an efficient intermodal transportation system. Travelers enjoy the convenience of transferring among many different modes such as bus, subway, commuter rail or ferry without worrying how many coins they possess. Payments can be made by using a single magnetic stripe card or even acontactless card. Fare amount is deducted from the previous balance of the card. Advanced technologies such as electronic data processing and storage, magnetic recording technology, microcomputer and data communication enhance the development of the multimodal automated payment system.

Automated fare payment system has many advantages in addition to multimodal payment facilitation. It makes fare differentiation possible. Distance-based or time-based fare structure can be administered more easily. Hence, fare structures can be more equitable. Also, cash or coin handling can be eliminated. It improves the vehicle security and reduce the cash handling cost. Without the jam of coins and dollar bills at the fare boxes, fare boxes are thus more reliable and easier to maintain. The accounting and financial settlement process are thus automated. Electronic fare payment has been widely used in many European and Asian countries. Washington Metro and San Francisco BART systems are amongst a few to use electronic fare media in the public transport in the U.S.

1.2.3 Fleet Management and Vehicle Operations

In order to improve the efficiency and effectiveness of transit service, the transit fleet should be managed well. Fleet management relates directly to vehicles and operations.

Automatic Vehicle Location (AVL) system is a computer-based vehicle tracking system that has been widely used in the U.S. in recent years. At least 58 AVL systems are either in operation or in the process of installation or planning, while there were less than twenty such systems four years ago. AVL has many benefits in different aspects. Real-time location of the vehicles can be determined via the system. This kind of information is very useful for vehicle dispatcher. The dispatcher can keep track of the location of each vehicle and make appropriate dispatching adjustments if services are disrupted or deviated from normal schedule due to some unexpected congestion or other incidents. Dispatchers are thus more responsive to vehicle disruptions or delays. Bus drivers pay more attention to their schedule adherence. The system improves the schedule of many transit systems, resulting in more efficient and on-time operations. Moreover, AVL increases safety and security of the drivers and passengers because any in-vehicle emergencies can be notified at once and appropriate measure can thus be made. The information is also useful for travelers and can be transmitted to traveler information system and displayed.

Geographic Information System (GIS) is also very useful in public transit. The graphical interface of GIS can display the bus stops, bus routes, shelters, facilities and emergency call locations using different map layers. Also, it can process and analyze the origin and destination data, and on-time performance data. Based on the analysis, GIS can prepare the trip planning route choice, determine the shortest path for paratransit vehicles or door-to-door van, and match rides for ride-sharers.

APTS technologies generate new communication requirements. Conventional communication service used by most transit agencies nowadays often cannot satisfy the need of APTS technologies completely. Cutting-edge technologies such as trunked radio, digital radio, cellular phone, low earth orbit satellite service or overlaying on transmissions by conventional commercial FM radio stations help meet those new communication requirements. These strategies can ease the strain on the communications network and utilize the frequency spectrum better. The advancement of communication technologies enables the operators and dispatchers to transmit data or voice messages more efficiently and more effectively.

Automatic passenger counters (APC) collect passenger boarding and alighting data. These data are mainly for the purposes of future planning, passenger forecasting and scheduling, national database reporting, provision of traveler information, or decisions on corrective measures. To take advantage of the location information, some agencies include APC in their AVL systems.

1.2.4 Transit/Ride-sharing Demand Management Technologies

Transit and ride-sharing demand management technologies focus on managing the demand more effectively and utilize the existing infrastructure better through advanced and innovative technologies. Through a combination of the strategies including good coordination of transportation service providers, enhanced incident management and increased incentive towards shared rides, both efficiency of intermodal transportation system and modal share of transit are expected to increase.

Real-time ridesharing is also called dynamic ridesharing or single-trip ridesharing. The riders send in requests for rides just before the trip starts. The requests are spontaneous. According to the origins and destinations of the riders and drivers, the central matching center would match the ride pairs.

1.3 Research Questions

The goal of this research is to improve the efficiency and effectiveness of intermodal passenger transportation using APTS. In order to solve the problem correctly and determine the usefulness of the thesis, the following questions were considered seriously when conducting the research for the thesis. The thesis should answer these questions.

- What factors contribute to inefficiency and ineffectiveness of passenger intermodalism?
- Given the problems, what role can ITS play to help solve the problems?
- Is ITS the best or the most suitable way?

To answer the first question, the thesis will investigate the problems of intermodal passenger transportation in the United States. The thesis will look at several kinds of intermodal connections. Afterwards, the thesis will answer the second and third questions by looking at various types state-of-the-art APTS technologies and how these technologies facilitate the public transit and benefit the public. The thesis will determine if there is a match between APTS technologies and improved passenger intermodalism..

To analyze intermodal passenger transportation, we focus on airport ground access. This has the most comprehensive coverage of different aspects of intermodal passenger connections. The thesis will look at current applications of APTS in the area of airport ground access although there are not many such applications.

- What barriers are there to limit people to using transit or other high occupancy vehicles to access the airport?
- Can ITS technologies help remove those barriers?

1.4 Thesis Organization

This chapter has briefly introduced the background of the thesis. Research questions have also been presented.

Chapter Two looks at the status of the intermodal passenger transportation in the United States. It will discuss the characteristics and problems in four different kinds of intermodal connection: ground-air connection, commuter-intercity rail connection, auto-transit connection, and inter-transit connection

Chapter Three reviews the literature of the Advanced Public Transportation Systems applications in many U.S. cities. A variety of information technologies are presented. The chapter also examines the development and implementation of different systems in public transit across the U.S.

Chapter Four looks at the current APTS applications on the airport ground access and other intermodal linkages in different airports. These applications can guide us in developing new applications for future improvements of passenger intermodalism.

Chapter Five gives the background of the Boston Logan International Airport, the Logan 2000 and the Intermodal Transit Connector projects.

Chapter Six is a case study that investigates how to integrate APTS into Logan 2000, Intermodal Transit Connector and MBTA transit systems as strategies to improve the efficiency and effectiveness of the airport ground access and the intermodal transport in the Boston area. A prototypical intelligent intermodal transportation system for ground access to Logan Airport is designed.

Chapter Seven concludes the thesis by summarizing the results of the research and by providing some insights for further research.

Chapter Two

Intermodal Passenger Transportation In The United States

Intermodal passenger transportation occurs when two or more modes of transportation are involved in the door-to-door trip. Unlike most other countries, the United States has traditionally paid little attention to the intermodal passenger transportation, especially for the intermodal connections that involve public transportation. To better understand the current status of intermodal passenger transportation in the U.S., this chapter discusses four types of intermodal connections in the U.S. The four types are respectively ground to air connections, commuter to inter-city connections, auto-transit connections, and inter-transit connections. Each type of connection has its advantages and problems. We will discuss the characteristics of each type of connection as well as their current status in the U.S.

2.1 Ground to Air Connections[2]

Ground accesses to the airport are usually dominated by Low Occupancy Vehicles (LOV) which include autos, taxis and private bus operators. On average, Low Occupancy Vehicles accounts for 82.7% of the modal share for airport ground access in U.S.[3] Thousands of parking spaces are often available for automobiles at every U.S. airport. Abundance of parking spaces is a large incentive for people to access the airport by auto.

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[2] Cunningham, Lawrence F. and Gerlach James H. Ground Access Assessment of North American Airport Locations. Final Report. September 1996.

[3] Ibid.

Also, baggage handling is also a big issue for airport ground access. LOV handle baggage more easily than any other modes, especially for the modes that require transfers.

Access by Low Occupancy Vehicles

Private automobiles, taxis, and rental cars are categorized as low occupancy vehicles (LOV) in this study. Nevertheless, each distinct mode of LOV has its own characteristics and accounts for different portion of modal share in ground access to airports. The modal share of private automobile is directly related to the population density of the cities where the airports are located. Distance from the airport from CBD is also an important factor. LaGuardia Airport and Washington National Airport have the lowest use of private automobiles -- 31.5% and 33% respectively. On the other hand, airports that are located in cities where population are scattered extensively around the region such as Seattle Sea-Tac Airport (78.8%) and Toronto's Lester Airport(75%) both have a very high market share of automobiles.[4] In these cities, transit access may not be available in the outlying suburbs. For the suburbs where transit services are available, a number of transfers are required to access the airport via transit. The long travel distance between these airports to the outlying suburbs makes taxi an very expensive and unpopular option.

The nature of travel can affect significantly the market share in taxi, private limousines and rental car market. Taxis are often used in business travel. Rental cars are popular among leisure/vacation travel. Automobiles are used widely for families or friends visit. For example, Washington National Airport has the highest taxi share of 36% in the nation since business travels accounts for the largest proportion (62%) of airport usage at the National Airport which is located only six miles away from Downtown Washington.[5] Numerous business travelers use taxi to travel to attend a variety of meetings and conferences in many different government institutions, embassies, office buildings, conference centers, hotels and other business-related facilities that are all located in Downtown Washington and close suburbs such as Arlington in Virginia.

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[4] Ibid.
[5] Ibid.

Similarly, vacation travel dominates the airport usage of the Miami International Airport. It attracts 12.4 million international travelers, which account for 43% of the total passengers of the airport.[6] The high percentage of vacation travelers can explain the fact that Miami has the highest market share of rental cars in ground transportation modal split in airport access among all major U.S. airports. The rental cars take the travelers to a number of beaches, resorts and sightseeing points through Miami and Southern Florida.

Transit and High Occupancy Vehicles

Direct transit access to airports, especially heavy rail, is rarely available in the United States. In U.S., only seven airports have some kind of rail access. The modal share for the rail access ranges from 2% to 6%, with an exception of 9% in Washington National Airport. The airports whose market shares are in the high end (close to 6%) are usually the ones being located in the cities where population densities are high and rail service is relatively competitive in terms of service quality and many other factors. Most of these seven airports, however, do not have direct rail access to the airport terminals. Some kind of shuttles are usually provided to connect the rail station to the airport terminals. Boston Logan International Airport is a typical example. The MBTA subway has an "airport" station on the Blue Line. However, passengers need to transfer to a shuttle from that station in order to access the main airport terminals. Signs are not clear enough in directing passengers to public transit or other transportation services. For example, not until a passenger crosses the taxi waiting area to the shuttle bus station could one realize that there is a shuttle bus stop to take one to the MBTA subway station. Figure 2-1 illustrates a simple schematic of the Boston Logan International Airport. San Francisco International Airport is another example that illustrate the inefficient access to the airport. Neither BART (Bay Area Rapid Transit) nor Caltrain (Commuter rail system) has direct access to the San Francisco International Airport. However, a shuttle bus connection is provided between the Caltrain station and the airport. At the same time, a local bus is needed to connect between the BART station and the Caltrain station. Consequently,

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[6] Ibid.

sometimes as many as three or four intermodal connections plus one or two transfers within BART system are required to access the airport. The need of multiple transfers makes the passenger trip more inconvenient. As a result, only 3% of the travelers use this option to access the airport.[7]

Most airports do not have bus access to the airport or only a few bus routes are available to access the airport except for Philadelphia, whose bus services indeed have only an 1% modal share in airport ground access. On the other hand, dedicated express bus services have been quite successful in some metropolitan area such as Boston and Washington. In Boston, express bus services called "Logan Express" have been developed to collect the travelers in some suburban areas which do not have rail access to airport. Travelers can thus park their cars in the park-and-ride lots and get onto the express bus that directly takes them the airport terminals. Indeed, research have been conducted in Boston to determine the marketing needs and to explore the potential market for this kind of services. "Washington Flyer" provides similar services from the Washington National Airport to various suburbs in the Metropolitan Washington area.[8]

In this study, High Occupancy Vehicles (HOV) includes all kind of vehicles that have a higher passenger seating capacity than LOV. On average, non-transit High Occupancy Vehicles (HOV) has a 13.2% modal share in airport ground access in major U.S. airports. Breaking down the statistics into individual modes of HOV, we can obtain the following results. New York JFK Airport has the highest share (8.4%) of airport shuttle among all major U.S. airports. Chicago O'hare Airport has the highest share (7.8%) of courtesy vans and Cleveland Hopkins Airport has the highest use of other HOV services at 15.5%.[9] Table 2-1 illustrates the modal splits of all kind of ground access to 19 major airports in U.S.

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[7] Ibid.
[8] Ibid.
[9] Ibid.

Most of the above HOV provide fixed-route service with either designated stops or en-route flexible stops. Door-to-door van service, combining the characteristics of transit and automobile, is an alternative way of providing demand-responsive and direct ground access to the airport in addition to automobile and taxis. Travelers need to call in advance to reserve a seat in the door-to-door van. It is a good way to reduce automobile access to the airport while maintaining the convenience of direct access to the airport from home or office.

2.2 Intermodal Commuter-Intercity Connections

Intermodal connections between intercity trains and different commuter transportation modes are similar to ground-air connections in their inherently intermodal nature. Long-distance travel is the main purpose of both types of trips. Commuting modes accessing train station or airport are often viewed as subsidiary links. Train station access and airport access, however, have striking differences in their characteristics. Access to intercity train (AMTRAK) station from public transit is better than access to the airport because the major train stations are usually located at the downtown area of any cities while airports are mostly located in outlying suburbs. Since the downtown area or Central Business District has the highest concentration of transit service in a metropolitan area, accessing the inter-city train stations is very convenient using public transit. Connections can be made easily between local transit and inter-city train or commuter rail. For instance, the two main rail terminals in Boston, North Station and South Station, can be directly accessed by Green, Orange and Red Lines of the MBTA subways and a number of bus routes. Figure 2-2 illustrates the MBTA subway map and commuter rail map. On the other hand, automobile access sometimes is not as convenient as transit access to the train station because of the limited parking and traffic congestion in downtown area. Parking charges are often high in the downtown area.

2.3 Auto-Transit Connections

The automobile is the dominant mode of urban transportation in the U.S. Automobile provides high flexibility and convenience to travelers. It provides door-to-door services to the travelers. Accessibility to transit discourages people from using transits. People do not want to walk for more than a certain duration of time (commonly 15 minutes) to take the bus. Efficient and effective auto-transit connection would help facilitating people to access transit. Park-and-ride lot and kiss-and-ride taxiways are some of the solutions to the accessibility problems.

A park-and-ride lot is designed to facilitate auto-transit connections by providing car parking for the transit users. Most park-and-ride facilities are free of charge. Usually, a park-and-ride lot is located next to the transit stations. People can park their cars in the lot and get on the bus at the stations. In their returning trips, they get off the bus and drive back home. Park-and-ride lots have been so popular in many places that a problem evolves: the park-and-ride lots become so full that the late comers cannot get a space and are forced to drive.

Kiss-and-ride is a designated area at the transit station where people can drop off friends or families to ride the bus or rail. On their returned trips, the transit passengers can be picked up by their friends or families from the transit station. Kiss-and-rides usually do not have problems during the morning peak since the automobiles leave once the passengers get dropped off and get on the bus or train or wait at the station. During the afternoon peak, nevertheless, tens of cars are waiting for the buses or trains all at once resulting in traffic congestion at the curb-side as well as the nearby streets. If the buses or trains are delayed, a serious traffic blockage may occur at the kiss-and-ride area unless sufficient spaces are provided.

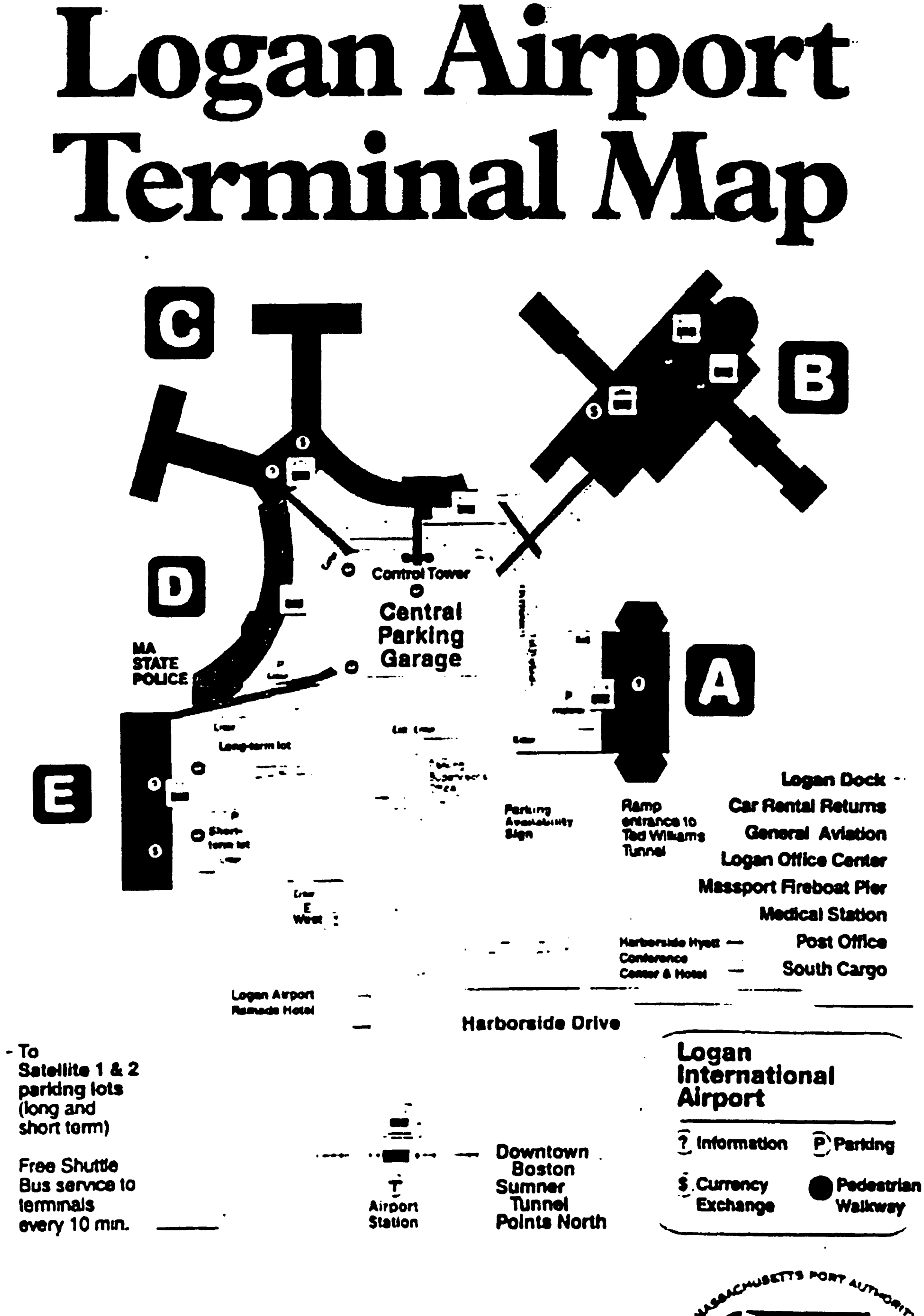

Figure 2-1 Schematic diagram of Logan International Airport.

Source: Massport Official Home Page [http://www.massport.com/logan/logan.jpg]

MASSACHUSETTS PORT AUTHORITY

massport INTERNATIONAL

The Massachusetts Port Authority

Table 2-1 Modal Split of the Ground Access to 19 Major Airports in U.S.

Source: Ground Access Assessment of North American Airport Locations

Modal Choice	Atlanta	Boston			Chicago			Cleveland	Wash DC / Baltimore	
	Hartsfield	Logan	O'Hare	O'Hare	O'Hare	Hopkins	Hopkins	Hopkins	Entire Region	BWI
			Departing	Arriving		Departing	Arriving			
Automobiles/Private	59.9%	40.1%	50.8%	50.6%	50.7%	69.7%	47.2%	58.5%	46.0%	64.0%
Rental Cars	14.7%	14.0%							14.0%	17.0%
Trucks						0.7%	0.5%	0.6%		
Security or Police						0.4%	0.2%	0.3%		
Taxi	7.4%	18.2%			•	5.4%	7.4%	6.4%	24.0%	7.0%
Limo (Private)		8.4%								
Taxi or Limo			25.1%	22.9%	24.0%					
Subtotal Single Occupancy Vehicles	82.0%	80.7%			74.7%	76.2%	55.3%	65.8%	84.0%	88.0%
Hotel Bus/Van	3.7%	1.9%	6.4%	9.1%	7.8%	3.9%	7.5%	5.7%	5.0%	4.0%
Rental Car Shuttle						6.5%	19.3%	12.9%		
Airport Bus/Limo	2.2%	4.2%							5.0%	7.0%
Tour Bus/Cruise Line										
Limo (Shared)	3.6%	4.4%								
Other Shuttle	3.3%					13.4%	17.6%	15.5%		
Subtotal Multiple Occupancy Vehicles	12.8%	10.5%			7.8%	23.8%	44.4%	34.1%	10.0%	11.0%
Bus	2.4%									
Rail/Train									5.0%	
Bus &/or Train			5.8%	4.9%	5.3%					1.0%
Subway		5.8%								
Ferry		1.1%			-					
Subtotal Multiple Occupancy Public Transit	2.4%	6.9%			5.3%	0.0%	0.0%	0.0%	5.0%	1.0%
Other	2.1%	2.0%	11.8%	12.1%	12.0%				1.0%	1.0%
Don't Know/No Answer			0.4%	0.6%	0.5%					
Sum of Percentages	100.0%	100.1%	12.2%	12.7%	100.2%	100.0%	99.7%	99.9%	100.0%	101.0%

Table 2.1 (continued)

Modal Choice	Wash DC / Baltimore					Miami		Miami	Portland	Toronto
	Dulles	National	Newark	La Guardia	JFK	MIA		MIA	PDX	LBPierson
						Weekday Departing	Weekend Departing			
Automobiles/Private	58.0%	33.0%	51.8%	31.5%	43.2%	42.8%	32.1%	37.5%	63.0%	75.0%
Rental Cars	18.0%	11.0%	11.5%	5.0%	3.8%	25.5%	24.0%	24.8%	23.0%	
Trucks										
Security or Police										
Taxi	14.0%	36.0%		32.8%	17.4%	12.2%	14.3%	13.3%	3.0%	
Limo (Private)			19.1%	19.3%	19.9%	1.9%	0.7%	1.3%		
Taxi or Limo										20.0%
Subtotal Single Occupancy Vehicles	90.0%	80.0%	82.4%	88.6%	84.3%	82.4%	71.1%	76.8%	89.0%	95.0%
Hotel Bus/Van	5.0%	6.0%	2.5%	1.1%	3.1%	3.7%	4.0%	3.9%		
Rental Car Shuttle						See Rental Car Above				
Airport Bus/Limo	5.0%	3.0%	4.8%	7.1%	8.4%	1.7%	2.1%	1.9%		
Tour Bus/Cruise Line						7.6%	19.8%	13.7%		
Limo (Shared)			1.7%	2.0%	2.8%				10.0%	
Other Shuttle						3.4%	2.7%	3.1%		2.5%
Subtotal Multiple Occupancy Vehicles	10.0%	9.0%	9.0%	10.2%	14.3%	16.4%	28.6%	22.5%	10.0%	2.5%
Bus										
Rail/Train		9.0%								
Bus &/or Train			1.1%	1.1%	1.1%	1.2%	0.4%	0.8%	1.0%	
Subway										
Ferry				0.1%	-					
Subtotal Multiple Occupancy Public Transit	0.0%	9.0%	1.1%	1.2%	1.1%	1.2%	0.4%	0.8%	1.0%	0.0%
Other	0.0%	1.0%			0.3%					2.5%
Don't Know/No Answer										
Sum of Percentages	100.0%	99.0%	92.5%	100.0%	100.0%	100.0%	100.1%	100.1%	100.0%	100.0%

Table 2.1 (continued)

Modal Choice	Seattle	Philadelphia	St. Louis	San Francisco	Oakland			
	Sea-Tac	PHL	Lambert	SFO	OAK			
						Average	Minimun	Maximun
Automobiles/Private	78.8%	49.0%	63.4%	46.0%	70.3%	54.1%	31.5%	78.8%
Rental Cars	5.2%	18.0%		13.0%	15.0%	13.8%	3.8%	24.8%
Trucks						0.6%	0.6%	0.6%
Security or Police						0.3%	0.3%	0.3%
Taxi	2.6%	5.0%	12.0%	11.0%		14.2%	2.6%	36.0%
Limo (Private)		10.0%	0.1%	2%		10.2%	0.1%	19.9%
Taxi or Limo					5.6%	16.5%	5.6%	24.0%
Subtotal Single Occupancy Vehicles	86.6%	82.0%	75.5%	72.0%	90.9%	82.7%	65.8%	95.0%
Hotel Bus/Van	3.7%	3.0%	6.1%	6.0%	2.5%	4.4%	1.1%	7.8%
Rental Car Shuttle			2.1%			7.5%	2.1%	12.9%
Airport Bus/Limo	6.6%	4.0%	0.9%			4.9%	0.9%	8.4%
Tour Bus/Cruise Line		3.0%		4.0%		6.9%	3.0%	13.7%
Limo (Shared)			0.8%	3.0%		3.4%	0.8%	10.0%
Other Shuttle	1.7%		12.5%	12.0%	1.9%	7.0%	1.7%	15.5%
Subtotal Multiple Occupancy Vehicles	12.0%	10.0%	22.4%	25.0%	4.4%	13.2%	2.5%	34.1%
Bus		1.0%				1.0%	1.0%	1.0%
Rail/Train		2.0%				5.3%	2.0%	9.0%
Bus &/or Train	1.4%			3.0%	4.2%	2.0%	0.8%	5.3%
Subway						#DIV/0!	0.0%	0.0%
Ferry						0.1%	0.1%	0.1%
Subtotal Multiple Occupancy Public Transit	1.4%	3.0%	0.0%	3.0%	4.2%	2.2%	0.0%	9.0%
Other		5.0%	2.1%		0.5%	2.5%	0.0%	12.0%
Don't Know/No Answer						0.5%	0.5%	0.5%
Sum of Percentages	100.0%	100.0%	100.0%	100.0%	100.0%	101.1%	92.5%	101.0%

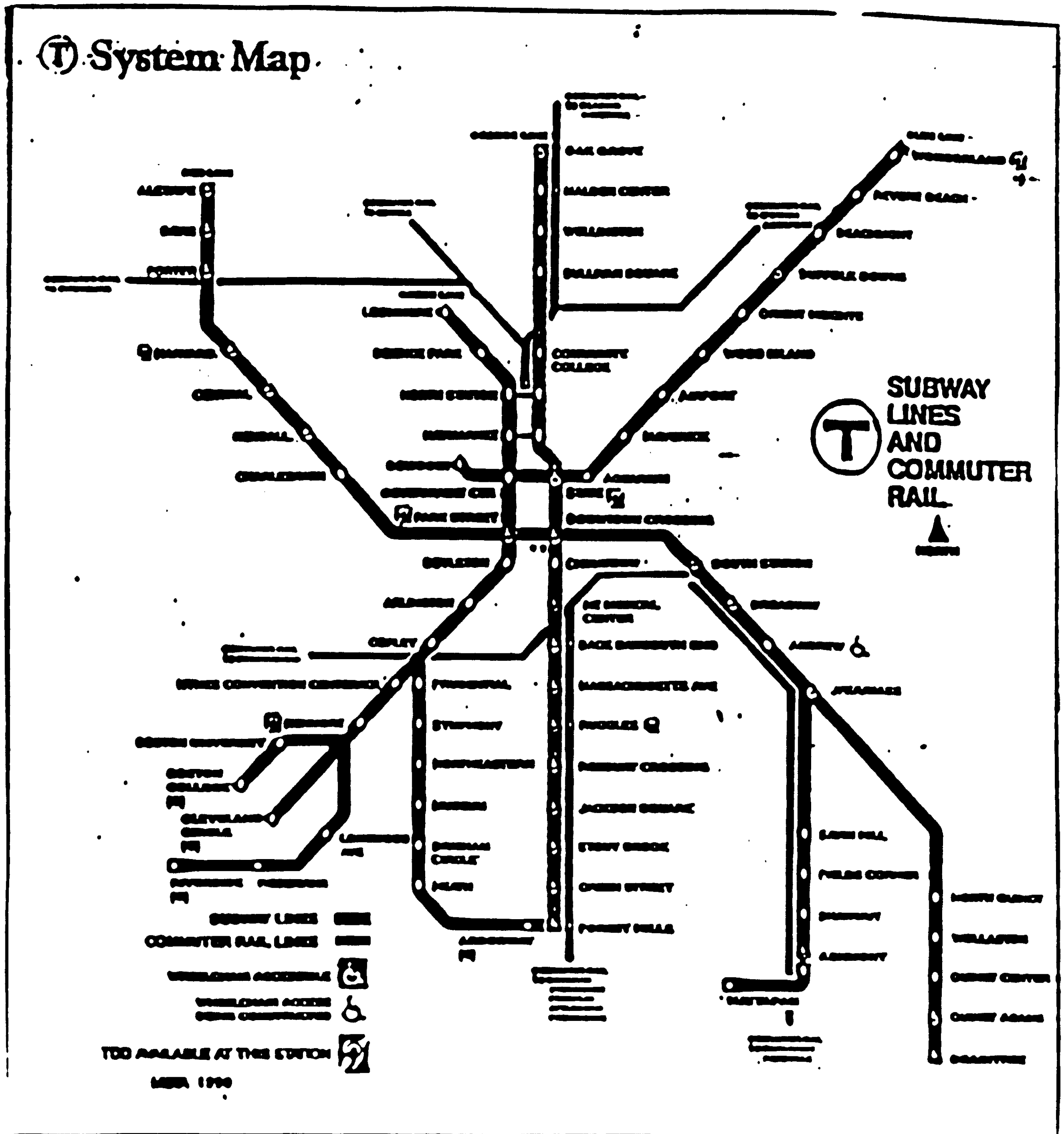

Figure 2-2 MBTA Subway and Commuter Rail Maps.

Source: MBTA

2.4 Inter-Transit Connections

Transit services is often downtown-oriented due to the higher demand in downtown commuters. Direct transit service is thus often available to the users who commute to CBD. However, demand is much lower in inter-suburban routes or other non-downtown commuting routes. The low demand in some of these routes cannot support a direct service. Therefore, some travelers need to make one or more connections in order to complete their trips since direct service is not available in these routes. Transfer time is always a big concern from these travelers. Inefficient transfer between two modes or routes often results in long waiting time and thus degrades the service quality. Indeed, transfer time is stochastic due to many factors. Passenger loading, traffic congestion, bad weather and other traffic incidents may cause bus delays. A bus delay may degrade the service quality in two ways. The delay of a bus may cause the passengers missing the buses to which they are connecting. It also prolongs the waiting time of those passengers who connect to this bus. Disruptions of other transit services such as subway or light rail can cause similar problems.

2.5 Chapter Summary

This chapter discussed four types of intermodal passenger connections in the U.S. For each type of connection, the chapter looked at its characteristics and its current status in the U.S. Through the discussion, we understand better the advantages and problems for each type of intermodal connection and how they affect the passengers in making modal choice decisions. The next chapter will review some literature on the Advanced Public Transportation Systems applications in North America and will discuss different types of technologies necessary to build up the systems.

Chapter Three

Current Development Of Advanced Public Transportation Systems (APTS)[10]

Advanced Public Transportation Systems (APTS) is a branch of the Intelligent Transportation Systems (ITS). The APTS program was created by Federal Transit Administration as part of the U.S. Department of Transportation's ITS initiative. ITS, as stated by USDOT (1996) stated, "*... involves the integration of electronics, communications, navigation, passenger information, computer, and control technologies into the transportation system. It is a tool to enhance transportation mobility, energy efficiency, and environmental protection.*" The APTS program was established "*to encourage innovation and to develop worthwhile approaches that use advanced technology to improve public transportation and ride sharing.*"

This chapter will review the development of APTS technologies and their applications around the U.S. We will first look at the APTS applications in delivering traveler information to the transit passengers. Then we review the various kind of technologies needed to support the APTS. Afterwards, this section will review the electronic payment technologies and their usage in transit.

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[10] Lam, Jimmy. The Application of Information Technologies to Public Transportation. Massachusetts Institute of Technology, 1994;

United States Department of Transportation, Federal Transit Administration. *Advanced Public Transportation Systems: The State of the Art -Update '96*. FTA-MA-26-7007-96-1

3.1 Traveler Information

APTS provide travelers with information on different mode of public transportation as well as traffic information to facilitate travelers in making pre-trip and en-route transportation decision. Information can be provided in many different locations such as home, office, transit station, transportation center, airport, and transit vehicles. Information can be classified as static and dynamic (real-time). Static information is the information that does not change with time in the short run such as bus schedules, bus routes, and maps.

Dynamic or real time information is the information that changes with time and that needs to be updated. Information on location of the bus vehicle or roadway traffic information are some of the examples of dynamic or real time information. Both the static and real-time information is accessible through a variety of media such as telephones, cellular phones, pagers, internet, monitors, variable message signs, and kiosks. In this part of the chapter, section 3.1.1 to section 3.1.4 discuss the different components of APTS in delivering the traveler information to the passengers at different points of the trip. Afterward, section 3.1.5 will present some example cases which show the applications of different ATIS components in the transit systems.

3.1.1 Intermodal Traveler Information Systems

One of the major applications of APTS is to provide intermodal transportation information for the travelers. Here we call it Intermodal Traveler Information Systems (ITIS) Intermodal Traveler Information Systems (ITIS) provides information on both highway and transit travel. For the highway aspects, the system conveys real-time information about traffic conditions, incidents, construction, weather conditions, park-and-ride lot space availability, as well as static information regarding routes, direction and travel services. At the same time, the transit components convey real-time transit vehicle arrival and departure information, system disruptions, and carpooling opportunities, as well as static information on transit services, schedules, fares, routes, stop locations, and ride-matching information. ITISs can be provided through the integration of transit and highway information on a variety of media, such as kiosks, electronic signage and personal computers.

The development and implementation of the ITIS have been developed in many cities. The systems of Anaheim, Denver, Houston, and Minneapolis/St. Paul are discussed in the FTA's Review of and Preliminary Guidelines for Integrating Transit into Transportation Management Centers. Section 3.1.5 will illustrate one of the applications of ITIS in Atlanta, Georgia.

3.1.2 Information for Pre-Trip Planning

Travelers usually plan and make appropriate travel arrangements before making a trip. Accurate and timely pre-trip information can help travelers make some informed decision such as modal choice, route choice, and departure times. Pre-trip information can be very comprehensive so that travelers can benefit from as much information as possible before making any decision. Transit routes, schedules, maps, intermodal transfer information, and fares are all important pre-trip information. With these pieces of information, travelers can set up an itinerary for their trips no matter how many modes the trips may involve. Nowadays, most new systems can help customers locate nearest transit stops and provide detailed instructions on how to get from the origin stop to the destination stop within the transit systems. The instructions show clearly which route to take at the origin stop, where to make connection to other route or mode, and finally how to get from the destination transit stop to the end of the door-to-door trip.

Phone-in Requests

When customers call in the transit agencies to obtain information, it usually takes quite a while for the operators to obtain the needed information and to communicate information back to the customers. Automation can help reduce information retrieval time and can thus handle a higher volume of calls. The next step of automation is to create a system which can update the recorded message automatically in very short intervals. A hotline with frequently updated recorded information can be set up. This can reduce or eliminate a number of operators, provide instantaneous information and can accommodate a high volume of calls at the same time. It is particularly useful during peak hours.

Internet

Nowadays, Internet is a rich source for information. Traveler information can be posted, obtained, and exchanged through the Internet. Many Internet sites provide a variety of traveler information such as real-time traffic information in addition to transit schedules and routing information. Browsing through the Internet at home or office can help the travelers to plan ahead before their trips. For example, the web site of Seattle Metro at http://transit.metrokc.gov/ provides the following information:

- Bus routes, schedules and fares information.
- On-line ride-matching
- Vanpool information
- Bicycling information
- Ferry schedules and routes
- Ferry congestion information

The ITS program at Princeton University had maintained a web site (http://dragon.princeton.edu/~dhb/) that provides very comprehensive intermodal travelers information around the world as follows:

- Information on highway, transit, and rail systems throughout the world that includes fares, schedules and timetables, subway navigation around the world, and current traffic conditions.
- Worldwide airports and airlines information.
- Directory of transportation resources
- Other information related to transportation such as publications, conference and similar proceedings and links to transportation-related web pages.

As the Internet becomes more and more popular and advanced, the development of web pages with a variety of real-time transit and traffic information is essential to facilitate pre-trip planning.

3.1.3 In-Terminal/ Wayside Information Systems

"In-Terminal and Wayside Information Systems provide schedule updates and transfer information for passengers already en route." [11] "This information includes arrival and departure times, information on transfers and connections, information on other regional transportation services and information on related services, such as park-and-ride availability".[12]

In-terminal and wayside information has traditionally been distributed in the form of static signs and paper schedules or route maps. Conventionally, only static information is available to travelers. Real-time en-route information has begun to be available to travelers with the aid of Automatic Vehicle Location (AVL) technologies, which will be discussed later in this chapter. The information includes vehicle location, status and the projected waiting time of next bus. Nowadays, real-time information can be provided via information kiosks, variable message signs, or television monitors. This kind of system is still in its early stage in the U.S. Only few systems are in operation although many are being planned.

The advance of communications technologies can expand the capacity of information flow from one transit system to multi-modal transportation systems. Both static and real-time information of other modes can be delivered to a particular transit system and can be displayed via the in-terminal and wayside information system. The communications,

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[11] Ibid.
[12] Schweiger, Carol L., Review and Assessment of En-Route Transit Information Systems, July 1995.

AVL and other type of information technologies will be discussed in details in section 3.2.

3.1.4 In-Vehicle Information Systems

In-vehicle information systems provide information on routes, schedules, and connecting services. On-board displays, announcement systems, and communication devices are part of the in-vehicle information systems to support the transit user en route. Transit agencies use these technologies to make the needed information more user-friendly, to facilitate the transit trip, and to comply with the Americans with Disabilities Act(ADA) requirements. Visual and audible information, as ADA requires, should be provided at all fixed-route transit vehicles "at transfer points with other fixed routes, other major intersections, and destination points, and intervals along a route sufficient to permit individuals with visual impairments or other disabilities to be oriented to their location."[13] Disabled person can request announcement or display of any stop inside the vehicle.

3.1.5 Example Cases

3.1.5.1 Atlanta Traveler Information Showcase[14]

The 1996 Summer Olympics was held in Atlanta, Georgia. To facilitate both athletes and visitors from all around the world, the Metropolitan Atlanta Rapid Transit Authority (MARTA) has been implementing many ITS projects to connect their multimodal transit system with an advanced transportation management system (ATMS) and an advanced traveler information system. "Traveler Information Showcase" is part of the advanced traveler information system. In the showcase, a variety of traveler information can be

[13] Transportation for Individuals with Disabilities; Final Rule. 56 FR 45640, September 6, 1991.
[14] The Traveler, "Atlanta To Showcase Traveler Information.", Issue One, July 1995, pp. 1-3.

obtained from many different devices such as information kiosks. Static information such as schedules and routes of bus and rail, fare information, direction to transit stops and stations, or information on hotel, restaurants, point of interest and other tourist information is available. Real-time information such as updates on construction, detours, road-closures, traffic congestion and incidents on major highways and roadways.

Traveler information is available through various technologies. Two hundred information touch-screen kiosks are located throughout Georgia at transportation centers, airport, Olympic arena, and many other places. Also, interactive television are installed in hotel rooms so that tourists can access the needed information directly from their rooms. Moreover, there is a dedicated transportation information channel on cable TV to show different modal information as well as real-time traffic information. Besides, traveler information is also available through in-vehicle navigation devices and wireless, hand-held computers as personal communication devices.

To develop a traveler information system, a Global Positioning System (GPS) is employed to identify specific position information. At the same time, a Geographic Information System (GIS) is applied to enter this location information and to provide mapping capability. Hence, location information on MARTA's service area and schedules can be developed with the help of these technologies. *"About 10,000 bus stops and 2500 landmarks are mapped and will be integrated with the schedule information to be used in the traveler information system. This information will be available through 200 information kiosks throughout Georgia. The kiosk interface will assist users with trip planning. The interface to Atlanta ATMS will give MARTA dispatchers access to Atlanta-area traffic conditions to improve bus-schedule performance and customer service."*[15]

[15] United States Department of Transportation, Federal Transit Administration. *Advanced Public Transportation Systems: The State of the Art -Update '96*. FTA-MA-26-7007-96-1

The Traveler Information Showcase also has an Internet component that is developed by Maxwell Laboratories. MARTA schedules and locations, route guidance, real-time traffic information and other online services are available to the public through the Internet. Besides the information showcase, Automatic Vehicle Location system will be installed in 250 MARTA buses. In-vehicle stop announcement system will be installed in 100 buses. Also, automatic passenger counting system will be brought into 15 buses. Variable Message Signs will be installed at fifteen locations around Atlanta to display the real-time customer information.

3.1.5.2 Minnesota Guidestar[16]

Inconvenience is often a weak point of mass transit. Bus schedules are easily affected by unexpected external conditions such as weather and road conditions. As an integrated APTS/ATIS, Minnesota Guidestar has completed a year-long project designed to provide real time information on bus schedules and location and trip planning guidance for the passengers on their home, office and school computers.

The Travlink study was aimed at improving the commute from the western suburbs of Minneapolis to the central business district or the University of Minnesota. Out of the 800-bus fleet, 80 buses were selected to equip with Computer Aided Dispatch/ Automatic Vehicle Location systems in conjunction with GPS and GIS to gather and update information related to passengers' travel. The bus operator and the dispatcher center can have two-way communications. Differential GPS allows the dispatcher to know the location of the bus to within 100 feet. The GPS receiver can provide position data to the vehicle's on-board processor, which then displays messages about vehicle status to the driver. Through the process of GPS-based position data by CAD/AVL system, the real-

[16] Wright, James L. "Travlink: An Intelligent Commute in Minneapolis" ITE Journal, June pp 41.

time vehicle status information can be sent to the ATIS through SmartTrack. Information are available to commuters in four ways:

1. Electronic signs
   - Located at four park and ride lots along I-394.
   - List the next five buses scheduled to arrive and their status.

2. Display monitors
   - Located at two park and ride lots along I-394.
   - List the next ten buses scheduled to arrive and their status.

3. Interactive touch-screen kiosks
   - Located at three public sites in downtown.
   - Provide current bus status, electronic schedules and map.
   - Possess features that allow travelers to plan a trip.
   - Provide other information such as updates on construction, detours and traffic incidents across the whole Minneapolis-St.Paul area.

4. On-line system
   - Allows commuters to access the electronic bulletin board through computer terminals or personal computers.
   - Distributed to employers in downtown Minneapolis and more than 300 commuters.

Evaluation

Ridership is a good way to evaluate the success of the system. Since the Guidestar system is available only in part of the whole transit system, a comparison was thus conducted between the Travlink participants and the rest of the system. Despite reduced bus services due to bus strike in October 1995, the ridership among Travlink participants was six percent greater than that among members of the control group - the regular riders. Travelers have made good use of the system. Usually they used the system to check whether buses were on time during peak hour and checked if there was any delays along their route for leisure activities on weekend.

Reactions to the Kiosks

- Bus schedules and bus fares were the most popular static menu items.
- Interactive menu was more heavily accessed than static menu.
- Users mainly were interested in the information on trip planning and road conditions such as construction and incident delays.;
- Users were less interested in requesting the real-time bus schedules that is the main feature of the interactive menu.

Reactions to the On-line system

- On-line users also accessed the interactive menu more frequently than the static menu. However, unlike kiosk users, online users relied heavily on the real-time bus schedules and often wanted to obtain more information than was available for the eighty buses involved in the study.
- Online users often get updates on the delays, incidents and detours on the interactive menu.

Next steps

Through the FHWA's model deployment initiative, a number of cities have been selected as the models to implement an intelligent transportation infrastructure. As one of the deployed model, Guidestar has installed CAD/AVL system for transit fleet management and passenger counting. In addition, signal prioritization and on-board video surveillance for security management of transit. Real time traveler information on kiosks and online information may be expanded to the whole system.

3.2 Supportive Technologies for APTS [17]

The functioning of APTS require a number of different technologies to support the complete process of information flow. For example, location technologies help identify the location of vehicles. The most essential technology is undoubtedly information technology. Information Technology (IT) is concerned with the handling, manipulating and presenting of information usually through text, pictures and sounds using a computer, tape recorder, robotic device or other external equipment. Parker(1996) defines information technology as *"a term for encompassing all forms of technology used to create, store, exchange, and use information in its various forms (business data, voice conversations, still images, motion pictures, multimedia presentations, and other forms, including those not yet conceived). Among other uses, IT includes both telephony and computer technology in the same word."*

Information technologies are fundamental for APTS applications. The application of information technologies has two major benefits. First, information technologies work with a number of technologies such as vehicle location technologies needed to obtain real-time information (with the aid of AVL and APC) and deliver information to the different users such as travelers and dispatchers (with the aid of communication technologies). Without these kinds of technologies, real-time information is hard to obtain and impossible to deliver to the travelers in a timely manner. Second, information technologies enable better real time control of operations, which leads to improvements in schedule adherence and service reliability. Hence, the technologies can reduce overcrowding and improve service quality. Increased service quality improves the image of the transit agency, increases ridership and thus brings in more revenue from passengers. This section illustrates the use of different type of technologies including

[17] Lam, Jimmy. The Application of Information Technologies to Public Transportation. Massachusetts Institute of Technology, 1994; United States Department of Transportation, Federal Transit Administration. *Advanced Public Transportation Systems: The State of the Art -Update '96*. FTA-MA-26-7007-96-1

Automatic Vehicle Location (AVL) systems, communications systems, Automatic Passenger Counter (APC), and Geographic Information Systems.(GIS) The end of this section illustrates the second benefit particularly by discussing the Automatic Vehicle Monitoring/Control (AVM/C) system.[18]

3.2.1 Automatic Vehicle Location Systems

Automatic Vehicle Location (AVL) technologies are essential for the generation and delivery of real-time information on vehicle location as well as for fleet management and operations. A number of AVL technologies are available. Each technology has different benefits and drawbacks and will be discussed as follows.[19]

3.2.1.1 Odometer and Dead Reckoning

Odometers were among the first AVL technologies to be tested. An odometer measures the rotation of the axle and calculates the distance traveled by the vehicle. Differential odometer is more precise than ordinary odometer as it has sensors on both axles instead of one. The readings are updated and recorded automatically. At the start of each new trip, the odometer will be reset. As an option, the odometer can be linked to timer so that relative locations and times of the vehicle can be collected as long as the route is fixed.[20]

Since the odometer is quite inexpensive, almost all vehicles today are equipped with odometers. However, it could be very inaccurate since it only measures the distance traveled instead of the location. When the vehicles go off-route, the location measured thereafter will be inaccurate. In addition, as the measurement is axle-based, the odometer

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[18] AVM/C system is product of different information technologies.
[19] For reference purposes, a summary of AVL systems used in a number of transit agencies in North America is included in Appendix B.
[20] Lam, 1994.

reading becomes inaccurate if the wheel is slippery or if the vehicle does not travel in a straight line.[21]

To improve the accuracy of odometers, another AVL technology called dead reckoning has been developed. Based on the measurements generated by distance and heading devices on the vehicles, dead reckoning algorithms compute the vehicle's location relative to a known initial condition. The heading device, usually in the form of gyrocompasses or magnetic compasses, aids dead reckoning to improve location accuracy to an acceptable level.[22] A dead reckoning system is quite cheap relative to other AVL technologies and is estimated to cost about $1500 per vehicle[23]. Also, dead reckoning technologies have been proven and used in some transit agencies such as Chicago CTA, Houston Metro, and London Ontario.

3.2.1.2 Global Positioning Systems (GPS)

Global Positioning Systems make use of the satellite technologies. The receiver on the vehicle receives the signals from three or more different satellites from a network of 24 satellites. The signals from different satellites are received at different times because the satellites are different distances from the receiver. The distances between the satellites and the receiver can thus be calculated from the time differentials. As a result, the location of the vehicle can be determined by a mathematical process called trilateration. The technique is simple. The location of an object in the form of a set of coordinates can be determined when the distances between the object and three external points are known. The accuracy of GPS is about the nearest 50 to 100 meters. Differential GPS can increase the accuracy to the nearest 5 to 10 meters. It is the most precise technology among all AVL applications. The only problem encountered is the potential blackout by different urban structures. High-rise buildings, tunnels or even areas with heavy foliage can easily

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[21] Ibid.
[22] Ibid.
[23] Hamiltion, G.B., Polhemus, W.L., "Automatic Vehicle Location in Canada: Location Technology", Proceedings, Automatic Vehicle Location in Urban Transit, Canadian Urban Transit Association.

block out the signals from the satellites when the vehicles pass by these infrastructures. The location information of the vehicles can be lost for a period of time.

The only hardware requirement is the GPS box that can receive the signals and perform the trilateration. It costs about $800 to $1000 an unit.[24] After years of operational field tests, most transit agencies have begun to adopt the GPS technologies as their AVL systems. The list includes Detroit SMART, Minneapolis MTC, Chicago PACE, Tucson SunTran, Miami MDTA, New York NYCT and many other agencies.

3.2.1.3 LORAN-C

Loran-C is similar to GPS in the way it computes the location of the vehicle. Like GPS, receivers are installed in the vehicles in a Loran-C system. Instead of receiving signals from the satellites, the receivers get the signals from the ground-based antennas. Loran-C technology is not as advanced and accurate as GPS technologies. The measurement of vehicle location has a marginal error of about 100 to 200 meters. Differential Loran-C can reduce the marginal error down to 30 to 40 meters.

In general, Loran-C maintains better signal locks than GPS in urban areas. However, signal locks are lost when the receiver units approach power stations. In terms of geographical coverage, Loran-C covers most of both east and west coasts, but lacks coverage in mid-west, while GPS has full coverage all over North America. The cost of Loran-C receiver is about the same as GPS.[25] Only a few transit agencies like Rochester, Pennsylvania and Sheboygen, Wisconsin have applied Loran-C in vehicle control and monitoring.

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[24] Gomes, Lamberto and Heti, Gabriel. "Taxi Emergency and Location System for Metropolitan Toronto," Proceedings from the Vehicle Navigation and Inrmation Systems Conference, IEEE Vehicular Technology Society. 1991.

[25] Hamiltion, G.B., Polhemus, W.L., "Automatic Vehicle Location in Canada: Location Technology", Proceedings, Automatic Vehicle Location in Urban Transit, Canadian Urban Transit Association.

3.2.1.4 Signposts

There are several kinds of signpost systems. Traditionally, the system consists of a series of roadside proximity beacons installed along a bus route. These beacons are known as signposts. The signposts emit their ID at a certain radio frequency that would be detected by the buses when they come by the signposts. The signpost and vehicle ID can identify the location of the bus. Passive identification is another signpost-related technology. In a passive identification system, readers are placed along the route and they read the information from the tag that is anchored to the bus. The location of the bus is thus determined and stored at the readers. In both cases, location data can then be sent to a control center through wireless transmissions. According to Gome et al.(1991), signpost equipment costs about $3500 per vehicle and $1000 per signpost. In addition to the high cost, signposts are inflexible because some of the signposts need to be relocated if a route changes.

Signpost technologies have been proven in many operation field tests. Currently, many agencies combine the signpost systems with the odometer system to increase the accuracy. Los Angeles LAMTA, Seattle Metro, San Francisco Muni, Tampa Hartline, and Newark NJC are amongst those agencies.

3.2.1.5 Map-Matching

Map-matching is a supplement to the above AVL technologies in order to remedy any errors generated by other techniques. Computer algorithms are used to match the actual path of the vehicle with a set of feasible paths on the map. If a vehicle's position is detected to be beyond any feasible path on the map, the algorithm will compute the closest feasible path and location. The vehicle will be relocated to the computed position. This technique has no hardware requirement, but intensive software requirements. It can be a cost-effective supplement if the needed software is already in place in the vehicles for other applications. Figure 3.1 illustrates the general components of AVL systems.

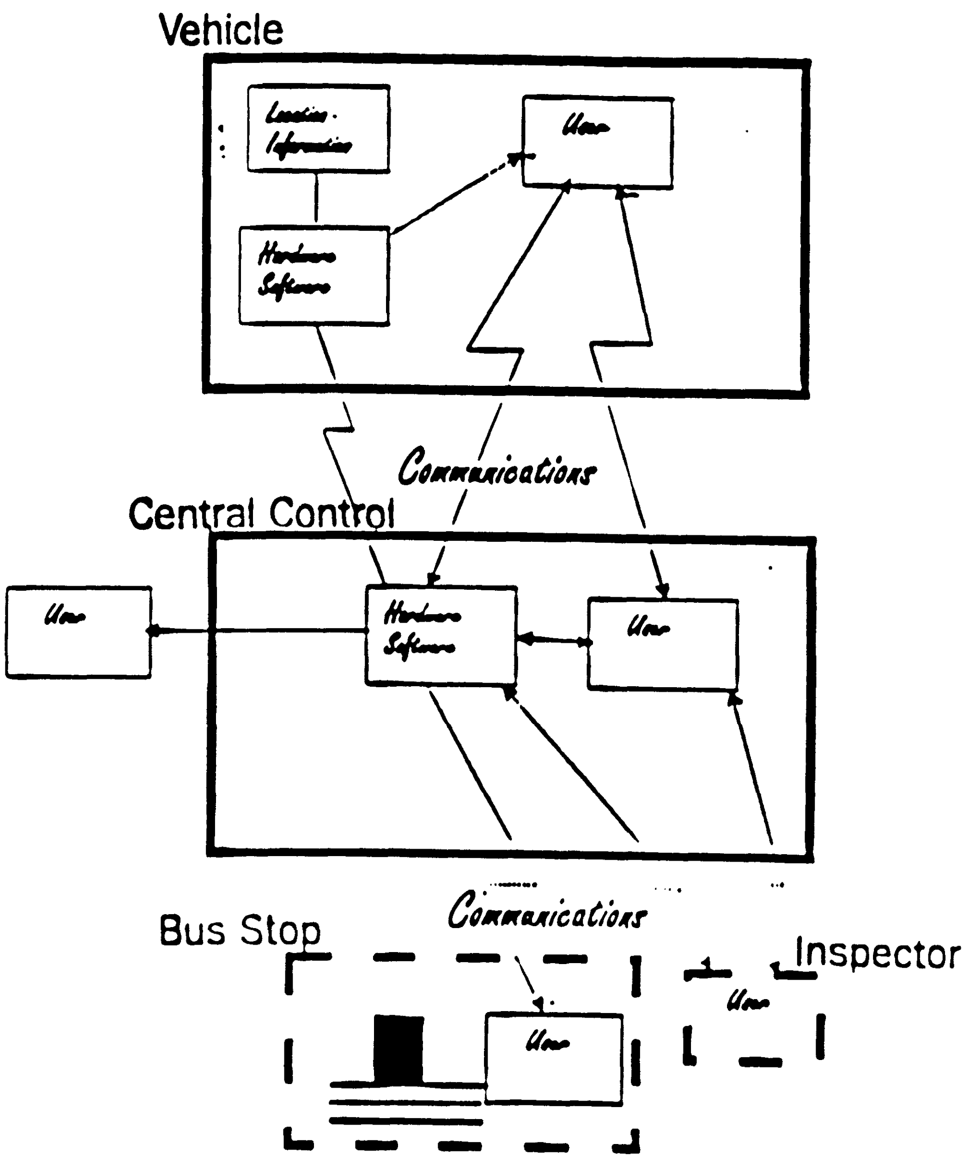

Figure 3-1 General Components of an AVL system.

Source: Lam[12]

3.2.2 Automatic Passenger Counters

Automatic passenger counters are used by transit agencies to collect data on passenger boarding and alighting by time and location. Treadle mats and infrared beams are two of the most common technologies for automatic passenger counters. Treadle mats are placed on the footsteps at the front and back doors of the vehicle. When the passengers board or alight, the pressure of the walking steps activate the APC. Infrared beams operate in a similar way. Two infrared beams are placed across the passengers' path as they board or alight the vehicle. The infrared beam is interrupted when a passenger moves up or down the doorsteps of the vehicles. Hence, the APC registers the boarding or alighting respectively. Working hand-in-hand with AVL technologies, the vehicle location is recorded when boarding or alighting occurs. The information can be stored and transmitted to the central computer for both future use and real time applications.[26]

The information obtained from APC can be used for both real-time applications and for planning purposes. The information can be inputted to real-time traveler information systems to indicate the passenger volume of the bus. A variable message sign at the bus stops can display messages like "On route number one, two buses are coming. The first one is two minutes away and is full. The second one is four minutes away and is empty." Also, information can be input to dispatchers so that they can make immediate corrective decisions. Moreover, the information is very useful in future scheduling, fleet planning and positioning new shelters for high demand stops.[27]

APC has many advantages over other data collection techniques. First, the data collection cost is lower since no personnel is required for data collection. Also, data processing time can be reduced and the procedure can be simplified. Moreover, the "real-time" nature of APC provides real-time passenger data to the travelers and dispatchers. In

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[26] USDOT, 1996.
[27] Ibid.

addition, since the information is very useful in service planning, the use of APC can increase overall operating efficiency. Today, about 20 transit agencies in North America use APC. Most of them such as Atlanta MARTA and Tucson Sun Tran use infrared beams. A few agencies like Seattle Metro and Chicago PACE use treadle mats. A summary of the APC applications in various transit systems in North America in included in the Appendix B for reference.

3.2.3 Communications Systems

Communications systems play a vital role in delivering information among vehicle operators, dispatchers and travelers. Poor communication technologies can be a bottleneck in the process of information flow. Communication technologies have already been used widely in conventional day-to-day transit operations. APTS will further increase the communications requirements. The following applications requires the use of communications technologies.

- Pre-trip intermodal transportation information at origin such as home and office.
- In-terminal and way-side information for travelers.
- In-vehicle on-board information displays.
- Communications among buses and control centers: Delivery of voices, passenger data, vehicle locations, and traffic information.
- Communications among different modes.
- Electronic fare payment systems.

A variety of communications technologies are available. This section will discuss the most common ones including conventional radios, microwave communications, cellular communications, spread spectrum system and cable/wire communications. Also, we will look at the strengths and weaknesses of each application.

3.2.3.1 Conventional Radios

Radio communications have been used in many transit agencies in daily bus operations for more than two decades. Controllers, dispatchers and operators use radio equipment to notify each other in case of special incidents, emergency or serious traffic congestion. Subsequent decisions can thus be made.

Radio signals can be transmitted on various carrier waves in UHF and VHF bands. Frequency Modulation (FM) transmission is the most common way of transmission. Since Federal Communications Commission (FCC) regulates both the bandwidth and power output, only limited frequency channels are available for the transit agencies which need to share the bandwidth with the public.

Two types of radio communications can be used: analog and digital. Analog radio communications are often subject to urban or atmospheric interference. More and more noise is added whenever the signal is processed and relayed. The signal at the destination may have been distorted greatly. On the other hand, digital radio communications provide clear reception since the analog waves are converted into digital signals before transmission. Fewer distortions occur during the digital signal transmission compared to analog signal transmission and a high signal quality is resulted at the destination.

3.2.3.2 Microwave Transmissions

Microwave transmissions, like radio communications, use electromagnetic wave as a form of transmission. Microwave has a much higher frequency than radio waves (UHF and VHF bands.) Because of the very high frequency, the signals can be transmitted with less distortions as there is much less background noise. Therefore, microwave transmission is quite suitable for voice transmissions among transit vehicles and control center. Also, the signals are less affected by atmospheric conditions since they are more line-of-sight oriented. However, microwave transmission costs much more due to the higher power requirement to emit and transmit such high frequency wave.

3.2.3.3 Cellular Communications

Cellular communications are now a popular way of telecommunications in the world. Cellular phones, for instance, have a widespread use all over the world. Indeed, cellular technologies can be viewed as a subset of electromagnetic wave transmission. By using multiple low-powered transmission antennas, a territory can be divided into a number of cells. At each cell area, a localized bandwidth is used. Therefore, the same frequency can be reused in other non-adjacent cells. As a result, the capacity of bandwidths can virtually be multiplied by the number of cells.[28]

Because of the competition in the cellular telephone market, a number of cellular telephone networks have been built by different telecommunications companies. The market competition and the use of higher frequencies result in high sound quality. Transit agencies can benefit from the existing cellular network by subscribing to the cellular services. The cost can be very high since the service provider can charge the agencies by every minute of usage. Consequently, the cellular networks have been used mostly for backup purpose for the transit agencies, in case of system failures.

3.2.3.4 Cable Communications

Compared to all other wireless communications, cable communication is the most reliable form of communication. Cable communication is not subject to any kind of interference by other signals or noises in the atmosphere. With the optic fiber technologies, the cable transmission can handle a large volume of signals and maintains the high speed. However, cable communications are not feasible for communications between mobile objects. Therefore, cable systems can only be used for transmission of

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[28] Lalonde, Georges, "Radio Communications in Urban Transit Systems", Proceedings, Automatic Vehicle Location in Urban Transit, Canadian Urban Transit Association. 1988.

information between control center, train stations, bus stops, signposts and other stationery parts of the system. Wireless communications technologies are required for communications among vehicles and control center.

3.2.3.5 Other Communication Technologies

In addition to the more common use technologies as described above. The State of the Art (1996) has mentioned the following technologies:

- *Low earth orbit satellite services: satellite communication services under development, i.e., IRIDIUM system;*
- *Personal communication services: still in the development stages, but will allow communications anywhere;*
- *Spread spectrum systems: rather than operating at a single frequency, spread spectrum systems transmit a low power signal with the information to be transmitted distributed over a band of frequencies. "Receiver intelligence" is used to decode the transmitted information. Such low powered systems need not be licensed by the FCC;*
- *Shared spectrum: co-existing on a shared spectrum basis with other non-transit public safety users through use of digital features of trunking;*
- *Wireless data services: utilization of wireless data services such as Cellular Digital Packet Data (CDPD), and commercial services such as ARDIS;*
- *Commercial mobile radio: for some transit services; and*
- *Integrated communications system: making use of a combination of mobile radio and other services such as those outlined above.*

3.2.4 Geographic Information Systems[29]

A geographic information system (GIS) is "a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modularity and display of spatially referenced data.."[30] GIS combines a relational database with multi-layered maps. A GIS requires a workstation or personal computer, a software package that contains map/database interfaces, and data from government, agencies or private sectors). Through GIS, users can conduct queries to visualize and analyze the relationship between different kind of data that share similar geographic location. Transit agencies can use GIS for operations planning, AVL operations, demand forecasting, and solving operation or planning problems. For example, transit planners can overlay the transit system map with the query-layer that shows the automobile ownership so that they can plan or modify the bus routes to serve the captive riders better. Also, GIS can help present spatial information such as bus routes, subway lines, transfer points, points of interest or any traveler's information utilizing different map layers. The State of the Art (1996) presents a variety of displays or analysis with the aid of GIS as follows:

- *bus routes, streets, parking lots, facilities, shelter locations, ridership loadings, running times, scheduling, bus assignments, dead-head routings, accidents, and customer complaints - for service and facilities planning;*
- *street and route maps, service performance monitoring, vandalism location and history, and emergency call location identification - for operations purposes;*
- *land uses, employer sites, demographic data, and travel patterns -for market development;*

[29] USDOT, 1996.

[30] Federal Interagency Coordinating Committee Technology Working Group, A Process for Evaluating Geographic Information Systems, Technical Report 1, U.S. Geological Survey Open-File Report 88-105. 1988.

- *bus route maps, trip planning route choices, on-time performance data, multi-media displays, pass sales outlet planning, and customer complaint data - for customer information/srevice purposes;*
- *customer address location, serice qualificaiton determination, and service performance statistics - for Americans with Disabilities Act service operations; and*
- *origin and destination of ridesharing applicants, custom bus service requests, and HOV lane violations -for other transportation service analyses.*

3.3 Fleet Management: Automatic Vehicle Monitoring/Control System[31]

Automatic Vehicle Monitoring/Control (AVM/C) System is an APTS application in fleet management. The system utilizes most of the information technologies described above, including communications technologies and AVL technologies. The system attains better real time control of operations and leads to improvements in schedule adherence and service reliability. Consequently, it reduces overcrowding and improves service quality from the standpoint of the user. Increased service quality attracts more ridership, and thus passenger revenue increases.

It is found that the routes equipped with AVM/C system can be operated with fewer drivers and vehicles than the routes without. Service reliability increased. Gaps in service exceeding 15 minutes were reduced by 60%. Number of runs lost due to excessive traffic congestion was reduced by 30%.

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[31] Morlok, Edward K., Bruun, Eric C., Blackmon, Kimberly J. Battle, Federal Transit Administration, University of Pennsylvania Department of Systems, and United States Technology Sharing Program. *Advanced Vehicle Monitoring and Communication Systems for Bus Transit: Benefits and Economic Feasibility.*

System Composition

The AVM/C system consists of components associated with the dispatcher location and the vehicles respectively. The components are illustrated below.

Components associated with the dispatcher location

- Central computer that collects data from the fleet.
- Processing software to sort, filter and perform short term storage of the data.
- An interface that will present and interpret the data for he dispatcher.

Components associated with the vehicles

- AVL system for providing the location information for the vehicle.
- Driver interface system for communication with the dispatcher.

In addition to the necessary components, the following components can be appended as options.

- Tactical Response Assistance Software
- Enhanced Driver Interface System
- Automatic Passenger Counting System
- Passenger Information System
- Route and Scheduling Planning Assistance Software
- Vehicle Maintenance Software

To illustrate the flexibility of the AVM/C system, Table 3-1 lists a wide spectrum of the variances from which can be selected for each component of AVM/C. The quality and features of the system can vary with different combinations of different variances of each component. The hardware and software components are mainly advisory in nature. Bus operations cannot be controlled in the bus transit system using these components. Therefore, training is important so that dispatchers, drivers and supervisors can make use of real-time data. More training would be required if more sophisticated software is installed to the system.

Variances
Advanced Vehicle Location (AVL)
• Loran-C
• Radio Signposts
• GPS
• MSS
• Deduced Reckoning
• Passive ID Tags
• Infrared Detection
• Combined System using tachometer, etc.
Automatic Passenger Counter APC
• Doorway Electric Eye Counter
• Doorway Treadle Mat Counter
• Weight Sensors
• Hand-held Electronic data logger
• Manual counting
Hardware/Software Link
• Real-time data transfer
• Batch Transfer
• Automatic data integration and analysis
• Combined system

Table 3-1 Variances of System Components for the AVM/C Systems

Source: Morlok, Edward K. et al. [13]

Vehicle Maintenance System

- Real-time Database Update
- Batch transfer
- Data upload from fleet
- Automatic exception report software
- Driver interface items

Driver Interface

- Voice radio, open channel
- Voice radio, private channel
- Digital communication, menu driven
- Digital comm., enhanced tactical
- Combination

Dispatcher Interface

- Basic display of positions and times
- Basic display plus exception report
- display with recommended tactical response
- Remote displays for supervisors

Passenger Information

- Call-in
- Bus stop display
- Bus stop inquiry panel
- In-bus display
- In-bus synthesized voice
- In-bus dispatcher announcements

Table 3-1 (Continued)

Benefits of AVM/C Systems

AVM/C systems have a number of benefits. Through AVM/C system, the vehicle operators or dispatchers can use real-time controls to respond to undesirable situations through immediate, temporary intervention. Also, planners can use the compiled data in a management information system to plan permanent changes to routes, schedules, fleet and personnel deployment.

Moreover, the system can improve dispatcher tactical intervention and control over service. It would result in more punctual bus operations, more uniform passenger loading, and compensation for traffic problems and other disturbances more quickly and effectively. Passenger will have higher satisfaction because of the improved service. Some of the drivers and field supervisors will notice better working conditions and reduced workload.

Furthermore, the system can allow some intelligent short run changes to some operations. These include changes to avoid some chronic problems and to redeploy reserve drivers, reserve fleet, and supervisors to where they are most needed. The end result is reduced operating costs to achieve the same or better performance.

3.4 Electronic Fare Payment Systems[32]

Electronic fare payment systems are payment systems that make use of electronic, computer and telecommunications technologies to handle transactions in the transit systems and to keep track of the transaction records for accounting purposes. Electronic fare payment systems typically require electronic cards, electronic card readers,

[32] United States Department of Transportation, Federal Transit Administration. *Advanced Public Transportation Systems: The State of the Art -Update '94*. FTA-MA-26-0007-94-1; The State of the Art - Update '96. FTA-MA-26-7007-96-1.

microprocessors as well as the software packages. In buses, electronic fare boxes themselves are the electronic payment systems. In heavy rail systems, the systems are integrated with the turnstile systems to control access and to process fare transactions. Travelers purchase the electronic card in advance. The card value is recorded and is deducted during each trip whenever the reader validates the information obtained from the card. The card is invalid when it reaches "zero value" or expires. Electronic fare payment systems can reduce or eliminate the cash handling problems for both passengers and operators. The instant transaction processing ability of the systems facilitates passenger movements. The following sections will introduce the types of electronic fare cards, look at a number of different payment media in transit systems, and discuss integrated fare media.

3.4.1 Types of Electronic Fare Cards

A variety of electronic payment media have been developed in recent years. To choose between different cards, we need to evaluate each card on the basis of certain criteria. Since different electronic payment technologies are under development at different paces, the features, costs, and qualities of different electronic payment cards are all different. Some have been developed for years and are widely used in different types of transit systems all over the world. Some are very advanced and have many features, but their development may be still in early testing stages and there are still many problems to solve. Some applications may be sophisticated and reliable, but costly. This section will discuss some of the fare media and look at their benefits and drawbacks. The fare media include magnetic stripe cards, contact-type integrated circuit cards, proximity cards, and capacitively coupled cards. Figure 3-2 and 3-3 illustrate the types of transit systems that use magnetic fare card and other advanced fare technologies.

3.4.1.1 Contact Types

Magnetic Stripe Cards

Magnetic stripe cards are one of the earliest developed electronic payment and have been used widely in transit (especially subway) systems around the world for years. Also, they have widespread uses in a number of commercial, banking, or institutional applications such as credit cards, ATM cards, and some student ID cards. Magnetic stripes can be marked on cards made of materials like thick paper or thin plastic. The more coercive magnetic strip cards, being used in many transit systems, have a higher security and can thus impede potential counterfeiters. On the other hand, the less coercive magnetic strip cards can be easily written and are good for temporary use. All magnetic stripe subway or bus tickets are read-only[33].

Integrated Circuit Smart Cards

The another type of contact smart card, "*Integrated Circuit Smart Cards*" as described by State of the Art(1996), "*each contains a microcomputer in addition to electronically erasable programmable memory (EEPROM) and read-only memory (ROM). The EEPROM can be used for storing information on the cash content of the card, use history, and other data subject to change. ROM is used for storing the microprocessor's operating program, as well as card identification data. The microcomputer makes possible the performance of computational routines involved in verifying a user's positive identification number as must be done for some transactions; guarding against tampering; and providing for data encryption, if necessary, for security or privacy. The high immunity to tampering made possible by encryption can help guard against a card's cash content being tampered with, while allowing its cash content to be increased by valid transactions.*"

As a predecessor of the contact-type smart card, contact-type IC EEPROM cards have been widely used as telephone cards for many years. The cards are sold in fixed

[33] Ibid.

denominations such as $10 or $20 and the card value is deducted whenever phone calls are made until the value is exhausted. A particular logical structure in their memories only allows reduction in value, but not permits increase in the value of the card.

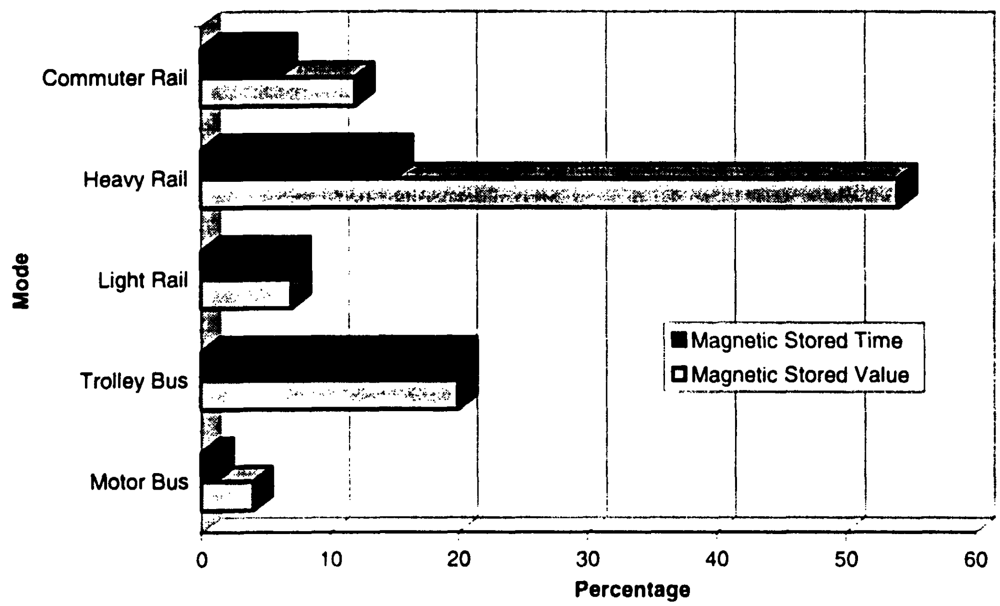

Figure 3-2 Percentage of Systems Using Magnetic Fare Card

Source: State of the Art 1994 [23].

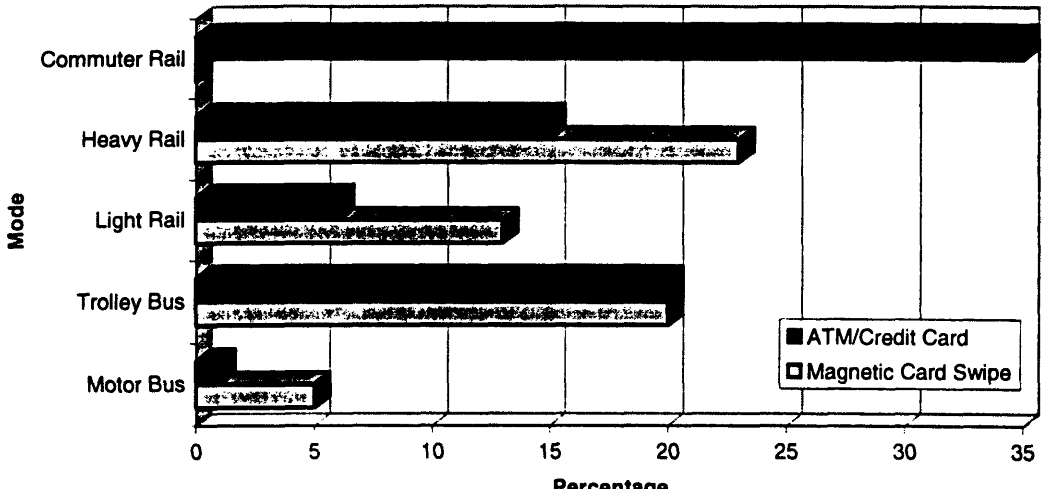

Figure 3-3 Advanced Fare Equipment Usage Percentage by Different Transit Systems

Source: State of the Art 1994 [23].

3.4.1.2 Non-contact Types

Proximity Cards

Proximity cards make use of radio frequency inductive coupling. The coupled circuits do not require physical contact but the circuits must be in proximity. An induction coil is placed in the card read-writer unit at the turnstiles or fare boxes. The coil generates an RF magnetic field that can couple to another induction coil embedded in the card. A mini power conditioning system is an essential component within the card to extract power from the RF magnetic field, regulate it, and provide it to the card's circuitry as long as the card is in the proximity of the read-write unit. The amount of energy in the RF induction field created by the read-write unit limits the range of distance between the write-read unit and the card over which proximity card systems can be made to work.[34]

[34] Ibid.

Proximity smart cards are a combination of the contactless capabilities of proximity cards and the operational capabilities of contact-type IC smart card. Its development has further advanced the smart card technology.

Capacitively Coupled Cards

State of the Art (1996) describes the capacitively coupled cards as follows:

"Capacitive coupling between card and read-white unit is the second technique used to eliminate the requirement for physical contacts. Capacitive coupling requires cards to each have two or more areas of metal foil covered by very thin layers of plastic insulator that are intimately positioned adjacent to similar areas in the read-write unit, thus creating capacitors that couple the circuits in the read-write unit and card. Both power and signals can be sent via this coupling. Capacitive coupling eliminates direct physical metal-to-metal contacts that can wear and corrode, thus increasing lifetime and reliability."

3.4.1.3 Combination

Combi-cards, which combine the features of both contact cards and contactless cards, are currently being developed in the smart card industry. People can use the card in contactless mode for quick fare payment in transportation, while they can use the card in contact mode for ATM machines or retail purchases. A multi-application card for both transit and human services seems like a natural fit. As most financial institutions have built their ATM network and electronic payment system in most commerce, transit agencies can benefit from the large infrastructure that financial institutions already have in place for card distribution and reloading of the cards through ATMs.

3.4.2 Fare Payment Media in Transit Industry

Many forms of payment media are available to the public. Most systems are moving towards the electronic payment media. In transit industry, transit passes are a popular fare media among many transit systems. Customers only need to purchase the pass in advance and can use it for a specified month or other designated duration without limits. The passes can be sold in the form of regular paper ID or electronic card. If regular paper passes are used, a transit inspector is needed at the subway entrance gate to visually check the validity of the passes possessed by the passengers. On buses, bus operators are responsible for visually inspection of the passes. On the other hand, users only need to swipe their passes through the reader on bus fare boxes or subway turnstiles if magnetic stripe cards are used. Boston MBTA and Seattle Metro are some of the transit systems that use transit passes.

Stored value fare cards are getting popular in transit industry. In transit systems such as New York City MTA and Hong Kong MTR and KCR, stored value fare cards are used. The cards are usually sold in different denominations such as $5 or $10. Fare amount is automatically deducted at each trip. For flat fare payment structure, the fare amount is deducted at the entrance gate when the card is read. Distance-based fare structure can be administered by installing readers at both entrance and exit gates. Hence, the origins and destinations (O-D) of the trips can be recorded and appropriate fare amount is deducted from the card. Also, the fare revenue can be split easily among multiple agencies with the aid of the O-D records. Figure 3-4 show the schematics of stored value cards.

The concept of credit cards can also be applied in transit fare payment systems. Transit passengers can have their transit accounts and obtain a transit charge card in the form of read-only magnetic card or bar code ID card. Each time when the passengers enter or exit the transit stations or buses, the usage of the card are recorded and appropriate fare are charged to their accounts. So far, only Phoenix Transit bus system employs a similar scheme.[35] The bus users there can pay their bus fare by credit cards. Indeed, many transit systems have started to install the ticket dispensing machine that take debit or credit cards for payments.[36] Chicago's CTA and San Francisco's BART have implemented these kinds of cashless purchase machines. Also, Seattle's Metro, Portland's Tri-Met have installed vending machines that take ATM cards and can avoid the service charge imposed by the credit card companies.

As the ongoing applications and demonstrations at U.S. transit authorities indicate, presently available smart card technology can meet many fare collection requirements. Interoperable systems will accelerate the introduction of smart cards, just as standardization benefited the personal computer industry. Many transit authorities plan to request that contractors offer multiple sources for smart card equipment so that they are not dependent on single vendor's technology.[37]

The followings are some of the transit agencies that adopt smart card technologies.

- MTC initiated the Translink project to provide a single fare that could be used in multiple transit operators. It aimed at improving customer's convenience and
- reducing the cost of administering different fare media. They started with the paper magnetic stripe card.
- Atlanta MARTA Visacash contact smart cards are widely used for traveling on MARTA.
- AATA in Michigan Ann Arbor has accepted the cards on their buses and would eventually like to issue contactless or combined "contact and contactless" card for transit pass holders.

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[35] Schwenk, Judith C., Bus Fare Payment with Credit Cards in Phoenix, draft case study report, Volpe National Transportation Systems Center, Cambridge, Massachusetts, October 1995.

[36] Multisystems, Inc. et al., Chapter 7: Emerging Fare Payment/Media Purchase Developments.

[37] Dinning, Michael G. Smart Cards: Deburking the myths. Mass Transit, July/August 1997.

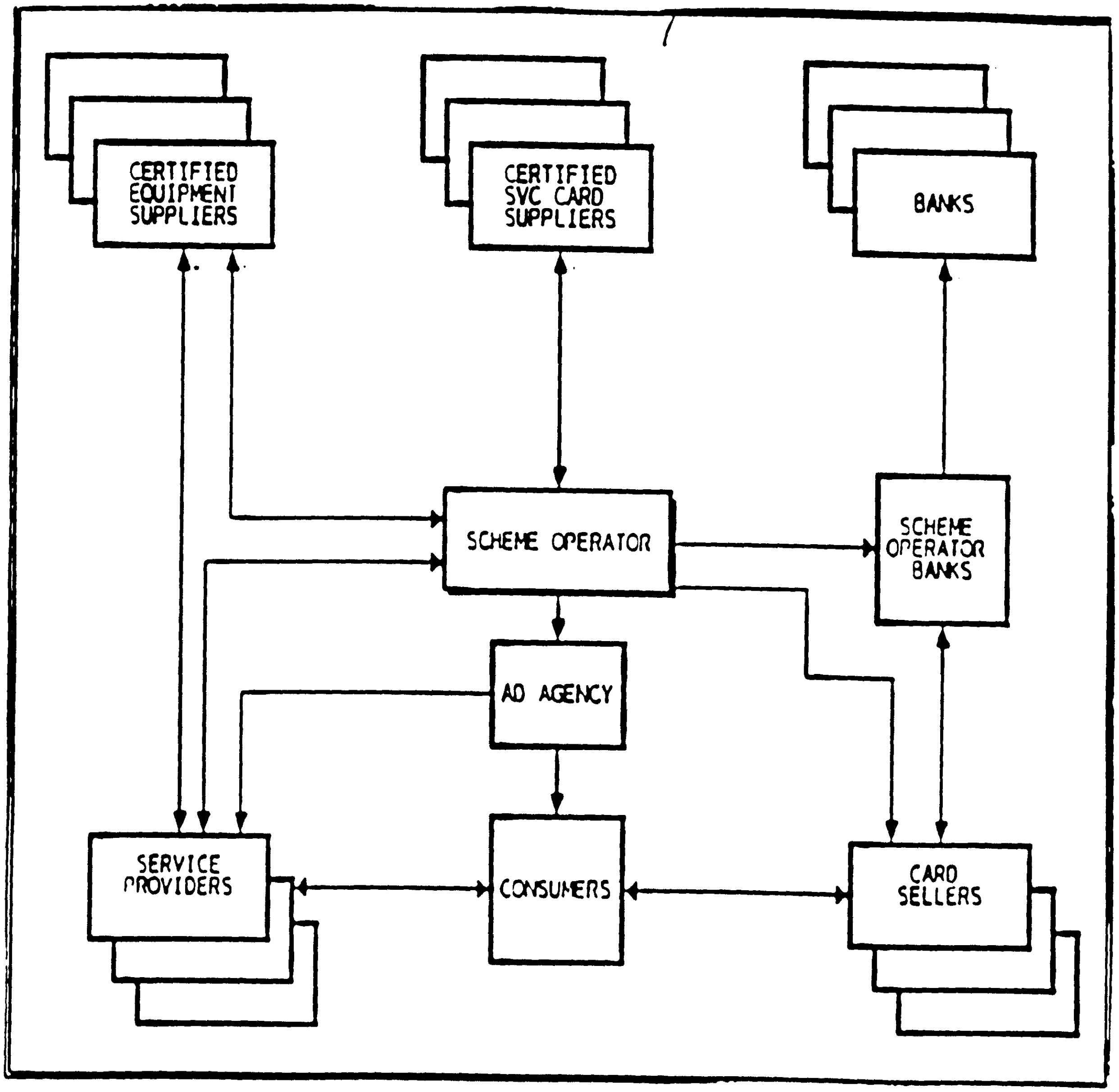

Figure 3-4 Schematics of Stored Value Cards

Source: State of the Art 1994

- Washington Metro SmarTrip
- Puget Sound area Smart Ride
- Ventura County Smart Passport
- Chicago Transit Authority Gold Card
- San Francisco Bay Area Translink Card.

3.4.3 Integrated Fare Media

The major use of smart card in the context of intermodal passenger transportation is to make the whole system a seamless system. One way to step towards the goal of a seamless system is to integrate the fare media of different modes into a single, integrated fare media. With the aid of the microprocessor installed in the card, a smart card can store a variety of information such as remaining fare value, origin and destination information, time and day of travel, and cardholder status. As a result, the same card can be used across different transit systems which have different fare policies and payment methods once the smart card readers are installed in all systems. For instance, a flat charge would be deducted from the card once the passenger uses the card in the system that has a flat fare structure. When the same passenger travels on a system that has a distance-based fare structure, the card would record the origin (O) and destination (D) information when it passes the reader on the turnstiles at the origin station and the destination station. The processor of the card would compute the fare amount based on the O/D information and the amount would be deducted from the card. At the same time, the same information would be passed to the card reader at the destination turnstile and recorded in the fare accounting system. Similarly, entry and exit times would be recorded and fare amount would be calculated accordingly in a time-based fare system. The revenue from the sales of smart cards would be allocated according to the records of the smart card readers. The application can be extended to commercial use. The same card can be used as a debit card when purchases are made in the participating stores. If the integrated fare media can be adopted by most transportation systems in the world, the card can become a true "world pass". When a traveler uses any of the modes, he would not view them as different modes. If the contactless card is used, the traveler does not even need to take out his card from his pocket or wallet and can easily transfers between all of the modes. In summary, the integrated fare media have the following generic benefits:

- Increased convenience for riders.
- Lower money handling costs.
- Increased flexibility of fare structures
- Effective and efficient cooperation between transit providers.

After discussing different types of electronic payment cards and different kind of fare media, we should realize the use of smart card technology is to facilitate both the travelers and the service providers. Although different transportation systems would adopt different kind of smart card technologies, they should be all sharing the same goal as above. Regardless of the types of the card, to summarize, a smart card should possess the following capabilities:

- Ability to speed up the fare collection process.
- Ability to traverse across different fare media.
- Ability to store value: Data can be read from and written into the card for value augmentation and reduction.
- Flexibility of card usage: Cards can be used in banking, commerce and other area.
- Low failure rate.

3.5 Chapter Summary

This chapter reviewed different types of APTS applications in the U.S. First, we looked at the applications of APTS to provide traveler information at different points on a transit trip. We discussed each of their components such as in-vehicle or wayside information systems. We also reviewed a variety of technologies required to support the APTS applications such as communications technologies and AVL technologies. All of the APTS applications require the use of the technologies we discussed. At last, the chapter discussed the electronic fare payment systems and looked at the possibilities to integrate different fare media using smart-card technology. After discussing both the intermodal passenger transportation with an emphasis on ground-air connection in chapter two and reviewing the APTS applications in U.S in chapter three, chapter four will discuss the current APTS applications in the airport ground access and look at some of the feedback from the users.

Chapter Four

Current APTS Applications In Airport Ground Access

Air travel itself is inherently an intermodal transportation The complete process of air travel consists of several trips. Air travel requires a ground trip to access the airport. Then, a plane trip takes place to take the passengers from one airport to another one. Finally, there is an egress trip to take the travelers from the airport to their destinations. In total, there are at least an air transportation mode and two ground transportation modes involved in the whole trip. Because of the inherently intermodal nature of air travel, the study of airport ground access is particularly important in the context of intermodal passenger transportation.

This chapter is a study of how we make use of the Intelligent Transportation Systems to improve the efficiency and effectiveness of the ground access to the airport. This study will focus on the access of airport via transit and high occupancy vehicle. First, the study will look at the current situation in airport ground access and analyze the problems of public transit and HOV access. Then it will examine current applications of ITS that facilitate the airport ground access and look at some of the feedback of those applications from the public.

4.1 Ground Access to Airports: Current Situation and Problems[38]

Automobiles dominate the ground access to and from all major U.S. airports. Airport shuttles, hotel shuttles, door-to-door vans, rental cars, taxis and other high occupancy vehicle (HOV) come after autos. Rail and bus transit are the least frequently used mode

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[38] Cunningham, Lawrence F. and Gerlach James H. Ground Access Assessment of North American Airport Locations. Final Report. September 1996.

for airport access in U.S. although airport-related employees often take public transit. Most U.S. cities do not have direct rail access to the airport. People need to transfer to shuttle bus or other modes from the rail station to the airport terminals. This even worsens the rail usage for airport access.

Automobiles and other Low Occupancy Vehicles

Private automobiles, taxis, and rental cars are categorized as low occupancy vehicles (LOV) in this study. Nevertheless, each distinct mode of LOV has its own characteristics and accounts for different portion of modal share in ground access to airports. The modal share of private automobile is directly related to the population density of the cities where the airports are located. Distance from the airport from CBD is also an important factor. LaGuardia Airport and Washington National Airport have the lowest use of private automobiles -- 31.5% and 33% respectively. On the other hand, airports that are located in cities where population are scattered extensively around the region such as Seattle Sea-Tac Airport (78.8%) and Toronto's Lester Airport(75%) both have a very high market share of automobiles.[39] In these cities, transit access may not be available in the outlying suburbs. For the suburbs where transit services are available, a number of transfers are required to access the airport via transit. The long travel distance between these airports to the outlying suburbs makes taxi an very expensive and unpopular option.

The nature of travel can affect significantly the market share in taxi, private limousines and rental car market. Taxis are often used in business travel. Rental cars are popular among leisure/vacation travel. Automobiles are used widely for families or friends visit. For example, Washington National Airport has the highest taxi share of 36% in the nation since business travels accounts for the largest proportion (62%) of airport usage at the National Airport which is located only six miles away from Downtown Washington.[40] Numerous business travelers use taxi to travel to attend a variety of meetings and conferences in many different government institutions, embassies, office buildings,

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[39] Ibid.
[40] Ibid.

conference centers, hotels and other business-related facilities that are all located in Downtown Washington and close suburbs such as Arlington in Virginia.

Similarly, vacation travel dominates the airport usage of the Miami International Airport. It attracts 12.4 million international travelers, which account for 43% of the total passengers of the airport.[41] The high percentage of vacation travelers can explain the fact that Miami has the highest market share of rental cars in ground transportation modal split in airport access among all major U.S. airports. The rental cars take the travelers to a number of beaches, resorts and sightseeing points through Miami and Southern Florida.

Transit and High Occupancy Vehicles

Direct transit access to airports, especially heavy rail, is rarely available in the United States. In U.S., only seven airports have some kind of rail access. The modal share for the rail access ranges from 2% to 6%, with an exception of 9% in Washington National Airport. The airports whose market shares are in the high end (close to 6%) are usually the ones being located in the cities where population densities are high and rail service is relatively competitive in terms of service quality and many other factors.[42]

In this study, High Occupancy Vehicles (HOV) includes all kind of vehicles that have a higher passenger seating capacity than LOV. On average, non-transit High Occupancy Vehicles (HOV) has a 13.2% modal share in airport ground access in major U.S. airports. Breaking down the statistics into individual modes of HOV, we can obtain the following results. New York JFK Airport has the highest share (8.4%) of airport shuttle among all major U.S. airports. Chicago O'hare Airport has the highest share (7.8%) of courtesy vans and Cleveland Hopkins Airport has the highest use of other HOV services at 15.5%.[43] Table 4-1 illustrates the modal splits of all kind of ground access to 19 major airports in U.S.

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[41] Ibid.
[42] Ibid.
[43] Ibid.

Table 4-1 Modal Splits for Ground Access to Major Airports in the U.S.

Source: Ground Access Assessment of North American Airport Locations

Modal Choice	Atlanta	Boston			Chicago			Cleveland	Wash DC / Baltimore	
	Hartsfield	Logan	O'Hare	O'Hare	O'Hare	Hopkins	Hopkins	Hopkins	Entire Region	BWI
			Departing	Arriving		Departing	Arriving			
Automobiles/Private	59.9%	40.1%	50.8%	50.6%	50.7%	69.7%	47.2%	58.5%	46.0%	64.0%
Rental Cars	14.7%	14.0%							14.0%	17.0%
Trucks						0.7%	0.5%	0.6%		
Security or Police						0.4%	0.2%	0.3%		
Taxi	7.4%	18.2%			•	5.4%	7.4%	6.4%	24.0%	7.0%
Limo (Private)		8.4%								
Taxi or Limo			25.1%	22.9%	24.0%					
Subtotal Single Occupancy Vehicles	82.0%	80.7%			74.7%	76.2%	55.3%	65.8%	84.0%	88.0%
Hotel Bus/Van	3.7%	1.9%	6.4%	9.1%	7.8%	3.9%	7.5%	5.7%	5.0%	4.0%
Rental Car Shuttle						6.5%	19.3%	12.9%		
Airport Bus/Limo	2.2%	4.2%							5.0%	7.0%
Tour Bus/Cruise Line										
Limo (Shared)	3.6%	4.4%								
Other Shuttle	3.3%					13.4%	17.6%	15.5%		
Subtotal Multiple Occupancy Vehicles	12.8%	10.5%			7.8%	23.8%	44.4%	34.1%	10.0%	11.0%
Bus	2.4%									
Rail/Train									5.0%	
Bus &/or Train			5.8%	4.9%	5.3%			•		1.0%
Subway		5.8%						•		
Ferry		1.1%			-					
Subtotal Multiple Occupancy Public Transit	2.4%	6.9%			5.3%	0.0%	0.0%	0.0%	5.0%	1.0%
Other	2.8%	2.0%	11.8%	12.1%	12.0%				1.0%	1.0%
Don't Know/No Answer			0.4%	0.6%	0.5%					
Sum of Percentages	100.0%	100.1%	12.2%	12.7%	100.2%	100.0%	99.7%	99.9%	100.0%	101.0%

Table 4-1 Modal Splits for Ground Access to Major Airports in the U.S. (cont'd)

Modal Choice	Wash DC / Baltimore					Miami		Miami	Portland	Toronto
	Dulles	National	Newark	La Guardia	JFK	MIA		MIA	PDX	LBPierson
						Weekday Departing	Weekend Departing			
Automobiles/Private	58.0%	33.0%	51.8%	31.5%	43.2%	42.8%	32.1%	37.5%	63.0%	75.0%
Rental Cars	18.0%	11.0%	11.5%	5.0%	3.8%	25.5%	24.0%	24.8%	23.0%	
Trucks										
Security or Police										
Taxi	14.0%	36.0%		32.8%	17.4%	12.2%	14.3%	13.3%	3.0%	
Limo (Private)			19.1%	19.3%	19.9%	1.9%	0.7%	1.3%		
Taxi or Limo										20.0%
Subtotal Single Occupancy Vehicles	90.0%	80.0%	82.4%	88.6%	84.3%	82.4%	71.1%	76.8%	89.0%	95.0%
Hotel Bus/Van	5.0%	6.0%	2.5%	1.1%	3.1%	3.7%	4.0%	3.9%		
Rental Car Shuttle						See Rental Car Above				
Airport Bus/Limo	5.0%	3.0%	4.8%	7.1%	8.4%	1.7%	2.1%	1.9%		
Tour Bus/Cruise Line						7.6%	19.8%	13.7%		
Limo (Shared)			1.7%	2.0%	2.8%				10.0%	
Other Shuttle						3.4%	2.7%	3.1%		2.5%
Subtotal Multiple Occupancy Vehicles	10.0%	9.0%	9.0%	10.2%	14.3%	16.4%	28.6%	22.5%	10.0%	2.5%
Bus										
Rail/Train		9.0%								
Bus &/or Train			1.1%	1.1%	1.1%	1.2%	0.4%	0.8%	1.0%	
Subway										
Ferry				0.1%	-					
Subtotal Multiple Occupancy Public Transit	0.0%	9.0%	1.1%	1.2%	1.1%	1.2%	0.4%	0.8%	1.0%	0.0%
Other	0.0%	1.0%			0.3%					2.5%
Don't Know/No Answer										
Sum of Percentages	100.0%	99.0%	92.5%	100.0%	100.0%	100.0%	100.1%	100.1%	100.0%	100.0%

Table 4-1 Modal Splits for Ground Access to Major Airports in the U.S. (cont'd)

Modal Choice	Seattle	Philadelphia	St. Louis	San Francisco	Oakland			
	Sea-Tac	PHL	Lambert	SFO	OAK			
						Average	Minimun	Maximun
Automobiles/Private	78.8%	49.0%	63.4%	46.0%	70.3%	54.1%	31.5%	78.8%
Rental Cars	5.2%	18.0%		13.0%	15.0%	13.8%	3.8%	24.8%
Trucks						0.6%	0.6%	0.6%
Security or Police						0.3%	0.3%	0.3%
Taxi	2.6%	5.0%	12.0%	11.0%		14.2%	2.6%	36.0%
Limo (Private)		10.0%	0.1%	2%		10.2%	0.1%	19.9%
Taxi or Limo					5.6%	16.5%	5.6%	24.0%
Subtotal Single Occupancy Vehicles	86.6%	82.0%	75.5%	72.0%	90.9%	82.7%	65.8%	95.0%
Hotel Bus/Van	3.7%	3.0%	6.1%	6.0%	2.5%	4.4%	1.1%	7.8%
Rental Car Shuttle			2.1%			7.5%	2.1%	12.9%
Airport Bus/Limo	6.6%	4.0%	0.9%			4.9%	0.9%	8.4%
Tour Bus/Cruise Line		3.0%		4.0%		6.9%	3.0%	13.7%
Limo (Shared)			0.8%	3.0%		3.4%	0.8%	10.0%
Other Shuttle	1.7%		12.5%	12.0%	1.9%	7.0%	1.7%	15.5%
Subtotal Multiple Occupancy Vehicles	12.0%	10.0%	22.4%	25.0%	4.4%	13.2%	2.5%	34.1%
Bus		1.0%				1.0%	1.0%	1.0%
Rail/Train		2.0%				5.3%	2.0%	9.0%
Bus &/or Train	1.4%			3.0%	4.2%	2.0%	0.8%	5.3%
Subway						#DIV/0!	0.0%	0.0%
Ferry						0.1%	0.1%	0.1%
Subtotal Multiple Occupancy Public Transit	1.4%	3.0%	0.0%	3.0%	4.2%	2.2%	0.0%	9.0%
Other		5.0%	2.1%		0.5%	2.5%	0.0%	12.0%
Don't Know/No Answer						0.5%	0.5%	0.5%
Sum of Percentages	100.0%	100.0%	100.0%	100.0%	100.0%	101.1%	92.5%	101.0%

Ground access to the airport can be divided into three major market segment: Travelers, "greeters and meeters", and airport employees. Each market segment has its own characteristics. Therefore, when we look at ways to improve ground access to the airport, we must consider the three markets separately.

Travelers

There are two types of travelers: business travelers and leisure travelers. The expenses of business trips are often reimbursed by the companies. Therefore, the business travelers are usually less sensitive to prices of travel. They are more willing to a pay higher cost for time and convenience which are the more important factors for them. They usually carry light baggage. Leisure travelers are more price sensitive than business travelers, but still are less price sensitive than regular commuters. Baggage handling is a big issue for this type of travelers.

Greeters and meeters

Greeters are those who welcome the arriving travelers or say farewell to departing travelers. Meeters are those who have meetings with the travelers at the airport. This group of people usually come to the airport during midday. This market resembles the off-peak market.

Airport employees

Airport employees account for a large proportion of airport users. Since they need to commute to the airport daily, their concern with transportation cost are just like other commuters. Also, they do not need to carry any luggage. Transit seems to be a good option for this market segment. As stated by Anis(1997), there is a catchment area for the airport employees since they usually live around or close to the airport. This market resembles other commuting markets. Instead of going to CBD, these group commute to the airport.

Factors affecting Ground Access Choices: Problems for Airport Ground Access by Transit

There are many factors that affect the modal choice of ground access to the airport. In particular, transit access to airports has a number of barriers. First of all, the peaking characteristics of airlines are quite different from those of transit services. According to Anis(1997), midday is often the peak period for flight departures and arrivals. The rest of flights departures and arrivals are dispersed quite evenly throughout the day. On the other hand, transits have dual peak periods in the morning (usually around 7-9am) and afternoon (usually around 3-6pm) respectively. The compatibility of the airport service hours and the service hours of public transit is important. The problem of difference in peak period is not a problem for the market of airport employees, who commute to airport in regular commuting peaks. However, it affects the other two markets significantly. If the service hours of a particular transit mode is concentrated on certain time of the day, travelers are less likely to access the airport via that mode at other hours that have low service frequency. This applies to most commuter rail services. Commuter rails usually serve mainly the peak period travelers such as students or working class. Midday and night services are typically less frequent in commuter rail lines. As a result, these commuter rail services cannot meet the needs of most travelers who have different departures and arrivals throughout the day.

Baggage Handling

For the market of Travelers, baggage handling is another important issue that affects the modal choice. Because of the duration of air travel, most travelers carry baggage on the course of their travel except some short-trip business travelers. Hence, transportation of both travelers and their baggage needs to be considered for each ground transportation modes. For direct-access modes such as autos, taxis and door-to-door vans, travelers only need to load their baggage to the trunk of the cars and unload them when they get to the airport. Baggage handling, however, is a big problem in public transit.

Since transit is not a direct mode that can take the travelers directly from their homes to the airport, transit riders need to walk, get on the bus or train, transfer to other bus or train, get off and walk to the terminal. It is very inconvenient for them to carry the baggage in the transit trip unless special accommodations are provided. It is even harder for disabled persons to do so. The first question to be asked is whether the transit compartments have enough space for both passengers and luggage. Conventional transit vehicles do not allow spaces to place baggage. Also, there is not much space for the passengers to move inside the vehicle with their baggage. For buses, door step and narrow door are obstacles to boarding and alighting movement of passengers with baggage. For heavy rail, the fast closing movement of the doors may not allow enough time for boarding and alighting movements of the slower streams of passengers with baggage. If transfers are required, more walking movements would be involved. When transfers take place within the same station platform, the passengers only need to walk across the platform and get on to the other train. However, it is much harder for passengers to handle the baggage when the transfers require walking up and down the stairways or long distance walk.

Service Frequency

Service frequency and travel time are certainly among the most important attributes considered in modal choice. Travelers can have more flexibility in their schedule as service frequency increases. If the transit mode has a long headway, the passengers have to take the bus or train at a particular time. Consequently, they arrive at the airport earlier than needed and spend more time at the airport. Departing passengers still can plan their plan their transit trip based on the transit schedule. However, the situation for arriving passengers is more adverse since they cannot plan their flight according to the bus or subway schedule. After claiming the baggage, the travelers need to wait for a period up to the length of headway.

Travel Time

Travel time is obviously an important factor to consider when making mode choice decisions. Perceived travel time often affects the decision more than actual travel time. Wait time and transfer time is often perceived to be longer than actual. Inefficient scheduling of different transit routes may result in long waiting time for transit connections. For example, there is a connection between bus 1 and bus 2 at point A. Ideally, bus 1 and bus 2 arrive and depart at the same time so that passengers can transfer between the buses instantaneously. However, it is not often the case. Sometimes bus 2 departs before bus 1 arrives. As a result, the bus 1 passengers miss the connection to bus 2 and need to wait for the next bus to come. If bus 2 has a long headway, the passengers must wait for a long time. The long wait time for connection can create a negative image for transits.

Familiarity of Transit Routes

Some travelers may not be familiar with the transit routes. It is a particular concern for the tourists, but not a problem at all in both markets of airport employees and meeters and greeters. Because of the non-familiarity with the routes, travelers may refrain from taking transit to avoid confusion of the routes and to prevent from getting lost.

After discussing the current situation and problems of the airport ground access, the following sections will review some ITS applications that facilitate airport ground access. To date, few ITS applications were available to facilitate airport ground access. Information kiosk is the only ITS application that are popular in airports. First, we will look at the use of information kiosks in Los Angeles International Airport and some airports in California and analyze the user characteristics and their feedback. Then, we will discuss the ITS applications designed for the new Hong Kong International Airport and Atlanta Hartfield International Airport.

4.2 Los Angeles International Airport and Selected Airports in California[44]

In 1993, an airport ground transportation information kiosk demonstration program has been taken place at four airports in California: Metropolitan Oakland International Airport, San Jose International Airport, Sacramento Metropolitan Airport, and Burbank Airport. At the same time, 50 information kiosks of the same kind were installed in Los Angeles International Airport. These kiosks are touch-screen kiosks that provide travelers ground transportation information as well as information on airport services. A handset is also installed at the kiosks for the passengers to make reservations on a selected service. Each kiosk consists of the ground transportation information database of its own airport as well as those of other four airports. As a result, the travelers can access the information of other four airports. The kiosks were installed in both arrival and departure areas in the airport so that the passengers can access the information while they wait for departure or after they just arrive. Appendix A illustrates the information provided by these kiosks.

A survey was conducted to look at the kiosk user characteristics and to evaluate the user satisfaction with the information provided. The survey target is quite comprehensive. It includes the arriving and departing passengers, passengers who connect between flights, and meeters and greeeters.

Surveys were conducted on both kiosk users and general airport users. The sample size consists of 896 kiosk users and 1064 airport users. The kiosk users were interviewed at different locations at each airport so that the data can represent the kiosk use at each particular location. Respondents are selected sequentially throughout the interviewing period. Interviews for airport users are only conducted in certain part of the airport. The

[44] Gosling, Geoffrey D. and Lau, Samuel W. Evaluation of a California Demonstration of an Automated Airport Ground Transportation Information System. 1994.

responses of the airport user interview represent only the airport users who wait in the terminal lounges, baggage claim areas, and ground transportation curbfronts.

4.2.1 Characteristics of Kiosk Users

Of all the kiosk users who respond to the surveys, 31.9 percent were arriving passengers, 27.2 percent were departing passengers, 7.3 percent were passengers who make flight connection, 32.9% were meeters and people who drop people off at the airport. Other kiosk users only accounted for the remaining 0.7 percent. In all five airports, male respondents accounted for about two-third of all kiosk users at each airport consistently. Most of the kiosk users were in the age groups of 18 to 35 (47%) and 35 to 50 (37%). These groups included the college students, young and mid-career professionals.

In terms of trip purpose for those air-traveling kiosk users, vacation trips accounted for 42.6 percent of all trips. Business trips came second (28.0%) and 2.8 percent traveled for convention or conference. Friends and relatives visitors accounted for 17.2 percent of all trips and the remaining 9.4% were trips with other purposes.

Half of the air passengers who use kiosk traveled alone. Twenty-nine percent of the users traveled with one other people. Air party size of three and four persons accounted for 8 percent and 7 percent of all kiosk users. The remaining six percent of kiosk users had an air party size of more than five people.

More than half of the kiosk users had two or less air trips either originating from or destining at the airport being surveyed. Travelers having increasing number of trips accounted for a lesser portion of kiosk users. This result reflects that kiosks were mostly used by travelers who had less experience traveling via the airport where those kiosks were in place.

4.2.2 Modal Split of Kiosk Users

The majority of kiosk users commuted to the airport by automobiles. Twenty-eight (28) percent were either dropped off to or picked up from the airport by someone who uses automobiles. Twelve percent traveled by automobiles which were parked at the airport. Rental cars and door-to-door van each accounted for 15 percent modal share. Nine percent of the kiosk users used taxi. The remaining 12 percent of the kiosk users were either not sure of their modal choice or they traveled by other modes.

4.2.3 Information Sought by Kiosk Users

When being asked whether they use the kiosk to seek for specific information or just out of curiosity, only Los Angeles International Airport has a high percentage (72%) of the respondents who used the kiosks to obtain specific information. In other four airports, more respondents used the kiosks out of curiosity rather than seeking specific information.

Different users may seek for different information at the airport kiosks because they contain many different categories of information. Twenty three (23) percent of the kiosk users sought for specific transportation services such as door-to-door vanpools. Eighteen percent of the users sought for information on different ground transportation options. Hotel information accounted for 17 percent of all categories. Fifteen percent of the users sought for information on the airport terminal. Information on rental car, taxi, map, and parking accounted for five percent, two percent, four percent, and one percent of all inquiries. Twenty-six percent of the inquires went to other type of information.

The information kiosk indeed influenced the modal choice of ground transportation of the travelers. It affected the arriving passengers the most. Thirty seven (37) percent of the arriving passengers changed their ground transportation modes after using the kiosks.

Only nine percent of the departing passengers and four percent of the connecting passengers changed their modal choices because of the kiosks.

The types of information sought by arriving passengers were different from those sought by departing passengers. For instance, the largest portion of arriving passengers (24%) used the kiosks to look for specific transportation services information. Also, a higher percentage of the arriving users sought the information on hotel, rental car, taxi, and map. At the same time, a higher percentage of the passengers in departure area looked for the information on airport terminals. This reflects the particular needs of each type of passengers.

4.2.4 Kiosk Effectiveness

The information kiosk was quite effective in several ways, as reflected by the survey results. First, it provided useful information for travelers. Half of the kiosk users found the kiosk information very useful to them. Nearly a quarter of all users found the information somewhat useful. The remaining 12 and 13 percent of the users found them not very useful or not useful at all. Also, the information kiosk seemed to provide most travelers with the information they want. Half of the kiosk users (51.2%) had been successful obtaining the needed information from the kiosk. Thirteen point nine percent (13.9%) has been partially successful obtaining the needed information. About one-third (34.9%) could not obtain the desired information from the kiosk. Moreover, the kiosk was very user-friendly. The kiosk was generally very easy to use. (76.5%) Some (18.8%) found it somewhat easy to use. Only a small portion (3.4%) of the users found it somewhat difficult to use and very tiny portion (1.3%) of them found it very difficult to use. The responses of the ease of use was compared between different categories according to gender and age. The ease of use was very similar for male users and female users. Although ease of use decreased as the age increased, the majority of all age groups found the kiosk very easy to use. The results reflected that the kiosk was user-friendly regardless of gender or age.

If a product is effective, users usually would use it again. A majority (58.8%) of the users indicated that it was very likely for them to use the kiosks again on the next visit to the airport. About a quarter (27.6%) of the users said they were somewhat likely to use the kiosks on the airport visit. Only a minority of the users (9.3% and 4.3%) mentioned that they were not too likely and not likely at all to use the kiosks at their next airport visits.

Finally, the arriving passengers who had used the kiosks were asked about the utility of providing ground travel information at the origin airport. Forty point six (40.6) percent and 27.2% of the users found the utility very useful and somewhat useful respectively. Only less than a third of the users found it not very useful or not useful at all. These users maybe those who were picked up by friends or relatives or who drove back home themselves or curious users with no special purpose in using the kiosks. The fact that majority of the users find the information useful supports the further development of information kiosks in airports and possible expansion to other places such as transit station and tourist center.

4.3 Hong Kong International Airport

Like many other densely populated cities, Hong Kong relies heavily on public transit. The very high demand makes the transit system in Hong Kong an extensive, fast and reliable system with high service frequency and high accessibility. Public transit often has the highest modal share of all modes. Hence, travel time and service frequency is not so much a problem as other airports. Baggage handling becomes almost the only problem needed to be handled in airport access at the new Hong Kong International Airport.

Remote Baggage Check-in

The new Hong Kong International Airport will have a remote baggage check-in system as well as the regular check-in facilities at the airport. The remote check-in counters would be located at two main Airport Express Rail Stations: Hong Kong Station and Kowloon

Station. The remote check-in facilities aim at facilitating the passengers who would access the new airport by the airport railway. At the rail terminals, the baggage handling system would be similar to the regular systems at the airport. Passengers can go to the appropriate airline counters at the rail stations, check-in their baggage and get the boarding passes. The baggage would be transported to the airport by sealed container within dedicated carriages or rail cars via the airport expressway (highways) or the airport railway.

Transportation Center

The modal split of ground transportation access to the new airport is estimated to be 43 percent for travelers using rail link, 22 percent for automobile users, 19 percent for taxi users, and the balance is split among bus services, tour coaches, and hotel vehicles.

The transportation center (TC) would be located directly adjacent to the passenger terminal building at the new airport. It will be a very large four-level intemodal ground transportation complex. The complex consists of the MTRC Airport Express Link rail station and a public transportation interchange with facilities for buses, taxis, tour coaches, hotel shuttles, and parking facilities. Variable Message Signs will be installed at the transportation center to display the flight information as well as the intermodal transportation information.

Airport Express Link will be part of the inter-linked railway network in Hong Kong. The main MTR subway, KCR commuter link, the Airport Express Link, the future Northwestern Railway Link and the light rail systems will be all linked together to serve the whole Hong Kong region. The transportation center thus provides a gateway to the airport from the whole region.

Internal Transportation Facilities at the Airport

Three link bridges distribute the travelers from the transportation center, via a transition deck, to specific check-in counters within the terminal departures hall. Forty-eight travelators (automated walkways) will be installed all over the airport to reduce the walking requirement of the passengers. The travelators can take the passengers directly to different airport facilities. An automated people mover will also be built to move passengers around the airport in a longer distance. The people mover system has stations in different terminals, the transportation center, and the shopping area at the airport. Since the passenger terminal has an area of 515,000 square meters, both the travelators and the automated people mover can reduce the walking requirement of the passengers.

4.4 Hartfield International Airport, Atlanta, Georgia[45]

As a component of the computerized transportation management system, airport kiosks at the Hartfield International Airport assist passengers to choose modes. They display the real time highway traffic information as well as alternative routes. The kiosks in the airport form a two-way kiosk system. They enable air travelers to access highway congestion, travel times and suggested travel routes once they get off the plane. Links are established to several airlines to provide updated flight information to kiosks located at visitor impact locations such as Olympic venue sites, Georgia world congress, Peachtree center and Georgia welcome center. All these kiosks work in coordination with the information showcase discussed in Chapter Three.

For air passengers, convenience was perceived as the most important service variable. A passenger survey was conducted on air travelers at the Hartfield International Airport on their opinion on airport access by transit. Use of transit to avoid traffic was the top-ranked advantage using transit. Handling luggage was the disadvantage mentioned most.

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[45] The Traveler, "Atlanta To Showcase Traveler Information.", Issue One, July 1995, pp. 1-3.

Suggestions

As rail directly goes to the airport, more applications can be developed to create an information flow among the rails, the airport, and the planes. Train information can then be obtained at the airport or the planes. In-train display can be designed to deliver the flight information as well as other intermodal information.

4.5 Summary

Currently, there are only a few number of ITS applications at the airports around the world. Airport information kiosk is the first step of applying ITS technologies to facilitate the air travelers. However, many existing ITS technologies can be explored and applied in the context of airport. Next two chapters will focus on how to apply those ITS technologies in the intermodal passenger transportation for the ground access to Boston Logan International Airport as a case study. Chapter Five will first look at the background of Logan Airport, and the proposed Logan 2000 and Intermodal Transit Connector (ITC) project. Afterward, Chapter Six will present a prototypical design of an intelligent intermodal transportation system for ground access to the Logan Airport.

Chapter Five

Background of Logan Airport, Logan 2000 and Intermodal Transit Connector [46]

This chapter will present the background of the Logan Airport, Logan 2000 project and the Intermodal Transit Connector. First of all, Section 6.1 will look at the general background of the Logan Airport as well as the modal split in ground transportation access to the Logan Airport. Section 6.2 will then present a number of transportation components of the Logan 2000 Project. Section 6.3 will look at the proposed Intermodal Transit Connector. Both Sections 6.2 and 6.3 will show how these proposed infrastructure would help improve ground access to Logan Airport in the future. All of the background information will pave the way to the discussion of a prototypical design of an intelligent intermodal passenger transportation system for access to Logan Airport in the next chapter.

5.1 Background

Boston's Logan International Airport is the sixteenth busiest airport in the U.S. The airport is unique in many ways. It is only three miles away from downtown Boston. Also, it is one of the seven airports in U.S. that have rail access. Rail transit has a 6% modal share of airport ground access. In 1993, Logan handled about 24 million

[46] Cunningham, Lawrence F. and Gerlach James H. Ground Access Assessment of North American Airport Locations. Final Report. September 1996;

Dieterich, M., Toney, D., and Miller, J. Logan Airport Intermodal Transit Connector: A Strategic Link in the Metropolitan Boston Transportation System. Interim Report. MassPort Infrastructure Development Research Group. MIT Center for Construction Research and Engineering. October 1997;

Rizzo Associates, Inc. Technical Memorandum. Evaluation Process and Criteria Logan 2000 People Mover Project. 1996.

passengers. With a projected growth rate of 5 to 10%, the number of passengers is expected to reach 45 million by year 2010. Figure 5-1 illustrates the location of Boston Logan International Airport.

Logan 2000 is an improvement plan with a goal of accommodating growth. Previous travel demand forecasts have shown that there is a need of a second airport in the year 2000. Logan 2000 can postpone the need for a second airport to supplement Logan. Logan 2000 includes the renovation of existing terminals, construction of new terminals, construction of a people mover system, and the activation of automatic vehicle inventory system.

The land-side access conditions should be managed well to cope with the future increased demand for air travel. The increase in the use of High Occupancy Vehicle (HOV) to access the airport is essential both in meeting the future increased demand of airport users and in meeting mitigation commitments. A series of initiatives to improve the use of HOV to access the airport has been undertaken to increase the efficiency of the transportation systems for ground access. A balanced ground access transportation can help Logan to maintain its economic competitiveness and to meet the regional economic, transportation and environmental goals.

Currently, High Occupancy Vehicle usage, including transit, airport bus, hotel bus, van, ferry, and all other kind of shared vehicles, has a 28% share of all ground transportation access to airport, despite the dominance of automobile's usage for airport access. Table 5-1 shows the detailed modal split of ground transportation access to the Logan Airport. They include the MBTA subway, water shuttle, hotel shuttle, private bus and limousine services. To meet regional economic, transportation and environmental goals, the share of HOV in airport ground access should increase from 28% to 35%. Therefore, a high

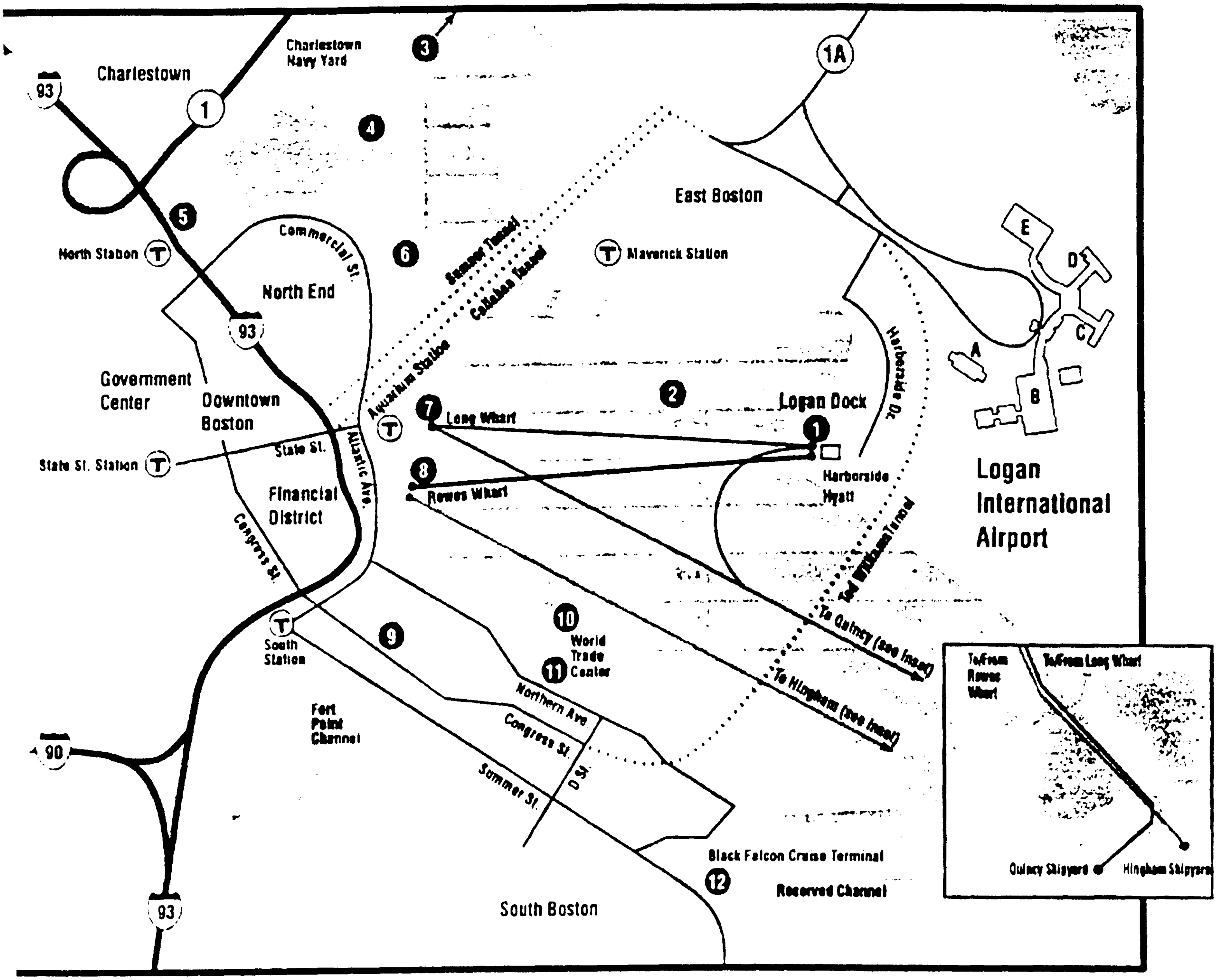

Figure 5-1 Boston Logan International Airport.

Source: Massport Official Web Page [http://www.massport.com/logan/map.gif]

MODE	Modal Share %
Private Automobile	40.1
Taxi	18.2
Rental Car	14.0
Private Limousine	8.4
Subway	5.8
Shared Limousine	4.4
Airport Bus	4.2
Other	2.0
Hotel Bus/Van	1.9
Ferry	1.1
Total	100

Table 5-1 Modal Split for Ground Transportation Access to Logan Airport

Source: 1993 Air Passenger Survey, MASSPORT

level of transit[47] usage is desired to attain this goal. As noted above, six percent of the air passengers use the MBTA Blue Line subway for airport access and egress. Airport shuttles transport these passengers back and forth between the airport terminals and the MBTA airport station. The target of Massport is to double the transit share in airport ground access from 6% to 12%.

[47] Transits are considered a type of HOV in *Ground Access Assessment of North American Airport Location by Cunningham et al.*

The Intermodal Transit Connector (ITC) is a futuristic "urban ring" concept in linking different transit modes to the Logan Airport. Unlike traditional transit routes which usually run from different outlying area of the cities towards downtown (radial routes), ITC runs on a circumferential route linking major transportation centers including South Station, Logan Airport, and Chelsea Commuter Rail Station. The connector increases the number of the connection points among different MBTA subway and commuter lines as well as an alternative transit route to access the airport. MBTA subway and commuter systems map are shown in Figure 2-2 earlier in the thesis. ITC is expected to be an heavily used transit route in earlier 21st century. Major components of ITC, including the circumferential transit system and modernization of the Blue Line, are expected to generate additional transit services accessing the airport. Also, as shown from chapter three, Advanced Public Transportation System technologies can help integrate the new systems and facilitate the passengers in many ways. Section 5.3 will discuss the ITC in details.

As one of the strategies in Logan 2000 project, Transportation Demand Management (TDM) is a good way to solve many transportation problems and a good method to affect people's decision to switch modes. Since airport employees do not have the baggage handling problem encountered by most air passengers, they are more able than air passengers to use transit to access the airport. The TDM strategy is to force the airport employees to use transit by converting employee parking spaces to commercial parking spaces. As air travel activities grow, the demand for parking spaces will increase. Higher parking fees can be charged for commercial use after the conversion to discourage travelers from using automobiles as well as maintaining the parking revenue (Lower quantity demanded but higher price) for the airport. The parking constraints and pricing strategies may induce both the air passengers and the airport employees to shift to HOV modes.

In spite of various demand and supply management strategies to affect travelers' mode choice decisions, a majority of passengers still access the airport via automobile or taxi.

The pickup and drop-off activities are expected to increase significantly by year 2000[48]. Taxi traffic will experience a similar growth. The further growth of automobile and taxi will worsen the congestion at airport roadways and terminal curbs. At the same time, this phenomenon will have a negative impact on the HOV such as door-to-door van or long distance shuttle bus services.

5.2 Logan 2000 Project

The Logan 2000 project consists of several components. Automatic vehicle inventory system, people mover system, elevated walkway, the third parking garage, and the automated taxi dispatch system are the transportation components of Logan 2000. Figure 5-2 illustrates the schematic of various components of the Logan 2000 project.

Both the people mover system and the automated walkway system facilitate internal passenger movements among different passenger terminals, parking garages and the MBTA subway station. The people mover system can connect the terminals to the MBTA subway Airport Station directly. It thus eliminates the use of a connecting shuttle and creates a seamless system. The people mover aims at providing high quality, convenient and reliable service for air passengers, tourists and employees. It can also reduce the environmental impacts caused by buses. MBTA ridership is expected to increase because of the convenience. The automated walkway system is designed to connect the passenger terminals to the existing and the new parking garages.

Automatic Vehicle Inventory (AVI) system is designed to control the curbside airport traffic: the dwell time and repeated circling of airport terminals by private transport

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[48] Logan Growth and Impact Control Study estimated that the pickup and drop-off activity will increase by 30% to 60% during the period between 1994 and 2000.

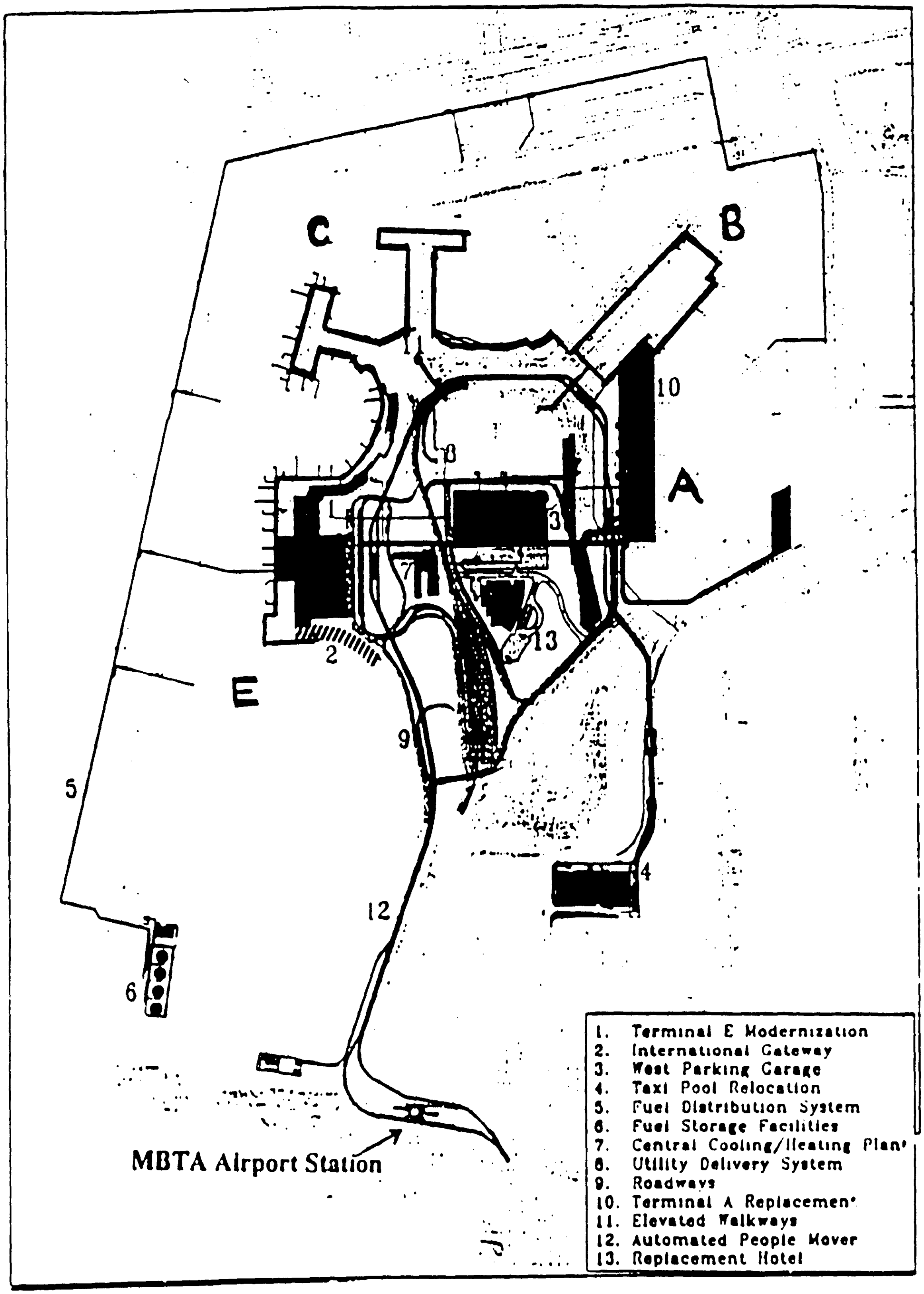

Figure 5-2 Logan 2000 Schematic

Source: Massport

operators. Billings can be made to those operators according to the dwell time and number of circling. The system can reduce the emissions from idling vehicles as well.

The third parking garage can enhance the capacity to relieve the saturated flow during the peak time. The enhanced Automated Taxi Dispatch System is designed to accommodate about 700 taxis and meet a throughput goal of 900 cabs per hour to the curb to meet expected customer demand during peak travel periods.

5.2.1 People Mover System

The People Mover System is designed to provide a fast, reliable and convenient connection among the airport terminals and the MBTA airport station. Figure 5-3 shows design of the people mover system. Air passengers can transfer from the MBTA subway to the People Mover System via a fully temperature-controlled, cross-platform. The passengers will no longer need to wait outside the airport station for a shuttle to come. The arriving passengers can get on the people mover at the terminals instead of going out to the airport roadways to look for the shuttle station.

The People Mover System will achieve a set of goals based upon the identified problems. The system can facilitate airport access for major users of MBTA Airport Station: both air travelers and employees. By reducing the transfer time and barriers to transfers, the People Mover System can improve the effectiveness of rail access to the airport. Combined with the intermodal transit connector, the People Mover System can consolidate the connectivity between the airport and the regional transportation system and achieve the 35% HOV goal set by the Massport. Moreover, the system can reduce shuttle trips and terminal curb congestion, and improve airport ground traffic circulation. Furthermore, the system can attain the environmental goals of the region by lowering the future projected traffic congestion at the airport and on the related highways. In addition,

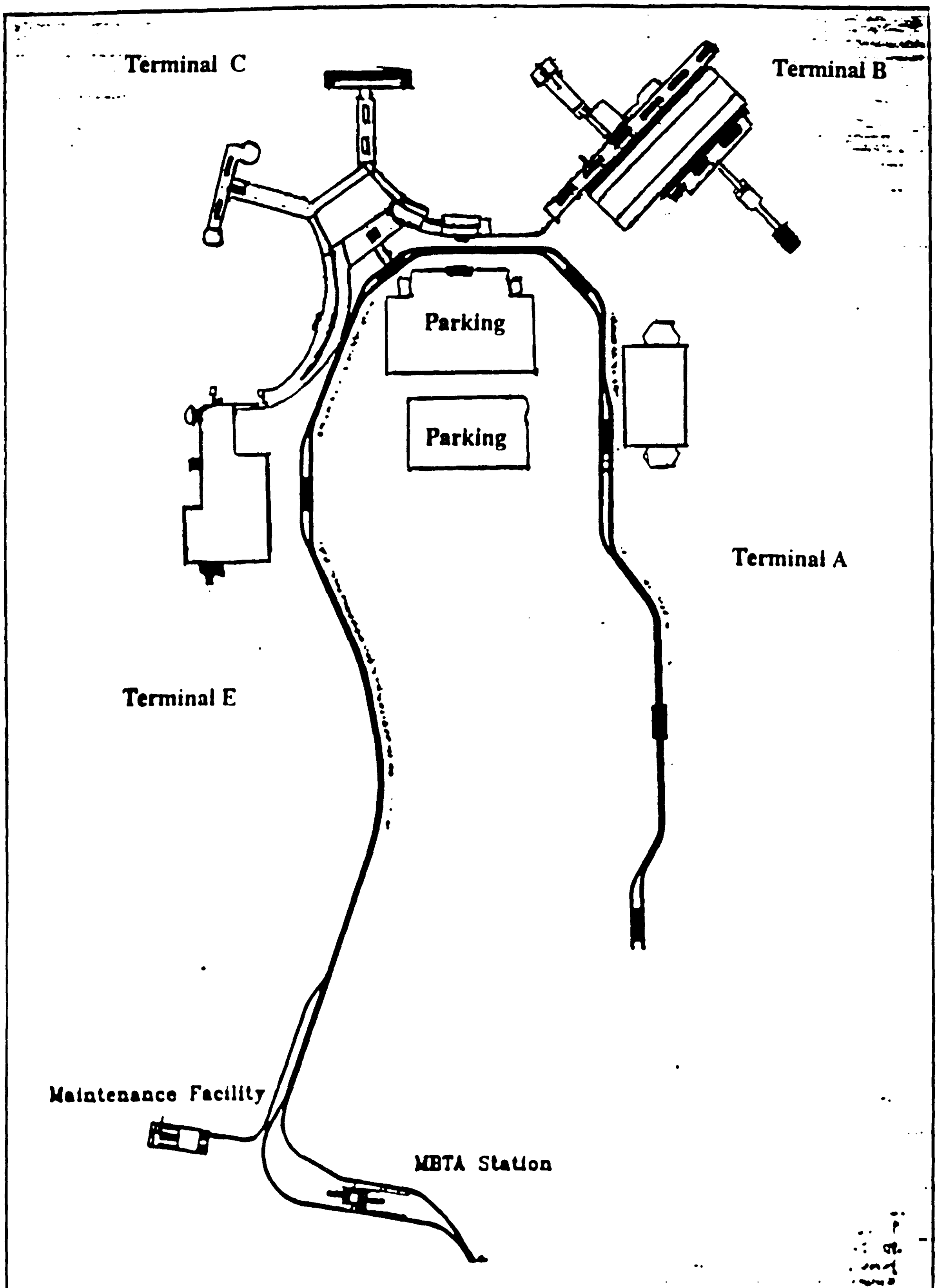

Figure 5-3 People Mover System.

Source: Logan 2000 Projects -- Projects Summary Report.

the system is aimed at increasing the economic competitive power of the airport and the New England region by improving the image of Logan Airport as a highly efficient, accessible, convenient and reliable airport for business and leisure travelers. However, the implementation of the People Mover System is subject to the availability of funding. The whole plan is very likely to be shelved due to insufficient funding.

5.2.2 Automated Walkway System

Elevated walkways will be built to connect the new parking garage to the two existing garages and the airport terminals. It provides direct and convenient movement between garages and terminals for passengers parking at the airport and people mover riders. Also, it can reduce drop-offs and pick-ups at the terminals. A fully climate-controlled environment will be built in the walkway corridors. The walkway will be automated in some of the sections so that passengers do not need to carry their heavy baggage for a long walk from the parking to the terminals and vice versa. Figure 5-4 shows the schematic diagram of the automated walkway system.

5.2.3 Automated Taxi Dispatch System (ATDS)

The Taxi Pool personnel need to keep track of the demand for taxies at each terminal and manage the flow of taxies from the taxi pool to the curb in order to meet customer need without creating traffic bottleneck. The enhanced ATDS is designed to accommodate about 700 taxis and to meet the goal of 900 cabs per hour to the curb to meet expected customer demand during peak travel periods. The new site will be farther away from the terminals. The taxi pool relocation has the following objectives:

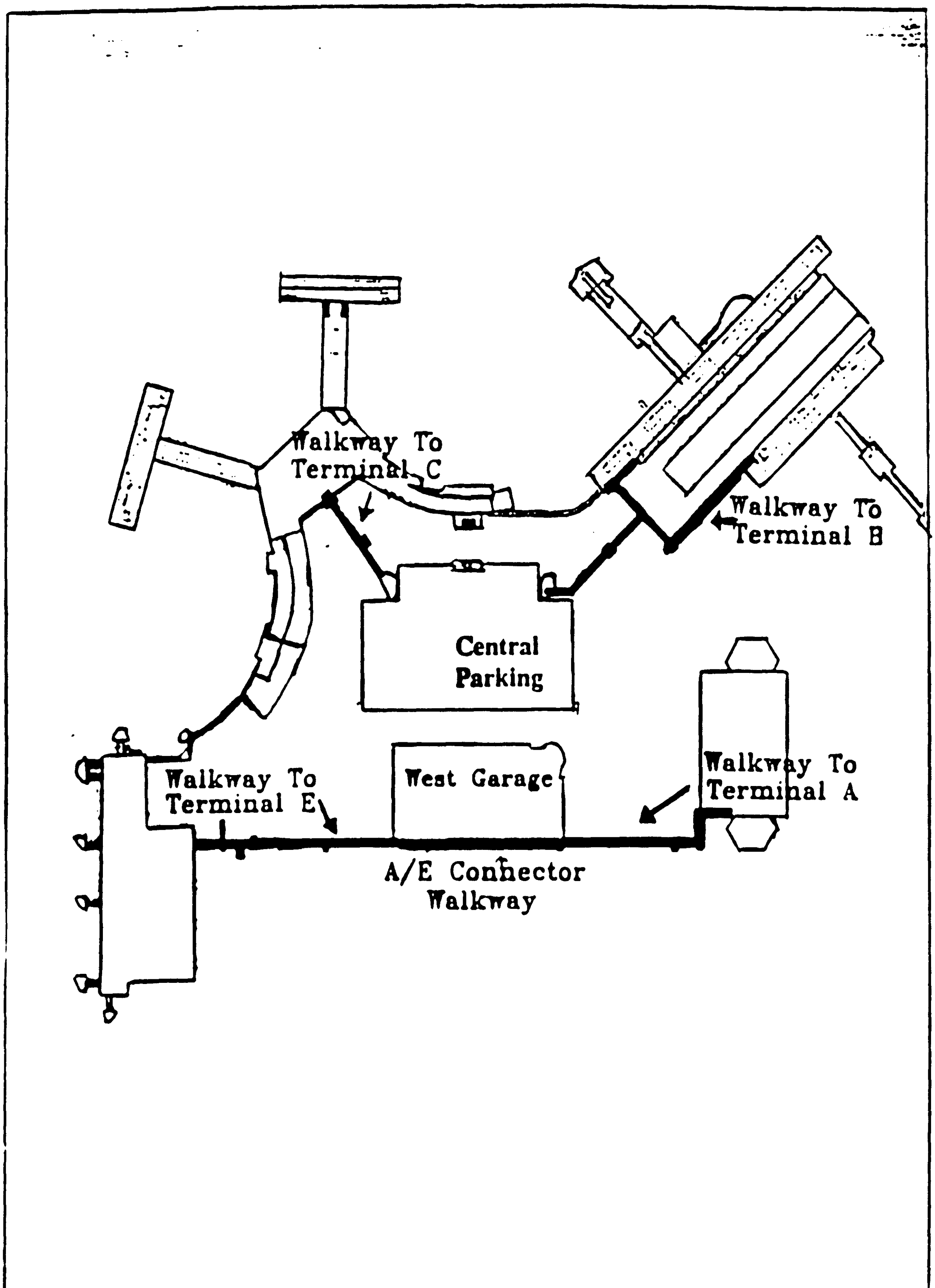

Figure 5-4 Automated Walkway System.

Source: Logan 2000 Projects -- Projects Summary Report.

- Relocate the taxi pool to the new site before its closure due to the construction of the Third Harbor Tunnel.
- Increase the size of the taxi pool to optimize its revenue and operations potential.
- Provide state-of-the-art revenue collection equipment to:
  - Ensure cab availability for the convenience of the passengers.
  - Minimize processing time for all cabs.
  - Avoid losing revenue from dispatched cab.
- Provide a better environment for taxi drivers who often need to wait at the taxi pool for a long time before being dispatched.

5.3 Intermodal Transit Connector

Not every mode of transit is available in every part of the urban area. In Metropolitan Boston, most places have bus services and some areas have access to MBTA subway services. Remote suburbs either rely on commuter rail or express bus services. These transit modes are connected at some points. All subway and commuter lines are mostly radial routes from the Boston Central Business District (CBD). Only certain bus routes are circumferential routes. This makes non-CBD oriented travel difficult. For example, to travel a short distance from Chelsea to Airport, a traveler has to take the infrequent commuter rail to North Station, transfers to Green Line, gets off at the Government Center to transfer to Blue Line, and gets off at the Airport Station. From there, he still needs to take the airport shuttle to the airport terminals. Illustrated by figure 5-5, Intermodal Transit Connector (ITC) is based on the "Urban Ring" concept to link the major transits in the urban area and to provide a circumferential route. The ITC consists of the following three stages.[49]

[49] Dieterich, M., Toney, D., and Miller, J. Logan Airport Intermodal Transit Connector: A Strategic Link in the Metropolitan Boston Transportation System. Interim Report. MassPort Infrastructure Development Research Group. MIT Center for Construction Research and Engineering. October 1997.

Phase I Add south loop bus service from Logan, via the Ted William Tunnel to World Trade Center and South Station Transit Center until Transitway opens. (See figure 5-6 for details.)

Phase II Expand and move south loop services into Transitway (See figure 5-7 for detailed illustrations.) The ITC will run from the South Station, via the Transitway and Ted William Tunnel, to the Logan Airport.

Phase III Upgrade service to rail from Boylston Station to Wood Island Station: Silver Line. (See figure 5-8 for detailed illustrations)

The new Silver Line will have the following schematic of stations: Boylston - South Station - (via Transitway) - World Trade Center Station - (via Rail Tunnel under Harbor) - Logan Hyatt Hotel Station and Rental Car areas - Terminals A/B - Terminal C - Terminal E (New International Gateway) - Wood Island - Chelsea

The ridership on ITC would be evaluated from time to time. Phase III is tentative depending on many factors. The project would proceed to phase III if the following conditions are satisfied:

1. ITC performs well during phase I and II.
2. The demand for the ITC service is sufficient.
3. Funding support is available.

Otherwise, the ITC would continue to stay in phase II and the service would continue to be evaluated regularly for the potential conversion to phase III.

Systems Requirements

- Procurement of five smart buses.
- Procurement of "smart" display technology.
- Procurement of fixed rail vehicles and systems at phase III

- Procurement of other APTS applications. (optional)

Many factors need to be considered before proceeding to phase III of the project. The projected success of ITC project is based on the future development of the area east of South Station where Massport has a lot of ownership. If South Boston is not developed as anticipated, the usage of ITC may not be as high as projected. In this case, will ridership and revenue streams justify the major capital expenses under Phase III? Therefore, the evaluation of ITC during phase I and II plays an important role to determine the worthiness of further capital investment on ITC.

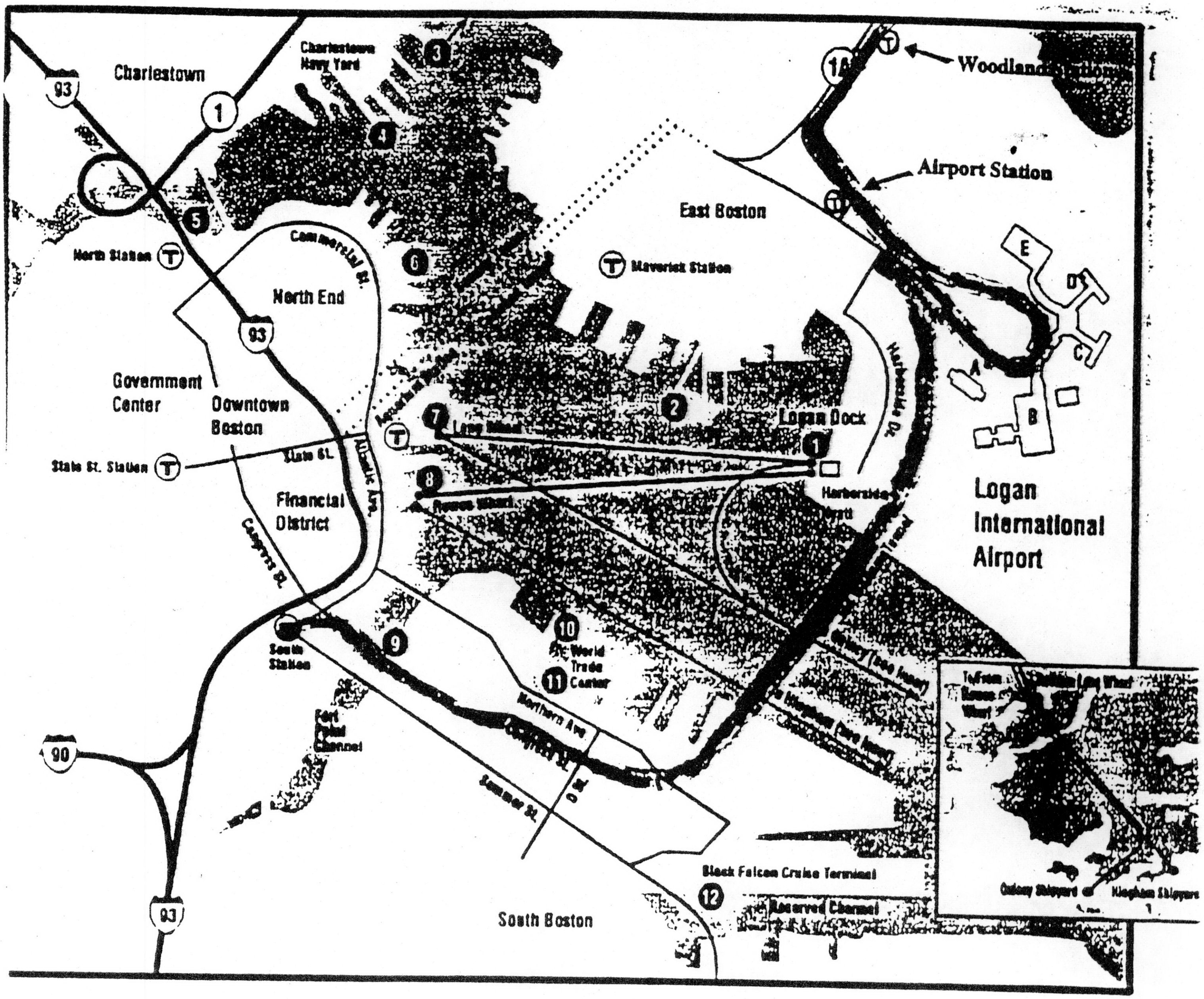

Figure 5-5 . **Intermodal Transit Connector connects Logan Airport with various transit modes in the Metropolitan Boston area.**

Source: Massport Official Web Page (http://www.massport.com/logan/map.gif)

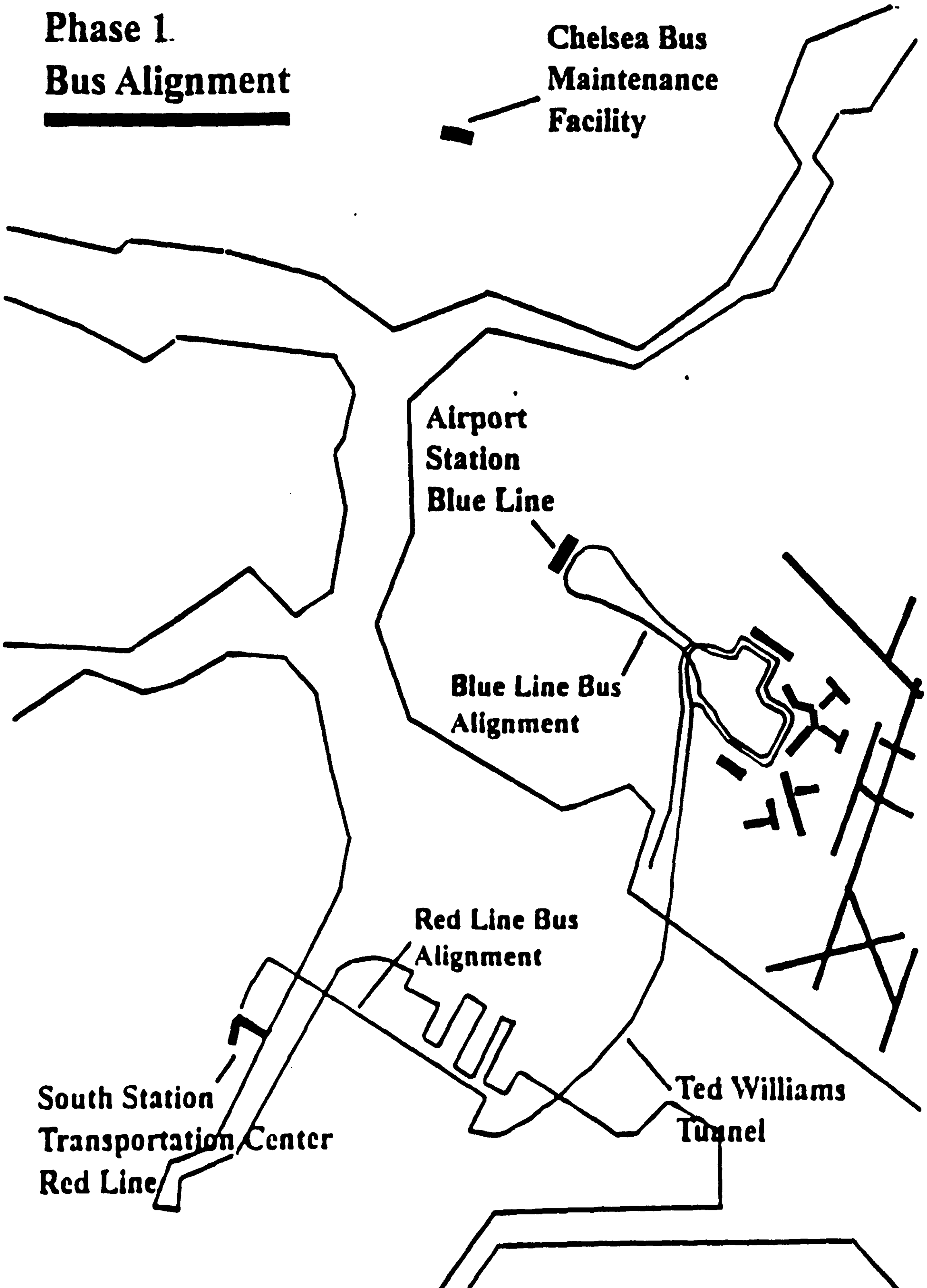

Figure 5-6 Phase one of Intermodal Transit Connector [4]

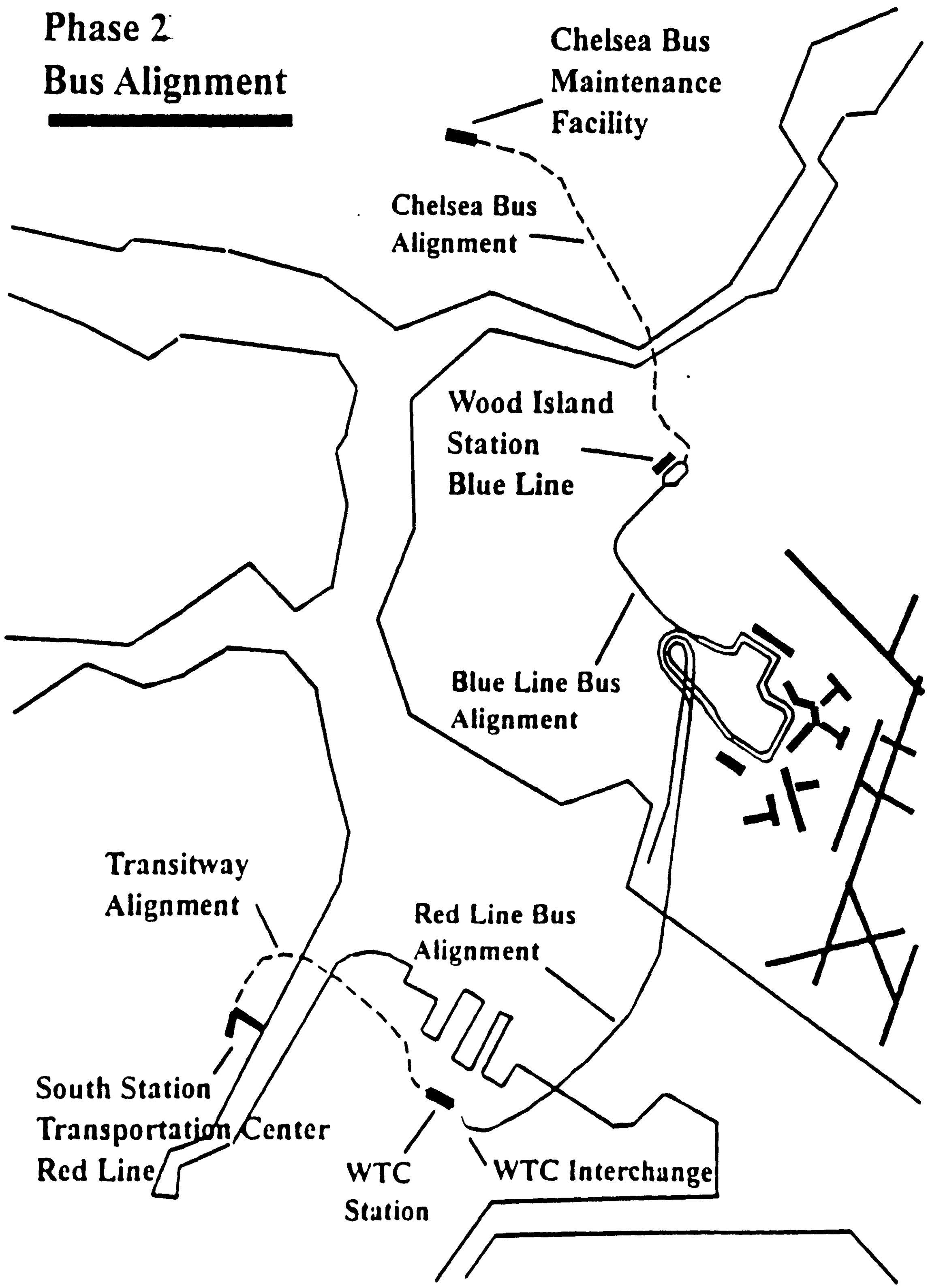

Figure 5-7 Phase Two of Intermodal Transit Connector [4]

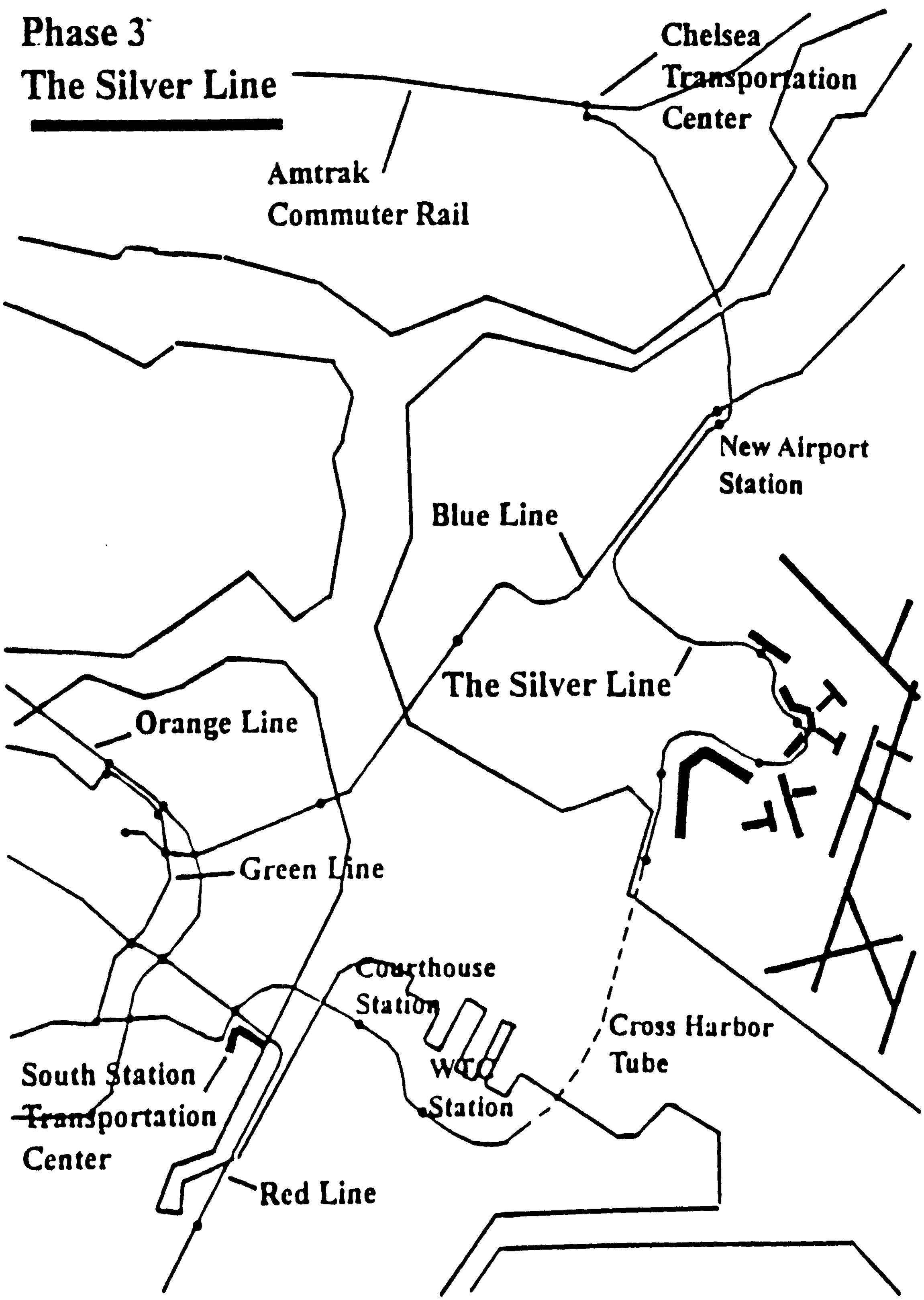

Figure 5-8 Phase Three of Intermodal Transit Connector [4]

5.4 Chapter Summary

This chapter presented the background of the Logan Airport, Logan 2000 project and the Intermodal Transit Connector. First, we looked at the general background of the Logan Airport as well as the modal split in ground transportation access to the Logan Airport. Then we presented the transportation components of the Logan 2000 project and the proposed Intermodal Transit Connector to see how these proposed infrastructure might help improve ground access to Logan Airport in the future. All of the background information paved the road for the discussion of a prototypical design of an intelligent intermodal passenger transportation system for access to Logan Airport in the next chapter.

Chapter Six

Prototypical Design of the Intelligent Intermodal Transportation System

After reviewing the current ITS applications in both public transit and airport ground access, the thesis proceeds to the next stage of actual design. The last chapter presented the background of the Logan International Airport and looked at the idea of the Logan 2000 and the Intermodal Transit Connector projects. This chapter is a case study on applying the ITS technologies to improve the intermodal transportation trip to or from the airport. Section 6.1 will first identify the traveler needs at each link of the complete process of the air travel trip. Section 6.2 will present a prototypical design of the Intelligent Intermodal Transportation System. Applying ITS technologies to improve the efficiency and effectiveness of the intermodal door-to-door air travel trip, the design is oriented towards the intermodal passenger transportation linkage to Logan International Airport. Section 6.3 will present the conceptual design of some special applications that can be applied throughout the process. Finally, Section 6.4 will present a set of scenarios describing how the travelers and various transportation operators can benefit from the above design.

6.1 First Step: Identification of Travelers' Needs at Each Link

Applying APTS technologies to improve the efficiency and effectiveness of intermodal passenger transportation is complex since many different transportation modes, hubs, and jurisdictions are involved. We need to look at the passenger trip as an intermodal door-to-door trip and identify the need of the traveler at each link of the trip. Once the need of passenger at each step of the whole process is identified, appropriate strategies will be recommended. A prototypical design of the "Intelligent Intermodal Transportation System" will then be suggested for the whole intermodal transportation system including the Logan 2000, Intermodal Transit Connector, MBTA transit systems and other modes accessing Logan Airport. Here we call this system the "Logan-T Smart System." The smart system will consist of various components such as smart stations, smart trains, smart buses, smart airport and smart planes. Each component will be applied to the design of the Logan-T Smart System and will be discussed in more detail later in this chapter. This section will focus on identifying the needs of passengers.

A complete door-to-door trip is a complex process that involves many steps. The schematic of a typical door-to-door plane trip is shown in Figure 6-1. Thousands of combinations can be obtained when planning a plane trip. The most important part of the trip is undoubtedly the flight. Days of the year and times of the day are the first set of decision variables to be made by a traveler. Choice of airline carrier comes next. Depending on the nature of the trip, the flexibility and the personality of the travelers, accommodations and ground travel arrangements are made in advance or during the trip. Since there may be few alternatives to the booked flight, missing a flight is very costly to the travelers. Therefore, travelers usually allow more time to get to the airport because slack time should be allowed for uncertain traffic conditions, uncertain check-in time, walk time, time to look for the check-in counters, right terminals, security checks, and potential unexpected events.

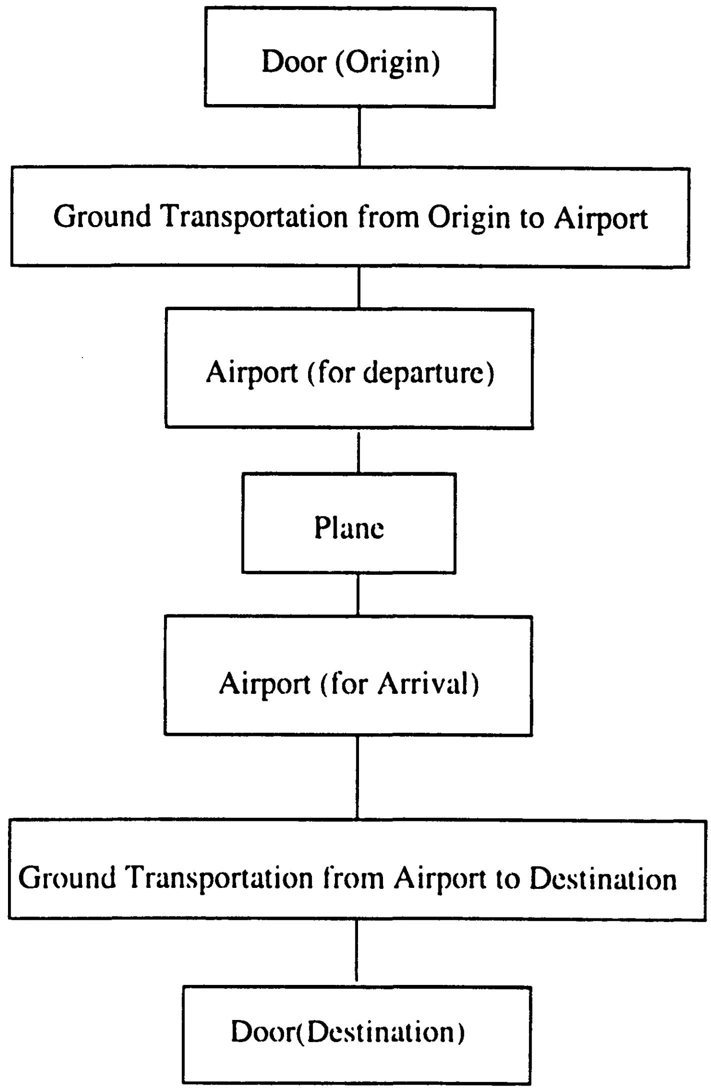

Figure 6-1 A Door-to-Door Intermodal Trip

6.1.1 Door (Origin)

Before leaving home or office or any other origins, travelers need to decide when to leave and which mode to take to the airport. The most important types of information for the travelers are flight information and ground transportation information. Travelers usually need to know the flight status such as "whether the flight is on time or not" so that they can make appropriate changes in their travel plans if the flight schedule changes. If minor delays occur, travelers might leave for the airport later than originally expected. If significant changes such as serious delays or flight cancellation occur, travelers need to change their arrangements. For business travels, travelers might need to purchase another plane ticket to ensure on-time arrivals or to reschedule the meeting time, day or place. If a traveler is supposed to be picked up at the destination airport, (s)he needs to inform the pick-up party that there is a change in flight schedule. Figure 6-2 illustrate the information flow for passengers at the trip origin.

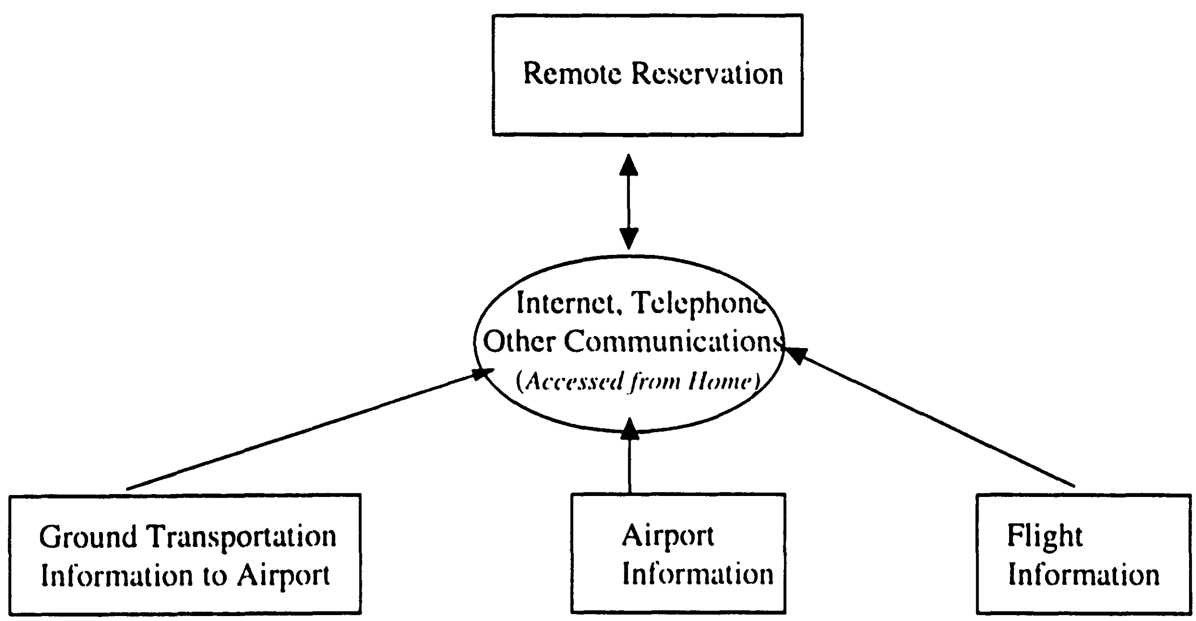

Figure 6.2 Information Flow for Passengers at Trip Origin (Home or Office)

Ground transportation and traffic information aids travelers in making the modal and route choices and to enhance the choice set for travelers, as more modal information is given. First of all, limited modal information limits the choice set. If information of "alternative modes" such as public transportation or airport shuttle is incomplete or hard to obtain, people most likely would choose direct and instantaneous demand responsive modes such as automobiles and taxis. Estimated travel time of each mode at different time of the day can help the travelers in planning their trips. This can avoid incorrect guesses that make the travelers arrive at the airport either too early or too late. People may have a set of perceived travel time of each mode that may deviate from actual travel time. Travel time information can thus give travelers an objective measurement of each mode. Traffic information allows travelers to make their modal choices or route plans according to the traffic conditions at different highways and arteries. Travelers are subject to the risk of missing the plane without the presence of some critical real-time information, including closure of highway ramps, streets, tunnels or particular lanes as well as disruptions of subway or commuter rail service, or temporary service suspension of a particular bus route.

Telephone reservations of flights, hotels, various ground transportation services such as door-to-door vans, and other travel related events have been very common for years. However, with only a few phone numbers, travelers usually cannot get a complete picture of various characteristics of each distinct service provider. The Internet can be a good way to provide a more complete picture of all service listings and their characteristics. Travelers can check the availability of each service at real time. Nowadays, travelers can purchase air tickets in advance via the Internet. As time goes by, Internet may give travelers more reservation options to negotiate with different service providers at the same time for different attributes such as cost and connection times between different modes.

6.1.2 Ground Transportation to the Airport for Departure

Once travelers decide when to leave their origins and which modes to take, the travelers proceed to the next stage of the travel process of the trip. If the travelers choose the direct modes such as automobiles and taxis, dynamic traffic information and route guidance would be useful to them. Door-to-door van operations provide similar kind of services. Nevertheless, door-to-door vans need to pick up different passengers at various locations. It would be helpful to the passengers if in-vehicle display exists to show the remaining pick-up locations and estimated times to raise the comfort level of the travelers.

If the travelers choose to take public transit, they have much more needs to be satisfied. First of all, the baggage needs to be handled. Many travelers carry a certain number of baggage that can easily obstruct the passengers themselves to travel on public transportation. Remote baggage check-in system is a good way to solve this problem. It will be used extensively in the new Hong Kong International Airport and Airport Railways. Remote check-in counters are set up at two of the main airport railway stations. Passengers can check-in their baggage once they arrive the train station. Afterward, they can maneuver around the rail system easily. Figure 6-3 illustrates the schematic of an integrated baggage and ticketing check-in system.

Second, route guidance within the transit systems is especially important when transfers are required to get to the airport. Route guidance provides the shortest path between a pair of origin and destination for the travelers. Different travelers have different travel preference. Some travelers just want to minimize their total travel time regardless of how many transfers or wait time. Others might prefer the path with minimum number of transfer regardless of the travel time. Others may like the path that minimizes the wait time. A route guidance system can achieve different objectives of each distinct user. Appropriate advice will be given to the travelers to suit their special needs. The system will be discussed in more detail in Section 6.3.

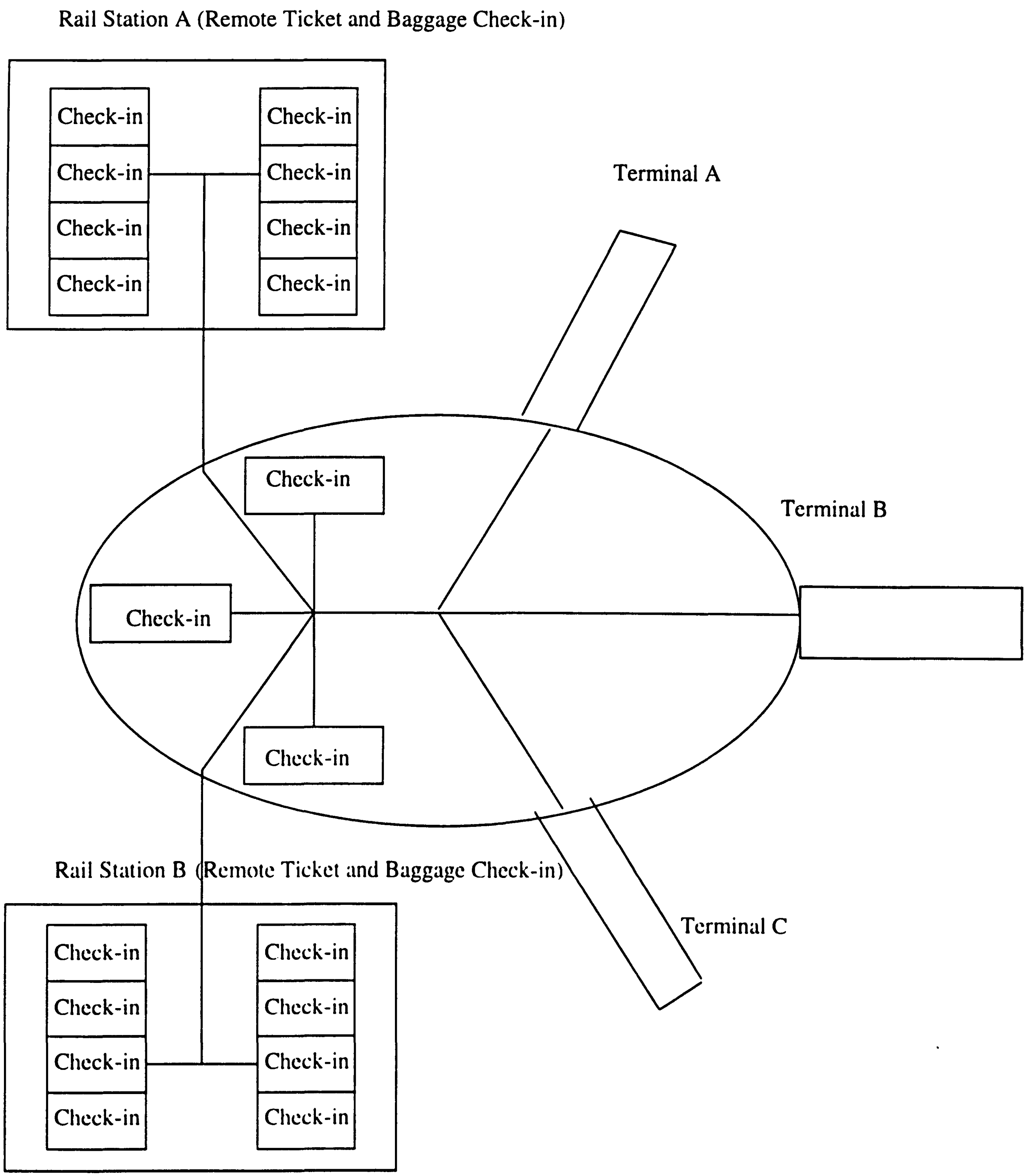

Figure 6-3 Integrated Baggage Check-in Systems

Figure 6-4 demonstrates a sample procedure for a route guidance system. A good route guidance system should provide the following information:

- Complete information for each possible route.
- Clear directions for each route choice.
- Accurate estimates of wait time, transfer time, and in-vehicle travel time of each mode.
- Recommendations of particular route with clear, sound reasons.
- Real time transit information for transit riders is just as significant as the real-time traffic information for drivers. Real-time transit information can give the passengers a sense of security because the travelers can anticipate their projected wait time and travel time. Example of real time information includes automatic vehicle location and real-time display of dynamic bus schedule.

The Smart Station, Smart Trains and Smart Buses can satisfy the above travelers' needs. A prototypical design of these three Smart pieces will be elaborated in section 6.2.1.

Dynamic Intermodal Route Guidance System

- Select desired origin.
- Select desired destination.
- Select the range of departure time from the origin. (ie: 14:30-14:45)
- Select desired arrival time at the destination. (ie: 15:50)
- Indicate constraints such as upper limit of travel time, wait time, out-of-pocket cost, or number of transfers.
- Computer makes use of the shortest path algorithm, takes the constraints into consideration, and calculate the desired travel path.

Figure 6-4 An Instruction Screen for Dynamic Intermodal Route Guidance System

6.1.3 Airport for Departure by Airplane

Once the travelers arrive at the airport, they want to get familiar with the airport to facilitate their movement at the airport. First, all travelers would like to know where the check-in/ ticketing counters are. At some airports, all the airline check-in counters are located in the main terminal. Travelers need to locate the counter within the main terminal. In other airports such as Logan Airport, the airline check-in counters are located in the different terminals where the departure gates are located. Travelers need to find out the specific terminal where the check-in counter is located. Then they have to find out how to get to the terminal and subsequently to the check-in counter.

After checking-in their baggage and getting the boarding pass, passengers need to look for the departure gates. Depending on the airport configuration, the gates may or may not be in the same terminal as the check-in counters. Sometimes, travelers may have to get onto the people mover system or automated walkway to access other terminals. For instance, Seattle SeaTac International Airport uses the mover system to connect different terminals. Houston International Airport applies the automated walkway to facilitate the passenger movement between terminals. Appropriate guidelines to direct the passengers around the airport are necessary so that they can maneuver around the internal transportation system at the airport. Moreover, travelers may want to use the facilities at the airport such as restaurant, business center, duty-free shops, and telecommunications center. Information of those facilities such as their locations and scope of services would be helpful to the travelers.

6.1.4 Plane

When the travelers are on the plane, they have a lot of time to spend on the flight. Therefore, it is a good time for them to get themselves familiar with the destination city. Information on the destination airport, ground transportation and accommodations in the city are important information for travelers to review on the plane. Because of the travel time of the flight, a much longer time can be spent on searching information during the flight. On the plane, travelers can also make reservations on various kinds of transportation modes via Internet or radio communications. Therefore, more options and details can be provided to the travelers. Information flow for passengers on the plane is shown by Figure 6-5.

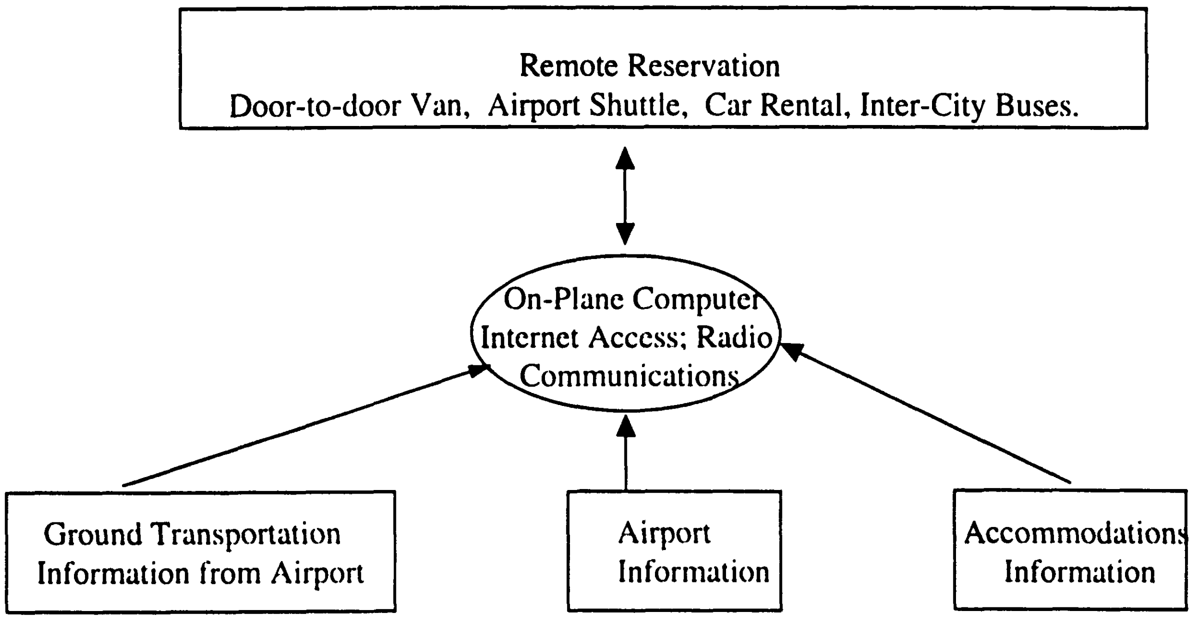

Figure 6-5 Information Flow for Passengers on the airplane

6.1.5 Airport for Arrival

At the destination airport, the information desired by the travelers is different from that at the origin airport. The arriving passengers want to know where to pick up their luggage. Information on ground transportation is the most essential information needed by the arriving passengers so that they can find out where and which modes to take to get to their destinations. If the travelers are to be picked up by someone, they need to look for the meeting place.

6.1.6 Ground Transportation from Airport to Destination

Once travelers decide which modes to take to get to their destination, the travelers proceed to the next stage of the travel process of the trip. For travelers who are new to the city, information on ground transportation is essential to them. For those travelers who return back home, real-time information is valuable for them to make their modal choice, given the fact that they are already familiar with the ground transportation. If they choose the direct modes such as automobiles and taxis, dynamic traffic information and route guidance would be useful to them. Door-to-door van operations provide similar kind of demand-responsive services. However, door-to-door vans need to drop off different passengers at various locations. Therefore, it would be helpful for the passengers if in-vehicle display is available to show the route of the van and the remaining drop-off locations as well as the estimated times to raise the comfort level of the travelers.

If the travelers choose to take public transit, they have more needs to be satisfied. First of all, the baggage needs to be handled. Baggage delivery service is a good solution to the problem in some airports in other countries. In Japan, baggage delivery service is available at Narita International Airport to deliver the baggage for the travelers from the airport to the destination so that the travelers can take public transportation to their destinations. Many people use this service to avoid taking the taxi which is expensive. An intelligent baggage identification system is required to identify and sort the baggage to ensure each piece of baggage arrives at the right place.

Second, route guidance within the transit systems is especially important when transfers are required to get to the destination from the airport. Route guidance provides the shortest path between a pair of origin and destination for the travelers according to different travel preference. A good route guidance system should provide the following information:

- Complete information for each possible route.
- Clear directions for each route choice.

- Accurate estimates of wait time, transfer time, in-vehicle travel time of each mode.
- Recommendations of particular route with clear, sound reasons.

6.2 Prototypical Design: Logan-T Smart System

A well developed infrastructure can provide more opportunities for people to choose. However, without a good integration of each individual piece of infrastructure and a good information system, people may not make the best decision due to the lack of information or ineffective presentation of information to the people. Consequently, the making of an efficient and effective intermodal passenger transportation system requires several components:

- High quality infrastructure and services of each mode: Bus, subway, train, taxi, plane, etc.
- Well-integrated modes: Access, transfer time, reliability, etc.
- Organized, well-presented, complete, and updated information on all modes available to travelers.

The previous section has identified the needs of travelers who engage in an intermodal air trip. This section will present a prototypical design of applying ITS technologies to improve the efficiency and effectiveness of the intermodal door-to-door air travel trip. The prototype will meet the needs identified in section 6.1 and contain the three components mentioned above. We call this prototype an "Intelligent Intermodal Transportation System". In this study, the design is oriented towards the intermodal passenger transportation linkage to Logan International Airport. Section 6.2.0 through section 6.2.4 will present the prototypical design. First, section 6.2.0 will present the design of the intermodal information hub. Afterward, section 6.2.1 will present the design of the smart transit which includes the smart bus, smart train, and smart station. Then, section 6.2.2 will demonstrate the design of smart airport. Next, section 6.2.3 will show the design of the smart plane. Finally, section 6.2.4 will present the application of smart card in this case study.

As mentioned in section 6.1, the Intelligent Intermodal Transportation System for the Intermodal Transit Connector, the MBTA, Logan Airport, and other transportation modes and transportation centers involved will be named "Logan-T Smart System". "Logan-T" will be used throughout the text to represent the designed system.

6.2.0 Design of Logan-T Intermodal Information Hub: Airport/South Station Control Centers

To effectively link and transmit real-time information of different modes, an information hub is essential. Intermodal information control centers at the Logan Airport and at the South Station will be two information hubs for the Logan-T Smart System. Intermodal information from different sources will be gathered and centralized at the control center. The information will be filtered, sorted and regrouped into useful information to different targeted users based on a set of different decision-making tools ranging from the traditional decision support systems, knowledge-based expert systems to cutting edge algorithmic tools like neural networks and fuzzy logic. The sorted information will then be distributed through different channels to a variety of end users.

Both control centers will be networked and will be connected to different data sources as well as output terminals. The control centers and the output terminals can be described as a client/server system so that the output terminals do not need a high memory requirement while getting the specific information when needed. The information sources from where data will be sent to the control center include:

- Airport: Interactive information kiosks (passenger information and request)
- Aircraft: Communication device from pilots and crews.
- Private Vehicle Dispatchers: Ride information such as seating availability.
- ITC Buses: AVL systems.

- MBTA Trains: AVL systems and train detection system.
- Control/Dispatch Centers: Controllers, inspectors, fleet dispatchers.
- ITC and MBTA stations: Interactive information kiosks (passenger information and request)
- Transportation and tourist center: Information kiosks (passenger information and request)
- Internet for home and office users.
- Real-time information service providers (such as SmartTravelers):

Output terminals include:

- Airport: information kiosks, airport screen displays, airline counters, variable message signs and announcement systems.
- Aircraft: communication device for airplane crew, passenger monitors at seats, and announcement systems.
- Private Vehicle Dispatchers
- ITC Buses: In-vehicle display units, announcement systems, and bus operator interface.
- MBTA Trains: In-vehicle display units, announcement systems, and train operator interface.
- Control/Dispatch Centers: Controllers, inspectors, fleet dispatchers.
- ITC and MBTA stations: In-terminal and wayside information systems, kiosks.
- Transportation and tourist center: Information kiosks and variable message signs.
- Internet for home and office users.
- Real-time information service providers (SmartTravelers): information can be obtained via beepers and cellular phones.
- TV/Radio/Cable and other multimedia.

In addition to the network connections, the control centers are equipped with computer processing units, data collection, processing, control and storage units, and a number of other standard computer hardware. At the same time, the centers will install the sophisticated software such as GIS, programmable real-time statistical and analytical software as well as the decision tools mentioned above.

Here are some examples of the information flows from the data sources to various terminals via the control center. Suppose there is a change in some flight status, the real-time airline arrival and departure information would be updated to the control center at the Logan Airport. The database for flight information at the control center would be updated at once. The information would then be prioritized. Emergencies or important flight changes, such as serious delays or cancellations of those flights that were scheduled to depart or arrive in next hour or two, will be sorted out as priority messages. These messages would be sent to different output terminals mentioned in the previous page, such as in-vehicle display units and in-terminal display units. Message like "*UA 413, originally departing for Chicago at 14:45, is canceled. AA 75, NW 78, CX 812, BA 68, and US 653 will delay arrivals due to inclement weather. Call 56-LOGAN for detailed information.*" would be displayed at the VMS at Logan Airport and the in-vehicle display unit at the ITC buses and MBTA smart trains. As usual, the flight information screen at the airport would display the arrival and departure information according to the order of scheduled departure and arrival times. At the same time, a message with more detailed information would appear on the screen of the information kiosk. If the users inquire about the flight information, their queries would directly trigger a database search at the control center. The searched results would then be transmitted back to the user interface at the information kiosk. Figure 6-6 illustrates the schematic of the information flow of the whole Logan-T smart system. More details of the information flow of each kind will be discussed in the following sections.

Alternatively, a more decentralized system can be used so that the control center would have less system requirement. However, more powerful and sophisticated system will be needed for vehicles and other output terminals because more processing will be conducted at the decentralized locations rather than the control centers.

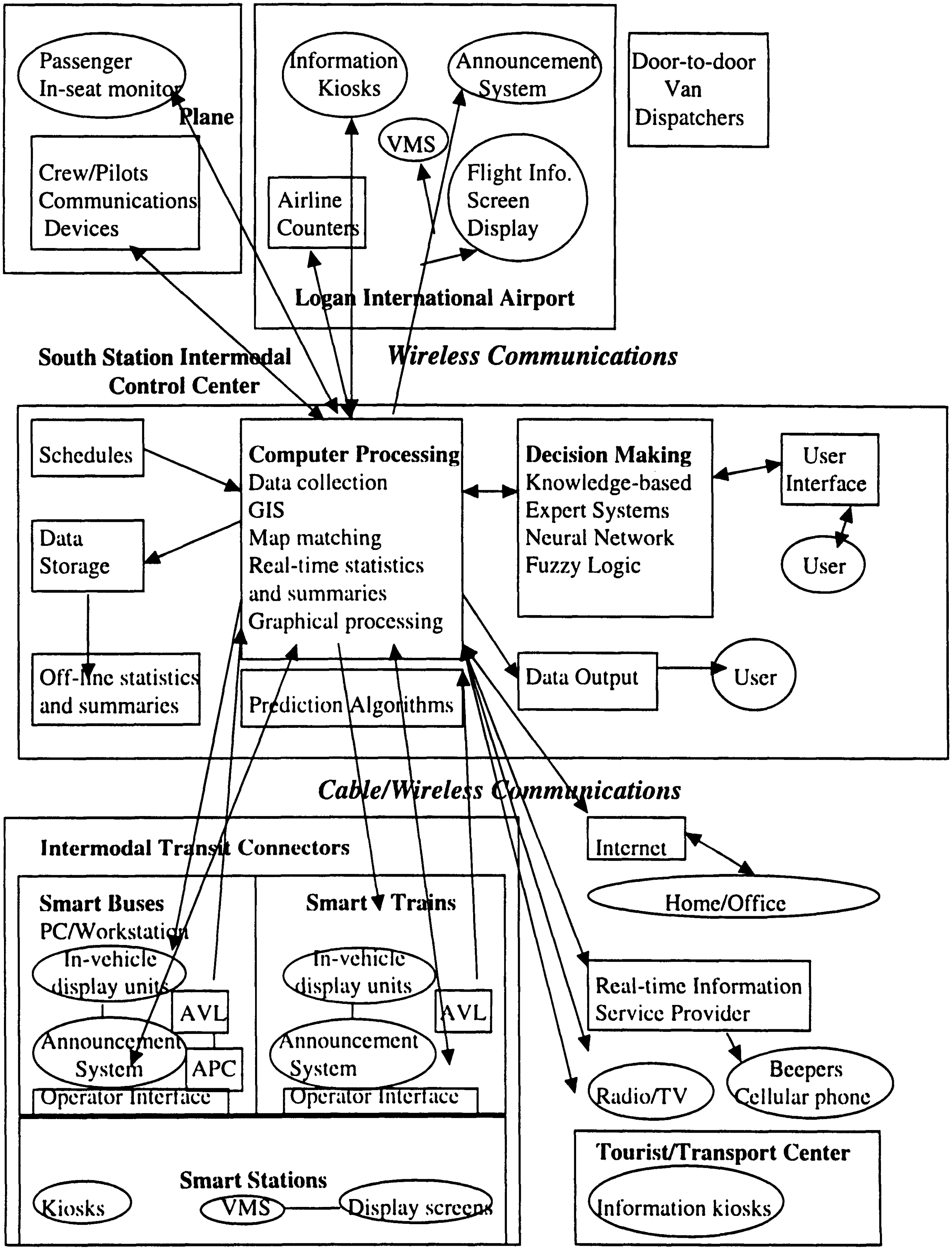

Figure 6-6 Information flow at the Logan-T Smart System via Airport/South Station Control Centers.

6.2.1 Design of Logan-T Smart Stations, Smart Buses and Smart Trains

6.2.1.1 Smart Buses and Smart Display Technology

As discussed in Chapter Five, smart buses will serve as the intermodal transportation connector (ITC) linking the Logan Airport directly to South Station Transit Center via the Ted William Tunnel and the new Transitway. The smart bus will stop at the MBTA Airport Station, all airport terminals, the Airport Hilton Hotel, the World Trade Center, and the South Station. Figure 6-7 illustrates the route of the smart bus. Because the route will provide direct access from the airport to the World Trade Center and Downtown Boston, business travelers are the main targeted market. The applications of smart buses can be expanded to other routes that provide services to the airport.

Basic System Requirements

The followings are the system requirements for the smart buses:

- User Interfaces: Terminal display screens, in-vehicle display units, announcement system.
- AVL Systems: Global Positioning System (GPS)
- Communications Systems: Digital radio system, radio control.
- Automatic Passenger Counter
- Electronic Fare Box installed with Smart Card Reader
- Central Computer Processing Units
- Data Processing and Control Units
- Data Storage/Memory
- Software Packages including in-built algorithms
- Network Connections to the South Station and Logan Airport Control Centers.

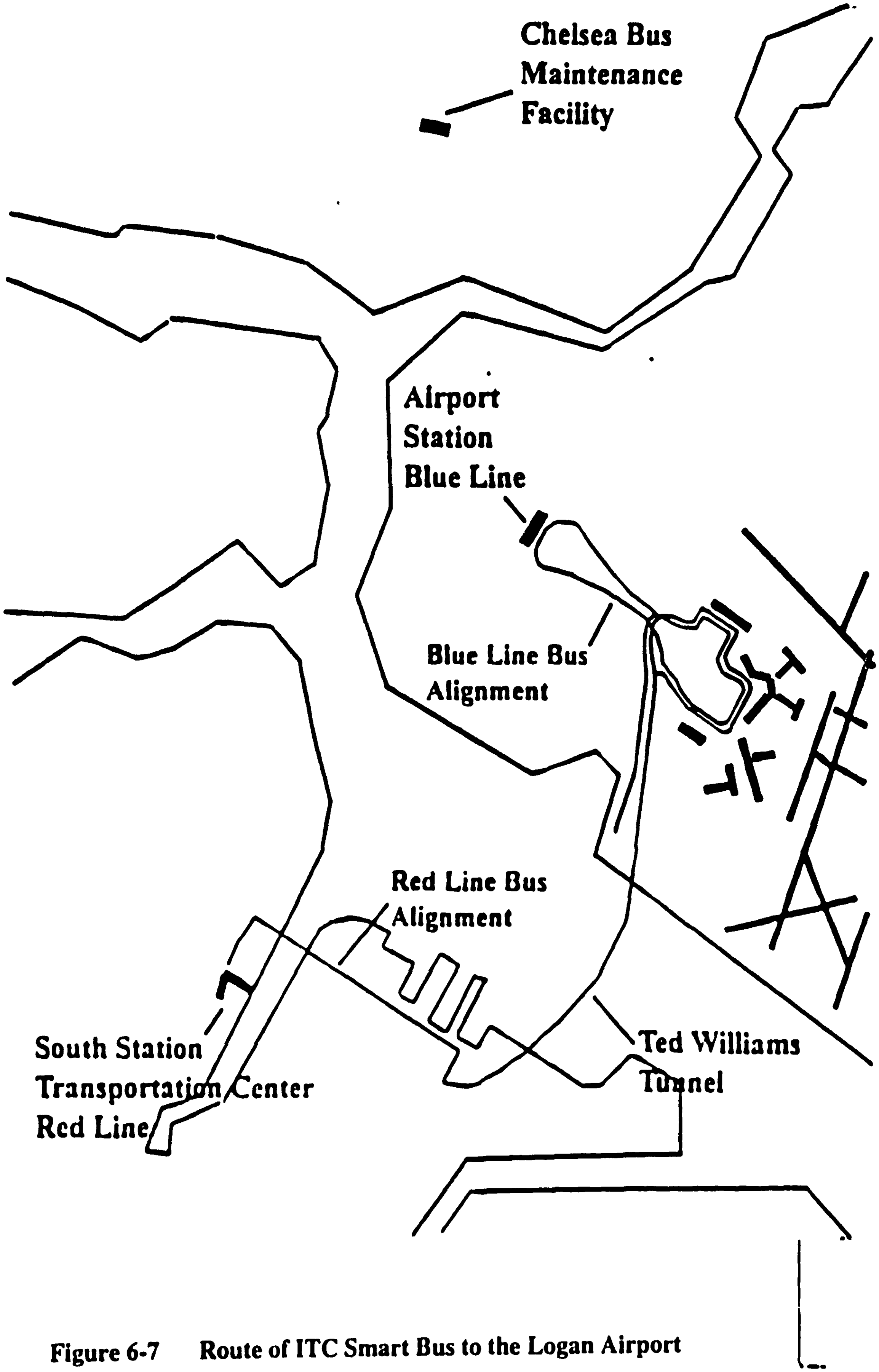

Figure 6-7 Route of ITC Smart Bus to the Logan Airport

Source: Logan Airport: The Intermodal Transit Connector. Interim Report[4]

Smart Displays

At each bus station, electronic screens will be installed to display the current locations of the buses and information such as the arrival and departure times of the next bus. The vehicle location of each smart bus is determined using Global Positioning Systems (GPS). Then the location data is compared to stored route data. Once they are matched, the message associated with the location is triggered. The message is stored in different formats: digitized sound and visual data. An automatic annunciation device can read the pre-programmed announcement to the bus passengers using the bus odometer or GPS. At the same time, the bus station display unit can show the moving digitized data.[50]

AVL technologies can also predict the arrival time of the smart bus at each bus stop. The calculation of these arrival times can be conducted using an algorithm within the Central Processing Unit(CPU). The signals from the buses, based on the battery-powered signposts, will inform the dispatcher at the smart bus dispatching center every 30 to 60 seconds.[51] Passengers at the bus as well as those who wait at various bus stops along the route can receive the same information as the dispatchers. All the information is displayed via the in-terminal display units or announced via the announcement system. At the same moment, the information is automatically updated at the information kiosks at each bus station along the route of the intermodal transportation connector. The information will be particularly useful when rerouting is needed as a result of accidents or bad weather such as snowstorm. Emergency condition at the new Ted William Tunnel can be reported quickly to the waiting travelers and dispatchers at the stations. Consequently, the dispatchers can temporally reschedule or redispatch the buses based on the projected delays at various bus stops. After dispatching some buses for temporary services, the dispatchers can send a message to the drivers and passengers at different buses and bus stops. At the same time, travelers can make adjustment responsive to the

[50] USDOT, 1996

[51] Ibid.

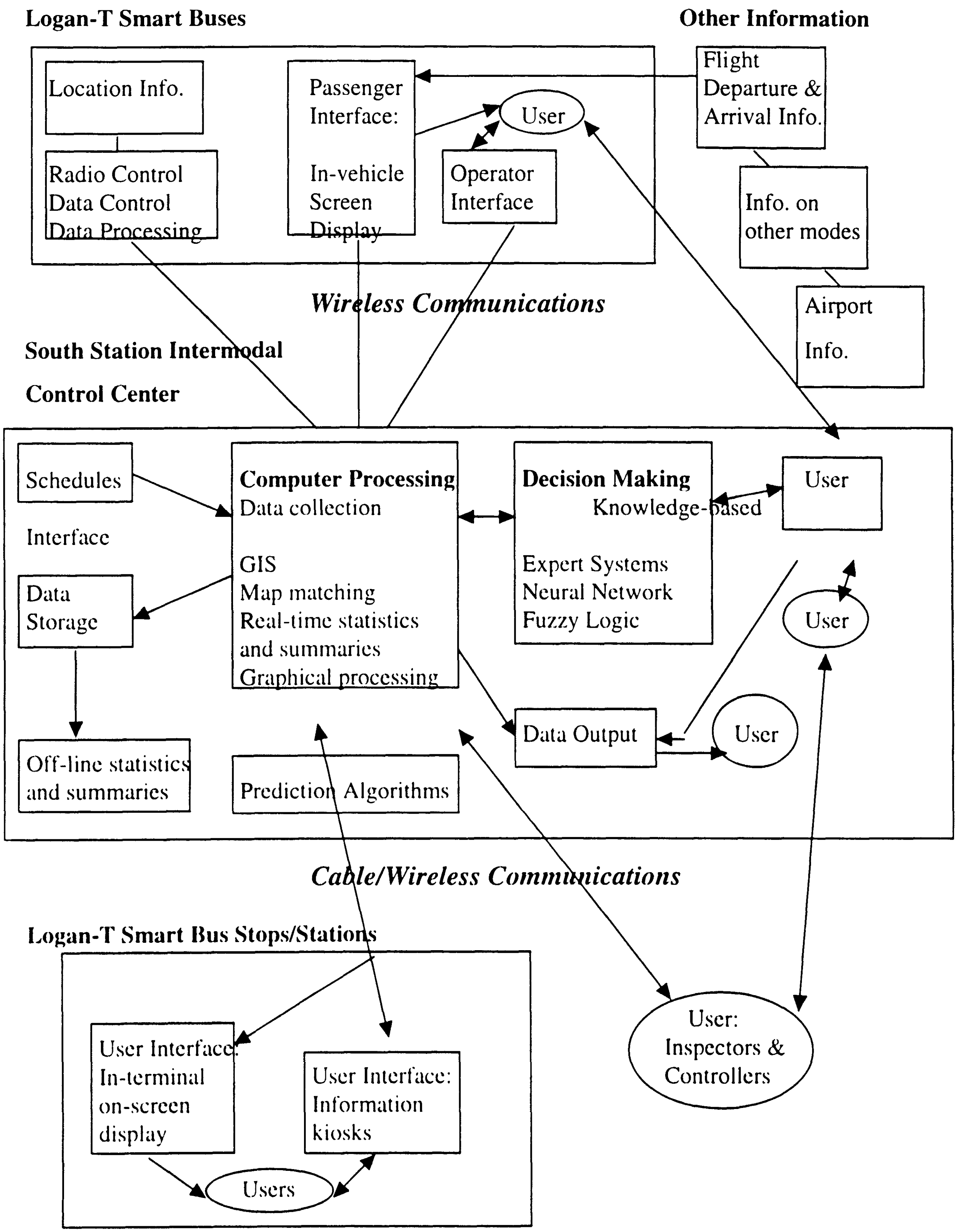

Figure 6-8 Logan-T Smart Buses and Smart Display Technology Scheme.

(Modified from the generic framework of hardware/software components in Lam, 1994) new situation. Figure 6-8 illustrates the information flow among the smart buses, control center, bus stations, and other information source.

Estimated cost of the display technology is about $1.5 million.[52] It includes the display units at the bus stations along the entire route of ITC.

In-Vehicle Display Unit

Display units will be installed on the buses to show the information most important to travelers: flight information, ground transportation information, and traffic information. The information is transmitted via digital radio system from the South Station Control Center to the smart bus. Digitized data can be displayed via the passenger interface and the operator interface. Traveler-related information will be sorted out at the control center and sent directly to the passenger interface -- the display units. Vehicle control or fleet management information will be filtered and sent directly to the driver interface unit – mini screen or digital radio receiver at the driver seat.

At least two display units will be suspended from the ceiling of the front and central portion of the bus facing towards the passengers. Since variable message can be displayed at the screen, updated information will be shown whenever real-time information is received. At the same time, some static information such as station names, intermodal transfer advice and greetings to passengers will be displayed interchangeably. Figure 6-9 shows some example of the displayed messages. When a passenger boards the ITC smart bus, a welcome message will appear on the display screen to greet the passenger. The message will also show the estimated travel time from the ITC bus station to the Logan Airport based on the traffic condition at that time. The travel time is computed using microscopic simulation models such as MITSIM in real time with the input of a set of independent variables such as travel speed. When there is a significant change in predicted travel time due to incidents, the display screen will update the travelers on the travel time information. After displaying the travel time, the screen will

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[52] Dieterich et al. 1997.

display real-time flight information. The message about flight status will be shown in a chronological order, starting with next departing flight. A message queue will thereby be established. Each message will carry two lines of departure information showing flight number, schedule departure time, flight status, gate number, and warning messages such as gate closing time. On average, each message will be shown for five to eight seconds depending on the urgency of the message. If there is enough time, arrival information will also be displayed at a faster rate (less than five seconds). The Logan Airport Control Center can interrupt the message queue any time when an emergency occurs. The upper portion of figure 6-9 illustrate a sample of display messages for three flights. Two of them are on time and the other one encounters delays.

Before each stop, the screen will display a message showing the name and description of the station. For instance, a message will appear on the screen saying "*Entering terminal E, get off here for all international flights*." At the same time, the announcement system would announce the additional information such as the airlines at terminal E: " *Get off here for the flights of the following airlines: Aer Lingus, Air Alliance, Air Atlantic/ Canadian Air, Air Canada, Air Nova, Alitalia, American Airlines.....*" When the ITC is about to enter the station where there are intermodal connections, an instruction message will appear to guide the travelers the procedure to make intermodal transfers. In a case when the ITC is entering the South Station, the screen will display the following information: "*Entering South Station. Change here for MBTA Red Line and buses, commuter rails, Amtrak, Greyhound, and Peter Pan. Red Line is located at the same level. All other modes are located at the Main Terminal Complex...*"

If there is serious congestion due to accidents near Ted William Tunnel (refer to Figure 5-6) or other roadways, the smart bus will inform the passengers about the congestion and expected delays. Message will also be sent to other vehicles and the control centers with the aid of digital radio so that the dispatcher and other ITC bus operators can make appropriate decisions to avoid the delay. Depending on the situation (such as location of the vehicle with respect to the traffic queue), the smart bus on the road can have several

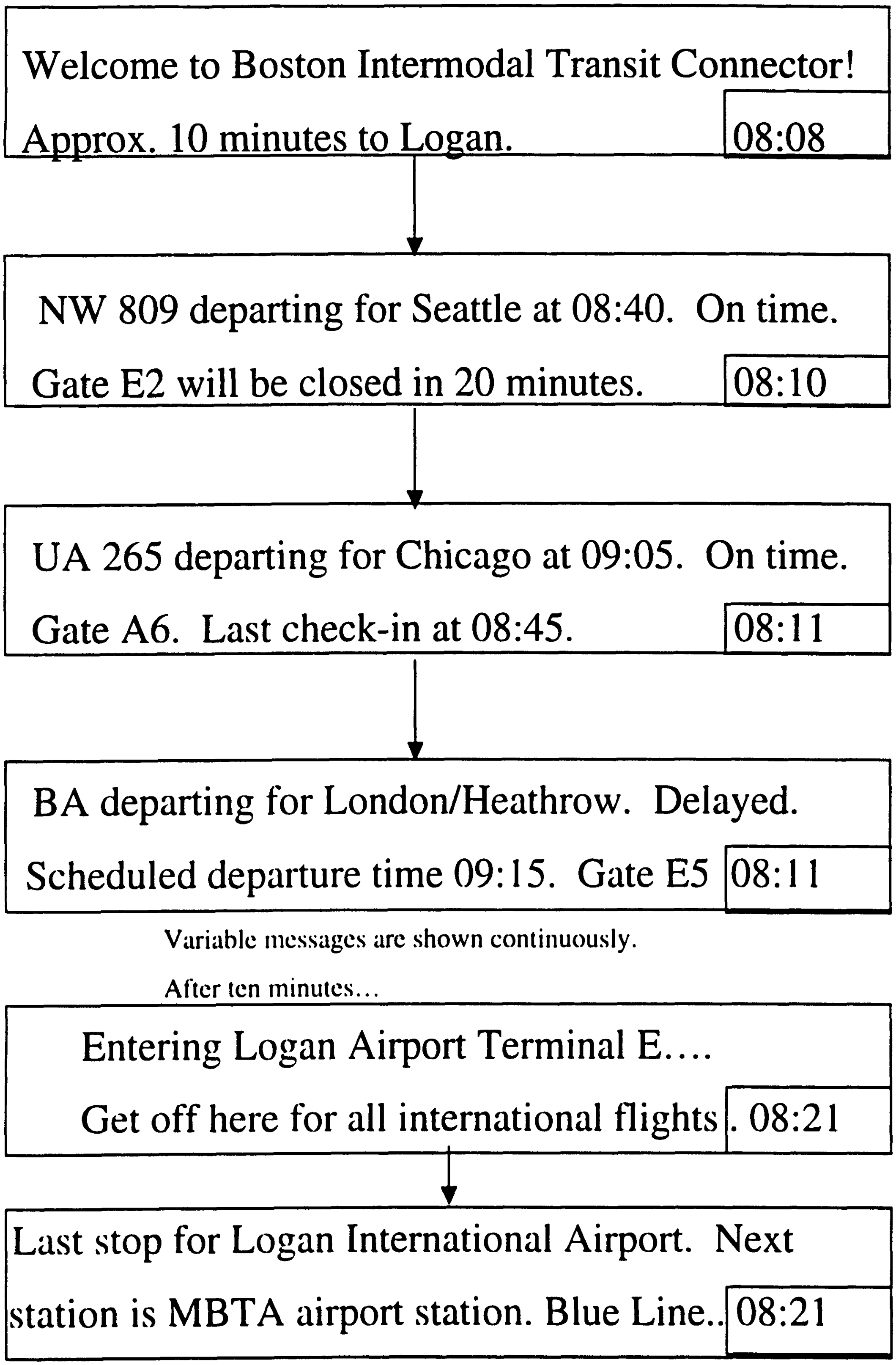

Figure 6-9 Variable messages on in-vehicle display units at the Intermodal Transit Connector.

Oil spill near Ted William Tunnel North exit.
Expect delays up to 45 minutes . 15:43

↓

Next stop is the last stop before entering tunnel.
Supplementary bus will take 15:43

↓

.... passengers back to South Station.
Switching to Red Line is recommended. 15:43

↓

Take inbound train to next stop, Downtown
Crossings. Change to Orange Line ... 15:44

↓

...Oak Grove direction. At next stop - State,
Change to Blue Line (Wonderland ... 15:44

↓

...direction) Get off at the airport station.
Take the airport shuttle/people mover .. 15:44

↓

.. to the desired terminals. We apologize for the
inconveniences. Have a nice trip! 15:44

Figure 6-10 Display messages to show rerouting information during incidents.[53]

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[53] For details of the MBTA subway lines, see MBTA system map in Figure 2-2.

options. If conditions permit, the smart bus can detour from its original route to avoid the delays. Otherwise, the smart bus can drop off the passengers at next bus stop or other points where a supplementary bus can pick up the passengers to take alternative routes or modes. Certainly, the smart bus would choose to stay at the same route if the above options cannot apply or if the congestion level is acceptable. In any case, the display screen as well as the announcement system will inform the passengers of any actions that would be taken. If there is a need for rerouting or transfer of passengers to other vehicles or modes, the display screen would provide the instructions and directions for the new travel arrangements. Figure 6-10 illustrates the type of messages displayed during the traffic incident.

Announcement System

Today, many buses and trains in transit agencies across U.S. are equipped with some kind of announcement system. The ITC smart buses will be installed with a real-time announcement system in addition to the in-vehicle display system. There are three announcement technologies: digitized voice message, pre-recorded message, and announcements made by drivers. Digitized messages contain the real-time information sent from various sources such as airplanes, Logan airport or MBTA trains. Similar to the way digitized data are transmitted to the in-vehicle display units, digitized voice messages will be sent from Airport or South Station Control Centers to the ITC smart bus announcement system. The messages will be converted to sound wave broadcasting directly through the speakers.

Pre-recorded messages contains static traveler information. This type of message includes station name, features of the stations, instruction for transfers, and welcome messages. Traditionally, this role has been undertaken by the drivers. The messages are pre-recorded in tape or CD-ROM and programmed to broadcast at appropriate stations. This type of message reduces the load of the drivers.

The third type of message, announcement made by the drivers, is mainly for back-up purposes. Since drivers have their own operator interface, they can obtain real-time information directly from the control center. If there is a problem in signal transmission from the control center to the announcement system, the driver can announce the information obtained directly via the driver interface. In this case, the driver has to decide what information to announce according to appropriate guidelines as well as his/her own professional judgment.

The essence of the announcement system is two-fold. First, since people can receive the audio information at a higher rate than visual information, recorded announcements can be made to indicate the functions in more details (terminals, airline counters, baggage claims, international gateway, parking garage, restaurants, hotels, customs, other modes of ground transportation) at each station. However, visual information is still needed to help travelers remember the important information. Second, both announcement system and display unit can provide great help to regular travelers and offer particular assistance to the visually-impaired and hearing-impaired persons and hence help meet the ADA requirements.

Smart Cards

Smart card technology can be applied to facilitate both the business travelers and the tourists. Electronic fare box and smart card reader will be installed to accept both cash and smart card. Eventually, when the use of smart card is more widespread, the cash portion of the fare box will be eliminated from the smart bus. The smart card can speed up the boarding process to the ITC smart bus. Passengers can use smart cards to pay for the fare of the ground transportation such as the connectors, MBTA subway, buses, commuter rails as well as shopping. Details about smart card applications in Logan-T will be discussed later in this chapter.

Access, Egress and Seat Design

Physical movement is an important aspect for air trip travelers with baggage. Access, egress and seating designs play a vital role in passenger physical movement. The smart buses with two different designs would operate on different types of routes. The first design involves the specially-designed bus and the platform which maximize the space at the vehicle compartment for efficient movement and for accommodations of passenger and baggage. The second design adopts the design of existing tour bus. Here, we will focus on the discussion of the first design.

The first type of design -- no-seated, stand-only, wide-door and low platform buses can operate on short-haul routes. Intermodal transit connector (ITC) is an ideal case for using this type of bus system. A bus station would resemble a subway station where a platform is built at each station. The platform design allows efficient movement of passengers and their baggage. It is more convenient for the passengers to load and unload the baggage between the bus and station platform. The wide door further enhances the boarding and alighting. Disabled persons with wheelchairs can access the vehicle easily. It also speeds up the access and egress process. The absence of seats provides a lot of extra room for both passengers and baggage, thereby increasing both the passenger and baggage capacities of the bus. Moreover, it allows easier movement of both passengers and baggage within the vehicle.

To make the system more efficient, access can be controlled in the same way as heavy rail by installing turnstiles at the bus stations. Tokens or tickets can be purchased at the vending machines. As a result, it can avoid the time-consuming queuing process of one-by-one fare box payment. Instead, a number of passengers can board at the same time. It further reduces the dwelling time at the bus station. Brazil has a successful example of platform-access bus system (Rutherford, 1996). The service efficiency of each route has increased significantly after introducing this innovative system. Given the similar characteristics of the infrastructure such as the platform and the turnstile-access control system, it is thus easy to convert the ITC bus system to the future silver line subway system.

The second type of design will be applied to long- hauled routes. Tour buses that are equipped with separate baggage compartment will be used. As there are only a few stops along the long route, much fewer passenger physical movements will occur. Travelers can load their baggage onto the baggage compartment at the bottom of the bus before boarding, and then unload them at their destinations. Inter-city commuting express buses such as Logan Express in Boston and many hotel shuttles are some good examples.

6.2.1.2 Smart train

Smart train would be used in the new Silver Line at the third phase of the intermodal transportation connector. Testing can be conducted at the Blue Line which consists of 12 stations including the airport station. If the performance testing gets a positive result, MBTA can expand the service and utilize the smart trains in other lines.

Basic System Requirements

Basically, smart trains and smart buses have similar system requirements. Most of the design of the smart buses discussed above can be also applied to the smart train design. The followings are the system requirements for the smart trains:

- User Interfaces: Terminal display screens, in-vehicle display units, announcement system.
- AVL Systems: Track Section Circuit System.
- Communications Systems: Digital radio system, radio control.
- Central computer processing units
- Data processing and control units
- Data storage/memory

- Software packages including in-built algorithms
- Network connections to the South Station and Logan Airport Control Centers.

The train will be specifically designed to serve the special needs of the air passengers. Each train would be equipped with overhead baggage compartments for light baggage. Seats would be minimized to supply extra room to accommodate the baggage. Seating arrangement would be specially designed to facilitate the movement of passengers and baggage. Current seating plan for the Red, Blue and Orange Lines is acceptable. Display units would be available on train to show the flight information, ground transportation information, traffic information, and other traveler information. The units should be placed horizontally at the top of the windows at both sides of the train. Figure 6-9 and Figure 6-10 earlier in the section discussing the smart bus can also represent the types of display on smart train.

Similar to the smart bus, recorded announcements would be made to indicate the functions (terminals, airline counters, baggage claims, international gateway, parking garage, restaurants, hotels, customs, other modes of ground transportation) at each station. When trains arrive at each station (esp. terminals stations), extra time should be allowed to clear all the passengers with baggage before the closure of the door.

Because the train has its exclusive right-of-way, track section closed circuit system can be used to determine the location of the train. Thus, most rail systems have provided radio announcements for stops. Therefore, it is much easier to identify the train location and deliver the traveler information. Based on the existing technique of radio announcements for stops, other information presented above can be added to the message at each stop.

6.2.1.3 Smart Stations

Taking public transportation sometimes is a difficult task for travelers, particularly for tourists. Travelers need to find out a route to get to their destinations. Afterward, they need to find out the location of the bus, subway or commuter rail stations, the transfer points and the appropriate platforms within the stations. Moreover, they need to know the estimated travel time of each mode, wait time, and transfer time. Travelers can easily get lost in a subway station when they cannot obtain the needed information to help them get to their destinations. Smart stations are designed to aid the travelers in all of above aspects as well as to meet the ADA requirements.

To serve specifically the air passengers, only major transit centers and stations with higher volume of air passengers would be designated as smart stations. Subway stations located near universities also generate higher demand for air travel information because many college students take MBTA subway to the airport. Therefore, the smart stations would include all stations along the ITC route, South Station Transit Center, Back Bay Transit Center, Airport Station, Government Center Station, Park Street Station, Downtown Crossing Station, North Station, Porter Station, Harvard Station, Kendall/MIT Station, JFK/U Mass Station, and selected commuter rail stations. However, other MBTA stations would be equipped with some smart components such as in-terminal display units and information kiosks.

The essential elements of a smart station include:

- Clear signs and guidance within and outside stations: Both static and variable message signs.
- Interactive information kiosks
- Easy access for all travelers

System Requirements

Here are the system requirements for the smart station.

- User Interfaces: Variable Message Signs (VMS), Audible Signs, Terminal display screens, Announcement System, Interactive Information Kiosks, and electronic transit system map.
- Smart-Card-Controlled Turnstile System.

- Communications Systems: Cable system, Digital radio system, Radio control.
- Central Computer Processing Units
- Data Processing and Control Units
- Data Storage/Memory
- Software Packages including in-built algorithms
- Geographic Information Systems
- Network Connections to the South Station and Logan Airport Control Centers.

6.2.1.3.1 Smart Signs and Guidance System

Variable Message Signs

Variable message signs (VMS) can be used for different purposes. First, they can be used for conveying updated or real-time multi-modal information to the travelers at the ITC, MBTA subway and commuter rail stations. Second, they can be used for displaying simple route instruction, multi-modal connection information, important phone numbers and advertisements. The following types of information are the best use of VMS:

- Welcome messages
- Reminder of the soon-to-depart flights
- Unexpected delays or early arrivals of the flight
- Detours or cancellations of the flight due to unexpected weather,(such as snow storms) maintenance problems, or other incidents.
- Updated traffic and weather information.
- Simple instructions for intermodal connection.
- Warnings such as "Do not leave your baggage unattended."
- Important or hotline numbers for travelers.
- Advertisements
- Reminder of the closing service of the ground transportation such as the last bus or the last train.

- Emergency.

VMS will be installed at the train platforms and mezzanines. Since the VMS is big and displayed in Light Emitting Diode (LED), it is thus the most direct way to draw the attention from the travelers. The VMS will be connected to the local data storage unit at each station as well as to the Airport and South Station Control Centers. The local data storage unit contains a standard package of pre-recorded messages tailored to the need of each station. For example, the data storage unit at the future World Trade Center(WTC) Silver Line Station will contain messages for special events or convention held in the World Trade Center. At the same time, the data storage unit at Chelsea Silver Line and Commuter Rail Station will contain information on trains towards the direction of Ipswich and Rockport. Nevertheless, both WTC and Chelsea stations will receive the same flight information from the Control Centers.

Audible Signs

Audible signs should be used in major MBTA transit stations and eventually in all stations. Just as conventional visual signs for sighted person, audible signs are designed to provide directional and usage guide to visually-impaired persons. The audible signs send information from installed infrared transmitters to hand-held receivers. At various locations at the stations, the visually-impaired persons with the receiver can hear the message whenever they walk by the audible signs. The messages inform the users of their locations, guide them the ways to the train platforms and show them how to board the trains. The messages also inform the users about the facilities at the station and help them get to those facilities. This technology can also help deliver the information to the illiterates in addition to the visually-impaired.[54]

Real-Time Announcement System

The real-time announcement system works as a supplement to the variable message signs to deliver instantaneous real-time multi-modal information to the travelers. Digitized

[54] USDOT, 1996.

voice messages are transmitted from the Control Center. The messages are transformed into analog sound wave and are announced via a number of loudspeakers throughout the station. For backup purposes, some of the station staffs are able to make announcement via the system. It is essential when emergency occurs at the station or when the messages cannot reach the announcement center due to transmission problems or interruptions on the route.

6.2.1.3.2 Interactive Information Kiosks

Interactive information kiosks provide a variety of travelers' information. With the Internet access to World Wide Web, travelers can access a lot more traveler information around the world. At the same time, the Internet could pose the danger of information overload in which a lot of non-travel related information can be obtained. Nevertheless, the information at the Logan-T Smart Stations will be filtered and only the following useful traveler information will be available at the kiosks at Smart Stations.

- Flight information: Flight departure and arrival information; Real-time flight status.
- Multimodal information: Modes, routes, directions, service frequency and hours, and intermodal connection details. The Dynamic Intermodal Route Guidance System will be illustrated in detail later in this chapter.
- Real-time traffic conditions.
- Real-time multimodal information: Location of the coming train/bus and the estimated time
- Real-time reservation of different transportation modes in Metropolitan Boston area and those at another airports. The reservation system will be illustrated in details later in this chapter.

Section 6.4 will present some scenarios that demonstrate how the travelers can access to the above information via the kiosks.

Optional services

Credit-card readers and ticket issuing machine can be installed at the information kiosks so that travelers can purchase tickets of other transportation modes from the kiosks. This service can save a lot of transaction time conducted by airline or travel agency staffs. Travelers can use the kiosks to make any changes like date and time of flights on their tickets through the kiosks

If a high resolution printer is acquired, maps and schedules according to the need of travelers can be printed out from the kiosk. As a result, they can carry a handy reference with them along their way.

Locations

As mentioned earlier, kiosks will be implemented at the ITC, major MBTA subway and bus stations to provide tourist information. Eventually, kiosks will be installed in all MBTA subway stations and most of the commuter rail stations. Gradual implementation of the kiosk system can spread out the system costs over a longer period of time.

System Requirements and Costs

- Hardware: Touch-screen monitor, Central Processing Unit (CPU), mouse, and keyboard.
- Software: Graphical interface, Internet browser, and GIS.
- Networking: Ethernet/cable modem connections; Group of kiosks can form a Local Area Network (LAN).
- Options: Credit-card reader, smart-card reader, printers, loudspeakers.

A basic, stand-alone traveler information kiosk typically costs about $7,500 to $10,000 for the hardware components. Depending on the type of software being used, the total cost per kiosk including the hardware and software components is around $20,000. The basic kiosks can only provide the World Wide Web access for the travelers. For additional features like credit card or smart card readers, it costs extra $5,000 per kiosk.

For those places where an existing network is already in place, the connection cost is low: less than $2000 per kiosk. Besides the initial capital cost, a comprehensive maintenance cost of the information kiosks is estimated to range from $2000 to $3000 per year per kiosk. The cost includes

- System testing for component malfunction
- Repair/Replacement of various system components
- Regular database update
- Routine cleaning
- Power consumption and Internet service charges
- Paper and toner supply.

6.2.1.3.3 Smart Access

A smart station should provide an easy access for all travelers. Because of the huge capital investments, airports have often been more successful to provide easy access for travelers than transit stations. Wheelchair or elevator access is essential not only to wheelchair users, but also important to travelers with baggage. At present, most of the stations at Red Line, Orange Line and Blue Line have wheelchair access. Surprisingly, there is no wheelchair access to the Airport Station. Elevators should be installed in all underground or elevated stations for easy access from the street to the mezzanine and from there to the platform. To minimize the moving difficulties of travelers with baggage and disabled persons, elevators and automated walkway will be installed in all stations to facilitate the transfers between different subway lines. It would require redesign of the subway stations in order to have enough space to accommodate new elevators and automated walkways. In new Silver Line stations, direct elevator/wheelchair access should be provided from surface streets or buildings to the platform. For instance, station entrance of the new World Trade Center Station would be available inside the World Trade Center. The travelers can purchase the ticket, token or smart card at the ground floor or basement of the World Trade Center. Then they pass through turnstiles and enter the platforms via elevators.

The smart station is the master piece in multimodal connections. Smart stations should work hand in hand with the people mover system, the airport terminals, other subway lines, commuter rail lines (South Station and Chelsea) and other buses services. The integration of all these modes can make Logan-T an intelligent seamless intermodal transportation system.

6.2.2 Design of Logan-T Smart Airport

As air travel is inherently intermodal, an airport become a multimodal transportation hub where different kinds of ground-air connections are made. At the same time, some flight passengers make the inter-flight connections at the airport. A "Smart Airport" is essential to fuse the passengers with the airport in one such that the travelers would feel comfortable to move around the airport, and think that they are in control of their choices and movements. Therefore, a "Smart Airport" should contain the following features:

- High quality infrastructure and services of each mode: Bus, subway, train, taxi, plane, etc.
- Good integration and coordination of all modes: Access, transfer time, reliability, etc.
- Organized, well presented, complete, and updated information of all modes available to travelers.

6.2.2.1 Airport Information System

Information is an essential element in an airport especially for the tourists. In all of the major airports, signs are present throughout the airport to guide the travelers around. Within a terminal, signs are usually helpful to direct the travelers to appropriate gates or check-in counters. However, some signs are not as expressive as they are intended to be.

In particular, the signs or directions to the ground transportation confuse the travelers easily. Because the nature of intermodal connections is complex, people can easily get lost in the airport while searching for the ground transportation.

At Logan International Airport, there are many different ground transportation modes to choose from. Since spaces are limited at the airport, the curb-side traffic is quite congested. The pick-ups often occur just outside the baggage claim areas to facilitate the baggage loading. At the same time, taxi cabs are waiting in the same area to pick up the travelers. This often results in double parking and further blockage of the traffic. Other ground transportation modes are located farther away from the terminal. Travelers need to cross the pick-up area to access other modes of transportation such as MBTA shuttle, Logan Express and hotel buses. However, signs are limited only in certain areas to show where to take different modes. The few existing signs are not clear to direct the travelers to take each mode. Hence, it is easy for travelers to get lost finding the right modes of transportation.

An airport information system is therefore essential to make a smart airport. The system include interactive information kiosks, variable message signs, sound guidance system, and others.

6.2.2.1.1 Interactive Information Kiosks

Interactive information kiosks provide a variety of travelers' information. With the Internet access to World Wide Web, travelers can access a lot more traveler information around the world. One of the web page, QuickAID ™ web page contains an airport directory of 30 major airports in the U.S, including Boston Logan International Airport. In fact, QuickAID ™ is currently a major kiosk service provider for many airports in the U.S. Appendix A illustrates the type of information and the user interface provided by QuickAID ™. It provides a detailed guide of the airport and other traveler information. For static information, the Logan Airport can use the information of QuickAID ™ in the information kiosk. Programs can be written to block out the access to web sites other than the QuickAID. Alternatively, the web pages of QuickAID can be stored as local files in the CPU of kiosks. Additional features can be added if needed. For real-time information and interactive features, special programs need to be developed.

The airport information kiosk provides mainly the following information.

- Ground Transportation Information
- Flight Information
- Hotel and Tourist Information
- Real Time Traffic Information
- Interactive Reservation of Ground Transportation (Section 6.3 will discuss in detail.)
- Yellow Pages
- Internet Access (Limited time to avoid prolonged use of the kiosks by one person)

Locations

The kiosks will be located in the areas at which the passenger volume is high. The presence of kiosks is particularly important for the tourists and business travelers. Hence, some kiosks will be installed at the waiting lobbies of the arrival gates at terminus A, B, C and E. Some will also be installed at the baggage claim area so that passengers can acquire the needed information while waiting for the baggage. Each people mover station should at least have one information kiosk to facilitate the intermodal transfers.

System Requirements and Costs

Basically, the system requirements and the unit cost of information kiosks at the airport and the transit station will be the same. The presentation in section 6.2.1.3.2. earlier in this chapter provides a good reference on system requirements and costs of the information kiosks.

6.2.2.1.2 Airport Ground Transportation Database

An airport ground transportation database is an essential requirement for the information kiosks. The information in the database is very useful for planners and other users besides the travelers. Planners from other airports may want to get the information so that they can put the Boston ground transportation information in the kiosks at their airports. Travel agents may want to obtain some data to provide different ground transportation options for their clients to plan their trips.

6.2.2.2 Variable Message Signs and Sound Guidance System

Variable message signs (VMS) can be used for different purposes. First, they can be used for conveying updated or real-time information to the travelers at the airport. Second, they can be used for displaying important phone numbers and advertisements. The following types of information are the best use of VMS:

- Welcome messages.
- Reminder of the soon-to-depart flights.
- Unexpected delays or early arrivals of the flights.
- Detours or cancellations of the flight due to unexpected weather,(such as snow storms) maintenance problems, hijacking, or other incidents.
- Updated traffic and weather information.
- Warnings such as "Do not leave your baggage unattended."
- Important or hotline numbers for travelers.
- Advertisements
- Reminder of the closing service of the ground transportation such as last bus or last train.
- Emergency.

VMS should be installed all around the airport. Since the VMS is big and displayed in LED, it is thus the most direct way to draw the attention from the travelers. The repeated, moving words can expand the display capability of the VMS. The specifications of VMS vary depending on the locations of the signs. Large signs will be used in the main terminal areas at terminal A, B, C, D and E. Smaller signs will be used in the waiting areas outside the departing gates within each terminal. VMS is vital in the way it can remind the travelers of any information they might have missed from the announcement system.

6.2.2.3 Make the People Mover System Smarter

The people mover system connects the MBTA subway station to the Terminals A, B, C, the International Gateway, and the hotel. Its major function is to transport the passengers between the airport station and the airport terminals. Figure 6-11 shows the map of the Logan Airport. In addition, a maintenance facility will be built in the North service area. The people mover should be spacious enough to accommodate the baggage easily. Signs as well as electronic voice speakers can be installed along the people mover system to guide the travelers where to get off. Information such as gate numbers, airline check-in counters, baggage claims, and ground transportation information can be announced along the mover system.

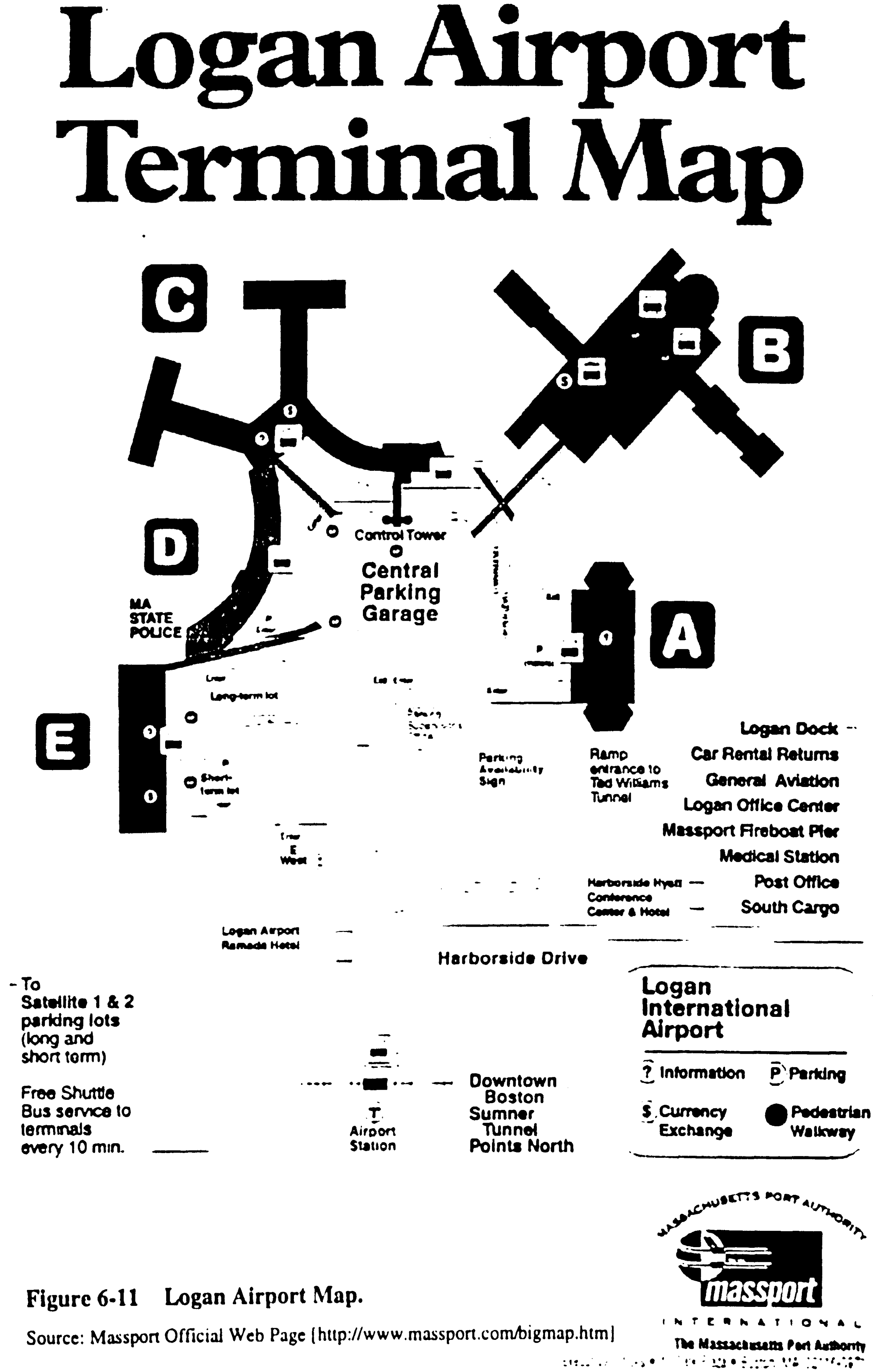


Figure 6-11 Logan Airport Map.

Source: Massport Official Web Page [http://www.massport.com/bigmap.htm]

Alternatively, a baggage mover system can be installed next to the people mover system so that passengers do not need to carry the baggage on the people mover system. If the system is computerized, passengers can check-in the baggage at certain points and indicate the destination of the baggage and pick it up at appropriate points at the airport. For example, once a passenger gets off from MBTA airport station, he can check-in the baggage at the station and indicates that he picks up the baggage at the airline counter at terminal C. Then he get himself on the people mover and can stop by any points without carrying the baggage around. In this case, he may want to stop by an airport restaurant to grab a sandwich and buy a newspaper. Thereafter, he gets back onto the people mover and gets off at terminal C. He can now go to the airline counter, points to his baggage and checks-in. This process is particularly convenient for families or group travelers.

6.2.3 Design of Logan-T Smart Airplanes

The smart airplane is an innovative idea to turn the flight time into an effective period to obtain important traveler information. In some larger air carriers nowadays, all seats are equipped with small video screens for personal entertainment. The equipment enables individual selection of entertainment such as movies or games at the own seat of every passenger. A Local Area Network (LAN) would be established on the plane. The LAN would be connected to the Internet using satellite communications. Each monitor at the seat can be connected to the Central Processing Unit (CPU) and becomes a computer terminal at the seat. Since all computer terminals share the memory at the mainframe CPU, the seats have enough space to accommodate the minimal hardware requirements. (IBM, Digital Equipment Corp., Sun Microsystems, and Silicon Graphics are some good mainframe systems manufacturers and service providers). The mini computer terminals can have two major functions: information access and desktop use. This thesis will focus only on the information access that facilitates intermodal passenger transportation.

System Requirements

To be successful, a smart plane should meet the following system requirements:

- Digital Radio or Microwave Communication System.
- Desktop computers
- Client/Server system in a LAN settings.

6.2.3.1 Pre-stored information for Designated Destinations

The on-plane computer can act as an information channel whether the plane has Internet connections or not. A customized information database and browser can be set up. The database should contains information of the destination airport, the ground transportation, hotels or other types of accommodation, attractions around the city, and yellow pages. Each airplane usually serves only certain designated routes. The origins and destinations are predetermined. Because travelers are only interested in the origin and destination cities, only the information from the databases related to the flight destinations would be included because the information from all other cities is not useful for the travelers. A lot of memory can be saved by this customization and the processing time of the queries can be speeded up.

6.2.3.2 Traveler Information Access

The computer can provide Internet or World Wide Web access. The default web site can be set to certain web pages such as QuickAID ™ that links to the major airports around the world. Travelers can obtain the information of the destination airport, the ground transportation, hotels or other types of accommodation, attractions around the city, and yellow pages. Moreover, travelers can use the search engine to look for their specific interest via the Internet. From the web, travelers can also make reservations for the ground transportation, hotel rooms or even entertainment such as seats for a musical performance. From these pieces of information, travelers can plan their travel arrangement easily before the plane lands onto the runway. They would know how to get around the airport, where to claim back their baggage, and where to get what they need at the airport. Also, they can carefully select the types of ground transportation to suit their travel needs in terms of cost, travel time, reliability and comfort. Whether the travelers are picked up by someone or use the private or public transportation providers, they know where to find it at the airport. They may even be able to print out the route maps and schedules of public transit, shuttle buses or other fixed route operators. For those who prefer demand responsive transportation, they might choose a taxi or reserve a seat at the door-to-door van. Besides, the travelers can plan for his trip in more details with the aid of the traveler information system and the World Wide Web. All the uncertainty or anxiety in a new airport can thus be eliminated. Instead, an intermodal travel plan can be established.

In addition, travelers can access to their electronic account, check or send any electronic mails from the computer terminal. Business travelers can send an electronic mail with an attached business documents to the other party to review before the business meeting or conference. Also, they can discuss business matters using Internet chat. The most important use of the Internet on plane is to inform the other party of any changes in arrival schedule of the flight due to bad weather, unexpected current or other reasons. Business travelers can reschedule or cancel their meetings beforehand.

6.2.3.3 Communications with Ground Transportation

Communications between the plane and ground transportation can make a significant impact on both passengers and airlines. The communications are especially useful to inform both the air passengers and plane crews about the status of the plane and the status of the passengers.

When a passenger is rushing to the airport via the MBTA train or ITC bus, he can use the radio communication equipment on the train or bus to inform the crew on the plane about his status, including his location and the approximate travel time from where he is to the boarding gate. The crew can confirm it by checking the source of the message and location of the vehicle where the message is sent. Similar applications can be used at the MBTA or ITC stations as well. If the travel time is within acceptable limit that allows the passenger to board the plane on or before the scheduled time, the crew will inform the airline check-in counter at the airport to speed up the check-in process for that passenger so that he can get to the plane on-time. At the same time, the crew could have an expectation on the arrival time of some last-minute passengers so that the plane can wait for them for another minute or two until the latest acceptable departure time.

The plane-ground communications are also very useful in ground transportation in similar ways. In door-to-door van operations, dispatchers arrange the vans and their departure times according to the estimated arrival time of the passengers who make reservations from the plane or via other media. With the aid of the plane-ground communications, the van dispatchers can obtain the accurate flight status of the planes. Therefore, they can decide whether they should wait for the passengers who are flying in. If the flights encounter long delays, the dispatchers can reschedule the passengers to other vans which depart later. When the plane is in range (jargon used in airline which means that the flight is about 15 minutes away from the airport), the van dispatchers would send a confirmation message to their customers on the plane. The message informs the passengers of the final van arrangements including the meeting place for pick-ups and scheduled departure time of the van. This kind of application can also be applied to other types of ground transportation such as hotel buses and airport shuttle (Logan Express).

ITC buses and MBTA trains have high service frequencies, so that this particular application does not apply to these modes. However, the communications are useful in these transit services for other purposes. When certain flights are delayed such that the planes are expected to arrive at the time beyond the normal service hours of ITC buses and MBTA trains, the dispatchers of the buses and trains could communicate with the passengers on the delayed plane. If there is a demand for the transit services by those passengers, the dispatchers can schedule additional emergency services to pick up those passengers. Again, the real-time flight status enables the dispatchers to know when to dispatcher the supplementary buses or trains to the airport.

Communications technologies can be useful to some standby and wait-listed passengers as well as those emergency travelers who need to make last-minute purchases. At the vehicles or stations, the travelers can obtain the status of the plane via the on-board or in-terminal display units, information kiosks or even Internet at home or office. They can make appropriate travel arrangement once they know whether the plane is full or not. At the same time, it is easier to arrange the seating priority for the unmet passenger demand due to overbooking.

Smart plane applications can have a very significant impact on the entire travel process as well as the information gathering process. In the past, little attention has been paid to the smart plane applications. The pioneering development of smart plane can turn into one of the future attraction of air travel.

6.3 Special Components

6.3.1 Dynamic Intermodal Route Guidance System (DIRTS)

When business travelers or tourists arrive at an airport that is new to them, they can get frustrated easily since they are not familiar with the airport or the city. They might have a specific destination but do not know how to get there. A guidance system is essential to direct the travelers to choose the right path by recommending the right transportation modes and by giving appropriate route guidance for the travelers. The Dynamic Intermodal RouTe Guidance System (DIRTS) is designed to perform the above functions in real-time. The system is accessible from every information kiosk in the Logan-T system, including the Logan Airport, ITC stations, and major transit centers as discussed in Section 6.2. The system software can be installed in the central server at the Control Centers or at the individual kiosks. The use of DIRTS was briefly mentioned in the previous sections which discussed the applications in the smart plane, the smart airport, and the smart station. This section will discuss the functions and system requirements of the system in detail.

User Procedure

At the information kiosk, the user can follow the procedure below to make an inquiry for getting to a particular destination from a chosen origin.

- Select the option of Dynamic Intermodal Route Guidance System.
- After entering the system, select desired origin from the pull-down menu or map or type in the name.
- Select desired destination from the pull-down menu or map or type the name in.
- Select the range of departure time from the origin. (ie: 14:30-14:45)
- Select desired arrival time at the destination. (ie: 15:50)
- Indicate modal preferences.
- Indicate constraints such as upper limit of travel time, wait time, out-of-pocket cost, or number of transfers.
- Computer makes use of the shortest path algorithm, takes the constraints into consideration, and calculates the desired travel path. A summary of other possible paths will be given as travel options. The screen will display the route maps and different attributes of each path such as travel time, wait time, cost, number of transfers, departure and arrival times, frequency of the services, and even estimated potential delays. If printer is attached, travelers can take the printout with them on the road.

The system would inform the travelers the advised bus, subway or commuter rail routes plus necessary connecting modes such as shuttle or taxi. Different sets of departure times and arrival times (Within the range of tolerated departure times and arrival times)of the whole trip will be presented to the travelers for reference. The system can also work with the Smart Card to provide real-time updated information for the travelers. Travelers can insert the smart card into the information kiosk when inquiring the route guidance information. The card can store the queries and results by referencing the locations of data. (Information would be static if the results are stored by value.) After a while, when the passenger travels on the bus, train or at the stations, he can insert the card to any device that contains the route guidance system.

System Requirements

The system software will be located in the central server at the Control Centers in a centralized client-server system. Alternatively, the software can be built in the individual kiosks in a distributed system. The traditional static route guidance system requires a GIS Software such as ArcInfo, ArcCAD, MapInfo, TransCAD, or a specially designed customized software to display spatial information on the map. Different layers can be created to represent the spatial data. A basic geographical map presents the basic geography of a place. A street map is a layer with all the street information. The most important spatial information for the dynamic intermodal route guidance system includes origins and destinations of the routes, stops along the routes, and the routes themselves.

Efficient algorithms are necessary in solving various transportation problems such as the shortest path problem, assignment problem, and traveling salesman's problem. Some of the GIS software have in-built algorithms along with the databases. Caliper's TransCAD has utilized a set of different algorithms to help solve the problems of vehicle routing, arc routing, and various network flow models.

For the development of dynamic route guidance system, it is essential to have dynamic, spatial-reference databases which contain information of all MBTA subway lines, bus routes and commuter rail lines as well as the location data in Greater Boston area. The database would be updated on a regular basis of about every 15 minutes or less. Using the AVL technologies, the bus and rail dispatchers can get very updated information on vehicle location and traffic conditions. All of the information would be gathered in a central location and the dynamic database would be updated automatically. Besides the technological requirements, a good administrative system is needed to manage the data and to monitor the reports to ensure:

- Accurate reports of the data from different sources.
- Consistent reports of the data long the same transit route and within the whole system.
- That the database get updated on a timely basis.
- That all computer terminals get equally updated information.

The monitoring of the reports is very important because the original intention of the real-time route guidance relies on the accuracies and timely reports of all real-time route-related information of all routes within the whole system. An intermodal passenger trip consists of two or more different transportation links. Late or missing reports of traffic information by some operators on certain links can ruin the dynamics of the trips that consist of those links.

6.3.2 Remote Reservation System for Door-to-Door Van Operations

Door-to-door van service is a popular demand-responsive transportation service available in many airports. The service has many advantages in serving air passengers. First of all, the van provides direct door-to-door service to or from the airport. Thus, the baggage can be handled more easily. Also, passengers can enjoy higher flexibility in departure time than other scheduled services; the schedule is responsive to the passengers. Although the service is more expensive than public transit, it is still much cheaper than taxi. At the same time, passengers can enjoy comfortable service which is comparable to taxis or private autos.

The demand responsive nature of the service makes it difficult for the van dispatchers to come up with an efficient and effective schedule. Since flights arrive at the airport at different time, it is hard to know how many passengers of each arrival will be picked up by their friends and relatives, how many will take transit and how many will take taxi or shuttle. Because of the uncertainty, each door-to-door van often end up taking just one or two passengers. Sometimes the van may take several passengers with destinations that are far apart. The poor passenger at the farthest destination may end up sitting in the van for two hours for the ride home.

Interactive remote reservation system is a good way to solve the above problems. Passengers can access the reservation system via computer terminals on the plane, information kiosks at the airports, or personal computers at home or office. The dispatchers can take the reservations from various locations immediately via the Internet. The system enables the door-to-door van service provider to know the destinations of the passengers arriving at different times, so that the dispatchers can group the passengers into different vans accordingly.

System Requirements

Network connections among dispatchers, airplanes, and airports are necessary. Internet can be utilized as a media of communication between the passengers and dispatchers. Information on different van service providers on major airports can be obtain from the Internet. Java or other object-oriented programming languages can be used to create programs to register travelers' information from one end to the other end of the U.S. Airline passenger database can be accessed by dispatchers so that they can verify the passenger information.

At the information kiosks at the originated airport or computer terminals on the plane, passengers can browse through the Internet to reach the ground transportation page of their destined airports. In that page, the travelers can select the kind of demand responsive transportation service. Next, they can enter their personal information, address of their ground destination, and the projected arrival time at the airport. At the same time, the airport van or shuttle dispatchers at the other airport should keep on checking the ride requests from the originated airports and the planes. Ride-matching can be conducted manually or automatically depending on the demand size and the complexity of the requests. Knowing the information of the arrival times and the destinations of different passengers, the van dispatchers can come up with routing plan that can load as many passengers as possible per van without significantly affecting the travel time of each passenger. The cost of operations can be reduced substantially since fewer vehicles are needed. At the same time, the service quality can be increased since matches can be pre-arranged according to the ground destinations of the passengers. As a result, passengers are no longer grouped to the vans purely according to stochastic arrival time of the passengers. Instead, passengers in the nearby neighborhoods can be grouped together in one van. A great deal of time can be saved for both passengers and operators.

6.3.3 Smart Cards: Electronic Fare Payment System

An integrated electronic fare payment system will be designed and applied to the Logan-T Smart System as well as the MBTA subway, bus and commuter rail system. This section will look at the requirements of the new electronic fare payment system for the Logan-T Smart System. Thereafter, an integrated multimodal fare media will be designed for the system.

6.3.3.1 System requirements

To implement the electronic fare payment system into the Logan-T Smart systems, the following components are required:

- Smart Cards.
- Electronic Card Readers (installed at turnstile systems and electronic fare boxes).
- Microprocessors: Process and record fare transactions.

Types and Qualities of Cards

As discussed in Chapter Three, there are many types of electronic payment to choose from: magnetic stripe cards, contact-type integrated circuit cards, proximity cards, capacitively coupled cards. To choose between the different cards, we need to evaluate each card on the basis of certain criteria. Since different electronic payment technologies are under development at different paces, the features, costs, and qualities of different electronic payment cards are all different. Some have been developed for years and are widely used all over the world. Some are very advanced and possess many features. However, their development may be still in early testing stages and there are still many problems to solve. Some applications may be sophisticated and reliable, but costly.

Contactless card would be used in Logan-T to speed up the passenger movement. In this system, the distance between the card and the read-write device should be no more than one feet. As a result, the travelers need not pull their cards out and the device can still read the information from the cards and write data onto them, provided the card is within one feet from the device. At the same time, the distance is short enough not to interfere with the devices on other turnstiles. Two adjacent turnstiles are at least three feet apart.

6.3.3.2 Multi-modal Fare Payment Integration

An electronic fare payment system will be set up for the intermodal transit connector and it will further expand to the whole MBTA system.

Distance-based Fare Structure (Use of Common Stored Value Ticket)

Proximity smart cards will be used for the Logan-T fare payment system. Because of the existing flat fare structure, the unit cost for short distance travelers is higher than long distance travelers. Following is a good example. Because the Red Line stations are quite evenly spaced between Alewife to Ashmont, we can define the distance between two adjacent station as unit station distance unit (SDU). Therefore, the passenger who travels from Alewife to Ashmont has indeed traveled 16 SDU. This passenger only has to pay an unit cost of 6.3 cent/SDU. For any other passenger who only travels between two adjacent stations(i.e.: from Porter to Harvard), the passenger incurs an unit cost of 85 cent/SDU – 16 times the unit cost of the former passenger. Therefore, the short-distance travelers indirectly subsidize the long-distance travelers.

Distance-based fare structure is a good way to assign a fairer share of the real transportation cost to the passengers. Therefore, the fare of the intermodal transit connector (ITC) and subsequently the whole MBTA system will be distance-based. Besides distance-based, the fare can also be based on the time of the day. Congestion pricing can be imposed. For example, an additional congestion surcharge of 25 cents to 50 cents can be deducted from the card value in addition to the basic fare. Basically, the smart card enables the creation of as many fare groups as possible. As long as users of each fare group register their user information onto the cards or purchase the preprogrammed smart cards, the card readers can recognize the stored information of each particular user. Based on the distance traveled, time of travel, and the fare group, the card will find the appropriate fare that matches all of the information. For instance, elders, children and disabled persons can get discount. The information of the discounted groups can be stored in the card. The electronic card reader reads this information from the card. Appropriate fare amount will thereby be deducted from the card. After each one-way bus or subway trip, the fare amount is deducted from the balance of the card. Cash, ATM, or credit cards can be used to purchase the smart card and to add extra monetary amount to the card to increase its balance. Vending machines will be available at most MBTA stations, Logan Airport, ITC stations, banks, and hotels. Moreover, the card users can charge their credit cards and raise the stored value in the card via the phone, Internet and information kiosk. Real-time communication device can send the updated information to all the smart buses and turnstiles. As a result, increment will be made as soon as the passengers use their cards.

The smart card system will gradually be implemented to the Logan-T system. It will go through operational tests, extended implementation of the smart card system, and finally full conversion to smart card system.

Operational Test

New turnstiles equipped with smart-card readers will be installed at the Airport Station and South Station. Smart-card readers will be also installed in the smart buses which serves as the intermodal transit connector (ITC). Coins will not be accepted at the smart buses. Smart card vending machines will be available at all ITC stations.

Extended implementation of smart-card system

After the operational test is proven, smart-card readable turnstiles will be installed at all subway stations. The turnstiles that take tokens and cash will still be in place in the transition period. Part of the MBTA bus routes will have operational tests on smart cards at this stage.

Full conversion to smart-card system

If the second stage has a continued success, the smart-card system will be fully implemented in the whole MBTA subway, bus, commuter rail, and commuter boat system. Token and cash payment will be gradually phased out.

6.3.4 Additional Ideas: Remote Baggage Check-in and Handling System

One of the biggest obstacles to transit access to airport is the inconvenient handling of baggage for the passengers when boarding and alighting the trains and transferring between different modes. Remote passengers baggage check-in can help solving this problem. Passengers can check-in their baggage before boarding the first transit vehicle at the origin and pick them up after they get off from the last transit vehicle at the destinations.

If a train has direct access to the airport, it is easier to implement the remote check-in counters at the rail stations. A similar conveying belt system can be installed at the rail station. Passengers can check in their baggage at the airline counter just as what they do at the airport. After checking in, they can just board the train to the airport. At the same time, the pieces of baggage are conveyed from the station to the train. The group of the baggage, which was checked in to same airline, gets onto the same compartment of the train. The train will get into a special terminal where the baggage will be unloaded and conveyed to the specific terminal according to the flights.

Remote baggage check-in and handling system certainly provides a lot of convenience to the travelers. However, we still need to consider the following problems:

Costs vs. Extensiveness of the Remote Terminal Locations

It is too costly to have too many remote terminals. If the terminals are not extensive enough, people would choose the modes that have direct access to the airport. The goal of moving people into transit cannot be reached under these circumstances.

System requirements

Will the remote check-in baggage system be fully automated or semi-automated? When unloading the baggages from the train or bus to the airport, do someone need to sort the baggages? Or automated process will take care of the sorting issues?

Transportation of baggage

How to transport the baggage? Belt-and-convey system is feasible within the terminal but not feasible for long-distance transportation of the baggage. Ground vehicles like buses or trains are needed to transport the baggages to the airport terminals.

Reliability problems

It takes a lot of time to transfer the baggage from the terminal to the vehicle, then to airport terminal, and finally to the plane. Can the baggage get to the plane on time?

Security problems

Passengers are most concerned about the security of their baggage. A number of transfers are required in the entire baggage handling process, starting from the remote check-in terminals. If security is not tight enough, baggage can get lost or get transferred incorrectly to other planes during the process.

Airline Participation

Airlines are not willing to set up counters for the remote terminals since this will just increase their overhead cost without bringing in additional benefits to the airlines.

6.4 Scenarios

The previous sections in this chapter have presented the design of every component of the Logan-T system. To see how each component works with other components of the system from the traveler's perspective and the perspective of different parties throughout the system, a set of scenarios will be presented below. Each scenario addresses different needs of different type of passengers and their travel nature.

Scenario One: Family Visit: Leaving Boston

Origin: Kendall Square, Cambridge, Massachusetts.

Destination: Long Beach, California

Logan-T APTS Components used:

Smart Plane: Route guidance system and remote reservation system for door-to-door van.

At-seat computer terminal: Tourist Information System.

Smart Airport: VMS and announcement system.

Right after the final exam, a MIT freshmen starts his trip to Long Beach, California where his parents live. He packs his baggage and walks from the dormitory to the nearest

MBTA "T" Station – Kendall Square. He approaches the information kiosk. First of all, he wants to check for the status of his flight. Therefore, he chooses the "flight information" option from the main menu and then clicks on the "departure information" hypertext on the subsequent screen. There are three types of searches he can choose from: by airlines, by departure time, or by origins. He chooses to search by the name of airline. The result shows that the flight is on time and will depart at gate C-11. Since he is new to the city, he is not familiar with the MBTA system and wonders how to get to the airport. Naturally, he clicks on the "how to get there?" hypertext. Then the screen that shows the instructions and maps appears instantaneously. Located at the lower left corner of the screen, the MBTA subway system map highlights the route from the origin (Kendall Station) and destination.(Airport Station) Next to the system map, the airport map highlights the route from the MBTA Airport Station to the departure gate C-11. After obtaining all the information he needs, he clicks the "print" button and gets a printout of the instructions and the maps so that he can read them on his way to the airport. Figure 6-12 shows the various screens mentioned above in a flow chart format.

On the train, the in-vehicle display unit shows him the detailed directions to transfer at Park Street and Government Center. This information facilitates him greatly in transferring to Green Line and then to Blue Line. After he gets off the Blue Line train, he takes the People-Mover to the terminal C, checks-in at the airline counters and gets on his flight at gate C 11.

Scenario Two: Business Travel: Arriving Boston

Origin: Palo Alto, California (via San Francisco International Airport)

Destination: Harvard Square, Cambridge, Massachusetts.

Logan-T APTS Components used:

Smart Plane: Route guidance system and remote reservation system for door-to-door van.

At-seat computer terminal: Tourist Information System.

Smart Airport: VMS and announcement system.

o

A visiting professor from Stanford has to attend a conference at Harvard. On the plane, he wants to check in advance how to get there from the Logan Airport. Therefore, he logs onto the computer terminal at the seat on the airplane and enters the main menu of the traveler information system. Figure 6-13 illustrates the screens of the graphical user interface. From the main menu, he chooses the option of "Ground Transportation." From the screen of the "Ground Transportation at Logan Airport", he enters the name of the destination "Harvard Square." Alternatively, he can locate the destination by zooming in from the regional map, to the city map and finally to a local street map that locates the destination easily. Next, the system shows the options of the transportation modes to get him from the Logan Airport to Harvard Square. He then clicks on each option and obtains the information of each mode. The information includes cost, estimated travel time, route, map and instruction for the whole trip. After reviewing all the modal information, he decides to take the door-to-door van to Harvard Square. Therefore, he clicks on the reservation hypertext to reserve a seat on the van. The page requests him to enter the travel information such as flight arrival time, destination, and his personal information such as name, credit card number, and number of baggage. The information is transmitted via digital radio system to the door-to-door van dispatcher in real-time. After the dispatcher verifies his personal information, he then enters the arrival time and the destination to the scheduling software. With the information from different travelers, an algorithm comes up with the shortest path for the vans in different regions. After the path and departure time is determined, the dispatcher sends the information, including both departure time and estimated arrival time of the van, to that professor before the plane arrives the Logan Airport. At the same time, a set of "beep" sound is sent to the professor in case he is not looking at the screen at the moment. After he gets off the plane, he picks up his baggage and heads towards the pick-up point for the van. Along his way, he can obtain the weather and traffic information from the VMS.

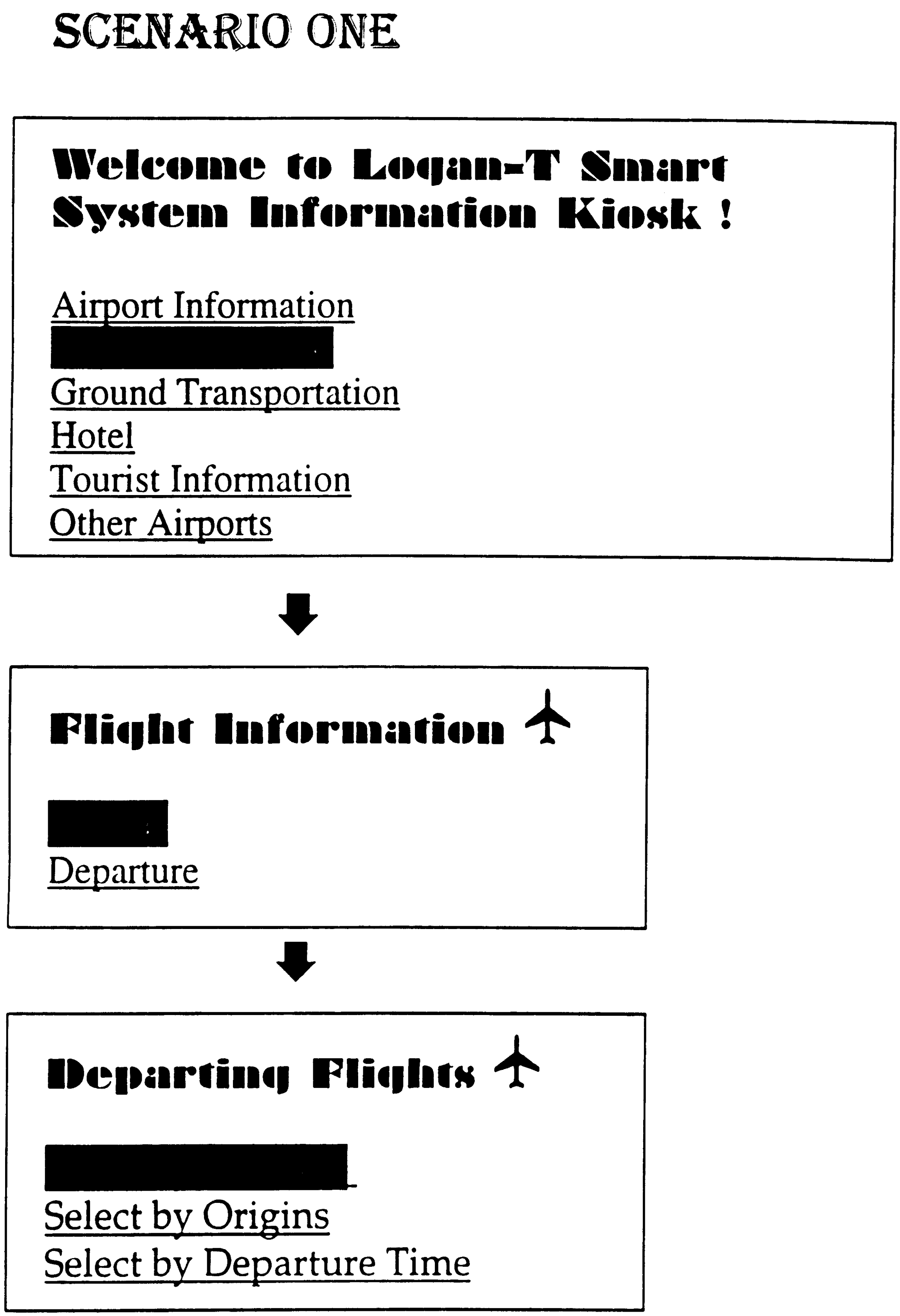


Figure 6-12 Scenario One of Traveling for Logan-T Smart System

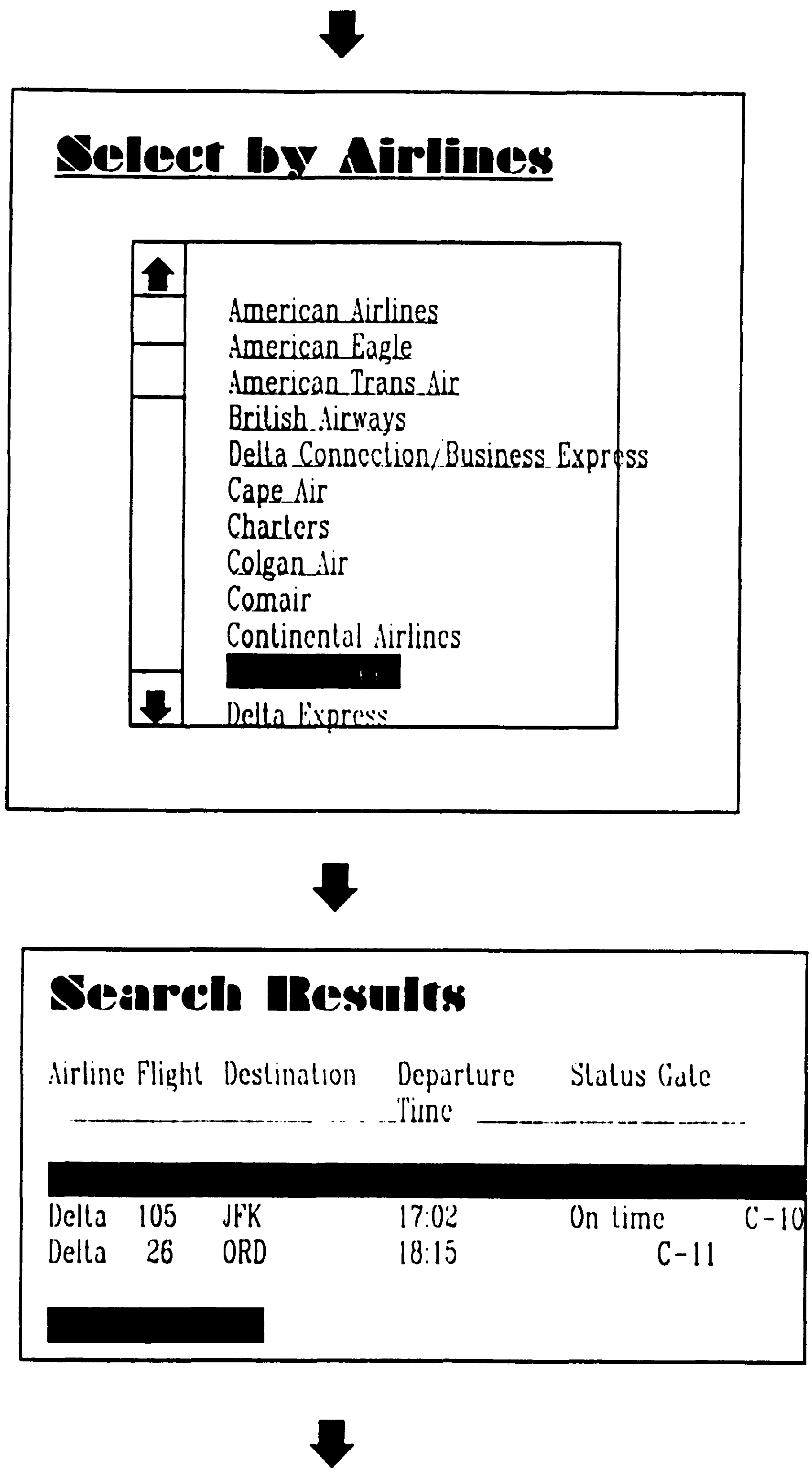


Figure 6-12 Scenario One for Traveling in the Logan-T Smart System (cont'd)

How to get there?

OPTION 1: VIA MBTA ONLY

You are at Kendall Square Station.

Take inbound [redacted] to Park Street

Change to [redacted]. Get off at the next station, Government Center.

Change to [redacted]. Get off at Airport station.

Take the People Mover to Terminal C.

At terminal C, check-in at Delta service desk and then walk towards Gate C-11.

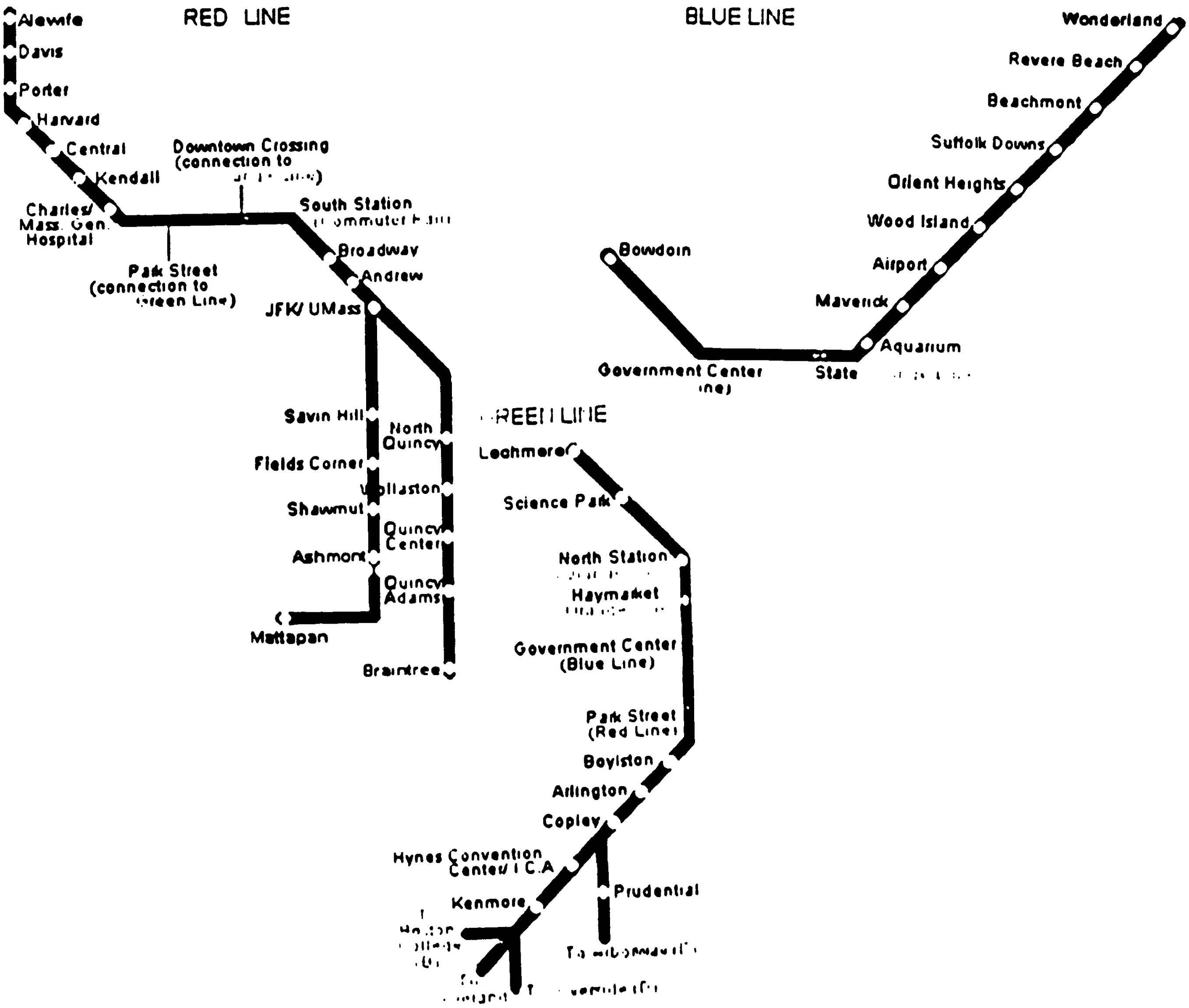


Figure 6-12 Scenario One of Traveling in the Logan-T Smart System (cont'd)

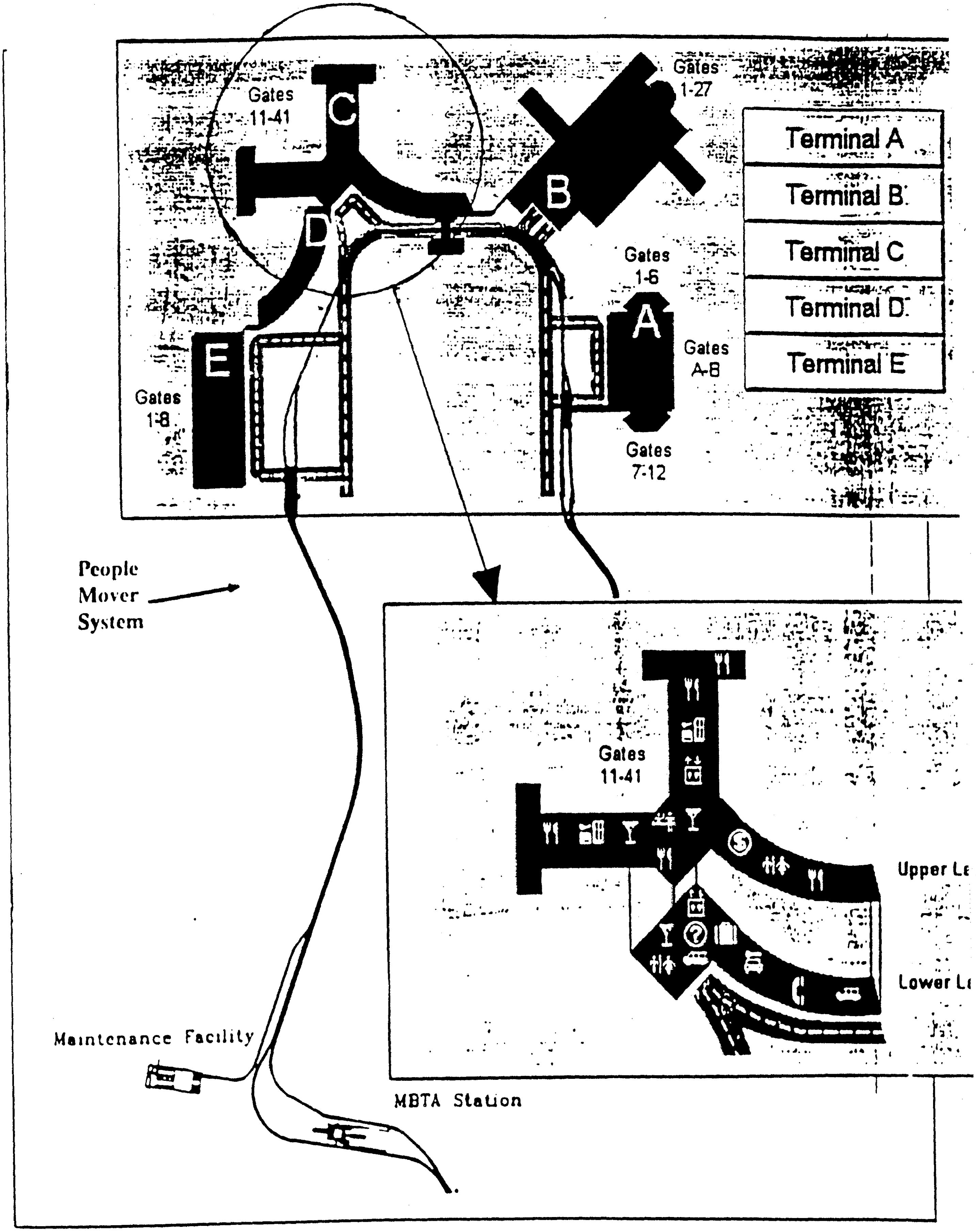


Figure 6-12 Scenario One of Traveling in the Logan-T Smart System (cont'd)

How to get there? *OPTION 2: VIA MBTA & ITC*

You are at Kendall Square Station.

Take inbound [redacted] to South Station

Change to [redacted] at the South Station Transportation Complex.

Get off directly in front of Terminal C.

At terminal C, check-in at Delta Airline service desk and then walk towards Gate C-11.

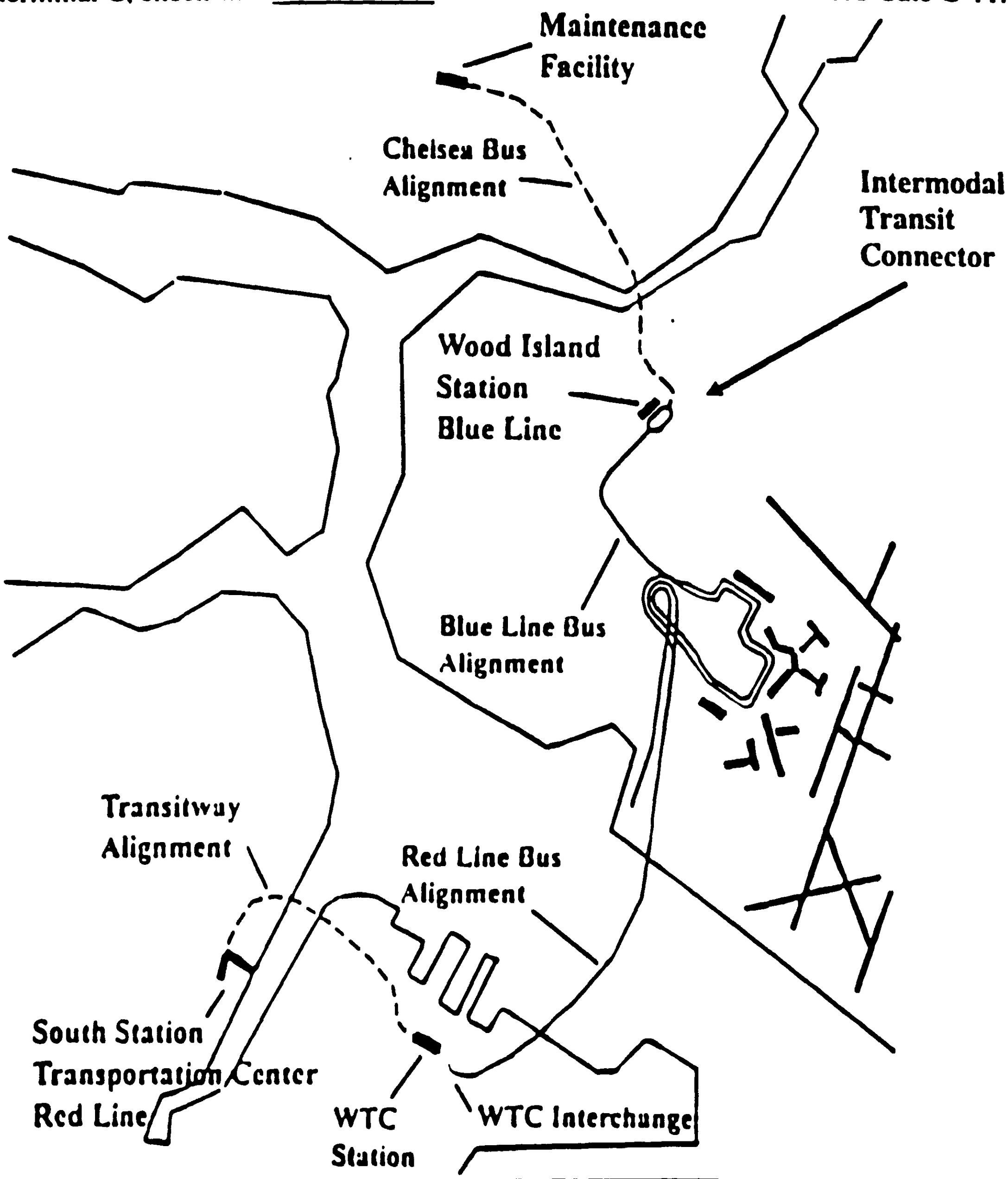


Figure 6-12 Scenario One of Traveling in the Logan-T Smart System (cont'd)

SCENARIO TWO

Welcome to Smart Plane Traveler Information System !

Airport Information
Flight Information
[redacted]
Hotel
Tourist Information
Other Airports

Ground Transportation at Logan Airport

[redacted]
Locate your destination via map

Enter destination Name

Harvard

Hanover
Hamilton
Harvard Avenue
Harvard Medical School/Dental School
[redacted]
Hater Hill

Figure 6-13 Scenario Two: Arriving Passenger make remote reservation for ground transportation on Smart Plane.

LOGAN ➡ Harvard Square

MBTA Subway	$0.85
Door to Door Van	$varies
Limousine	$37
Taxi	$20-25

MBTA $ 0.85

Estimated Travel Time: 35-40 minutes.

- Get on to the people mover system.
- Get off at the MBTA Airport Station.
- Take the Blue Line Inbound Direction.
- Change to Green Line at Government Center.
- Get on to trains that destine at Boston College, Cleveland Circle or other southbound trains.
- Get off the train next stop (Park Street) and Change to Red Line (To Alewife direction).

Get off at Harvard Square.

Logan to Harvard Square $42
Limousine Service

Toll Free: (800)672-7676 (from any United States location)

Boston Coach provides chauffeured sedan service from Logan International Airport. You can meet your driver at the following locations:
Terminal A, across the street from the main baggage claim exit; Terminal B,

Figure 6-13 Scenario Two (cont'd)

curbside at the upper level exit; Terminal C, designated limo stand at the third traffic island; Terminal E, yellow limo service booth at the third traffic island. Fares quoted do not include 18% service fee. Gratuities not accepted. If you are unable to locate your driver you must call (800) 672-7676 to avoid being charged as a no show. If you would like a chauffeur to meet you, ground coordinator support can be requested at $42 an hour for no less than two hours.

Logan to Harvard Square **$12-15**
Door to Door Van Service

Door-to-door Van service is available at Logan International Airport and delivers you to your designated destination. Travel time ranges from 20-30 minutes. You can meet your driver at the following locations:
Terminal A, across the street from the main baggage claim exit; Terminal B, curbside at the upper level exit; Terminal C, designated van stand at traffic island; Terminal E, van stand at the second traffic island.

[illegible]

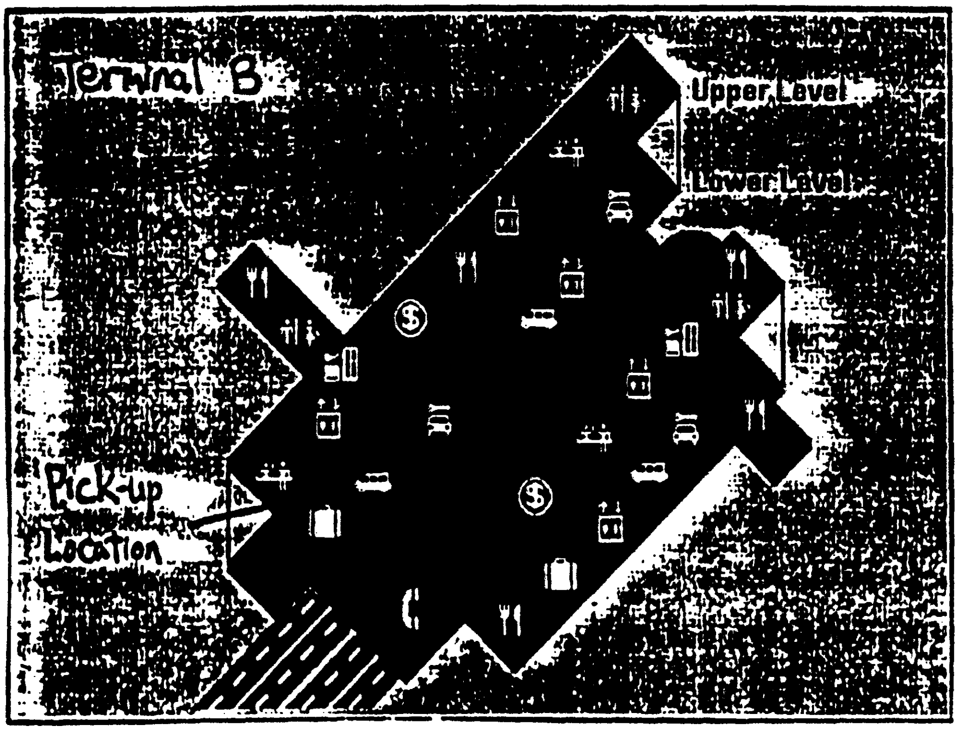
On-Line Reservation for
Door to Door Van Service

Name Phone
Destination Address

Flight Number
Scheduled Flight Arrival Time
Number of Baggage
Credit Card Number

Figure 6-13 Scenario Two (cont'd)

Dr. Einstein, here's the confirmation for your reservation. We will meet you at 22:00-22:15 at Terminal B, curbside at the lower level exit right next to Speedo Car Rental. The following map shows our pickup location.



Thank you for selecting Van-Go Van Service.

Figure 6-13 Scenario Two (cont'd)

Scenario Three Pleasure/Vacation Travel: Leaving Boston with delays

Origin: Needham, Massachusetts

Destination: Bahamas Islands

Logan-T APTS Components used:

Smart Stations: VMS, In-terminal Display Units.

Smart Trains: In-vehicle display and announcement system at ITC.

Smart Bus: In-vehicle display and announcement system at ITC.

Smart Plane: At-seat computer terminal: Tourist Information System.

A married couple from Needham (A city South of Boston) goes to Bahamas Islands for honeymoon. Both of them want to avoid during for whole trip. They check their baggage in early at the remote terminal in the Needham Commuter Rail Station. At the train station, they hear a message from the announcement loudspeaker that a rainstorm has been affecting the air traffic in most of the Southern New England including Boston.

A series of delays and cancellations of the flights are announced via the speaker. While they are waiting for the train to come, they look at the in-terminal display unit at the train platform. The screen displays the updated flight information starting from the soonest departing flight. Their flight is scheduled to depart two hours away. The couple finds that their flight is on-time from the screen. (The plane location is approximately one hour away in distance. The other hour is passengers turnover time for the plane at the airport.)

Next, the couple boards the train. On their way to South Station Terminal, they need to decide whether to take the MBTA subway or the ITC to the airport. The ITC is more direct but may enter traffic congestion. The subway takes longer time because it requires a number of transfers, but it avoids any unfavorable roadway conditions. The in-vehicle display assists them in making their decisions. It gives the complete directions in taking both the subway and ITC. The travel time from South Station to the Airport ranges from 28 to 43 minutes if one takes the MBTA subway. The in-vehicle time is only 13 minutes, but the wait-time and transfer time takes 15 to 30 minutes. For ITC, it normally takes only 12 to 15 minutes for the ride plus a 3-5 minute waiting time. However, the inclement weather causes serious congestion at the Ted William Tunnel. The estimated travel time can range from 35 to 60 minutes. Hence, they decide to take the subway. When the train gets close to the South Station Terminal, they check their flight status again from the in-vehicle display. This time the display indicates that their flight is delayed by 30 to 45 minutes. Because of the delay, they still have almost two hours left before the new departure time. So they decide to have a quick dinner at the South Station before proceeding.

After the dinner, they look at the variable message sign (VMS) at the South Station Terminal to check the traffic and flight information. The VMS shows that the traffic congestion at the Ted William Tunnel is clear now and the travel time for ITC resumes to normal (12 to 15 minutes). Also, their flight will arrive the airport in 40 minutes. Hence, they walk to the ITC terminal and get on the ITC.

At the ITC buses, they receive a lot of airport information in addition to the flight and traffic information. They find out that they need to go to Terminal E (International Gateway) to depart for Bahamas Islands, instead of the Terminal A for regular domestic flights for American Airline. Afterwards, they get off the ITC, check-in at the airline counters and get on their flights at gate E 4. On the plane, they spend most of their time browsing through the Internet to search for the tourist information in Bahamas Island.

Scenario Four Disabled Travelers: Arriving Boston

Origin: Seattle, Washington

Destination: Cambridge, Massachusetts

Logan-T APTS Components used:

Smart Plane: Announcement system

Smart Airport: Audible signs

A visually-impaired traveler is visiting her brother who studies in Boston. All of the visual information is useless for her due to her blindness. She can only rely on the audio information provided in the Logan-T system. On the airplane, she receives audio guidance from the in-built audio guidance system at computer terminal at the passenger seat. Basically, it provides almost the same traveler information, as provided visually by the regular information system, in an audio format. She speaks slowly to the receiver and then the speaker provides a set of options for her to choose from. Then, she responds to the system by speaking out the desired option – airport transportation and the ground transportation information. She receives the instruction from the system to show her way to take the special paratransit at the airport.

Once she arrives the Logan Airport, she obtains an hand-held receiver at the arrival gate. With the receiver at hand, she can locate herself wherever she moves. When the receiver The audible signs at various places transmit the location information and the information on surrounding environment to the receiver so that she can listen to those information. With the guidance, she safely walks from the arrival gate, to the baggage claim, and then to the paratransit stop at the airport.

6.5 Chapter Summary

This chapter presented a prototypical design of an intelligent intermodal transportation system for the access to the Boston's Logan International Airport. The design recognized the needs of the passengers in every step in the door-to-door trip. According to the needs, a prototypical smart system which applies the state-of-the-art APTS technologies was designed to improve the efficiency and effectiveness of the intermodal passenger transportation in the aspect of the access to the Logan Airport. The communication technologies and other cutting edge technologies enhance the information flow among the smart bus, the smart train, the smart station, the smart airport and the smart plane, which in turn help the passengers and the system operators in various ways. In the previous section, different kinds of scenarios showed how each component works with other components of the system to meet different needs of the travelers in different situation. Having completed the reviews and the prototypical design, we can proceed to conclude the thesis in next chapter.

Chapter Seven

Conclusion

This chapter will first look at the study approach of the thesis and will then summarize the thesis. Thereafter, we will present the research findings and research contributions of the thesis. Finally, some thoughts will be given for future research.

7.1 Study Approach

The thesis was broken into two parts for analysis. The first part was "Use of APTS as a strategy." The second part was "Promote the Efficiency of Effectiveness of Intermodal Passenger Transportation."

The first half of the thesis analyzed the two parts separately by

- examining the current status of intermodal passenger transportation in the U.S., and
- reviewing the existing uses of APTS applications in various transit systems and exploring the potential uses.

In the second half, the thesis synthesized both ideas to investigate how to use APTS as a strategy to promote the efficiency and effectiveness of intermodal passenger transportation and to discover whether the strategy can be successful. Since intermodal passenger transportation involves many aspects, the study would be more effective if we could single out an issue that covers most of the intermodal connections; the issue we selected was airport ground access. Regardless of what ground transportation mode a traveler takes to the airport, air travel itself is inherently intermodal, as nobody can fly directly from his home to any destination; intermodal connections are always required. By limiting the study scope to intermodal transportation related to airport ground access, we were able to study the different needs of a passenger at different points in the entire door-to-door trip in air travel. Also, we were able to focus on a meaningful issue since land-side airport access is increasingly problematic. The design of an improved intermodal system, based on the study of a single air travel trip for the trip, can have a significant impact on a number of different intermodal connections.

The next step was to investigate the potential success of the strategy. We first looked at the existing APTS applications in airport ground access and investigated the feedback from users. The investigation, together with the existing and potential benefits of the APTS technologies reviewed in the first part of the thesis, paved the way for the subsequent prototypical design.

7.2 Summary of the Thesis

Intermodal passenger transportation occurs when two or more modes of transportation are involved in a door-to-door trip. Unlike most other countries, the United States has traditionally paid little attention to intermodal passenger transportation. To better understand the current status of intermodal passenger transportation in the U.S., we first discussed four types of intermodal connections: ground to air connections, commuter to inter-city connections, auto-transit connections, and inter-transit connections. Each type of connection has particular issues. Looking at the characteristics of each type of connection as well as its current status in the U.S, this thesis described and explained the reasons for the inefficiency and ineffectiveness of the intermodal passenger transportation in the U.S. and discussed how these drawbacks have affected the passengers in making modal choice decisions.

Thereafter, the thesis reviewed different types of APTS applications in the U.S. First, we looked at the APTS applications in providing traveler information and their various components applied to public transportation systems. Then we reviewed the technologies required to support the APTS applications such as communications technologies.and

AVL technologies. Further, we discussed electronic fare payment systems and looked at the possibilities of integrating different fare media using smart-card technology.

After discussing both intermodal passenger transportation with an emphasis on ground-air connections and reviewing the APTS applications in the U.S, the thesis then studied how we make use of the Intelligent Transportation Systems (ITS) to improve the efficiency and effectiveness of ground access to the airport. In particular, this study focused on the access of airport via transit and high occupancy vehicles. The study examined current applications of ITS that facilitate airport ground access and looked at some of the feedback from the public concerning those applications. Currently, there are only a few ITS applications concerning airport access around the world. The airport information kiosk is the first step in applying ITS technologies to facilitate the entire air travel trip. However, many existing ITS technologies can be explored and applied in the context of airport access.

To illustrate how these technologies can be used, we performed a prototypical design of an intelligent intermodal transportation system. This involved Logan Airport, Logan 2000 Project and the Intermodal Transit Connector (ITC), which is the proposed transit express connecting the Logan Airport to the South Station. Therefore, the thesis presented their backgrounds to facilitate the presentation of the design afterward. After looking at the general background of Logan Airport we looked at the modal splits in ground transportation access to the airport. Also, we presented the transportation components of the Logan 2000 Project and the proposed Intermodal Transit Connector to see how these proposed infrastructures might help improve ground access to the airport in the future. The background information facilitates the presentation of a prototypical design of an intelligent intermodal transportation system for public transportation access to Logan Airport.

The presentation of the prototypical design of an intelligent intermodal transportation system to access Logan Airport was the capstone of the thesis. First, we structured the backbone of the door-to-door trip in air travel and identified the needs of the passengers at each step of the entire trip. According to these needs, a prototypical smart system which applies state-of-the-art APTS technologies was designed to improve the efficiency and effectiveness of the intermodal passenger transportation system in the access to Logan Airport. Communications technologies and other cutting-edge technologies enhance the information flow among the smart bus, smart train, smart station, smart airport and smart plane, which in turn assist the passengers and the system operators in various ways. The passenger can benefit from a variety of new ideas such as dynamic intermodal route guidance systems and remote transportation reservation systems. They can access the guidance system and reservation system via computer terminals on the plane, information kiosks at the airports and home computers. Finally, different kind of scenarios showed how each component works with other components of the system to meet different needs of the travelers in different situations.

7.3 Research findings and Research Contributions

Research Findings

In the introduction of this thesis, we addressed the following questions for the research.

- What factors contribute to inefficiency and ineffectiveness of passenger intermodalism?
- Given the problems, what role can ITS play to help solve the problems? Is ITS the best or the most suitable way to solve the problems?

In response to these research questions, the study has come up with findings that were presented throughout the thesis. Here is a summary of the major findings.

Contributing Factors to Inefficiency and Ineffectiveness of Intermodal Passenger Transportation

- **Lack of coordination among different modes.** For example, frequency of transit services may not meet the demand generated by frequent flight departures and arrivals. Passengers may need to wait for a long time at the airport for transit services.

- **Lack of multimodal information such as connection time and place for travelers.** Without complete multimodal information, travelers can only select the modes with which they are familiar.
- **Lack of efficient scheduling and route planning for some demand responsive modes**. For example, passengers who live in different parts of a region might be scheduled to take the same door-to-door van. This would cause unexpectedly long travel time for some passengers (to wait till other passengers got off at several stops) and a loss in revenue for the van operators.
- **Poor baggage handling during intermodal connection** makes it ineffective to connect more than one time in accessing the airport.

Role of ITS in solving the above problems

- Establish an interconnected network that permits a smooth flow of information among different modes and hubs.
- Provide user-friendly visual and audio interface to deliver intermodal transportation information and other traveler information to the travelers.
- Allow transfer of information among different users easily so that dispatchers and operators on different modes can coordinate better among themselves as well as with travelers.

Clearly, ITS can play an important role in intermodal passenger transportation in the three aspects above. As mentioned in the thesis, APTS technologies generate a lot of benefits. Below we will address mainly the benefits of our prototypical design. However, costs of the applications also need eventually to be evaluated to determine whether ITS is the most suitable way to solve the discussed problems. Section 7.4 will discuss some suggestions for further research on the costs of APTS application and our prototypical design.

Research Contributions

The research has identified the problems encountered in intermodal passenger transportation that make the it inefficient and ineffective. Also, the research reviewed the different APTS technologies as well as their applications. Moreover, it reviewed the current ITS applications in airport access together and compiled feedback from users.

A major contribution of the research was the design of a prototypical intelligent intermodal transportation system using APTS technologies. Airport access to Boston's Logan International Airport was used as a case study. The design was built around the proposed Logan 2000, Intermodal Transit Connector (ITC) and the existing MBTA transit systems, gearing towards to goal of a seamless intermodal system to access the Logan Airport. The new design, Logan-T Smart System, contains a set of "smart" components in each transportation mode during the entire door-to-door trip. The system itself is innovative in the way it links different transportation modes through the information infrastructures as well as the physical infrastructures. It allows interactive communications of real-time information among different types of users at different points within the smart system. The "smart" components are mostly original ideas plus some improved applications in APTS.

"Smart transit" as discussed in the thesis is unique in the way it handles intermodal information linking buses, trains, and the airport in the Metropolitan Boston area. "Smart plane" is an innovative idea for channeling information between the planes and the ground transportation modes. Although some planes allow passengers to make phone calls via their phone system, no ITS application has been developed to enable passengers on board or airplane crews to obtain real-time information from the ground transportation modes. With the introduction of smart plane, the planes would no longer be a "standalone" entity, but an important component in the intelligent intermodal transportation systems (Logan-T Smart System in this case.)

"Smart airport", as discussed in the thesis, is an improvement on the existing airport information system, which integrates with ITS technologies. So far, information kiosks are the only ITS applications being used in the airports. Existing variable message signs in some airports convey mainly airport and airline information. The messages delivered by this signs are not updated frequently enough to be qualified as real-time information.

Smart cards play a important role in the smart system to integrate different fare media of various modes into a single one. The integrated fare media facilitate the passenger movement across different transportation modes. Significant time can be saved for passengers and transportation service providers, as a result of eliminating the need of separate fare payments for each individual mode.

Real-time dynamic intermodal route guidance systems and interactive remote reservation systems are two innovative ideas that take advantage of the information infrastructures. The guidance systems help travelers to make or modify modal choices during the trips by giving real-time advice. The reservation systems assist passengers in making en-route reservation for demand-responsive transportation modes. At the same time, it helps operators schedule the vehicles and plan the routes more efficiently.

Real-time intermodal information is the main element of this research. Design of a systematic flow of the pieces of real-time information among different transportation systems is the essence of this thesis. The design fuses the information system into the whole intermodal transportation system. In the future, the information system will naturally become the standard part of the transportation infrastructure rather than an added-on element. At that time, an in-vehicle display unit will be just as important as the steering wheel of the bus. Sooner or later, travelers will expect to obtain real-time information on other modes just as nowadays they expect that the vehicle will take them to their scheduled destinations. As we have already entered the information age, the above scenarios are not hard to foresee in the near future and can help in introducing more passengers to take public transportation to and from the airport.

7.4 Future Research

Cost Issues

Many ITS technologies have been proven through a variety of operational tests. As mentioned earlier in the thesis, a number of transit agencies in the U.S. have adopted different types of APTS applications to their systems to facilitate passenger transportation and to assist in fleet management. To evaluate whether ITS is the best way to solve the problems in intermodal passenger transportation, we need to consider the costs as well as benefits of the system. This thesis has mainly looked at the benefit side of the ITS. In the future, more research should be conducted to investigate the cost side as well. Although we have presented some cost figures[55] of a number of individual APTS components, these figures can only be used for the purpose of reference, but do not reflect the market price of the applications. Since most designs of these applications are customized to the specific needs of each individual transit system, costs may vary significantly across different agencies. Understanding the needs for each application is important so that resources would not be wasted on procuring those components that do not meet one's need or the ones which provide unnecessary functions.

Our prototypical design involves both existing applications and new ideas. Some components such as information kiosks are more standardized because of the similarities in the requirements for most kiosk systems. The standardization makes it easy to estimate the price range. Other components such as Smart Bus and Smart Station require the technologies such as AVL, APC, and in-vehicle display units that have been tested or implemented in some other transit systems. As mentioned above, cost figures for these components are available, but they vary greatly.

[55] Besides the cost figures presented in Chapter Three, Appendix B also illustrates a list of costs of AVL, APC, and other periphery APTS components in various transit systems in North America. The source came from APTS State of the Art - Update 96.

A lot of research can be conducted on the innovative ideas such as Smart Plane, Dynamic Intermodal Route Guidance System, and Remote Reservation System. Since these applications have neither been used nor tested before, no cost figure is currently available. Research can be conducted to determine a more detailed design and to establish cost estimates for the required components of the design.

Research can also be conducted on the cost of building an intermodal information infrastructure. Since the infrastructure may contain some shared components or common architecture with the National Information Infrastructure(NII) and Intelligent Transportation Infrastructure(ITI), costs can be distributed among various infrastructure builders and users. The building of the infrastructure requires a high, front-loaded investments. Once the infrastructure is built, the cost of setting up each application should be low.

Once we determine the cost of each component, cost-benefit analyses can be conducted to evaluate the value of the prototypical system.

Seamless System: The "Black Box" Concept

A perfectly seamless intermodal passenger transportation can be attained only if the transportation process is completed entirely within a "black box"; the travelers can get their outputs (arrive the destination on time) once they enter the required inputs (costs of the travel package) without putting any effort to figure out the details of the black box (intermodal connections between the origin and the destination). In freight transportation, customers pay for a package that provides door-to-door transportation services for their goods. The logistics experts are responsible for the internal operations of the "black box" – freight intermodalism.

The prototypical design of an intelligent intermodal transportation system presented in this thesis is a step towards applying the "black box" concept of transportation logistics to passenger transportation. Whether this idea can turn into a real application depends on many factors. First, passengers are not freight and therefore cannot be handled in the same way freight handled in the transportation process. Considerations for humans, such as comfort level and number of connections during the trip, should be considered in the transportation process. It makes the logistics much more complex. Second, sophisticated coordination of different private and public entities is needed to ensure reliable connections among different modes so that the customers can get to the destination on time. When a mature market for door-to-door passenger transportation service exists, carriers can develop their own fleets of planes, trains and cars, just like most of the existing mail/parcel carriers today. Third, a well-developed information infrastructure is needed for real-time communications among different modes. The prototypical backbone of the intermodal information structure presented in the thesis can be a model for further development of a large-scale information infrastructure. To apply the "black box" concept in freight transportation to passenger transportation, the following research can be conducted in the future to investigate the issues above.

Identify the different characteristics of passengers and freight transportation

Freights and passengers are totally different kind of entities. Freights can be transported in bulk. In a given order, large quantities of homogeneous goods are packed in large containers and are transported from the origin (such as a manufacturer) to a number of destinations (such as distributors). The containers, instead of the individual goods, are transported. The goods are enclosed inside the containers securely until they arrive the destinations.

Passengers are heterogeneous. They do not travel "in bulk". Each passenger travels individually or travels with a few companions. Also, passengers can make decisions and are mobile. Even when a trip has been planned, a passenger can change or cancel the plan at any time. Any unpredictable decisions can be made at any time during the trip. On the other hand, freights are locked in the containers during the entire trip. Moreover, passengers have feelings. Each individual demands different services. Everyone has different requirements in different attributes such as comfort, walking time or connection time. Unlike freight, passengers cannot be packed in a container. The carrying capacity of each transportation mode is often limited by its seating capacity. Standing capacity is also considered in most public transportation modes. Furthermore, passenger transportation often involves not only the passengers, but also the baggage they carry.

The only concern for freight transportation is to get the freight from the origin to destination securely on time. Of course, this is also the main objective for passenger transportation. In addition to this main objective, the special needs of passengers should be considered when designing the "Black Box".

Investigate the problems in coordinating different transportation operators to attain the black box concept

In the past, there has been little coordination between different transportation modes. Each single mode operates individually. Service scheduling is subject to projected passenger demand and is not coordinated with the schedules of other modes. Coordination of the schedules of different modes makes it easier to arrange the modes in a package.

Because of competition among different transportation operators and the exclusive use of certain radio frequency, communications among different modes rarely exist. Bus operators only communicate with other operators in the same fleet. Similar scenarios apply to taxis, trains or even airplanes. Intermodal communications can help ensure that the passengers get connected to the designated mode. If there is a delay in one of the links during the trip, the delayed mode needs to communicate with the next connecting mode such that the next mode would wait for the passenger.

The prototypical design in this thesis can facilitate coordination among different modes through a number of smart components that allow communications among different modes.

Look at the feasibility of different options to attain the "Black Box" concept

"Middleman" Option

The service providers can act as a middleman and arrange all the necessary transportation services (air, ground and sea) according to the customer needs (O/D and other requirements). In this role, the providers need to reserve all the seats and are responsible for all the connections between different transportation modes, and make sure the passengers get to the right destination at desired time.

A tour package is a similar idea but with a lot of restrictions. Travel agencies provide tour packages for travelers at designated prices. Travelers can select the package that serves their interest the best in terms of the sightseeing points, length of travel, hotel quality, cost and other factors. The tours usually depart on certain days of the week to suit the needs of different customers. Once the customers purchase the service package, they can enjoy the entire trip planned by the travel agency, including all transportation, hotel accommodations, and meals. The travel agency gets discounted rates for airlines, hotels, and admission tickets for some places.

"Extended Services Provided by Airlines" Option

Airlines can be the "Black Box" service providers. They can work with the ground transportation providers or even other airlines to provide the service package. To attain more control in the connecting ground services, they can even set up their own vehicle fleets in ground transportation. The service can become one of the attractions to their customers as a marketing strategy. In this case, travelers can view it as an extended service provided by airlines.[56]

"Self-Owned Service Provider" Option

When demand for the "black box" services gets higher and the market is mature enough, service providers can invest in purchasing or leasing their own fleet of planes and ground

[56] Virgin Atlantic Airline provides ground transportation services for their passengers.

vehicles, just like some current mail carriers. In this case, the service providers have full control over the connections of the modes.

Research can be done to investigate the feasibility of each option and the ways to improve the level of service. Each option would have different service scope as well as flexibility of the service. Also, each option would have different requirements in term of staffing, scheduling, monitoring, and other factors in service planning. Further studies can be conducted to compare different requirements of each option and evaluate their advantages and disadvantages.

Apply operations research and logistics to optimize internal operations of the "Black Box"

For many years, operations research (OR) and logistics have been applied to optimize the seat and fleet assignment in airline industry and freight transportation. More sophisticated applications of OR and logistics can be used to assign the different transportation links to the trip optimally, based on the given objective functions (such as "minimize total door-to-door travel time" and constraints of the passengers such as cost and maximum waiting time.

Expand the research in developing information infrastructure for intermodal passenger transportation

Research can be expanded to further develop a good information infrastructure that can facilitate information flow between different modes. The intermodal information infrastructure can be developed and tested in selected cities, and can be incorporated into the National Information Infrastructure (NII) or the Intelligent Transportation Infrastructure (ITI). NII is an networking infrastructure designed to enhance information flow in the entire country. It is also called "Information Superhighway" – a concept which resembles the National Highway System built to enhance transportation in the U.S. ITI is a backbone built by computer, communications, and control systems to support a variety of ITS products and services in urban and rural area.[Public Technology Inc., 1996]

Scenario

If the "black box" concept for passenger transportation turns into a real-life application, the following scenario might happen in the future.

Miss Winslet lives in New York and needs to attend a conference in Paris. To avoid the burden of finding the ground transportation to and from the airports in both New York and Paris, she logs onto the Internet and browses through the World Wide Web to search for the door-to-door passenger travel package (comparable to existing door-to-door parcel delivery in fright transportation). She enters the following essential information.

1. Addresses of both origin and destination.
2. Departure time and date. (can be in the form of ranges, if flexible)
3. Expected arrival time and date. (can be in the form of ranges, if flexible)
4. Expected price range.

Then she selects the options of the following attributes to suit her needs. (Since human beings are different from freights, we need to take into account various attributes applicable to only human beings. Therefore, we need to add the following attributes to tailor to different needs of people.)

- Maximum travel time in addition to the standard information needed for parcel delivery
- Maximum number of transfers
- Types of carriers desired
- Comfort level (Options are available for detailed attributes)
- Maximum walking distance
- Types of facilities on board

Like parcels delivery, she has several options to choose from in terms of delivery time and security)

- Guaranteed arrival time (will arrive no later than the indicated arrival time)
- Urgent (Last minute reservation)

According to chosen options of each attribute, the service provider will come up with a set of different recommendations of travel packages starting from the one which fits her preference the best. The more constraints she enters, the lower the probability of creating a route that matches all her needs and the less number of final recommendations she will get. Each package clearly states the service cost, the time and day of departure and arrival, and a complete itinerary that shows all the modes used in the trip, their travel times, other necessary information. She then selects the best option and orders the service. From then on, all she needs to do is to get ready before the designated departure time.

Two days before the trip, she receives an all-in-one electronic boarding pass that allows her to access all transportation modes in the trip. She also receives complete instructions to direct her way during the trip, in case she gets lost for some reasons. On the departure day, she is picked up by a van at the scheduled time. The van drops her off in front of the airline check-in counter at the JFK Airport. Then, she checks in and walks towards the departure gate. A staff is stationed at the departure gate to make sure that she gets on the plane. Indeed, staff are stationed at all connection points to coordinate all the connections.

After a long flight, she arrives the De Gaule Airport in Paris. At the arrival gate, a staff welcomes her, shows her way to pass the custom, and directs her to the location of the pick-up van. At the same time, her baggage is delivered to the van by other staffs. Finally, she gets on the van on her way to a convention center in La Defense in Paris. She arrives the convention center half an hour earlier than the guaranteed arrival time and treats herself to a cup of French coffee.

In this thesis, scenarios have been used extensively to illustrate how different concepts can turn into a number of applications and how each application would be used if it becomes reality. These scenarios are our visions of the future. In 19th Century, Jules Verne created a scenario to tell about the journey to the moon. In the past, technological advancements have turned many scenarios, including the journey to the moon, into reality. The suggested research tasks presented above are the steps to investigate, test and evaluate the "Black Box" concept of passenger transportation. When the ideas are proven and implemented one day, the scenario above would come true.

Research can turn ideas into reality. More ideas can be generated during the research process. Thereafter, further research can turn those new ideas into reality. The world advances in this way. We hope this effort has advanced the transportation field.

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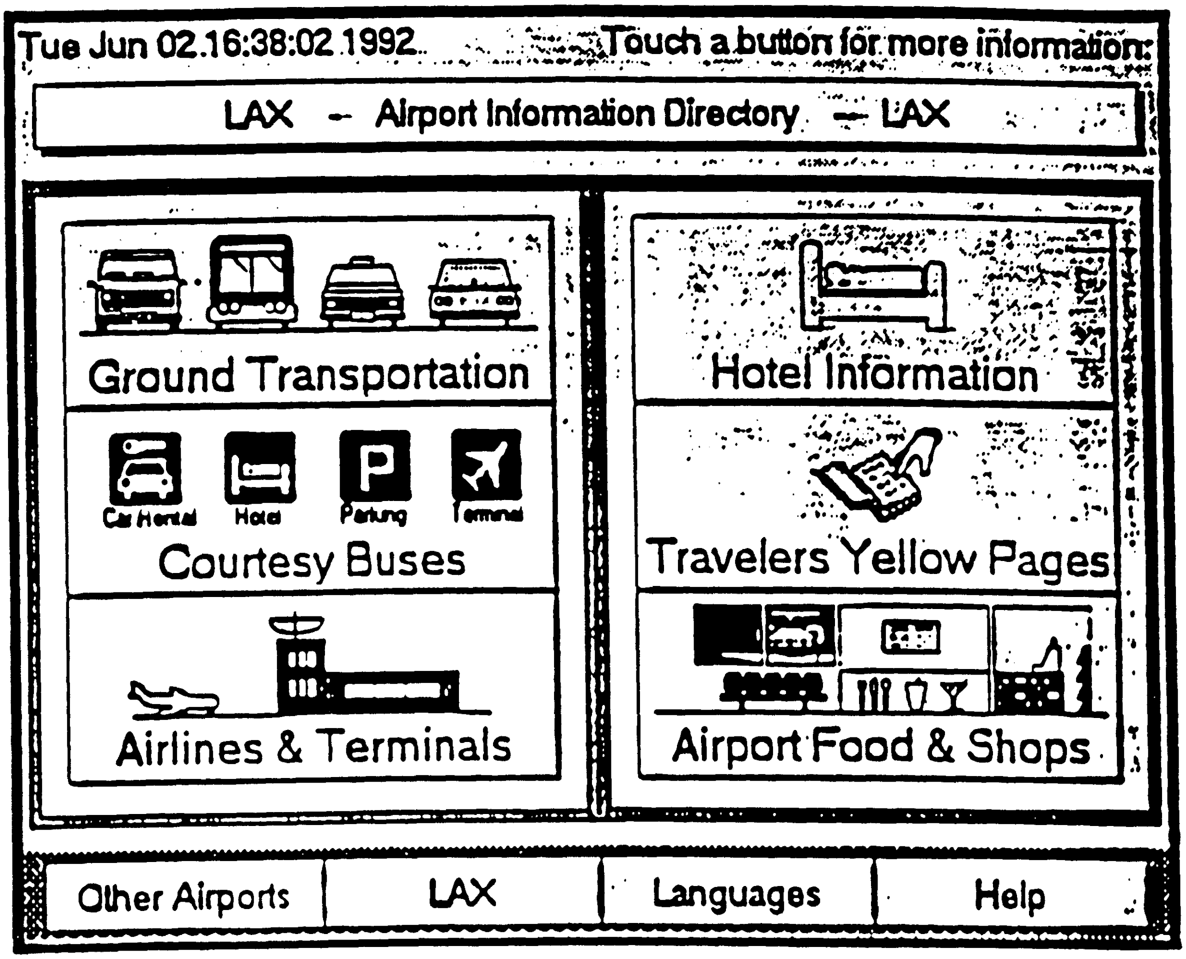
Appendix A

Sample of QuickAid Information Kiosk Interface[i]

[i] Source: Gosling, Geoffrey D. and Lau, Samuel W. Evaluation of a California Demonstration of an Automated Airport Ground Transportation Information System. Appendix A. 1994. Copyright (C) 1992 by TTMC inc.



QuickAID™

QuickCall Airport Information Directory

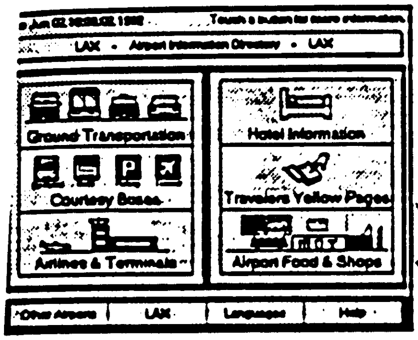
By

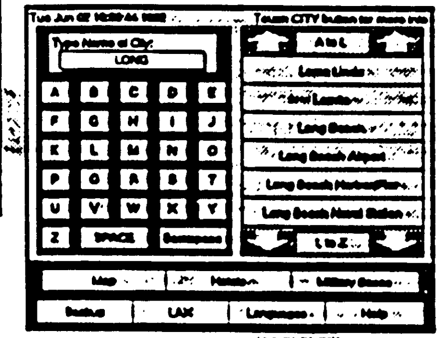
TTMC inc

travel • transportation • multimedia • computing

Ground Transportation

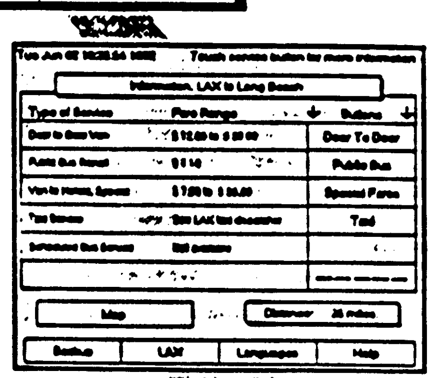
As Easy as 1, 2, 3



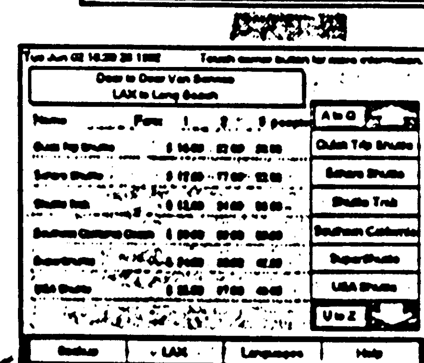


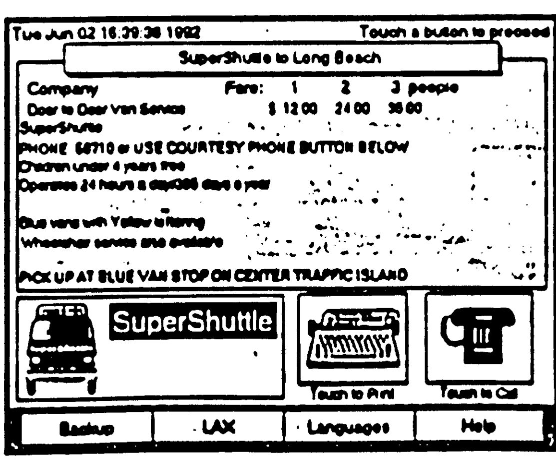
You can browse through our extensive collection of Ground Transportation options in **three easy steps:**

1. Choose a city,
2. Select a mode of transit, and
3. Choose your carrier.



If you need a reservation, the computer **can dial** for you. If you would like a record of your fare quote, ask for a **printout**. We even provide a **description of the vehicle** and information on where to meet your ride. And with five years of experience providing ground transportation information for LAX, you can rest assured that we know the field.

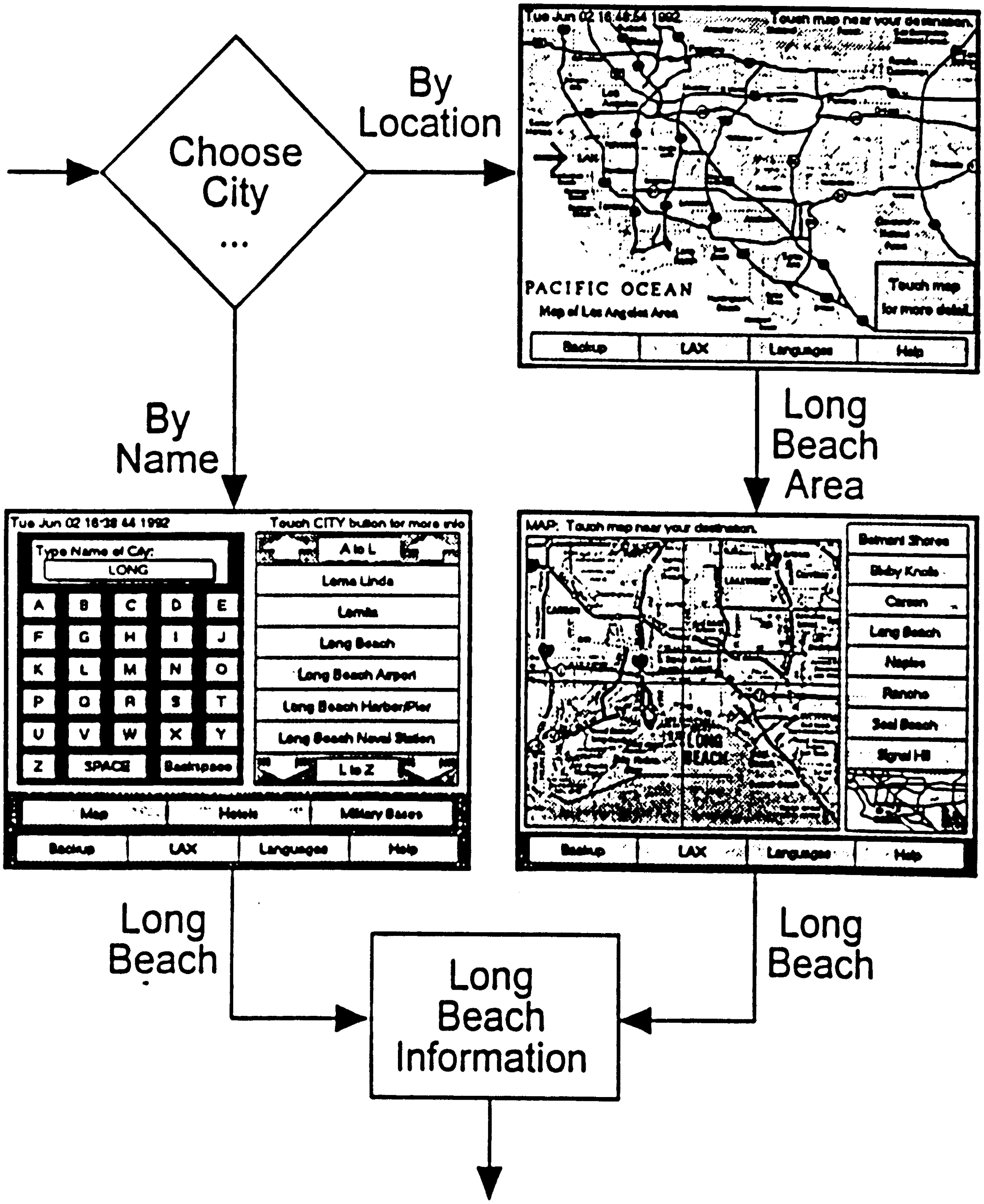




Choosing a City

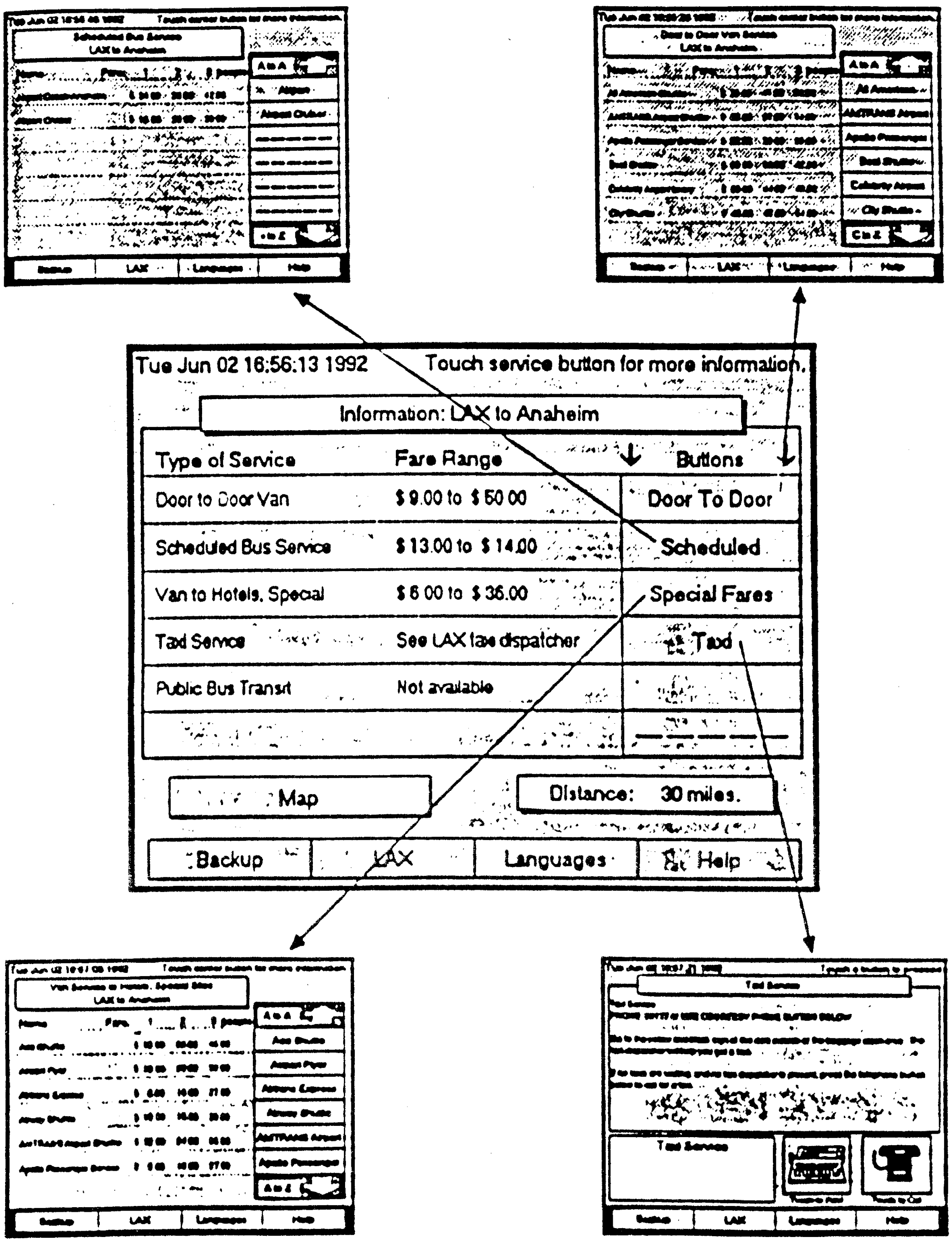
A picture may be worth a thousand words, but sometimes you need only one.
With QuickAID you have your choice:
- maps for those who know the location, or
- lists for those who know the name.

Either way, you end up with the same high-quality QuickAID information.

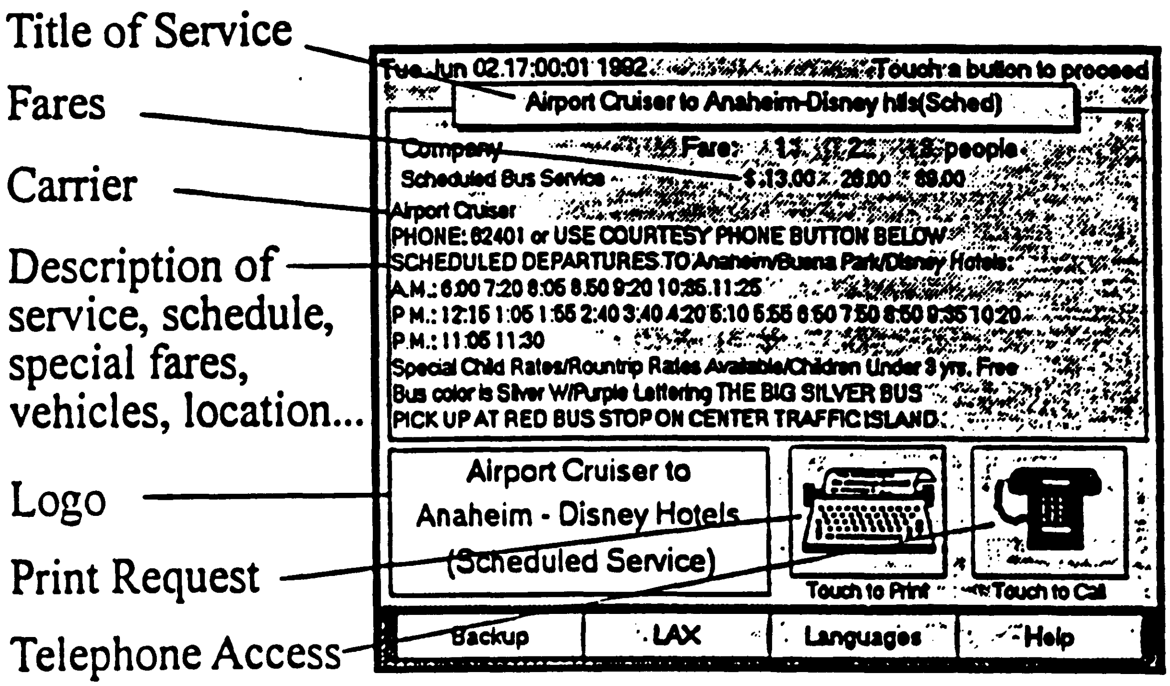


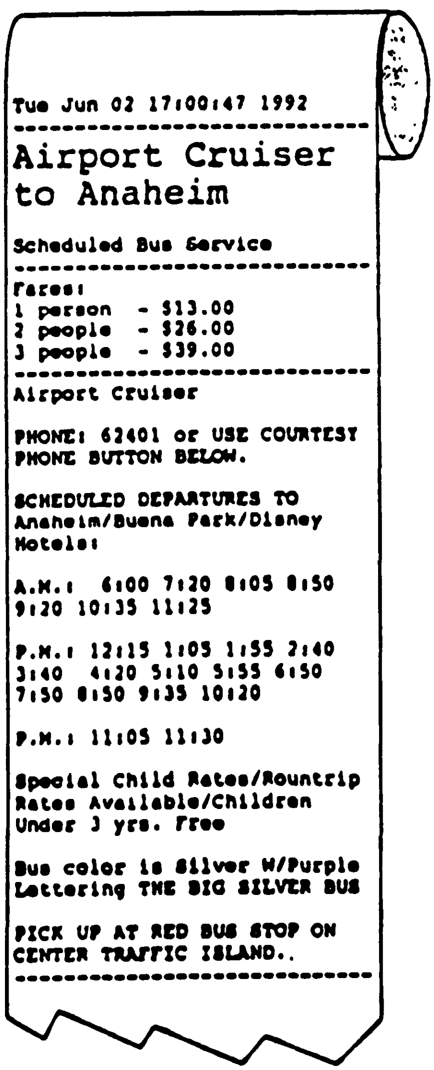
Modes of Transit

We are proud to offer information on a wide range of transportation options. QuickAID lists PUC-registered tariffs for single and group rates in a format convenient for comparison pricing. We are committed to providing useful, accurate, and up-to-date information on all airport carriers.



Choosing a Carrier





Tue Jun 02 17:00:47 1992

Airport Cruiser to Anaheim

Scheduled Bus Service

Fares:
1 person - $13.00
2 people - $26.00
3 people - $39.00

Airport Cruiser

PHONE: 62401 or USE COURTESY PHONE BUTTON BELOW.

SCHEDULED DEPARTURES TO Anaheim/Buena Park/Disney Hotels:

A.M.: 6:00 7:20 8:05 8:50 9:20 10:35 11:25

P.M.: 12:15 1:05 1:55 2:40 3:40 4:20 5:10 5:55 6:50 7:50 8:50 9:35 10:20

P.M.: 11:05 11:30

Special Child Rates/Rountrip Rates Available/Children Under 3 yrs. Free

Bus color is Silver W/Purple Lettering THE BIG SILVER BUS

PICK UP AT RED BUS STOP ON CENTER TRAFFIC ISLAND..

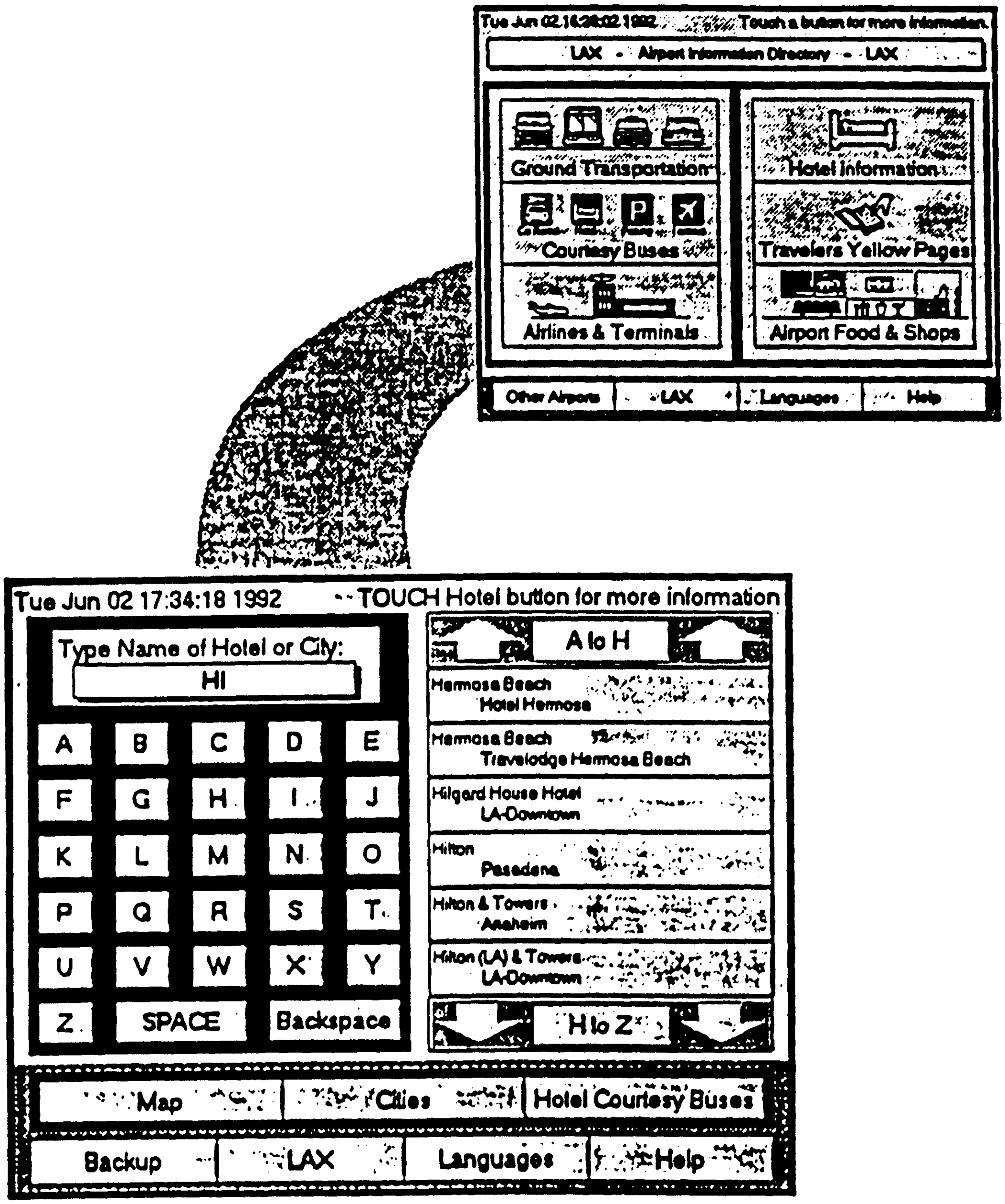
QuickAID makes getting a ride from the airport as easy as touching the screen.

At the push of a button, QuickAID will dial the carrier so that you can make reservations.

Make a copy of the information to take with you by pressing the Print button.

QuickAID helps you get the next trip out.

Getting to the Hotel

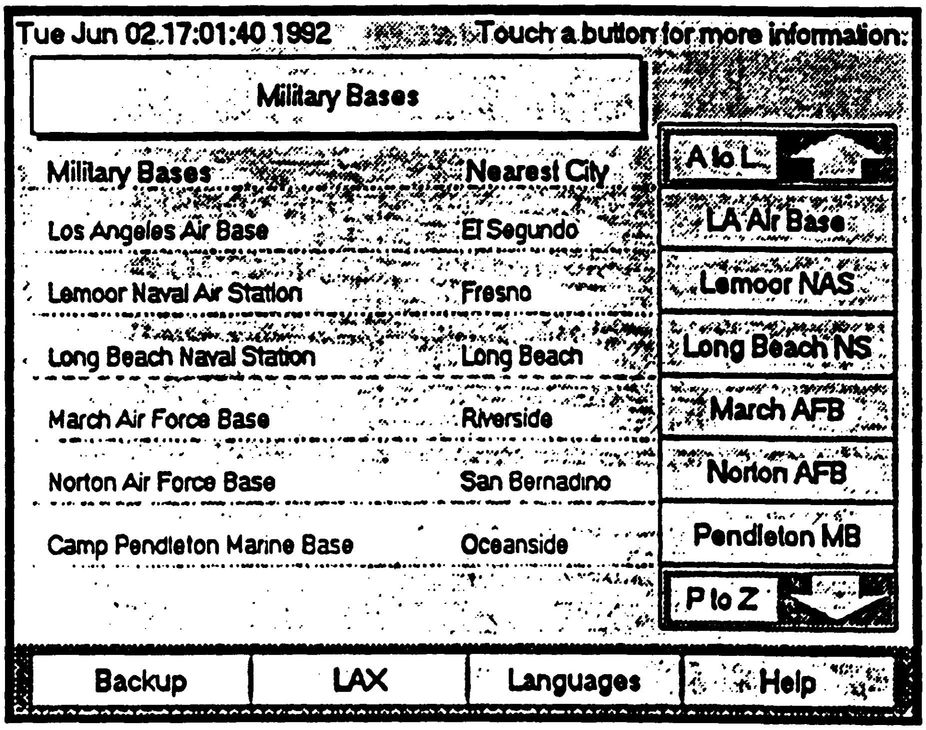


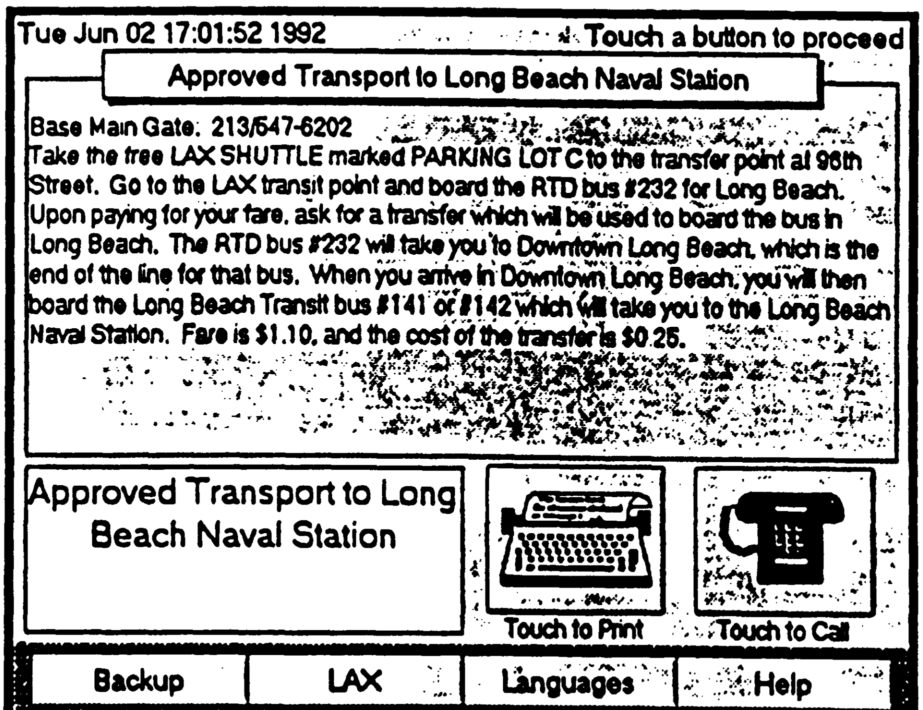
After a long flight, you want to get to your hotel quickly. With QuickAID, you can get to your hotel even if you don't know what city it is in. And if the hotel runs a courtesy bus to the airport, QuickAID will tell you about it - and let you call with just a touch of the screen.

QuickAID lists hotels by both name and city, for your convenience.

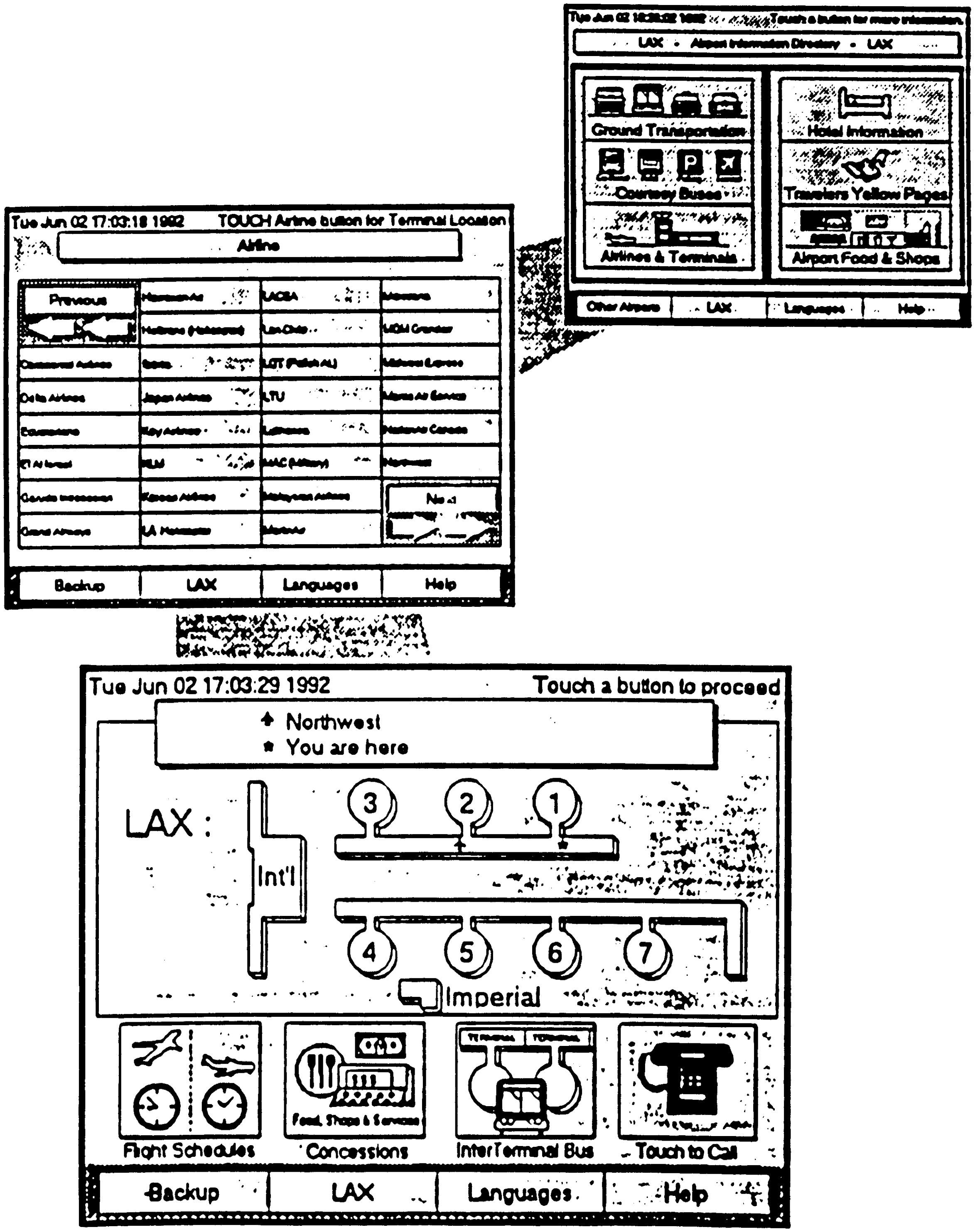
Beyond Curbside Pickup

QuickAID offers a wide range of information for arriving passengers, including airline and terminal locations, hotel courtesy buses, car rental agencies, parking lot buses, inter-terminal shuttles, and approved transportation to local military bases.





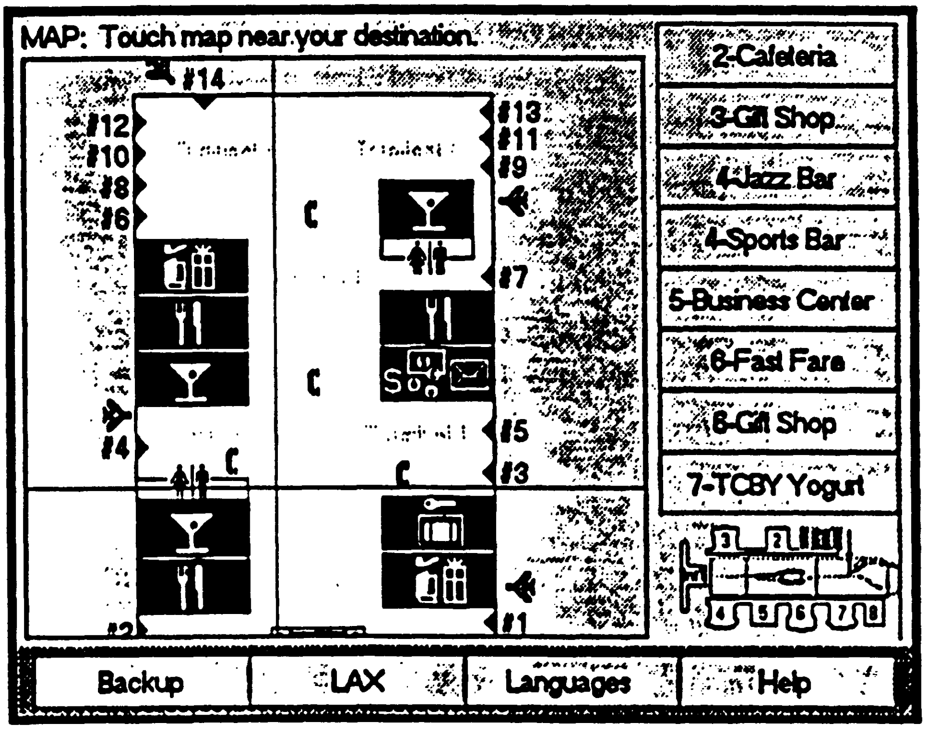
Where is my flight?

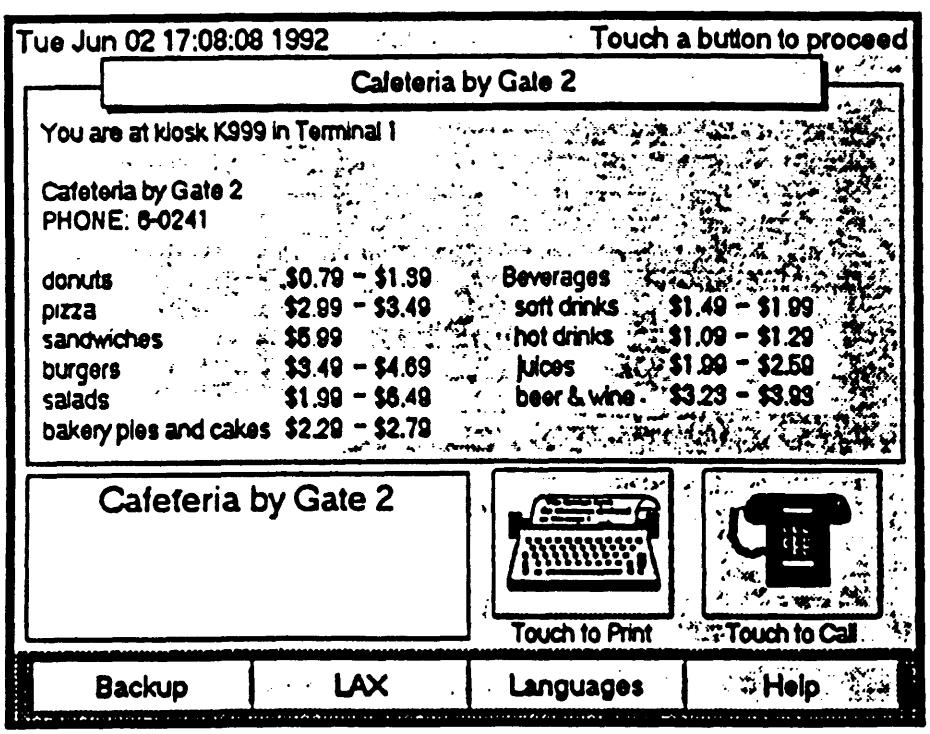


"Where is my flight? Where is ...?" Whether you are looking for Qantas or American, QuickAID offers a quick and easy way to see where you are and where you need to go.

Getting Things Done

QuickAID can help you make the most of your time in the airport. We provide detailed maps of the airport, as well as information about the menus, goods, and services of airport restaurants and shops.

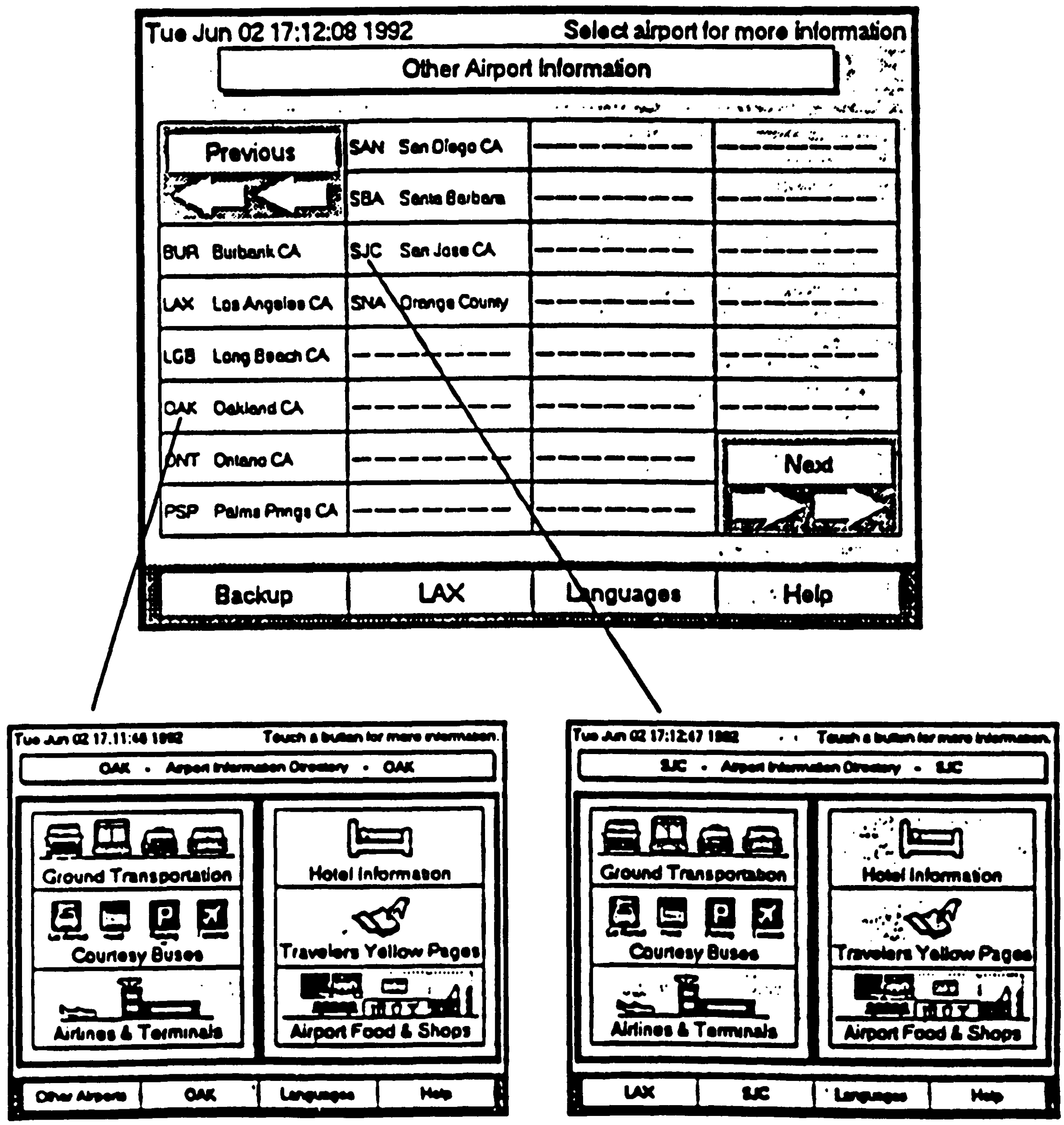




Connect!

Every journey has both an origin and a destination; one airport is only half the story.

When you use a QuickAID kiosk you can access information on any QuickAID airport. Which means that the next time you are waiting to board, you can consider places to dine during a layover, or arrange a ride to your hotel, or perhaps just familiarize yourself with maps of your destination. And with each new QuickAID airport, the QuickAID kiosk you know and use becomes that much better.



Appendix B

Summaries of APTS Technologies used in Transit Systems in North America[i]

[i] Source: United States Department of Transportation, Federal Transit Administration. *Advanced Public Transportation Systems: The State of the Art - Update '96*. FTA-MA-26-7007-96-1.

North American Transit AVL Systems

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Phoenix, AZ PTS	GPS	all 450			Bids due 12/95, Demand Response implemented first		CAD, SA	
Tucson, AZ SunTran	GPS	all ~200 fr	Rockwell Int'l	3.5	Installation began 12/95, 18-24 month implementation	p 40	CAD, PIkv (40 veh), APC, EP, SA, (SP)	
Alameda, CA Ferry Svcs.	GPS	all 2 ferry boats			RFP out - expected implementation during 1996		PIpk, PIv (one boat)	Major goal: enhance safety in fog and times of high boat traffic in harbor
Los Angeles, CA LAMTA	SO	all 2085 fr (ph)	Gen. R'wry Signal	~12	36 buses equipped now, install. on next 1000 began Oct/Nov	p 120	CAD, (PI), (SC), EP, SA, SP*	location accuracy "very good" in early test; minor software giltches
Napa, CA The Vine	GPS	all 18	3M Corp	0.13	prototype test began 3/95		CAD, PIp, SA, SP	
Oakland, CA AC Transit	GPS	all 702			RFP out Oct 1995	e	CAD, PIk, APC, EP, SA	
San Francisco, CA Muni	SO	all 1000	Motorolla		implemented 1985, used mainly for emergency response	"line poll"	SA	"not very accurate" due to low poll rate and SF hills; great for emergency resp.
San Jose, CA Outreach	GPS	15 bus, 55 van & taxi	UMA, Trimble		expected implementation early 1996		CAD, SA	paratransit system
San Mateo, CA SamTrans	SO	all 320	Motorolla		Operatonal Since 1994			

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

Vendor - the primary vendor/system integrator

Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)

Report - reporting strategy employed (bus to dispatch). "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time

Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

North American Transit AVL Systems (continued)

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Santa Monica, CA SMMBL	GBR (leased)	all 135	Teletrac	0.13	in regular use since 1992	*		system is leased - data is transferred on request but is not used in real-time
Stockton, CA RTD	GPS	all 106			RFP out 9/95, installed by early to mid 1996		CAD, PIp, (SC), EP, SA, SP	
Denver, CO RTD	GPS	all 900	TMS	11	Final acceptance anticipated 12/95	e/p 120	CAD, PIk, (SC), SA	some software difficulties early in the installation process
Cocoa, FL SCAT	GPS	12-13 of 28 fr	Harris Corp.		Demonstration Project, anticipated on-line spring 96		CAD, PIv, EP, SA	some difficulty obtaining dedicated radio frequency
Ft. Lauderdale, FL BCT	GPS	all 200 fr, all 30 sv			RFP out 7/95, contract 11/95-1/96	p 60	CAD, (PIp), (APC), SA	
Miami, FL MDTA	GPS	all 610	Ericsson, GE, Harris Corp.	14.5	Installing, testing system; expected complete 12/95	p 120	CAD, (PI), EP, SA	
Palatka, FL Arc Transit	GPS	all 14 fr all 6 dr	Management Analysts	0.44	Installing, testing system	p 3	CAD, (PIcable?), SC	Fully integrated card readers and medicaid billing system
Palm Beach, FL CoTran	SO	*none*	Motorolla		System abandoned			Interfered w/reg. comm.-possible future system w/new tech (GPS?)
Tampa, FL Hartline	SO	all 175	Motorolla		Regular operation since 1993	vi 120	(SC), SA	
Atlanta, GA MARTA	GPS	250 of 750 bus	TMS	7	Contractor on-board, operational by 3/31/96	vi 120	CAD, (PIk), PIv, APC, SA, (SP)	linked to state-wide multi-modal, multi-jusidictional ATMS

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

Vendor - the primary vendor/system integrator

Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)

Report - reporting strategy employed (bus to dispatch) "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time

Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

North American Transit AVL Systems (continued)

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Sioux City, IA Sioux City TS	GPS	14 of 32			Funding approved, preparing RFP		CAD	
Chicago, IL CTA	DR, GPS	all 2080 bus (ph)			Installation to begin early 1996	vi e	CAD, SC*, APC*, EP, SA*, SP	1st RFP out 94, not enough $ available re-issued in 1995
Chicago, IL PACE	prob. GPS	all 600 bus			RFP out 8/95, due 12/1/95		CAD, PI?, APC*, EP, SA, SP	
Rock Island, IL RICMT	GPS	all 58 bus			expected implementation spring 1996		CAD, PIcomputer, PIk, SA	
Gary, IN GPTC	GPS	all 32 (dr)		0.14	In bid process		CAD	
Louisville, KY TARC	SO	all 257 bus	Glenayre	2.5	Operational since 1994, resolving some issues	p 40	CAD, (SC), APC, EP, SA	insufficient accuracy in sched. database, had contractor problems
New Orleans, LA RTA	GPS	all 500+			Doing feasibility study		CAD, PIpv, EP, SA, SP	Previous test of kiosks - kiosks failed, mostly due to vandalism
Baltimore, MD MTA	GPS	all 935 (ph)	TMS	8.9	Bus install. proceeding, all rail done - complete 12/96	p 120	CAD, (PIv), (APC), SA	former sucessful test of Westinghouse Loran-C system on 50 buses
Montgomery, MD Ride-On	GPS	all 250	Orbital Sciences		Installation proceeding, expected complete by 10/96		CAD, EP, SA, SP	signal pre-emption a major component of system
Ann Arbor, MI AATA	GPS	all 70 fr all 10 dr			RFI out 7/95; expected to be installed by 3/96		CAD, PIcableTV, (PIk) SC*, EP, SA	agency terminated prior contract in late 1994

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North American Transit AVL Systems (continued)

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Detroit, MI SMART	GPS	all 250 fr all 150 dr	TMS	27-8	Installation began 7/95, to finish 7/96	p 120	CAD, (PIkp), (APC), EP, SA, SP?	Buses used as probes for MDOT freeway monitoring
Minneapolis, MN MTC	GPS	80 of 810 bus	TMS	6.5	1 year operational test, 12/94 to 12/95		CAD, PIk, APC* PImodem	Huge benefit to security in knowing bus' exact location
Kansas City, MO KCATA	SO	all 250 bus			Developing Specs for signpost upgrade, bid out 8 or 9/95	prob p	(APC), SA	Old signposts began malfunctioning 18months after installation
Raleigh, NC CAT	GPS	all 40 fr all 12 dr			Solicitation for Letters of Interest out 9/95		CAD, PIp, PIcableTV, SA	"Seemless (transit) system" with guaranteed, timed transfers
Winston-Salem, NC WSTA	GPS	3 of 17 dr	GMSI		Operational 5/95, to be expanded to all 17 vehicles	p	CAD, PIp, SC, SA	Part of CAD for dr system, focus of project was not on AVL
Newark, NJ NJT	SO	all 800 bs Essex Co.	Motorolla		2 lines done, installation of rest over next 2 years	sp, 600	CAD, SA, PIkp-disrupt'ns only	To use GPS for rail; investigating cellular tri-angulation
Albuquerque, NM Sun Tran	GPS	all 40 dr	On-line (software)		Software installed, RFP on MDTs due 9/95, AVL done 3/96	prob p	EP?, SA	Demand-response system
Albany, NY CDTA	SO	all 232 bus	Motorolla		Operational since 1994	p 240	CAD, EP, SA	
Buffalo, NY Metro	GPS	all 355fr, 35dr,25sv	Harris Corp.	96	Contract awarded 7/95, installation 8/95-1/97	e, p 120	CAD, PIv, (PIp), (APC), EP, SA	
Long Island, NY MTA LI Bus	GPS	all 318 bus			RFP out 9/95, 12-18 month implementation	e	CAD, PIv, SA	

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New York, NY NYCT	GPS, DR	all 170 bs on 4 rtes			RFP due 8/95, Installation expected complete 7/97	e	CAD, PIk, (PIp), EP, SA	Also 30 non-revenue vehicles
Rochester, NY RGRTA	GPS?	all 215 fr all 21 pt?			RFP out 1/96 for new radio system, possibly to include AVL		CAD?, PIv*, EP*, SA*	Existing test of 10 GPS actuated on-board enunciators on 2 routes
Syracuse, NY RTA	GPS	all 180 bs in core sys			Spec Development - no set schedule	probe	PIv, APC?, EP, SA	Goal: 95% schedule adherence
White Plains, NY Bee-Line	SO	95% of 332 fr	Motorolla		Regular operation since 1983, upgrading to GPS in 1½ years		SA	SO system reliable, but limited. GPS will have more options and include dr
Cincinnati, OH SORTA	GPS	all 380 fr opt 33 dr			RFP out 7/95, due 10/95		CAD, PIv, (PIk), (APC), EP, SA	had demo GM SO AVL in late 70s, early 80s. Very positive results.
Grand River, OH Laketran	GPS	all 64 dr all 14 fr			Best and Final Offer due 12/15/95		CAP, PI, SA	
Portland, OR Tri-Met	GPS	all 630 fr all 140 dr	Orbital Sciences	5.2	Final design review complete, installation began 11/95	e 300	CAD, (PI), APC, SP?, SA	engine probes gave false alarms
Rochester, PA Beaver County TA	LC	13 of 36 fr	Motorola	0.05	Regular operation since 1991, working on "next generation"	p	PI, SA	"valuable tool", on-time performance up, complaints are down
Scranton, PA COLTS	GPS	all 32 fr	AutoTrac	0.3	Regular operation since 10/94		CAD, PIv, SA	great record-keeping tool; "buses on time;" easier ADA compliance
Corpus Christi, TX CCTS	GPS	all 110 bus			RFP out in Fall 95		CAD, PIkv, APC, EP, SA, SP*	fully integrated system with police, fire, emergency response

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Dallas, TX DART	GPS	1200 of 1300 fr,sv	ElectroCom	16.4	Last glitches expected to be resolved by the end of 11/95	p 120	CAD, EP, SA	reliability problems in 1994, worked out
El Paso, TX Sun Metro	GPS	all 160 fr all 62 dr			Specs complete - project on hold for funding		CAD, (PI), APC, SA	
Houston, TX Metro	DR+ ???	all 1750 veh		22 + 6	radio/comm backbone procured, RFP for AVL released late 95		CAD, PIk, PIv?, (APC), EP, SA, (SP)	additional location technology will be determined in the bid process
San Antonio, TX VIA	SO	all 531 veh	Gen R'wy Signal	3.7	Regular use since 1987; examining potential upgrades	p 60		
Norfolk, VA TRT	SO	all 151 veh	F&M Global	2	Regular use since 1991	p 40	EP, SA	allows tighter scheduling, functioning very well, reduced pass. complaints
Woodbridge, VA PRTC	GPS	all flex-route	Gandalf		Installing AVL, expected compete by mid-1996		CAD, SA	new transit operation, major purpose of AVL to assist flexible routing of buses
Bremerton, WA Kitsap Transit	GPS	all 155 veh	3M Corp	0.6	Phase I testing (buses in central area) expected complete early 96	e	CAD, PIk, (PIpv), SA, SP	Phased project: II - outlying area buses; III - paratransit veh.; IV - ferries
Seattle, WA KC Metro	SO	all 1250 revenue	Harris Corp.	15	Regular use since 1993	p 90	CAD, PIradio*, APC, SA, SP?	operators rely on increased security
Milwaukee, WI MCTS	GPS	all 550 fr all 50 sv	TMS, Trimble, Motor	7.8	Final acceptance anticipated 12/95	p 45	CAD, (PI), (APC), SA	
Sheboygen, WI STS	LC	20 of 33 bus	II Morrow	0.1	Regular use since 1991			

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Halifax, NS MTD	SO	all 168 bus	(agency did integration)	1	Regular use since 1987, upgrades in progress, esp to software	p 30	CAD, PIpk, SA	more accurate info to public; had APC-not reliable; had EP-false alarms
Hamilton, ON HSR	DR	all 240 veh	RMS Industrial	6	Regular use since 1991	p 30	CAD, APC*, SA	on time perfomance went from 82-89% in last year
London, ON LTC	SO	all 160 veh	Siemens	2	Pilot install. on 1 vehicle of each type; operational early 1997	p 30	CAD, (PIp), (APC), EP, SA, (SP?)	Primarily for communication, holding buses for passenger transfers
Ottawa, ON OC Transpo	SO	all 825 veh	Amtech		Operational 3/95	st	CAD, APC*, SA	system to be evaluated over the next year
Toronto, ON TTC	SO	all 2300 veh	Bell Radio	38	Fully operational since 1992 (1st division on line in 1985)	poll 6	CAD, PIv, SA, SP	APC tried, double-counted; AVL gives much greater safety; 42 radio channels
Hull, QC STO	SO	all 183 veh	Fishbck & Mre, Gndlf		Operational since 1984, upgrading dispatch/PI software	sp	CAD, PIp, SC*, (APC), EP, SA, SP*	Many benefits (see text)

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North American Automatic Passenger Counter Applications

City System	Location	Counts	Vehicles	Vendor	Cost	Status (as of 9/30/95)	AVL Link	Xfer Freq
Tucson, AZ Sun Tran	GPS	ir beams	40/ 200			Bids returned 8/95, 12-15 month implementation	Yes	Daily
Oakland, CA AC Transit	GPS	-	100/ 702			RFP 10/95	Yes	Daily
Atlanta, GA MARTA	GPS	ir beams	15/ 250	Urban Transportation Associates		Installation proceeding, finish date 3/31/96	Yes	Daily
Chicago, IL CTA	SO	treadle mats	120/ 2000			Working out some bugs	No	
Chicago, IL PACE		ir beams	70/ 758	Urban Transportation Associates	~$1.5K/bus	Up since '87, plan: upgrade & link w/new AVL system	Linking	Daily
Louisville, KY TARC	SO	ir beams	68/ 257					Daily
Baltimore, MD MTA	GPS		25/ 900	Urban Transportation Associates		Planning as future addition to AVL	Yes	Daily
Minneapolis, MN MTC	SO	ir beams	10/ 830	Urban Transportation Associates	$150K (total)	Operational since 8/94, plan to expand to 50 equipped	No	Weekly
Columbus, OH COTA	SO	ir beams	30/ 310	Urban Transportation Associates	$171K (total)	Oper. since '84, upgrading software and hardware	No	a few days
Eugene, OR LCMTD	SO	treadle mats	12/ 95	Microtronics	$95K 1st 8, $16K new 4	Operational since 1986	No	Daily

Key:
Shaded columns indicate operational APC installations.
Location - technology used: SO = signpost and odometer, GPS = Global Positioning System, OS = odometer readings vs. scheduled position (post processing method)
Counts - method by which the system counts passengers (e.g., treadle mats or infrared ("ir") beams)
Vehicles - number equipped vs. number operated
Cost - total cost of system when the system was purchased (U.S. systems - U.S. $; Canadian systems - Canadian $)
(Cost variations may be due to varied capabilities and features.)
AVL Link - "Yes" - system is linked (or will be when installed) with an AVL system, "No" - not linked, no plans to link "Linking" - an existing, independent APC system will be linked to an existing or new AVL system
Xfer Freq. - indicates how often the data is transferred from the bus either to the central computer or to a temporary storage device.

North American Automatic Passenger Counter Applications (continued)

City System	Location	Counts	Vehicles	Vendor	Cost	Status (as of 9/30/95)	AVL Link	Xfer Freq
Portland, OR Tri-Met	OS	ir beams	80/ 635	Red Pine	$4.5K/bus, $5K/retrieval unit	Oper. since 1982, plan to link with new AVL system	Linking	Daily
Corpus Christi, TX CCTS						Part of AVL System - RFP out Fall 1995	Yes	Real-Time?
Seattle, WA KC Metro	SO	treadle mats	150/ 1000	Pachena; London Mat	$10K-$12K/bus	Operational since 1980, linking to (SO) AVL system	Linking	Weekly
Milwaukee, WI MCTS	GPS		50/ 550			RFP by end of 1995	Yes	Real-Time
Calgary, AB Transport Dep't	SO, GPS	mats, prox. sensors	30/ 580	Crayfield Digital	$280K 1st 25 $30K new 5	Operational since 1990	No	Real-Time
Winnipeg, MB Transit System	GPS	treadle mats?	35/ 530			RFP 10/95	No	Daily
Hamilton, ON HSRC	SO	vertical ir beams	32/ 240	London Mat - original system; updates in house	$6K/bus	Oper. since '86 with mats, changeover to beams 12/95	No	Daily
Montreal, QC STCUM	SO	treadle mats	175/ 1650	Wardrup	$2.5 million (total)	Under Installation		Daily

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