INTEGRATING ADVANCED PARKING INFORMATION SYSTEMS WITH TRAFFIC MANAGEMENT SYSTEMS

by

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SUMMARY

Parking, a key component in the efficient operation of a transportation system, has typically been ignored in many United States cities advanced traffic management systems. With the ever increasing problems associated with traffic congestion, including environmental and societal concerns, all efforts must be taken to reduce congestion and lessen its impact on the environment. One method that has been shown to alleviate congestion is providing drivers with advanced information so that they can make educated decisions regarding what route to take. Likewise, many European cities and cities in Japan have implemented Advanced Parking Information (API) systems that provide drivers with real-time information regarding the parking situation in participating facilities. These systems, in order to provide the biggest results, have been integrated with the advanced traffic management systems (ATMS) in their respective cities to insure that all aspects of the transportation system are included in the management system.

Despite the benefits experienced by cities that have implemented an API system including Köln and Frankfurt, Germany; Southampton, United Kingdom and Yokohama, Japan, few cities in the United States have integrated API systems with their ATMS. This is primarily due to a lack of knowledge of the API systems and their expected benefits. This paper attempts to inform the reader of the possible benefits of the API systems as well as illustrate their applications. Pittsburgh, Pennsylvania has an API system in place and St. Paul, Minnesota is planning an operational test of their API system in November 1995. These two American API systems as well as the systems previously mentioned are discussed in this paper.

While lack of knowledge has been cited as a reason for only a few API systems in the United States, there are other factors that make many United States cities less likely to experience significant benefits from the API system. Included in these factors are urban sprawl, the public/private partnerships that must be formed, and the fact that most commuters in the United States have a reserved parking space at their place of employment.

Cities that have implemented API systems have experienced an increase in the occupancy rates of their off-street parking facilities, a decrease in illegal parking, and a decrease in queue length and delay at the entrance to parking facilities. Also, reductions in search times were recorded.

Based on a literature review of the existing API systems and the proposed operational study in St. Paul Minnesota, a guideline for implementation was developed. This set of guidelines is primarily a checklist of considerations that must be taken into account including the recruitment of parking facilities that will participate in the system and focus groups to solicit public opinions before the physical implementation of an API system. Also included in this set of guidelines is the type of city that benefits from the integration of an API system with their ATMS. Included in this list is a city that is centrally developed, has a large number of special events, has adequate parking demand in the downtown area, and has perceived problems associated with parking. These guidelines were then applied to the city of San Antonio, Texas in a hypothetical implementation of an API system.

Increasing public awareness and concern for environmental issues and social needs requires transportation engineers to broaden the scope of transportation strategies and solutions to include integration, flexibility, and choice. Such an enlightened approach is essential if downtown areas are to remain centers of development, economic growth, and cultural interests.

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INTRODUCTION

Traffic flow in urban areas is one of the major sources of energy consumption as well as a source of network congestion and pollution. Local transportation agencies must take measures to smooth the patterns of traffic flow in urban areas, thereby reducing pollution due to automobile emissions and alleviating the problems associated with congestion. In large downtown areas, motorists searching for available parking can severely disrupt the flow of traffic. Information provided to motorists regarding parking has the potential to smooth the flow of traffic in urban areas to some degree. European transportation engineers as well as engineers in Japan have realized the potential advanced parking information (API) systems (also called parking guidance and information systems or PGI) have in reducing congestion in a densely developed downtown area.

For many years, city and business officials in large cities like New Orleans feared any parking regulations that had congestion reduction as an objective. Local officials and business owners feared that a reduction in congestion would mean a reduction in the number of visitors to the city and a reduction in retail activity for the downtown district. Because parking management and adequate, convenient, and reasonably priced parking supply are key components to a city's transportation system, they are crucial to vital commercial districts and healthy residential districts (1).

Many urban areas throughout the Untied States have implemented advanced traffic management systems (ATMS) to improve the flow of traffic within the area of concern. Most of these systems consist primarily of traffic control centers that manipulate signal timings to accommodate the current traffic situation in the most efficient manner possible, enforce ramp metering to smooth the traffic flow on freeways, and monitor incidents to restore the integrity of the transportation system as quickly as possible through incident management techniques. Traffic management centers also widely use variable message signs (VMSs) to notify drivers of congested areas on certain freeways and arterials and recommend diversion routes. Three objectives of traffic management are:

1. **Safety** - to prevent crashes with obstacles in the travel lanes such as a stalled vehicle or vehicles stopped in a queue, or dangerous conditions such as fog or slippery roads;

2. **Travel assistance** - to inform the drivers of events and traffic conditions to increase their comfort with the driving task; and

3. **Traffic control** - to limit disturbances and congestion by various measures of traffic control such as recommending diversion or restricting access and reducing the variation of speeds along a roadway for a higher capacity as well as rapid incident removal.

Messages posted on VMSs can fulfill objectives other than those listed above, but the messages will have more influence on driver behavior if they are formulated based on the objectives of traffic management (2).

Parking is a critical part of the transportation system that is commonly overlooked by transportation officials when developing an advanced traffic management system. A queue formed

at the entrance of a full parking facility spilling over into the travel lanes, can greatly affect the capacity of a roadway and result in inefficient use of the transportation facility. If, on the other hand, an advanced parking information system were in place, drivers would know the parking facility had no available spaces and choose to park in other facilities. Given the potential advanced parking information systems have in smoothing the traffic flow in dense urban areas and the benefits experienced by cities with advanced traffic management centers, integration of these two systems is logical for a city if the city is to gain the best possible results from their traffic management system.

Objective

The objectives of this paper are to:

1. Document API systems operating in some cities in Europe, Japan, and the Untied States some of which are integrated with the ATMS in their respective city;

2. Identify the reasons API systems are not more prominent in the United States;

3. Recognize the returns that are possible with the integration of API systems and ATMS as experienced by cities with such systems in place;

4. Create an implementation guideline for the integration of API systems with ATMS; and

5. Develop a case study of the integration of API systems with ATMS in San Antonio, Texas.

Study Approach and Scope

This paper is a product of an extensive literature review that covers advanced parking information systems currently in place or under construction in some European, Japanese and United States cities. Through phone interviews of transportation officials at traffic management centers, reasons for the lack of advanced parking information systems in the United States were also identified. This paper is intended to provide insight into API systems, considerations for implementation, a set of guidelines for implementation and a case study of a proposed parking management system for events in San Antonio, Texas.

EXAMPLES OF API SYSTEMS

Advanced Parking Information systems are some of the oldest and most developed of the driver information systems (3). Some groups of drivers spend up to 40 percent of their total travel time searching for a parking place. The main objective of API systems is to reduce the amount of time drivers spend searching for a parking space. Since the first advanced parking information system was installed in Aachen, Germany over 20 years ago, the idea has spread around the world with more than 30 systems in Germany, 25 in the United Kingdom, (3) and more than 20 in Japan (4). While many of the Japanese systems differ greatly from the European systems, the main objective of cities in these countries is to assist drivers to locate available parking without unnecessary travel. With the number of API systems in place in Europe and Japan it is surprising that API systems are no more prevalent in the United States; in fact, the author found only two such systems within the country.

Frankfurt, Germany

Frankfurt am Main is best known as the center of the German financial industry but is also an important industrial center and the major regional shopping center attracting many visitors into the downtown area. It has been estimated that of the 930,000 people who live in Frankfurt, approximately one-tenth of them work in the central downtown area of Frankfurt; however, the central area offers only 1900 on-street spaces, 8,800 spaces in public off-street parking facilities, and 8,000 private spaces. There are an additional 800 illegal parking spaces that are typically occupied (3).

During peak-periods of demand such as the pre-Christmas shopping time, many drivers coming into Frankfurt to shop had difficulty finding an available parking space and searched for a space for 10 minutes on the average. To help reduce parking search times and improve the distribution of demand throughout the parking facilities, the city of Frankfurt installed a parking guidance and information (PGI) system in 1992. This system was also implemented in hopes of reducing the number of drivers using on-street parking (3)

Frankfurt installed the PGI system in three phases, the first of which focused on part of the central downtown area. The PGI system first guides drivers to one of five subareas and then within a specific subarea, to a particular off-street parking area. The signs, seen in Figure 1, indicate the number of available parking spaces in a subarea or parking facility expected at the time the driver arrives at that particular area or facility. That is, the system has a built-in short term forecasting model to allow for travel time to the parking facility. The first stage of the implementation was installed in November of 1992 and included three of the five subareas including 12 facilities and 7,200 spaces. The second phase of the system was implemented in the end of 1993 and incorporated the remaining subareas with a projected third phase which will include signs directing drivers to the park-and-ride facilities on the outskirts of Frankfurt The total capital investment for the first two phases was DM 14.1 million ($10.2 million) with an estimated operating cost of DM 0.5 million ($362,000). These costs are shared by the City of Frankfurt and the State of Hessen.(3).

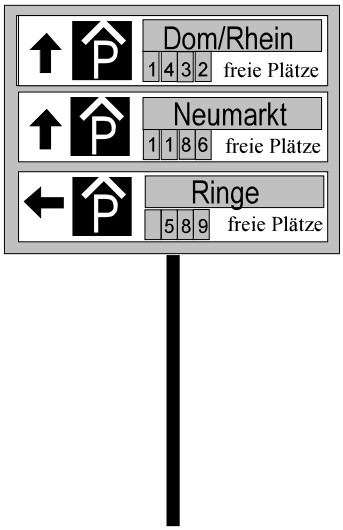

Figure 1. A Sample Dynamic Parking Guidance Sign.

SCOPE Project (Southampton, United Kingdom; Köln, Germany; and Piräus, Greece)

The SCOPE project comprising the cities of Southampton, Köln, and Piräus developed integrated systems of information classification and methods of relating such information to the motoring public. The project was developed to provide a vital service to drivers within advanced transport telematics through modern traffic and travel information services (5). The main objective of SCOPE has been the development and application of integrated urban traffic management (6). Southampton and Köln have developed advanced parking information systems that are to be integrated into their systemwide traffic management systems. On the other hand, the city of Piräus does not currently have an API system, but does have a system that provides travel and traffic information to travelers such as ferry schedules, inter-urban coaches, and train services.

Southampton, United Kingdom

The primary objectives of the City of Southampton system is to make the public more aware of the travel options available and encourage the use of public transportation by providing real-time information. Off-street parking facility information has been improved in Southampton through the introduction of occupancy detectors located in the parking facilities that are linked to the urban traffic control (UTC) system for all of the major city parking facilities (5). The UTC system in Southampton consists of several elements and forms a portion of the integrated information and control center found at the core of the ROMANSE (Road MANagement SystEm) project. The UTC system controls signalized intersections and coordinates an on-line information base. It also controls incident management, bus priority, and parking information. The system as a whole is used to

monitor network and parking conditions, interpret incoming information and make recommendations to the motorists to improve network performance. As the ROMANSE project specifically relates to parking management, it monitors the number of spaces in multi-story parking facilities. The UTC system then relays this information to approaching drivers so that they can spend less time searching for an available parking space. Drivers using on-street parking in Frankfurt must take time-stamped tickets form a ticket machine and pay the parking meter at the parking space based on the length of time spent in that particular space. The availability of on-street parking is monitored by returns from the ticket machines (6).

Köln, Germany

The current UTC system in the City of Köln consists of four subsystems which, for the most part, are independently operated. These subsystems include:

- Urban Traffic Control System,
- Parking Guidance System,
- Park-and-Ride Installations, and
- Various Signing Systems.

Within Köln's program for advanced traffic management, is a concept of an overall traffic system management which is being installed in a series of step-by-step activities (6). The aim of the City of Köln's system is to improve both the urban traffic management of Köln by advanced traffic control measures and the efficiency of the transportation system by providing motorists with travel and traffic information. A traffic system management concept has been developed to integrate the different existing and planned traffic systems (5).

As part of the SCOPE project, the City of Köln will be planning, installing, and assessing the use of variable message signs for Park and Ride Lots. In the first phase of the construction, two park-and-ride facilities were equipped with new installations for dynamic traffic information and control. Extension of this first stage includes the addition of 13 park and ride facilities. The regional and urban access roads to these facilities will be furnished with dynamic display installations at the roadside that will provide real-time information to the driver concerning the availability of parking spaces. Already in place in Köln is a parking guidance system that covers the central area of the city and includes over 30 parking facilities (7).

Figure 2 is a map of Köln that is part of a brochure provided to travelers in Köln to assist them in using the API system. The map of the city indicates the parking facilities that are part of the guidance system with the square parking symbol, their location, and identifies one-way streets and restricted turning movements. Also on this map are parking facilities located underground (symbolized with the letter "U") and parking facilities not currently included in the API system (symbolized with the circular parking signs). While the location of the parking guidance signs are not explicitly marked on this map, they are placed along the main roads leading into Köln and within the city. The signs used in Köln are the same type used in Frankfurt and can be seen in Figure 1.

Yokohama, Japan

The city of Yokohama is approximately 30 km (18.6 miles) southwest of Tokyo where more than 3.3 million people live. Due to its close proximity to Tokyo, Yokohama is the center for large commercial and industrial activities. All of the development in Yokohama has led to serious parking violations that hinder traffic flow in the downtown area. Therefore, the City of Yokohama has

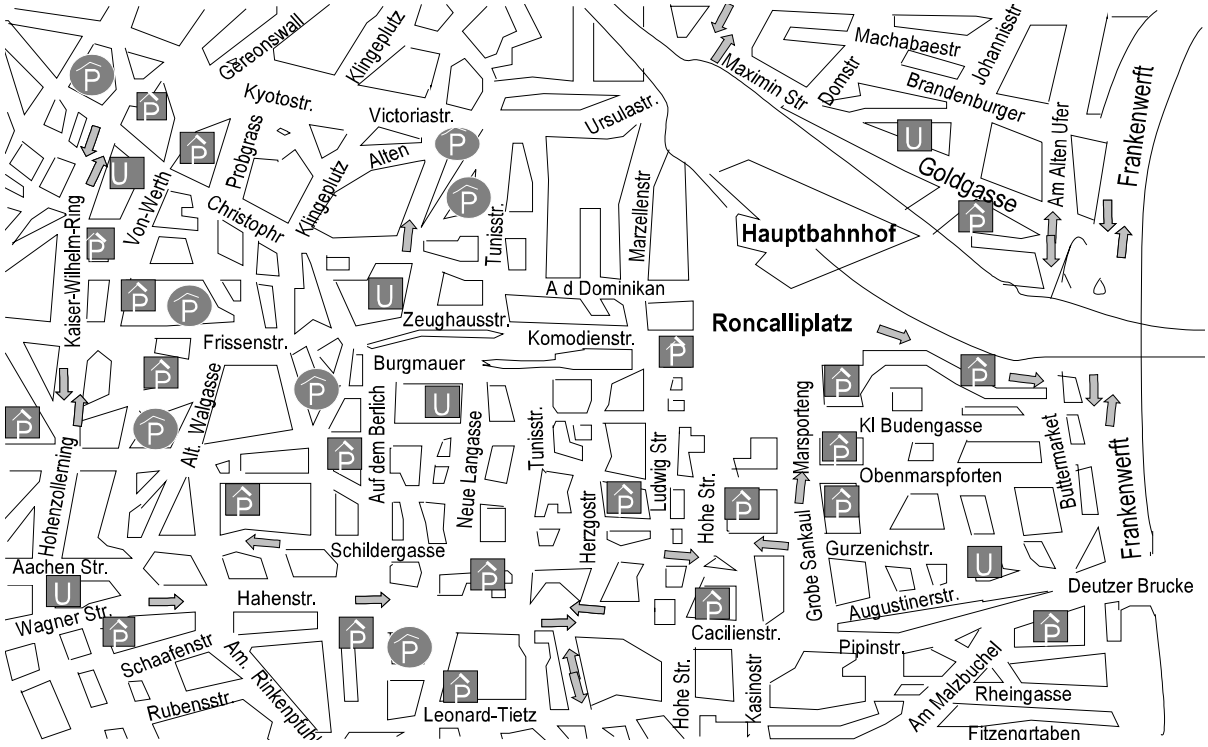

Figure 2. Map of Köln Parking Guidance and Information System.

introduced an API system, or parking navigation system, in conjunction with private parking facility owners and the Minister of Construction.

Beginning its operation in 1988, the Yokohama system provides drivers entering the city information regarding the current status of parking and guides them to a facility with available spaces. The system covers an area of 0.9 km^2 (0.35 mi^2) encompassing 16 parking facilities including 4,400 parking spaces. Of the capital needed for this project, over 28 percent came from the private sector (8).

The Yokohama API system divides the city into four zones as seen in Figure 3. As travelers approach the city, the API system notifies them of the parking situation within each zone via Zone Information Display Boards (Figure 4) that read "full," "crowded," or "vacant." There are a total of eight of these boards on the roads entering the city. Once drivers have entered a particular zone, they are notified of the availability of parking in each parking facility way of the Detailed Information

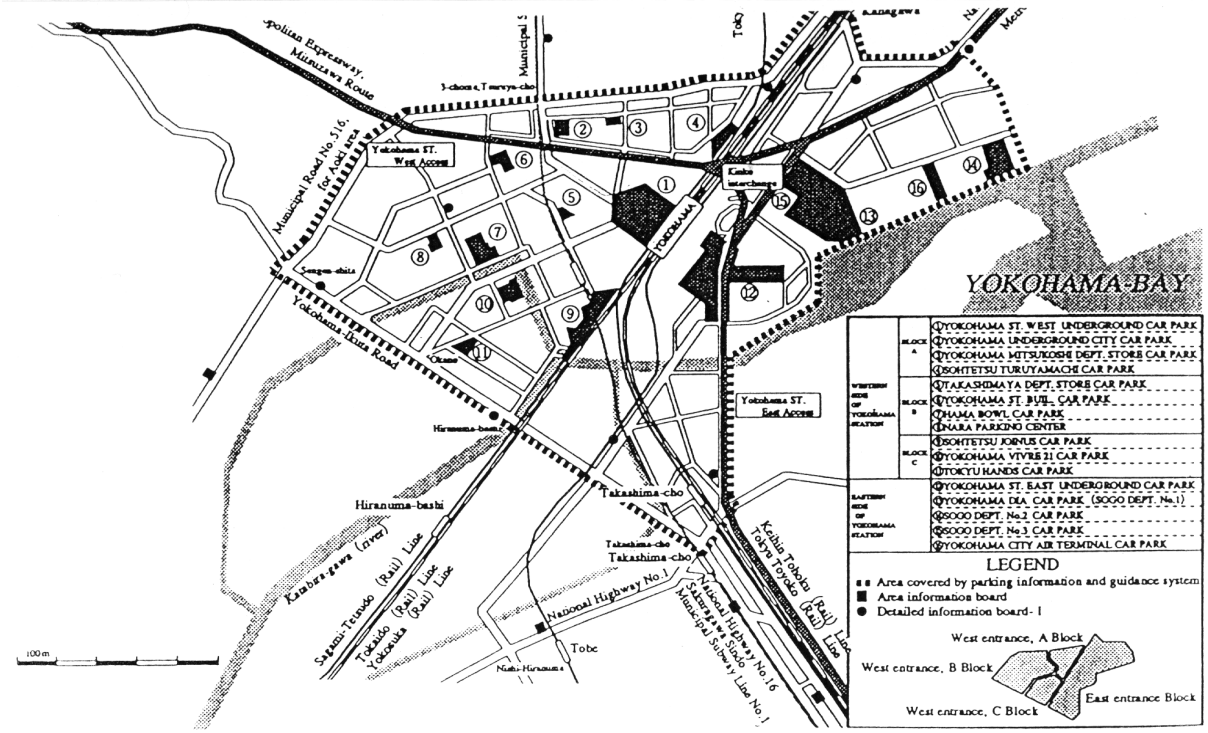

Figure 3. Map of API System in Yokohama, Japan (8).

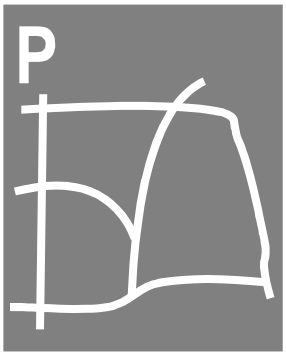

Figure 4. Zone Information Board (8).

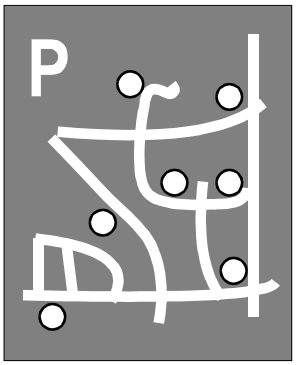

Figure 5. Detailed Information Board I (8).

Boards -I (Figure 5). These boards are installed on the main approaches to each zone. There are a total of nine of these displays. Both the Zone Information Board and the Detailed Information Board-I are controlled from a central control center that receives information from car monitoring devices installed at the parking facilities. The information displayed on the information boards is updated automatically through an exclusive telephone circuit. This technology allows the motorist to always know the current parking situation (8).

After drivers have seen the Zone Information Board and the Detailed Information Board-I, they will see the Detailed Information Board-II (Figure 6) which is a static sign that shows the names of the parking facilities and the direction to travel in order to find them. The final board that is displayed to the driver is at the entrance of the parking facility which will have the name of the facility and possibly whether it is full or vacant (Figure 7) (8).

Another city in Japan which was unnamed in the paper by Yagi has also implemented a type of API system; however, this system monitors parking meters. Where the parking meter supervision program is installed, drivers looking for parking places are first guided macroscopically to an area that has available spaces, then microscopically by parking fullness display boards to a specific location with available parking. The system is characterized by its strategic design factors including the unique parking meter monitoring that divides the street network into blocks and the most appropriate position for the parking fullness display boards (4).

With the parking meter management system, each parking meter is centrally controlled via the parking meter management equipment such that parking meter utilization can be monitored in real-time conditions; therefore, occupancy of each parking meter can be displayed on the parking fullness boards which can be easily noticed and understood by drivers. The information displayed for the drivers is divided into parking blocks with consideration given to traffic restrictions such as one-way streets and prohibited turning movements. Further away from the downtown area, drivers are given guidance to a supervision area that has available parking (4).

The system has been constructed to centrally monitor areas of parking regulations using the parking meters. The system consists of both equipment central to the system as well as local equipment that includes the parking meters themselves. The central equipment is connected to the local equipment by means of leased lines that allows two-way communication. The central equipment consists of the master controller, an operator terminal, and a supervision control terminal. The local equipment is that which is seen by the driver including the parking meter, the fullness display boards and the guidance information boards (4).

Figure 6. Detailed Information Board II (8).

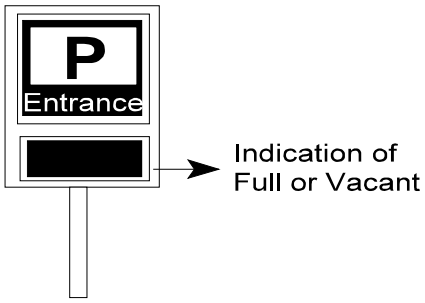

Figure 7. Individual Information Board (8).

Pittsburgh, Pennsylvania

The City of Pittsburgh attracts many visitors with sporting events and a largely developed downtown area and is trying to attract more visitors by installing an API system, one of only two in the United States. The API system was also implemented in hopes of creating an atmosphere in the busy downtown area conducive to visitors finding an available parking space with relative ease. The design of Pittsburgh makes it ideal for an API system. The heavy concentration of activities in the downtown area and Three Rivers Stadium provide for excellent opportunities for signing both as drivers enter the city and when they are driving in the downtown district (9).

Like the systems previously described above, the city is first divided into zones and the API system guides drivers to the zones with available parking. Once in a particular zone, the driver is then guided to a particular parking facility that has available parking spaces. The signs used in Pittsburgh display whether a facility is "FULL" or "OPEN" and uses arrows to point the motorist in the direction of the parking facility (9). An example of this type of sign can be seen in Figure 8.

St. Paul, Minnesota

Downtown St. Paul currently receives more than four million visitors annually, attracted by a variety of events at the St. Paul Civic Center, the many museums, and the world-renowned Ordway Music Theater which drew more than 180,000 visitors in a 12-week period during the run of *Phantom of the Opera*. With the St. Paul Civic Center Complex expansion and the arrival of an International Hockey League team, the number of visitors in St. Paul are expected to increase dramatically. This large number of visitors requires that measures be taken to insure efficient use of the downtown parking supply. While there is not a lack of parking in the downtown area, there is a perceived lack of ready access to parking facilities (10).

St. Paul's proposed API system will focus on a pilot test of the parking management system for major entertainment, athletics, and other special events in the Civic Center-Ordway Music Theater
area of downtown. The test will be developed to interface with the existing Major Events Management Program and the St. Paul Incident Management System. The pilot study will eventually be expanded to all of downtown St. Paul, including the riverfront, for normal workday parking as well as event parking. The operational test of the API systems will initially encompass a total of 5,000 parking spaces from a combination of 4,000 spaces in six parking ramps and 1,000 spaces in three surface lots (10).

The API system will provide motorists using the Interstate system with information relative to parking using variable message signs located on the interstate and primary streets near the test location as well as a continuously updated inventory of available parking spaces at each ramp. These dynamic signs are the same type used in Köln and Frankfurt and can be seen in Figure 1. Unlike the Pittsburgh system, this project will inform the drivers of the number of spaces available in a particular area and not just whether a facility is full or not. The electronic message signs will be located at key locations to allow motorists to select the most convenient parking location and access route without unnecessary travel due to full or congested parking facilities. Following some of the examples in Europe, the number of spaces will typically be displayed in a steady green light; however, as the number of spaces falls below ten percent of the facilities capacity, the number of spaces available begins to flash. When the total number of spaces that are not occupied falls below ten, the number is displayed in red. When a parking facility becomes full, the driver is simply directed to another facility by way of the variable message signs. Information on parking space availability will also be communicated to area-wide broadcasts with other traffic information through the overall Guidestar traffic advisory information management systems (10).

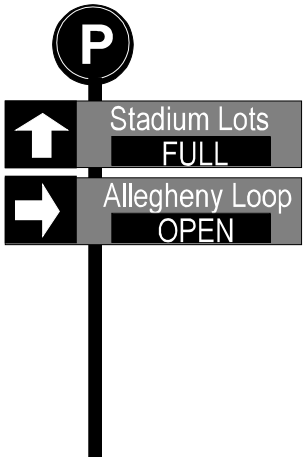

Figure 8. Pittsburgh API Sign.

WHY API SYSTEMS ARE NOT MORE POPULAR IN THE UNITED STATES

As mentioned previously, advanced parking information systems have not been widely implemented in the United States, but it is not because the country has failed to recognize the importance of managing traffic flow. Many cities across the United States, both small and large, have implemented advanced traffic management systems to help control, monitor, and alleviate congestion that may result in the breakdown of their transportation system. There are many reasons for API systems not being utilized in this country. Some of these reasons the author feels API systems are not more prominent in the United States are discussed in this section of the paper.

Lack of Knowledge

The idea of managing parking in a downtown area through the use of advanced information dissemination is not an area that has been explored to any great extent in the Untied States. For this reason, many of the transportation officials responsible for developing traffic management centers do not include a parking management aspect in their city's advanced traffic management system. Some efforts have been made in many cities such as San Antonio, Texas to manage parking during special events. The city of San Antonio, for more than 10 years, has been managing parking during special events such as professional basketball games by moving trailer changeable message signs to the approaching roadside a few days prior to the special event. These signs typically identify the location of parking facilities that may be used during the event. The information is given to the public in advance of the event to help them decide early on where an appropriate place to park is (11).

Urban Sprawl

A second reason for the lack of advanced parking management in the United States is urban sprawl. In the United States, the typical pattern for growth in cities is outward. Once the city has reached its outer limits for growth, it begins building taller buildings. However, this trend of growth away from the center of the city does not make it conducive to advanced parking information systems. European cities, on the other hand, are much more constrained in their growth and have very centralized areas of development making them prime candidates for an effective parking information system.

Public/Private Partnerships

In many cities of the United States, parking facilities are either restricted to certain users such as employees in a particular building or are privately owned. In order to implement an API system, there must be strong cooperation between the public agency installing the system and the private parking facilities both financially and operationally. However, parking facility owners want to know that the system will benefit them directly and financially before they are willing to invest the large sums of money necessary for this type of system. It is very difficult for a transportation engineer to provide an owner the benefits of participating in an API system because very little documentation has been done with regard to the benefits involved with such a system. This is primarily due to the difficulties related to data collection in this area.

Commuters Have Parking Places

Because land was readily available during times of development in many of the larger United States cities, businesses were able to build parking facilities exclusively for their employees. This insures the employee has an available space every morning and does not have to spend time searching for one. While some United States cities have recently introduced regulations restricting the construction of parking facilities for new buildings in the downtown area, there are few places that suffer daily due to lack of parking spaces.

Perceived as Advertisement

For an API system to work effectively, parking facilities must be referred to by name on the parking information boards. Some parking facility owners perceive this as a form of advertisement which it is. Occupancy rates of parking facilities included in an API system are much higher than those facilities that choose not to participate (12). One transportation engineer said that he felt there would be problems implementing an API system if public funds are involved in the system's implementation because parking facility operators may feel they should be included in the "advertisement" for the sake of equality (11). This would require that the API system include ALL parking facilities within the city which may prove to be very costly.

Summary

The development and growth of the United States is very different from European and Japanese cities. While many of the cities in the other countries were limited in the manner they developed, cities in the United States were able to spread away from the center of the city and create cities that cover much more land area than in many other countries. This is not conducive to API systems because the urban sprawl results in many people trying to go to many different areas as opposed to many people traveling to a common destination. This coupled with the fact that approximately 85 percent of American commuters that choose to drive their personal vehicles to work have a reserved parking space at their place of employment (13) makes it difficult to see the benefits of an API system. However, the applications of API systems in the United States is not a moot subject. There are many cities in the United States that do suffer from a lack of ready access to parking that could benefit from an API system, especially during special events.

RESULTS OF API SYSTEMS

Despite the fact that API systems are one of the most mature driver information systems, few serious attempts have been made to evaluate their impact. This section illustrates some of the results that can be expected with the implementation of an API system with respect to drivers' awareness of the parking information system, parking search behavior, redistribution of parking demand, occupancy rates of parking facilities, and the amount of time necessary for a driver to search for an available parking space as well as queue length at the entrance to parking facilities.

Driver Awareness and Use

After the API system was installed in Frankfurt, Germany, a two-part survey was conducted, the first part of which was conducted three months after implementation and the second, eight months after the original implementation. Figure 9 indicates the changes in driver awareness and driver use of the guidance system for both typical on-street parkers and off-street parkers. Drivers were surveyed on Tuesdays (represented with the square shaped markers) and "long" Saturdays (represented by the circular markers). The solid lines on the figure indicate the percent of the drivers surveyed that are aware of the API system while the dashed lines represent the percent of drivers that have actually used the system. Awareness of the system developed rapidly and remained fairly constant at 80 percent after three months of operation after which time, only marginal growth was experienced. This percentage of awareness is not expected to increase anymore because Frankfurt attracts many visitors. Awareness of the system of the on-street parkers and the off-street parkers is similar as expected; however, a higher percentage of off-street parkers have actually used the system. The use and awareness of the system are also higher on Saturday than on a typical workday such as Tuesday. This may be due to the fact that this particular Saturday is a "long" Saturday that comes only once a month wherein the shops in Frankfurt are opened two hours longer than normal Saturdays. This draws many people from the rural areas outside of Frankfurt (3). "Long" Saturdays may also attract infrequent visitors to the city who are not very familiar with the location of parking facilities within the city and rely more upon the API system to guide them to a parking facility.

Overall, it appears that approximately 50 percent of off-street parkers and 25 percent of on-street parkers have used the system to find an available parking space. Additionally, based on information gathered from questionnaires, on any given day, approximately 20 percent of drivers parking off-street will have used the API system, to assist them in finding a parking space (3).

Parking Search Behavior

An API system can influence parking behavior in terms of where a driver parks and how the driver finds the parking space. In Frankfurt, the results of a survey revealed that few drivers totally rely on the API system to locate a parking space even on "long" Saturdays when congestion is the worst. In the event that the desired parking space cannot be found, drivers will then consult the API message signs, using the system as an alternate plan. Unfortunately, the number of drivers who rely on the API system as a second plan is only comparable to the number of motorists who choose to park illegally. This is indicative of drivers unwillingness to forfeit their ability to make decisions on

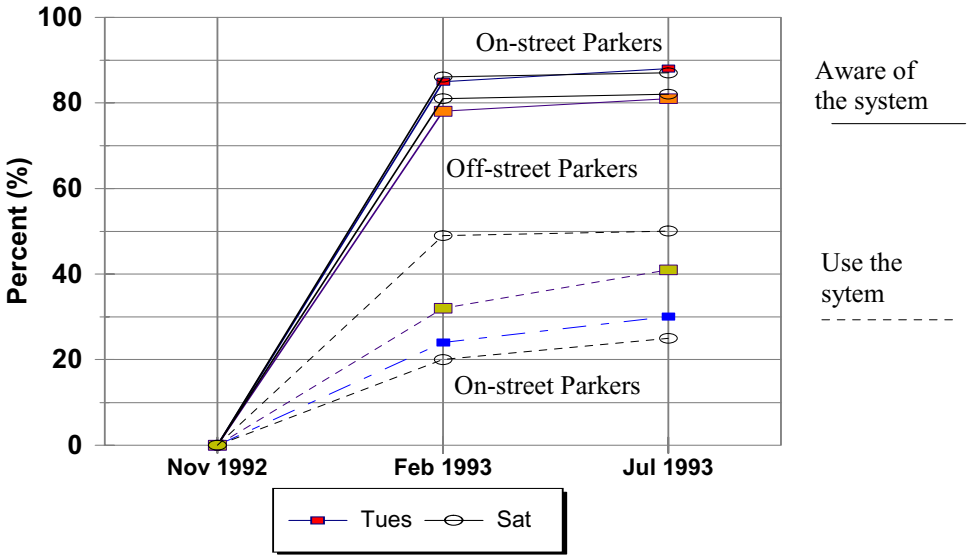

Figure 9. Development of Drivers' Awareness and use of the API over Time (3).

their own. This is supported by the number of drivers who said they use the system to check their previous decision or update it (3).

Redistribution of Parking Demand

In the Japanese parking meter monitoring project, the system was able to reduce illegal parking on the streets. During a 12-hour period between 8:00 AM and 8:00 PM, an average of 8.8 cycles per parking meter represented an illegal use. (A cycle was defined by each car that entered and left a parking meter.) This number of illegal uses represented 62 percent of all parking uses prior to the implementation of the parking meter management. After its implementation, there was a shift to legal parking that reduced the average percentage of illegal uses to 5.6 percent. Regular uses of the parking meter, or legal uses, increased 1.6 cycles per parking meter (4).

In the city of Yokohama, Japan, comparison of before and after data indicated that there was an 18 percent decrease of on-street parking and an increase of 21 percent in the number of drivers using the off-street parking facilities. This indicates a shift from on-street parking to the off-street parking lots (8). Similarly, in Frankfurt, the parking facility officials noted a more leveled utilization of the parking facilities. German researchers attributed this to informing the drivers of the lesser known parking facilities and directing them to these vacant spaces (12).

Occupancy Rates

Table 1 shows the increase in the number of vehicles using the largest off-street parking facility in Yokohama, Japan. There was a 21 percent increase in the number of vehicles utilizing the facility on a weekday, and a 5 percent increase during a holiday (8). The differences in the increases may be attributable to the differences in the level of saturation under these two situations. Similarly, the City of Frankfurt reported that the API system contributes to the saturation or full utilization of the more attractive parking facilities because drivers who assume these facilities are fully occupied are informed otherwise (12).

Table 1. Average Number of Vehicles Using Off-Street Parking in Yokohama, Japan (At the most popular parking facility) (8).

	Weekday		Holiday	
	1987	1989	1987	1989
Average Number of Vehicles (Vehicle/Hour)	16,635	20,165	29,368	30.896
Index (1987 = 100)	100	121	100	105

Search Time

Based on previous research, the City of Frankfurt was able to estimate the amount of time a driver, on the average, spent searching for a parking space. The approach involves relating the parking demand within a given time period to the search time of those drivers that found a parking space during that same time period, controlling for the background level of traffic flow in the area. In this particular research, the demand for off-street parking was estimated by the level of occupancy in the off-street facilities and information on the search times were calculated from the survey data. Figure 10 shows the relationship between search time and demand on a "long" Saturday in Frankfurt. From this figure, it can be seen that the API system reduced the search time of drivers at all levels of demand (4).

Queue Length and Delay

The City of Frankfurt also conducted studies to determine the effect the API system had on queue length and delay to the parking motorist at the entrance of parking facilities. Queue lengths are an important factor to consider because spillover from a parking facility into the travel lanes can result in severe deterioration of a transportation system, especially during times of peak demand. It was determined that both the queue length and the delay experienced by parking motorists were reduced. Figure 11 shows the reduction in queue length. The dramatic reductions in these

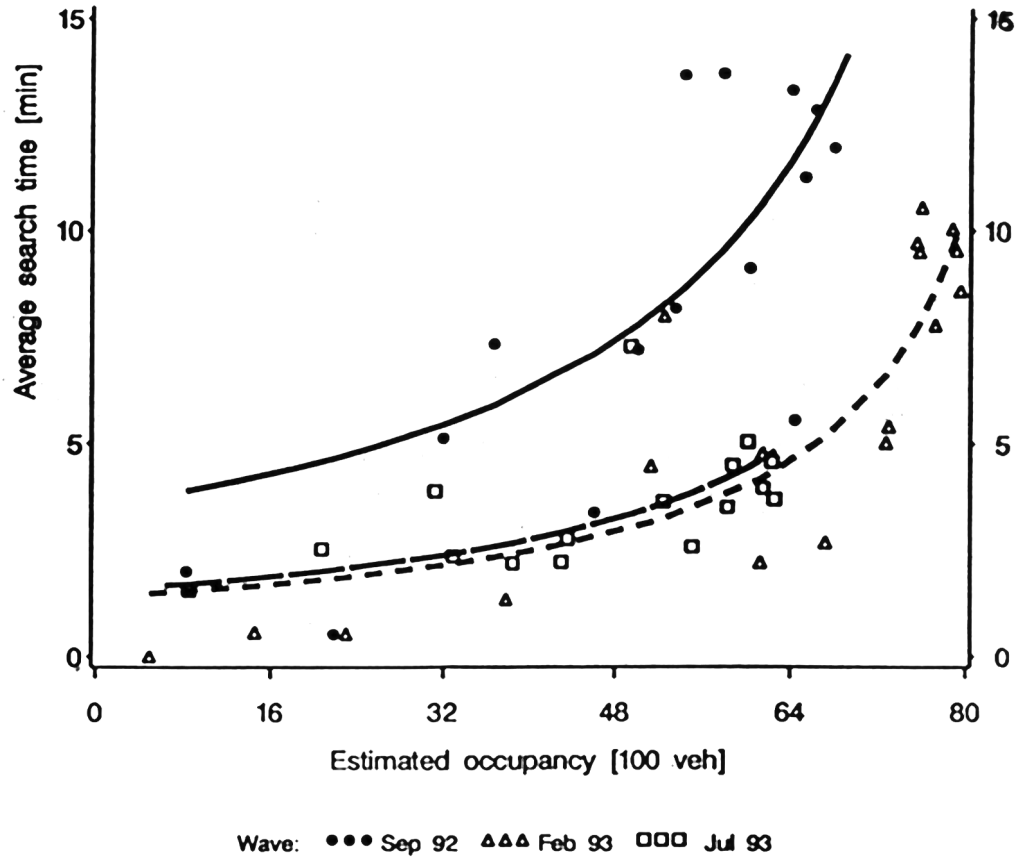

Figure 10. Estimated Search Time versus Occupancy (3).

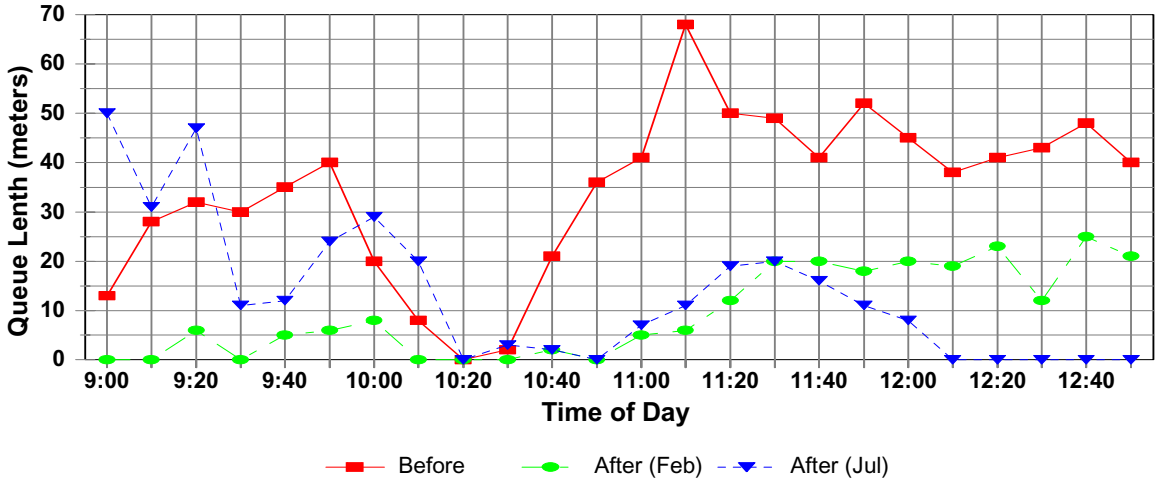

Figure 11. Queue Length Given Time of Day on a "Long" Saturday (12).

parameters were experienced primarily during times of high demand. The maximum delay is typically experienced at the most attractive lots. The reduction in delay was substantial at the higher demanded lots; it decreased from an average of 20 minutes to 10 minutes (12).

Summary

It is difficult to determine the total impact of an API system on a transportation network. There are many objectives of the implementation of such a system, but to measure them would be prohibitively expensive. The city of St. Paul is integrating the API system with the existing traffic management system that is part of the city's overall ITS program called Guidestar. The objective of this integration is to improve event traffic flow, reduce congestion, improve air quality, and avoid back-ups onto the freeways (10). However, these are going to be difficult to gauge because there needs to be a reference point for comparison. As Frankfurt, Germany discovered, it is difficult to identify the amount of downtown traffic attributable to traffic searching for parking places. The main benefits associated with an API system may be its ability to more evenly distribute parking demand and help visitors in an unfamiliar city feel comfortable navigating through the downtown area.

IMPLEMENTATION GUIDELINES

Prior to the integration of an API system with an advanced traffic management system, there are several factors that must be considered. The first of which is whether or not a city will benefit from the implementation of an API system. Factors that make a city more receptive to the advanced parking information system include:

- Areas of concentrated activities and parking facilities,
- Large number of special events that attract many visitors into the downtown area,
- Adequate parking demand in the downtown area,
- Perceived problems associated with parking, and
- Congestion.

With areas of concentrated development and parking facilities within centrally developed cities, the majority of the people traveling to the particular city are trying to all get into a relatively small area. If a city has not developed over a large land area, there is more likely to be a centralized concentration of activities that are not able to provide sufficient parking within close proximity to the event. Additionally, API systems typically have maximum performance during times of peak demand. Unless the number of parking spaces is close to the average number of drivers wanting to use downtown parking, there will not be a severe problem for drivers finding spaces with the exception of drivers who want to find the absolute closest space to their final destination. During special events, a larger number of people want to visit the city and park. Parking guidance during these times will greatly affect the flow of traffic and help reduce congestion and unnecessary travel.

The following is a set of guidelines for the implementation and integration of an API system with an advanced traffic management system developed by the author using the Minnesota Guidestar Program's Operational Test as a reference.

Implementation Planning

1. Build the coalition. In order to guarantee the successful implementation of an API system, all of its participants must be identified early and be involved in the planning stages. This requires that the local parking facility owners and operators, transit companies, and all public agencies involved with the transportation network and its management form a team to determine the best strategy for implementing an API system in their area. This coalition should begin by setting goals and objectives of the API system and establish the means by which these goals can be attained.

Building the coalition may prove to be the most difficult step in the implementation process because it involves recruitment of the parking facility owners and operators by showing them the benefits to be gained by participating in this type of system. Because there are limited sources that provide quantifiable benefits associated with API systems, demonstrating the potential owners have of gaining positive returns from their investment in the system will require creative measures. One method that may be incorporated in the implementation of an API system is implementing the system in phases beginning with parking facilities that are owned by the local city. If this method is to be used, it is imperative that significant data collection be performed before and after the initial

implementation to document the returns possible with API systems and persuade owners of privately operated facilities to participate in the future implementation phases.

In the case that there are no parking facilities that are owned and operated by the city or other public agencies, gaining participation of privately owned facilities may require the initial implementation of the API system be funded by the public agency in good faith that the private facilities, once realizing the benefits of the API system, will contribute to the funding for the system. Another method that may increase private facilities' participation is involving the major attractions in the city. If the generators of many of the trips to the downtown area believe that the API system has the potential to attract more visitors to the downtown area, they will most likely be willing to at least write letters of support of the system if not actually contribute to the funding for the system. Financial support from these types of agencies may have a "peer pressure" effect on the parking facility owners and operators and make them realize that the benefits to be gained from the API system are not limited to the transportation network, but that the system can benefit the participating agencies as well.

2. Define the system. Once the members of the API system coalition have been identified and confirmed, it will be relatively easy to determine the areas of the city that should be considered for operation of the API system. The locations of the participating parking facilities will help determine the size of the city to be included in the system. If the system is to be implemented in phases, there should still be an overall implementation plan that insures that the goals and objectives established by the coalition for the API system will be achieved when the final phase of the system is implemented. Additionally, when implementing the system in phases, it must be determined if the city will be divided into zones or regions and drivers will first be guided to a zone with available parking and then microscopically guided to a particular parking facility with vacancies. If this is the case, it may be best to implement the system in a zone-by-zone manner. If an API system is implemented in phases but not in a zone-by-zone manner, the implementing agency must keep in mind the overall plan of the API system to insure the proper location of informational signs to avoid redundancy in signing. Likewise, the signs used should allow the names displayed on the sign be changed during the addition of parking facilities in the later implementation phases. (This is not to say that the sign should be variable with respect to the name of the parking facilities listed on the sign, but changeable such that additional parking facilities can be added to the informational signs as they are incorporated into the API system. This will also allow for the signs to list only those parking facilities most readily accessible from the approach road the driver is using.)

3. Identify key access routes and sign locations. Once the participating parking facilities have been identified, the routes to them must be determined. This will involve interaction between the API system and the ATMS because as traffic congestion develops, the ATMS may provide motorists with alternate route information so that they can avoid congestion; however, the motorists that choose to use the alternate route information need the parking information as well as the traffic on the original access road. This step will require the API system be actively involved with the ATMS to insure traffic guidance signs are placed on the major access roads as well as those that are typically used for alternate routes during times of congestion.

Origin and destination studies conducted at parking facilities involved in the API system may also help determine the best placement of the informational parking signs by identifying the origins of the parkers' trips. By determining the origins of the trips that end in a particular parking facility, it will be easier to ascertain the routes taken by the users of the facility and the names of the facilities most commonly used by the drivers using a certain roadway. This information helps the coalition recognize what parking facilities need to be listed on what access routes.

4. Identify sign types and messages. There are basically two types of information message signs that are currently used: those that display the number of available spaces in a parking facility and those that report the degree of fullness of the parking facility. This may simply be a matter of preference; however, there has been limited research performed comparing the effectiveness of these types of messages given certain city types and levels of congestion. Generally, the parking information signs that display the level of congestion (full, congested or open) were reported to have more influence on drivers' behavior than those that indicate the actual number of spaces that are currently unoccupied (8). There are several manufacturers of the API signs that produce "off-the-shelf" signs that are simply ordered by the implementing agency and the signs operate similar to the traditional variable message signs using the same types of communication techniques.

5. Conduct focus groups. As with any addition to a transportation facility that is attempting to solicit a response from drivers, it is important to recognize what the driver needs and wants to make the driving task easier. Focus groups provide an opportunity to discuss the alternatives with the general public and have their input prior to the implementation of the system. By including the users of the system in the design phase of an API system, transportation engineers are able to better tailor the product to the motorists using the system. Focus groups also help identify possible driver responses to the information displayed on the informational signs and allow the transportation agency to estimate the number of drivers that will be influenced in their selection of a parking facility by the advanced information provided by the system. The sign and message types chosen in Step 4 may also be tested in the focus groups. It may be determined that in a particular city, displaying the number of spaces available as opposed to the state of congestion in a parking facility will have a greater influence on drivers' behavior. Parking facility owners should also be asked to observe the focus groups so that they can better understand the wants and needs of the users of their facilities and better understand the drivers' desires for advanced information during the driving task.

6. Refine the above specifications based upon focus group discussions. In order to insure the public will use the system and be supportive of it, it is important to incorporate as many of their ideas regarding the API system as are economically and technically feasible. This will help make the final system as user friendly as possible, and the public will feel as though they had a say in how it should be operated while the implementing agency will have a system more tailored to the users' wants and needs. As previously mentioned, it may be determined during focus group discussions that the sign type that was originally chosen for the API system is not as effective as an alternate sign type. Additional investigation into the type of sign may lead to the alternate sign type being used in the implemented system. The focus groups may also help identify the routes drivers take when trying to access parking facilities in the downtown area. If these routes differ from those identified earlier in the implementation planning process, then adjustments in sign locations may be necessary to ensure the largest possible number of drivers are being reached by the advanced information signs.

7. Define hardware components. The hardware components that must be considered include communications equipment, operations equipment, and control center equipment. The communications equipment requires that a decision be made at this point regarding how the communication between all of the components of the system will take place; will they take place over a leased telephone line or by way of fiber optics? Operations equipment will include the signs and sign mountings as well as any other variable message signs that may be used in the API system. Consideration may also be given to using static directional signs once the driver has reached the core of the downtown area. The control center components will include the computers necessary to operate the system as well as a possible emergency back-up in case a situation arises. While an API system may not be crucial to the normal operation of the transportation network and require computer redundancy, it may prove a vital part of the management system during special events within a city's downtown area. This is also an area where integration with the ATMS would be most beneficial to the API system because the same control center can be utilized. However, the API system could be set up to run autonomously yet share information with the ATMS to insure the most efficient method of guiding and rerouting traffic. Autonomous operation, while not essential, will allow the API system to continue to operate if ever a failure occurred with the ATMS.

8. Define maintenance requirements. For an API system to be fully utilized by the public, the public must trust that the information provided by the system is timely and accurate. This requires that the API system function properly all the time which requires routine maintenance and maintenance in times of a crisis to return the system to an operational state promptly. If the API system functions properly and provides the drivers with reliable information, drivers will use the API system most efficiently.

This step in the implementation process requires that a value be placed on the API system and how important it is at a given instant for it to be totally operational. For example, at three o'clock in the morning on a Tuesday morning, it will not be nearly as important that the system be fully operational as it is one hour prior to a special event in the downtown area. Certain alarms must be set to alert maintenance crews of the type and severity of a problem and how crucial it is to the efficient operation of the system. Routine maintenance, on the other hand, such as changing burned out light bulbs in the signs is also important if the public is going to trust the API system and see it as an important part of the transportation network.

Detailed Construction Documents

1. Prepare the plans. As with any construction project, a detailed plan must be developed to insure that the goals and objectives of the project are to be achieved. This step involves developing a time line for the implementation of the API system and identifying the parties responsible for each stage of implementation. For areas unfamiliar with API systems, as the United States is, an adequate amount of time must be allocated to public education to present the system to the users of the system and allow them to become familiar with the way in which it operates. This stage can also include an inventory of the participating parking facilities to determine the number of parking spaces in each facility.

2. Develop necessary software. The API system relies heavily on a central computer determining the number of available spaces at various parking facilities at a given time. This requires that all of

the parking facilities be coded into the computer (by zone if the system is to operate on a zonal basis) along with the total number of parking spaces at each. If the number of available parking spaces is to be displayed on the informational sign, it may be desirable to post the expected number of spaces that will remain available by the time a driver reading the informational board reaches the parking facility. This type of calculation is dependent upon the location of each sign and the congestion currently on the transportation network. Also of consideration at this stage of implementation is the methods that will be used for determining the number of spaces that are unoccupied in a parking facility. This can be done through input/output counts wherein loop detectors or some other counting device is placed at the entrances and exits to a parking facility and count the number of vehicles entering and exiting the facility. These numbers are then sent to the computer located at the traffic management center via leased line or fiber optics or various other modes of communication. Determining the number of available parking spaces can be as simple as a parking attendant counting the empty spaces and calling an automated answering machine that allows the parking facility operator to punch in the number of available spaces over the phone. The parking facility operator would be responsible for calling the automated answering machine once every predetermined length of time. The length of time would vary depending on the demand for parking and the prevailing traffic conditions.

3. Prepare construction estimates. Once the API system implementation has been planned, the cost of the implementation needs to be estimated. More than likely, a budget is already in place at this stage of implementation and planning, but it is at this stage that all of the hardware and expertise necessary for the implementation and operation of the system have been identified thus allowing a fairly accurate estimate of the entire project to be determined. This step should not only include a cost estimate, but a time estimate as well. The first step in this section of the implementation was developing a plan which should indicate the necessary time for each stage of implementation. If the system is to be installed in phases, the time to install each phase should be identified as well as the time that will pass between each phase of implementation. Time necessary for collecting before data that will be used to determine the effectiveness of the system may also be included in the time schedule. While the later phases of implementation may depend on the successfulness of the initial implementation, their cost and time needs should be reported to create a complete time and cost estimate for the entire API system implementation.

4. Prepare operations and maintenance manual. To insure proper operation of the API system, an Operations Manual should be produced. Included in the manual would be a description of the system as a whole and its various components and their interactions. Because integrating the API system with an ATMS is important if the full benefits of the API system are to be realized, information related to the way these two systems communicate may also be included in the operations manual. The maintenance part of the manual may simply be a list of trouble shooting items that say if this type of problem occurs, these are some possible reasons for it. Another item that may be included in this portion of the manual is the location of commonly needed items for maintenance including extra light bulbs and electrical wiring. It will also be necessary to include the phone numbers of several engineers that can make vital decisions regarding the operation of the API system should any decision concerning the proper functioning of the system be required.

Marketing Strategy

1. Prepare a marketing plan. Because the API system's success depends entirely on the public's participation, great efforts should be taken to educate the public how the system is to operate and how they as users can gain the most benefits from using the system. At this point, it may be advisable for the implementing agency to designate a member of the coalition as a public relations person who, along with a committee, can devise the marketing strategies that will be employed to gain public understanding and acceptance of the API system. The marketing plan should emphasize the involvement of the general public in the focus groups to better make the system more appealing to the drivers in the area planned for implementation. The types of media to be used for marketing need to be identified during the development of the marketing plan. Television, while it reaches a large number of viewers, is fairly expensive. The implementation of an API system will typically occur in a city that attracts a large number of visitors that will be unfamiliar with the area. For this reason, methods other than television should be explored as tools for marketing the API system.

2. Develop public information campaign. While drivers' acceptance of the system is dependent upon their experience using it, a massive public education program can result in an API system being used early in its initial operation. The larger the public education program, the sooner the city can expect to see results of people using the system because the public knows how the system operates and how they should use it prior to the system going on-line. As previously mentioned, API systems are used in cities that attract a large number of visitors, many of whom are unfamiliar with the downtown area and parking facilities. These are the people that stand to benefit the most from the API system. To alleviate problems that visitors may have using the system because they are not accustomed to it, informational brochures describing the API system should be included in mailed out tickets and visitors' information packets. These brochures should contain a map of the area of the city included in the API system showing the location of participating parking facilities and a brief description of the system and how drivers can use the informational signs to locate available parking.

Summary

Once these steps have been completed, original cost estimates may need to be revised to accommodate any additions or unforseen expenses. The guidelines above were presented in three different sections that are not necessarily in order of the way the tasks should be performed. The public relations committee could be developing the informational brochures while other members of the coalition develop the operations and maintenance manual. Also, these guidelines do not take into account the physical aspects of implementation such as placing the signs in the field and connecting the sign boards to the control center. These are steps which will vary greatly depending on the area of the implementation and the strategies to be used for communications. During deployment of the API system to the field, information should be disseminated to the public so that they are aware of what the API system is supposed to do once operational. The primary consideration when integrating the API system with the ATMS is to insure constant information sharing between the two systems such that their integration results in the most efficient transportation network possible. During times of special events and unusually high demand this is extremely important. If a parking facility has no vacancies, the ATMS can begin to reroute traffic away from this area and toward a parking facility that is less saturated while monitoring the congestion on the roads leading to the vacant parking facility. Additionally, the ATMS can manipulate the traffic

signal timings to allow better progression in the direction of areas with available parking. This would require that the API system be operated by computers and software that are compatible with that of the ATMS. If the ATMS has been designed with an open architecture system, expanding the ATMS to include or transfer information with an API system will not be extremely difficult compared to a system developed to operate as a single unit with no consideration for possible expansion.

CASE STUDY: SAN ANTONIO, TEXAS

San Antonio is the ninth largest city in the nation and has the problems associated with traffic that would be expected of a city this size. The city's health care, tourism, education, and military installations add to normal urban freeway traffic especially during peak periods. With maintenance, accidents, and construction, heavy congestion can occur in off-peak periods. With this type of demand on a transportation facility one can expect to have unacceptable delay, reconstruction that can not keep pace with the demand, and a large number of accidents. For these reasons, the San Antonio District of the Texas Department of Transportation decided to create a state-of-the-art advanced traffic management center: the Transportation Guidance System called TransGuide (14).

TransGuide

TransGuide's general benefits are projected to be improved traffic flow, decreased delays, fewer accidents, and immediate management and emergency response to any freeway incident. The specific goals of the system are to:

- detect incidents within two minutes;
- change all affected traffic signals within 15 seconds from alarm verification;
- allow the San Antonio police to dispatch appropriate response from the traffic operation center (TOC);
- assure system expandability and reliability; and
- support future ATMS and intelligent transportation system activities (15).

San Antonio has great potential to benefit from the integration of an API system with the TransGuide system, especially during special events. The concentration of activities in San Antonio are centrally located with fairly limited parking. The transit operator in San Antonio has contracted out the parking lots at various shopping malls on the outskirts of San Antonio to serve as park-and-ride facilities during special events. Typically these parking facilities are located just off of the interstate or primary highway entering the city. If drivers wanting to park at a particular parking lot exit the interstate to search for an available space only to find there are no spaces unoccupied, then the lack of advanced information has created extra travel time for the trip. Additionally, drivers on the outskirts of San Antonio can be notified of the parking situation in the central downtown area prior to the exits for these park-and-ride facilities and decide that they will park in one of the park-and-ride facilities if the inner city facilities appear to be heavily congested.

Given the fact that the computer system architecture is an open one to allow for expansion, integration into TransGuide would not be very difficult. For the purpose of this paper, a plan for an API system has been developed for special events in San Antonio given available parking downtown and in park-and-ride facilities located in the four corners of San Antonio, Texas. This plan was developed following the preceding implementation guidelines as closely as possible. Because this is a hypothetical implementation, not all of the guidelines were included in this case study. Some of the implementation guidelines require public involvement or did not fall within the scope of this research. For these reasons, "Implementation Planning" steps were terminated after a small

discussion on focus groups. Additionally, the implementation stage "Detailed Construction Documents" was also omitted.

Implementation Planning

Build the coalition. For the purpose of this paper, an inventory was taken of the parking facilities available for public parking in downtown San Antonio. Additionally, the Public Works Department of the City of San Antonio Parking Division was contacted (16) and a list of all public parking facilities owned and operated by the City of San Antonio was added to the inventory. While not all of the parking facilities in the downtown area were included in this inventory, a representative sample of them located in various parts of the city was. A map showing the location of each of the parking facilities included in the inventory can be seen in Figure 12. The circles represent the location of the parking facilities. Parking facilities owned by the City are represented with numerals, and the privately owned facilities are marked by letters. There are 20 facilities that the city owns and 20 privately owned facilities for a total of 40 parking facilities included in this inventory with 4 additional park-and -ride facilities on the outskirts of town. The coalition for the City of San Antonio API system includes: the parking facility owners and operators identified in the inventory, the City of San Antonio Public Works Department, the San Antonio District of the Texas Department of Transportation (TxDOT), TransGuide, and VIA, the local transit authority.

Because it is anticipated that the privately owned parking facilities will be apprehensive about contributing large sums of money to the API system, the City of San Antonio, with the help of TransGuide and TxDOT, will first implement the system involving only the parking facilities owned and operated by the City. This implementation will occur with consideration given to expansion of the number of parking facilities involved; it will be implemented anticipating that the privately owned facilities will agree to contribute to the funding of the project and become participants in the API system. Extensive data will be collected at each of the parking facilities including the privately owned ones, to determine the number of spaces available in each lot, the average wait for a parking space, and average turnover rate along with other measures of effectiveness.

Define the system. Now that the members of the coalition have been identified, the area to be included in the API system can be identified. The area of San Antonio included in this case study is bounded by the interchange of IH-10 and IH-35 in the northeast, and IH-10 in the west. At this time the southern border for the system is Durango Street. The eastern border is the Amtrak railroad track just east of US 281.

The system will be implemented in phases keeping in mind the overall goals of reducing driver search time for available parking facilities and increasing occupancy rates of participating parking facilities. Ridership on transit entering the city from the four park-and-ride facilities during special events is also expected to increase. The San Antonio system will be divided into four zones and named based on the major attractor located within that zone. Following is a list of the four zones. They are shown by the heavy black lines in Figure 12.

- Zone 1: Alamo Parking
- Zone 2: Riverwalk Parking
- Zone 3: Medical Complex Parking
- Zone 4: Hemisfair Plaza Parking

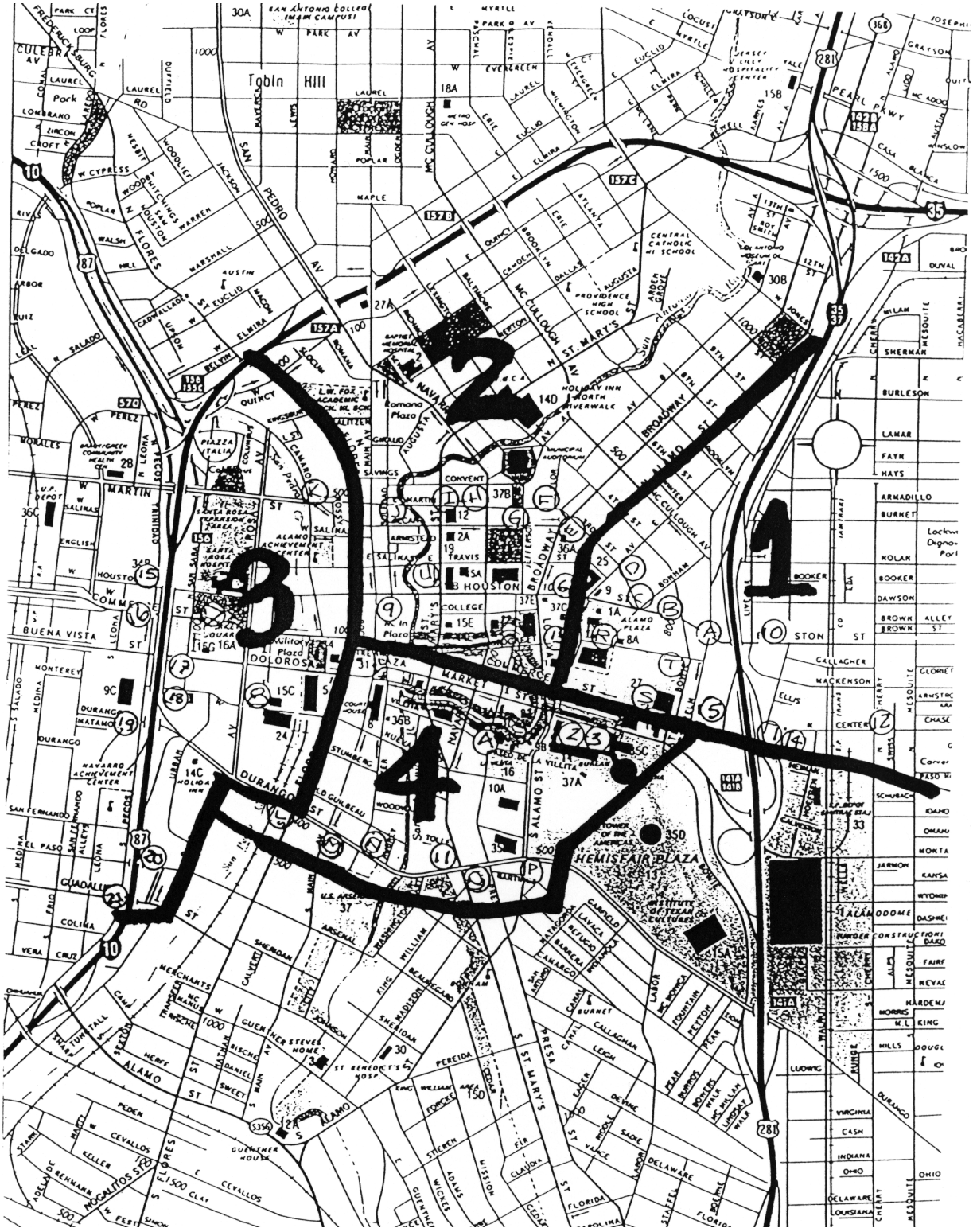

Figure 12. Map of San Antonio Parking Facilities and Zones.

Identify key access routes and sign locations. Origin and destination studies will be performed at participating parking facilities to determine the appropriate placement for the informational signs. Given the location of the parking facilities and the major access routes to the downtown area, a preliminary plan was developed to locate the informational signs. These locations can be seen in Figure 13. The circular markers represent zonal information boards while the triangular markers represent informational signs that will list specific parking locations. The zonal information signs are located on the major access roads entering the city prior to exits for the city. Figure 14 also identifies locations for zonal information signs so that people can decide to use the park-and-ride facilities based on the level of parking congestion in the downtown area without having to drive into the city and back to the park-and-ride facilities.

Identify Sign Types and Messages. The proposed sign type to be used in the San Antonio case study will display the level of congestion of the parking facilities or zones with the words "Full," "Congested," and "Vacant." When the parking facility is full, it will be displayed in red. During times of congested parking, the word "congested" will be displayed in a steady burning yellow until the there are less than 10 spaces available in the parking facility. At that time, the word "congested" will remain in yellow but begin to flash. During times when there is a low occupancy rate, the word "vacant" will be displayed in green.

Conduct focus groups. San Antonio has a very diverse population that must be equally represented in the focus groups. The focus groups will be presented with all of the information relevant to their understanding of the API system that has been developed to this point in the implementation planning process. Members will be asked to give their opinions of the system and asked to make recommendations regarding how it can be improved. Parking facility owners and operators will also be included in these groups to observe the drivers' reactions to the system and what it can do to make their driving task easier. For the San Antonio case study, private facility owners and operators will be invited to attend the focus groups whether or not they have chosen to contribute to the funding for the system. Hearing the general public discuss parking issues and what determines where they park may influence participation of private facilities. The next step in the Implementation Planning process involves refining the above specifications based on focus group discussions. Because this is a hypothetical implementation, there has been no focus group discussion to necessitate any revisions of the API system. The remaining elements of the Implementation Planning process include defining hardware components and maintenance requirements, two subjects that were not covered in the scope of this research; therefore, they were not discussed in the San Antonio Case Study.

Detailed Construction Documents

This stage of implementation requires that detailed work be done preparing the plans for the implementation of the API system. Included in this plan would be a time line for implementation as well as cost estimates for all equipment and labor required for the API system. According to the proposal for the St. Paul Operational Test (10), implementation of an API system including three ramp lots and six surface lots is nearing $750,000. This indicates that implementing an API system in San Antonio including the majority of the parking facilities in the downtown area will likely cost well over $ 1 million. Therefore, a strong emphasis must be placed on identifying the benefits that can be gleaned from such a system and how the efficiency of the transportation network can be increased as well as the occupancy rates of the participating parking facilities.

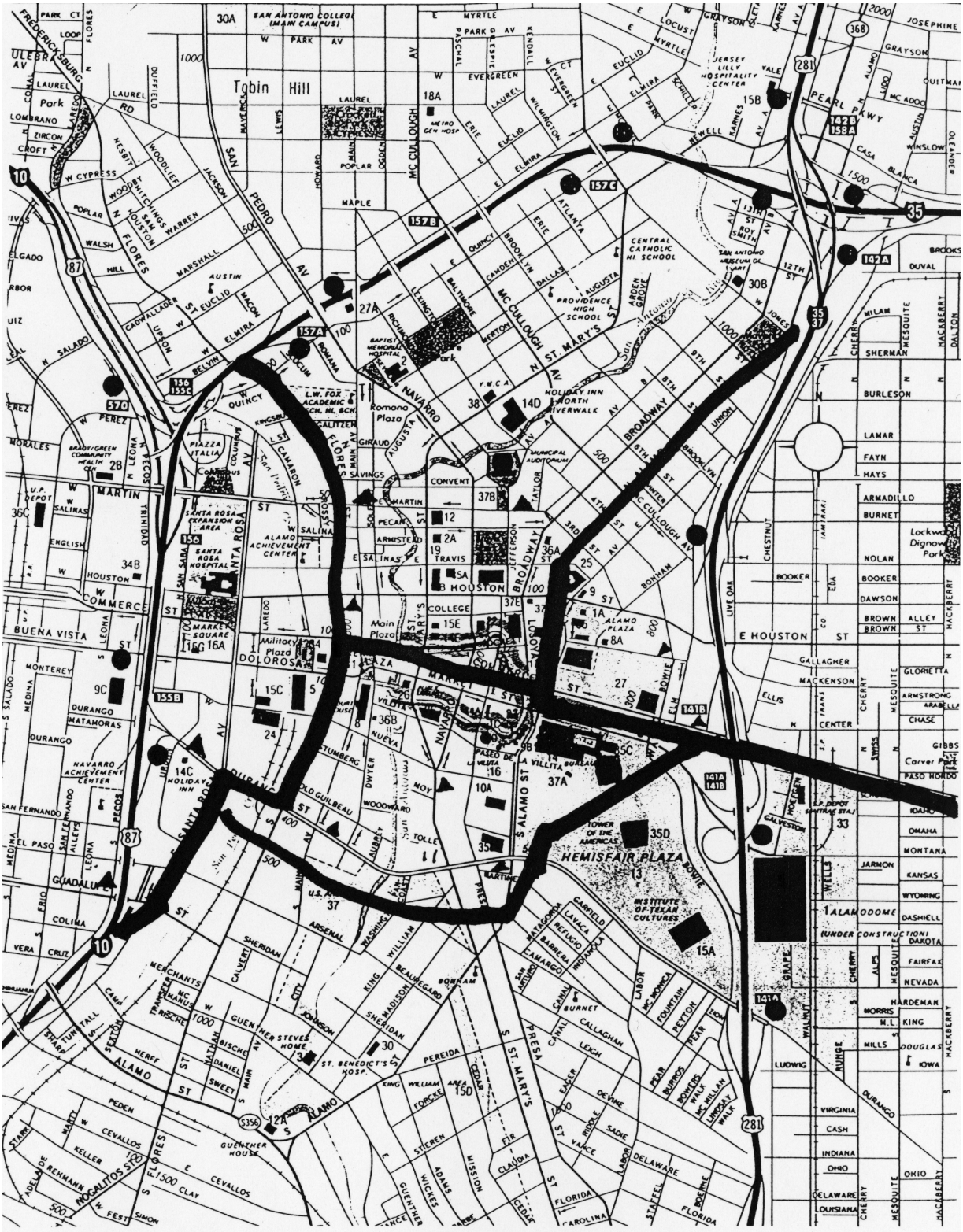

Figure 13. Location of Dynamic Information Signs.

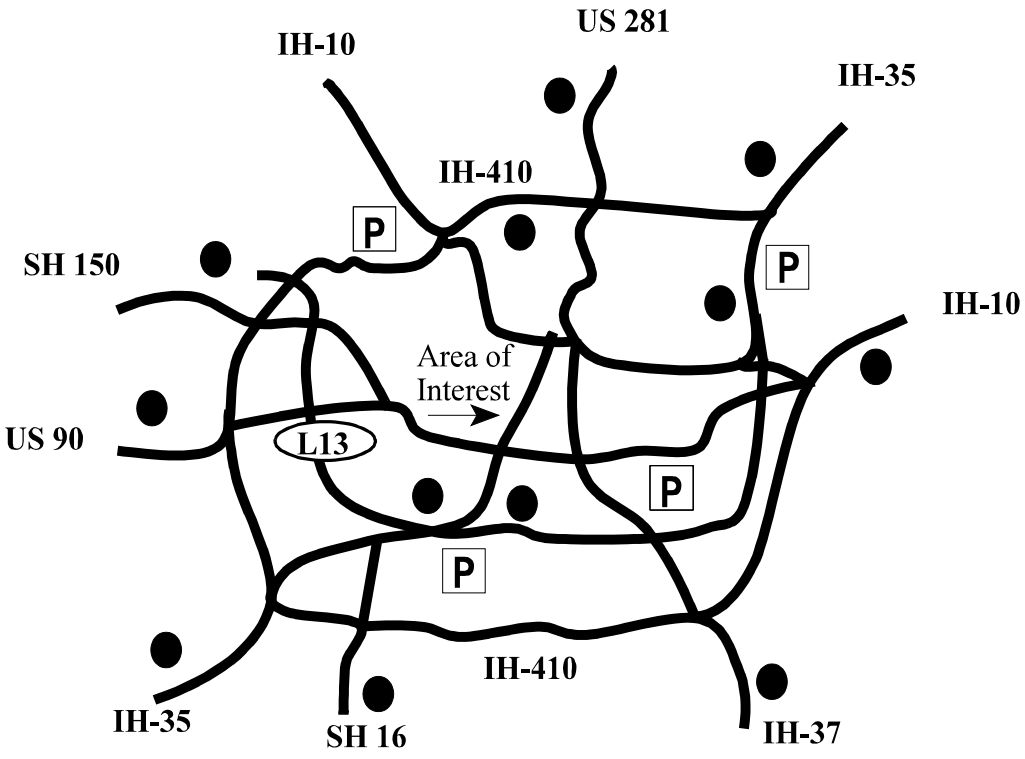

Figure 14. Placement of Zonal Information Signs.

Marketing Strategy

Because San Antonio is an attractor of many visitors, efforts must be made to have information concerning the API system included in tourist packets. The Visitors' Center is also a way in which visitors to the city can be educated about the API system along with the many tourist attractions in the downtown area. When events are held at the Alamodome such as a San Antonio Spurs game, a brochure indicating the location of various parking facilities and a description of the API system can be distributed with the tickets to the special events. If tourists request information on the Alamo, a map of the API system should be included in the literature as well as an indication of the zone, in this case the Alamo Parking Zone, in which the driver would most likely want to park.

The marketing of the API system should coincide with its physical implementation to promote immediate use of the system once it is fully operational. For the hypothetical implementation in San Antonio, it has been proposed that a phone number be listed on the public education information for drivers to call with any questions or concerns about the API system to make them feel more comfortable with the system.

Summary

For the San Antonio Case Study, physical implementation is the remaining step that must be complete. While this case study did not cover every aspect of implementation of an API system, it did illustrate the application of the author's guidelines as it was intended to do. Many of the decisions required for the implementation of an API system will be determined on a case by case basis, but this hypothetical application of the implementation guidelines was performed to demonstrate one possible method that could be performed to plan an API system implementation.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

An API systems must be supported by a specific environment if it is to benefit the motoring public. An API system can make travel into a downtown area easier and more comfortable to visitors, but there are many more considerations. A transportation system that suffers breakdown daily due to queue spillover from parking facilities could probably benefit greatly from the integration of an API system with its ATMS. However, a city that is not centrally concentrated may not be a prime candidate for API system implementation.

Much work in partnering and marketing must be performed in order to insure an effective, useful system prior to its implementation. Barriers that have been noted as reasons for the lack of API systems in the United States were: lack of knowledge of such systems, urban sprawl, lack of cooperation between public and private institutions, and the difficulty in gaging the results of the system. These obstacles must be overcome if a successful system is to be implemented.

Recommendations

With the eve- increasing number of registered vehicles and limitations of construction because of environmental issues, innovative methods to achieve a more efficient network must be explored. An API system has its objectives to distribute the demand of parking to match availability, reduce the queue length at the entrance of parking facilities, reduce the unnecessary travel and search time associated with locating an available parking space, and reducing illegal parking. Attainment of these goals would greatly improve any transportation network.

More research should be conducted on the applications of API systems to better pinpoint the type of cities that would benefit from their implementation. Additional, research would also include work load on operators in traffic control centers and how to best fund this type of system with public and private partnerships; what is a fair share? Further research would also investigate the effects API systems have on a driver's desire to drive alone.

Increasing public awareness and concern for environmental issues and social needs requires transportation engineers to broaden the scope of transportation strategies and solutions to include integration, flexibility, and choice. Such an enlightened approach is essential if downtown areas are to remain centers of development, economic growth, and cultural interests.

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REFERENCES

1. M.A. St. Mary. A Synopsis of the New Orleans On-Street Parking Management Program Evaluation Report. *ITE Journal*, Volume 56, May 1986, pp 29-32.

2. C. Caubet, J. Pejoan, A. Adham, and A. Nicolas. Basis of VMS Road Information Language. *Towards an Intelligent Transport System*. Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, Paris, France, 1994.

3. J.W. Polak and K.W. Axhausen. Measuring the Effectiveness of Parking Guidance Systems: A Case Study of Frankfurt/Main. *Proceedings of the International Conference on Advanced Technologies in Transportation and Traffic Management.* Singapore, May 1994.

4. M. Imaizumi, H. Yagi, M. Murai, and T. Hino. Parking-Meter Supervision System. *Towards an Intelligent Transport System*. Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, Paris, France, 1994.

5. R.S. Mansfield, S. Rupprecht, and C. Veinoglou. The SCOPE Project: Information Dissemination. *Towards an Intelligent Transport System*. Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, Paris, France, 1994.

6. M. McDonald, and P. Phillips. Urban Traffic Control (UTC) in SCOPE Cities. *Towards an Intelligent Transport System*. Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, Paris, France, 1994.

7. R.S. Mansfield and Bannister. The Use of ATT Applications for Public Transport in SCOPE Cities. *Towards an Intelligent Transport System*. Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, Paris, France, 1994.

8. I. Kawano. Parking Navigation System for Yokohama Station Area. *Towards an Intelligent Transport System*. Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, Paris, France, 1994.

9. *A New Intelligent Transportation Device: A Sign*. Linked-Orienting-Context Wayfinder Sign System. Informing Design, Inc. and the AGS Group.

10. *Minnesota Guidestar Program Operational Test.* Proposal for Civic Center/Ordway/Rice Park Area Advanced Parking Information System. St. Paul, Minnesota, April 1994.

11. Telephone interview with Mr.Pat Irwin of the Texas Department of Transportation concerning API systems.

12. Interview with Dr. Werner Brilon of Ruhr University translating Parkverhalten und Wirksamkeit des Parkleitsystems in frankfurt am Main. *Straßenverkehrs-technik*. January 1994.

13. P. Langdon. *A Better Place to Live: Reshaping the American Suburbs.* University of Massachusetts Press, Amherst, Massachusetts, 1994.

14. *Transguide Technology in Motion* a pamphlet. Transguide Operations Center, San Antonio, Texas.

15. *Transguide Technology in Motion* a booklet. Transguide Operations Center, San Antonio, Texas.

16. Telephone interview with Mr. Kenneth Johnson with the City of San Antonio Parking Division concerning parking facilities in San Antonio, Texas.

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