Metropolitan Model Deployment Initiative

San Antonio Evaluation Report

FINAL DRAFT

U.S. Department of Transportation

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Intelligent Transportation Systems

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16. Abstract

This report presents the evaluation results of the San Antonio, Texas Metropolitan Model Deployment Initiative (MMDI). The MMDI was sponsored by the US Department of Transportation and focused on aggressive deployment of Intelligent Transportation Systems (ITS) at four sites, including San Antonio, Seattle, the New York/New Jersey/Connecticut metro area, and Phoenix. The general focus of the deployments was on the integration of existing ITS and the deployment of innovative traveler information projects.

The San Antonio MMDI sought to make improvements in six key transportation goals. The first of these goals was the expansion and strengthening of the institutional framework necessary for successful ITS deployment and integration. The second goal was to improve traffic management through the expansion of the existing TransGuide freeway management system and the integration of a portion of that expanded system with a newly deployed arterial management system. The third goal of the San Antonio MMDI was to offer improved traveler information through enhancements to the existing TransGuide Web site and the deployment of 500 public agency in-vehicle navigation units and 40 information kiosks. The fourth goal involved the deployment of train-sensing capabilities to provide integrated highway rail / traveler information system. The fifth goal focused on an emergency tele-medicine system linking ambulances in the field with receiving hospitals to provide superior emergency services. The final goal was to offer an integrated, area-wide database of real-time traffic conditions. This database is intended to fuse information from multiple sources in order to provide travel speeds for freeways and major arterials. The AVI tag component, which uses probe technology, was technically sound, but failed to attain significant market penetration to provide arterial travel times.

This report focuses on the impact of these improvements in terms of system efficiency, safety, fuel consumption, customer satisfaction, cost effectiveness, and institutional impacts. Based on these metrics, the report concludes that the integration of ITS can offer substantial benefits, however, these benefits are not guaranteed.

In order to maximize the opportunities for success, the report recommends undertaking a strategic approach and preparing to make a long-term commitment to ensure successful ITS deployment and integration.

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PREFACE

This report describes the benefits to metropolitan transportation systems that may be achieved by integrating Intelligent Transportation Systems (ITS). Specifically, it describes the impacts experienced by the San Antonio Metropolitan Model Deployment Initiative (MMDI). The results of the evaluation are intended to assist planners, operators, and other transportation-related professionals in metropolitan areas across the nation who are seeking unique solutions to mounting transportation needs.

Readers are cautioned, however, that there may not be a direct correlation in results between the San Antonio experience and their own site. For example, prior to the MMDI, San Antonio was already an ITS-rich location. Consequently, the benefits achieved there were relatively conservative compared with what may be obtained at other, less developed sites. Nonetheless, many of the relative benefits and general lessons learned will be transferable and of great use to other sites considering similar deployments.

In autumn 1996, former Secretary of Transportation Federico Pena announced that the Phoenix, San Antonio, Seattle, and New York / New Jersey / Connecticut areas had been chosen to lead a new program to showcase ITS deployments. The MMDI program marked a significant step in ITS development across the United States. The initiative called for public and private sector partners to develop and integrate ITS technology to reduce travel times, improve safety, and provide enhanced travel information to the public.

Since the inception of the Federal ITS program in 1991, and earlier in some cases, regions across the country have been turning to new technologies in the sensors, communications, and computing power arenas to address mounting concerns over the marked increase in traffic and transit congestion. However, as is the case with any emerging technology, many pieces of these systems have evolved independently. MMDI was designed to integrate these various pieces to help realize the full potential of ITS.

Through this integration, the MMDI has not only demonstrated the value of ITS technology in improving transportation in the selected sites, but it has also provided numerous real-world examples of ITS technology's potential for other metropolitan areas across the country.

In order to ensure that these valuable lessons were documented and available to be shared, a detailed evaluation was performed for each of the four MMDI sites. In addition, a national evaluation was performed focusing on synthesizing findings across the program. This report summarizes the evaluation activities, findings, and conclusions that were undertaken to document the lessons learned from the deployment in San Antonio, Texas.

Similar to other MMDI sites, the San Antonio Model Deployment was characterized by a broad range of projects, from traveler information Web pages to remote communications systems for ambulances, with potential impacts ranging from improved safety to enhanced customer satisfaction. Consequently, the evaluators sought to develop a structured, organized approach to the analysis.

The result of this effort is summarized in the "Metropolitan Model Deployment Initiative National Evaluation Strategy." In general, this evaluation strategy follows two steps:

- The various projects in the deployment were considered in terms of the most relevant ITS components. These components are freeway management, incident management, traffic signal control, electronic toll collection, electronic fare payment, highway-rail intersections, emergency management, transit management, traveler information, and, most important for this deployment, integration between components.

- Impacts were examined using a series of “few good measures.” The measures considered were safety, system efficiency, fuel consumption, cost, customer satisfaction, and institutional impacts. Owing to limitations in currently available evaluation techniques, neither emissions nor benefit/cost measures were employed.

Beyond the general approach, there was the question of which components and projects to examine in detail and which measures to apply. For a number of reasons, including resources and project delays, not all projects would be given equal consideration. Furthermore, not all “few good measures” need be applied to every project. Therefore, a system was developed to identify and assign evaluation priorities.

In establishing these priorities a number of factors were considered:

- What is already known?
- What is not known?
- For what areas is something known, but we would like to know more?

These questions were posed from both a national and regional perspective. San Antonio project participants were asked to assist with the regional perspective through a process of evaluation priority rankings.

The result for San Antonio is an evaluation that examines 10 projects, covers 5 major ITS infrastructure components, considers some combination of 5 of the 6 “few good measures,” (emissions impacts could not be reliably determined) and reflects the interests of both the national evaluation team and the site partners. Similar evaluations were also conducted for the Phoenix and Seattle MMDI locations.

Readers interested in the experiences of the Phoenix and Seattle Model Deployments are encouraged to review the respective site reports. Those with a specific interest in the institutional issues examined in the Metropolitan Model Deployments should consider a document titled “Successful Approaches to Deploying an Intelligent Transportation System: Final Report,” by Alan DeBlasio.

Readers interested in an overall summary of all of these reports should reference the “Metropolitan Model Deployment Initiative National Synthesis.” These and other benefits documents, including information on the benefits of rural and in-vehicle applications of ITS, may be found on the Joint Program Office Web site at **www.its.dot.gov**.

Dr. Joseph Peters

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U.S. Department of Transportation

ITS Joint Program Office

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	(or "metric ton")	(or "t")		
		TEMPERATURE (exact)		
EF	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	EC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
EC	Celsius temperature	1.8C + 32	Fahrenheit temperature	EF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
fl	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with section 4 of ASTM E380. (Revised September 1993)

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LIST OF ABBREVIATIONS

ATIS	automated traveler information system
AVI	automatic vehicle identification
AWARD	Advanced Warning to Avoid Railroad Delays
EMS	Emergency Medical Service
EMT	Emergency Medical Technician
FMS	freeway management system
GPS	Global Positioning System
IM	incident management
IPR	intellectual property rights
ITS	Intelligent Transportation Systems
IVN	In-Vehicle Navigation
LMP	level of market penetration
MCC	Medical Center Corridor
MMDI	Metropolitan Model Deployment Initiative
O-D	origin-destination
TxDOT	Texas Department of Transportation
U.S. DOT	U.S. Department of Transportation
VMS	variable message signs

1. EXECUTIVE SUMMARY

This document presents results from the evaluation of the San Antonio, Texas Metropolitan Model Deployment Initiative (MMDI). The San Antonio MMDI was one of four deployments across the nation selected by the U.S. Department of Transportation (U.S. DOT) to promote the integration of Intelligent Transportation Systems (ITS). This report investigates the benefits and costs of the San Antonio deployment and provides an initial roadmap for ITS integration throughout the nation.

1.1 INTRODUCTION TO THE SAN ANTONIO MODEL DEPLOYMENT INITIATIVE

As in many regions of the nation, the traffic situation in San Antonio may be best characterized by a growing population coupled with a transportation infrastructure that is struggling to keep pace. In the last decade alone, traffic demands in the region have increased over 30 percent, while traveler delay has increased nearly 53 percent from a 1987 average of 17 hours per driver to a 1996 average of 26 hours per driver.(1) Accounting for excess fuel consumption and lost time, not to mention driver frustration and environmental impacts, this increased level of delay inflicts nearly $400 Million per year in losses on the San Antonio economy. Needless to say, community leaders and transportation officials have been searching in earnest for solutions to this problem.

One such solution that has received considerable attention in both San Antonio, and throughout the nation, has been the supplementation of traditional transportation operations and management with a growing range of advanced technologies in areas such as sensors, communications and computing power. To date, these advanced systems, known collectively as ITS, have already demonstrated considerable success in better managing transportation demands, reducing delays, improving safety, and enhancing customer satisfaction. However, as with any emerging technology, many pieces of these systems have evolved independently over time. Consequently, many practitioners feel that ITS have not yet reached their full potential.

The San Antonio MMDI seeks to unlock this lost potential through the integration of a series of new and existing ITS throughout the region. At the core of the initiative is the highly successful freeway operations system known as TransGuide. (2) This pre-existing system provides both the basic infrastructure and knowledge necessary for the model deployment initiative to pursue improvements in the management of arterial, freeway, and emergency services and in the provision of enhanced traveler information.

The improved traffic management is effected by integrating an expanded section of the TransGuide freeway system with a newly created arterial management system known as the Medical Center Corridor. Emergency management is improved through the integration of the TransGuide communication infrastructure with ambulances and area hospitals in the LifeLink project. Traveler information is improved through the synthesis of data from the TransGuide and Medical Center Corridor projects with train-crossing information from the Advanced Warning to Avoid Railroad Delays (AWARD) project and with probe data from the Vehicle Tags project. The assembled data are synthesized in the Travel data server and made available to roadway and transit users through a number of platforms, including In-Vehicle Navigation (IVN) units, kiosks, and the TransGuide Web site. A brief description of each of the resulting projects and their associated deployment and annual costs are included in **Table 1**.

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(1) "1998 Annual Urban Mobility Study: Web Site," Texas Transportation Institute.
(2) SWRI, "TransGuide Model Deployment Initiative: Design Report," San Antonio, Texas 1998.

Table 1. Overview of San Antonio MMDI Projects

	Cost		
Project	Deployment	Annual	Description
FMS Expansion	$26,576,000	$852,000	• Freeway and incident management system • 46.5 km expansion of existing TransGuide system • Lane control and variable message signs • Loop and camera surveillance on freeway and service roads
Medical Center Corridor	$525,000	$47,000	• 8.75 km arterial diversion corridor • Integrated with parallel TransGuide freeway system • Six dynamic message signs on arterial route • Special incident response signal plans to for diverted vehicles
In-Vehicle Navigation	$2,389,000	$102,000	• 529 units distributed to public agency-owned vehicles • Two different types of units installed – Zexel and Alpine • Provides route guidance and real-time information on traffic congestion, incidents, and highway-rail intersections
Kiosks	$1,526,000	$176,000	• Interactive kiosks at 36 indoor and 4 outdoor locations • Provides user with current roadway conditions, static transit information, and current weather information and forecasts
Web Page	$3,000	$29,000	• At time of evaluation, provided freeway travel speeds • Have since added travel times and are adding video images to the site
LifeLink	$3,251,000	$25,000	• Allows video and voice teleconferencing between University Hospital and an ambulance in the field • Deployed in 10 ambulances • Consists of five major components: video camera, two video monitors, intercom, wireless headset, and ambulance computer
AWARD	$351,000	$34,000	• Designed to help motorists and emergency response vehicles avoid delays due to trains crossing freeway frontage access roads • Delay information posted on VMS and IVN units
Travel Data Server	$372,000	$14,000	• Fuses data from a broad range of sources into a single real-time database for dissemination to a variety of users • Provides static information on transit and airline operations, dynamic information about incidents and road closings, and real-time estimates of link specific travel speeds or times
Vehicle Probes	$4,049,000	$74,000	• Passive automatic vehicle identification tag read when vehicle passes under an electronic interrogator mounted overhead • 53 reading locations • 40,000 tags distributed voluntarily

1.2 SUMMARY OF THE SAN ANTONIO MMDI EVALUATION

To ensure that the lessons of the San Antonio MMDI were documented, a detailed evaluation was performed. This evaluation considered the metrics of cost, system efficiency (delay, throughput, etc.), customer satisfaction, safety, and fuel consumption. A high level summary of the results of these various analyses is presented in **Table 2**.

Table 2. Summary of San Antonio Evaluation Results

Project	Network Efficiency	Customer Satisfaction	Safety	Energy Consumption
FMS Expansion	Average annual incident delay reduced 5.7% for all travelers	Travelers satisfied with VMS, but have suggestions for improvements	Average annual secondary crash risk reduced 2.8% for all travelers	Average annual fuel consumption reduced 1.2%
Medical Center Corridor	Average annual incident delay reduced 5.9% for all travelers	Being studied	Average annual secondary crash risk reduced 2% for all travelers	Average annual fuel consumption reduced 1.4%
In-Vehicle Navigation	Potential average annual incident delay reduction of 8.1% for users; no network impact	Para-transit satisfied; other agencies desire improvements; all need training	Potential for non-traditional safety impacts such as quicker fire response	Average annual fuel consumption reduced 3%
Kiosks	No impact	Limited usage; needs to be bundled with other information	No impact	No impact
Web Page	Average annual incident delay reduction of 5.4% for users; no network impact	Growing at 19% per year; large latent demand as high as 19 times larger than normal usage	Average annual secondary crash risk reduced 0.5% for users; no network impact	Average annual fuel consumption reduced 1.8%
LifeLink	No impact	EMTs like system; area hospitals not ready	No impact, but great benefits predicted for rural application	No impact
AWARD	None currently, but potential for 6.7% average network travel time reduction per train with increase in demand	Users are not aware of system due to low utilization of VMS and ATIS platforms	None currently, but potential for 8.7% network crash reduction per train with increase in demand	None currently, but prediction of small future fuel reduction
Travel Data Server	None currently	Travelers requesting more arterial data	None currently	None currently
Vehicle Probes	No direct impact – capable of estimating travel time within 2%	40,000 volunteered to use tags	No direct safety implications	No direct impacts

1.3 FINDINGS FROM THE SAN ANTONIO METROPOLITAN MODEL DEPLOYMENT

Based upon the analyses summarized in **Table 2**, the findings from the remaining Metropolitan Model Deployment sites, and the experiences of previous ITS deployments, a number of findings were made.

A strong institutional framework is essential for a successful ITS deployment.

A consistent finding throughout the evaluation of the San Antonio MMDI and, in fact, throughout the evaluations of all four MMDI sites, is the need for ITS deployments to be supported by a strong institutional framework of cooperation and regional support. While such a supportive framework is important for practically all applications of ITS, it is especially critical for those applications involving integration. Such integrated applications often involve multiple agencies, varied procedures, inconsistent technologies and competing, if not conflicting, visions.

Often the failure of just one institutional element in an integrated ITS deployment can severely impact the entire deployment. For example, liability concerns raised by the railways in the planning phases of the AWARD project caused the project to be significantly altered. Originally conceived as a safety system that would allow train engineers to view video images of track blockages, the system was modified to a system that provides information on train crossing delays to motorists.

On the other hand, successful institutional interactions may greatly enhance ITS deployments. One such example of this involves the relationship developed between the Texas Department of Transportation (TxDOT) and the San Antonio Police Department. By bringing the police into TransGuide, TxDOT found a partner that not only offered assistance in the core mission of reducing incident response and clearance times, but also an ally and powerful advocate in the competition for resources for additional ITS deployments. Since joining the partnership, the police management has become a prime mover in pushing for the instrumentation of an even greater number of roadways in the region.

Some specific steps that can be taken to ensure the development of a successful institutional framework include reaching out to non-traditional participants, such as the trauma centers of the area hospitals that worked with the LifeLink project. A second step is effective public outreach. For example, TxDOT’s use of a Public Information Officer and a successful media and public outreach campaign effectively relayed goals and services to the public. A third positive action is the use of innovative procurement techniques, such as TxDOT’s use of the Texas State Catalog to shorten the list of pre-qualified contractors. Use of the catalog reduced the time frame necessary to get the private sector involved. Other successful approaches are documented in the body of this report.

While the whole is not always mathematically greater than the sum of its parts, the integration of ITS can offer significantly improved benefits and reduced costs over isolated deployments.

While the integration of ITS within the San Antonio MMDI did offer significant benefits, the hypothesis that the whole is greater than the sum of its parts did not always hold mathematically true. A possible explanation is that the various MMDI sites were already ITS-rich before the initiative and, therefore, had above average base conditions to build on. Nonetheless, while the whole was not always greater than the sum of its parts, it was consistently greater than the impacts of any of the various ITS elements acting on their own.

For example, as **Table 3** illustrates, an integrated application of the Medical Center Corridor project’s freeway, incident and arterial management systems to a major incident results in a delay reduction of 470 vehicle-hours. While significant, at nearly 20 percent of the total delay, this reduction is not mathematically greater than the sum of the theoretical impacts of each element acting independently (557 vehicle-hours). Nonetheless, the 470 vehicle-hour reduction effected by the integrated system is significantly greater than could be achieved by any one of the independent components acting on their own. Incident management, the most effective isolated component, results in a reduction of only 382 vehicle-hours, 24 percent less than the integrated system. Therefore, while the integration hypothesis is not directly met, the impact benefits of ITS integration are evident.

Table 3. Reduction in Delay Associated with a Major Incident in the Medical Center Corridor

Treatment	Delay Reduction (%)	Delay Reduction (vehicle-hours)
Incident Management	16.2	382
Freeway Management	4.6	109
Arterial Management	2.8	66
Integrated System (all 3)	19.9	470

Furthermore, the integration of ITS services may offer benefits beyond those that may be measured in benefits evaluation. One such less tangible outcome of integration in San Antonio was the strengthening of the region's underlying institutional framework. Traditionally, many transportation officials have often operated in what is essentially a vacuum. Other groups such as the police or media may have operated on the periphery, but they have rarely been partners in solving transportation problems. The introduction and, particularly, the integration of ITS both facilitates and requires changes in this norm. For example, the sharing of video data from TransGuide and the TransGuide expansion has brought together a number of non-traditional partners, including transit, media, police, and emergency services. Together, these various agencies are expected to pass on far greater benefits to the traveling public than any one agency could on its own. For example, transit operators are now using video from the TransGuide freeway management system to more effectively manage special event demands. This may lead to increased transit ridership, which in turn may lead to reduced demand for the roadways being managed by the freeway operators.

Finally, in addition to these improved system and institutional impacts, the San Antonio MMDI has also indicated that substantial cost savings may be achieved through ITS integration. For example, the LifeLink project would have been considerably more expensive, if not infeasible, without the sharing of TransGuide's existing communication infrastructure.

Integrated freeway / arterial diversion corridors can significantly reduce delay, crash risk, and fuel consumption if operated in a careful, strategic fashion.

Considerable attention has recently been focused on the deployment of integrated arterial/freeway management systems. Such systems merge technologies and agencies across facilities, and often geographic boundaries, to create a seamless management corridor where incidents and traveler delays may be addressed in a coordinated, informed fashion.

While a number of these systems are currently under consideration or development, only a handful have actually been deployed. These include the INFORM project in New York, the ICTM project in Minneapolis, and the Medical Center Corridor (MCC) project deployed as part of the San Antonio MMDI.

As with many of the San Antonio MMDI projects, the core of the MCC lies in the region's existing freeway management system known as TransGuide. In particular, the MCC links an expanded 8.75 km segment of TransGuide's freeway and incident management capabilities with a newly deployed arterial management system centered on Fredericksburg Road, the area's major parallel surface street diversion route. Functionally, the system detects incidents and delays through a number of freeway-based video and loop detector stations. Information on these incidents is then relayed to incident management teams co-located in the TransGuide operation center and to travelers in the field through a combination of both freeway and arterial message signs and through freeway only lane control signals. Incident information is also relayed to the City of San Antonio's traffic management center (also co-located at TransGuide) where specially developed incident response signal timings may be invoked to help manage any additional demands placed on the arterial network as a result of the incident.

Modeling the expected impacts of this deployment over the course of a typical year and range of incidents indicates the potential for significant benefits. As **Table 4** illustrates, MCC operations should save the average traveler through the system over 1.8 hours of delay per year, or nearly 6 percent of the their total incident delay. Similar, though smaller benefits are also predicted for crash risk (reduced 2 percent) and fuel consumption (reduced 1.4 percent). Furthermore, these reductions may range as high as 19.9 percent for delay, 4.4 percent for crash risk, and 1.9 percent for fuel consumption when the most severe incident scenarios are considered.

Table 4. Summary of the Annual Impacts of the Medical Center Corridor

Annual Impact	Delay	Safety	Fuel Consumption
Network Change	↓ 84230 veh-hrs	↓0.6 crashes / year	↓ 4469 L / year
User Change	↓ 1.82 hrs / year	↓.05 crashes / Million km	↓ 0.1 L / year
Percentage Change	↓ 5.9%	↓ 2.0%	↓ 1.4%

However, these benefits are not guaranteed. Rather they flow from a carefully and strategically managed application of the various components of the integrated system. For example, there may be some pressure to inform travelers of even the most minor incidents (e.g., vehicle disablement) through the system's variable message signs (VMS). However, depending on user response this may actually lead to diminished benefits. Specifically, some drivers may overestimate the minor delay associated with the incident and erroneously divert to a slower or sub-optimal diversion route. When such a situation was examined in the simulation model (applying both incident management and message induced diversion to minor incidents) the positive impacts of the incident management component were found to be diminished from a 2.5 percent delay reduction to a 1.9 percent reduction when the message signs were enacted.

In a similar fashion, care must be taken not to overreact with the application of the system's incident-responsive signal timing plans. These fixed-time plans are designed to provide optimal signal control under conditions generated by relatively major freeway incidents. When the plans are invoked for either minor or moderate incidents they may lead to reduced benefits similar to those attributed to sub-optimal use of message signs. For example, applying the incident signal plans to a moderate freeway incident may reduce the positive impacts of the system's incident and freeway management systems from a 7.9 percent reduction in delay to a small *increase*. While San Antonio does not plan to operate the system under these conditions, it does illustrate the need for pro-active management of such complex systems.

While current levels of usage are low, there is a large potential market for Web-based ATIS services.

The current use of San Antonio's traveler Web site is relatively low. During the evaluation time frame, the site was used an average of 10,000 times per month. While this figure may sound large, it suggests a usage by less than 0.1 percent of all trips in the region. However, there are indications that substantial growth may be expected in the future. As in Seattle and Phoenix, use of San Antonio's Web site has been growing. During the evaluation time period, usage increased over 19 percent per year. Furthermore, spikes in usage, as high as 19 times normal usage that occur when the site is encouraged and promoted, such as during heavy flooding in October, 1998 (**Figure 1**) indicate that there is a large latent demand for the service. However, the fact that usage promptly returned to traditional levels following such spikes, suggests that while the market exists, continued growth will not solely arise from awareness, but likely from a combination of awareness and service improvements and, perhaps, increased congestion.

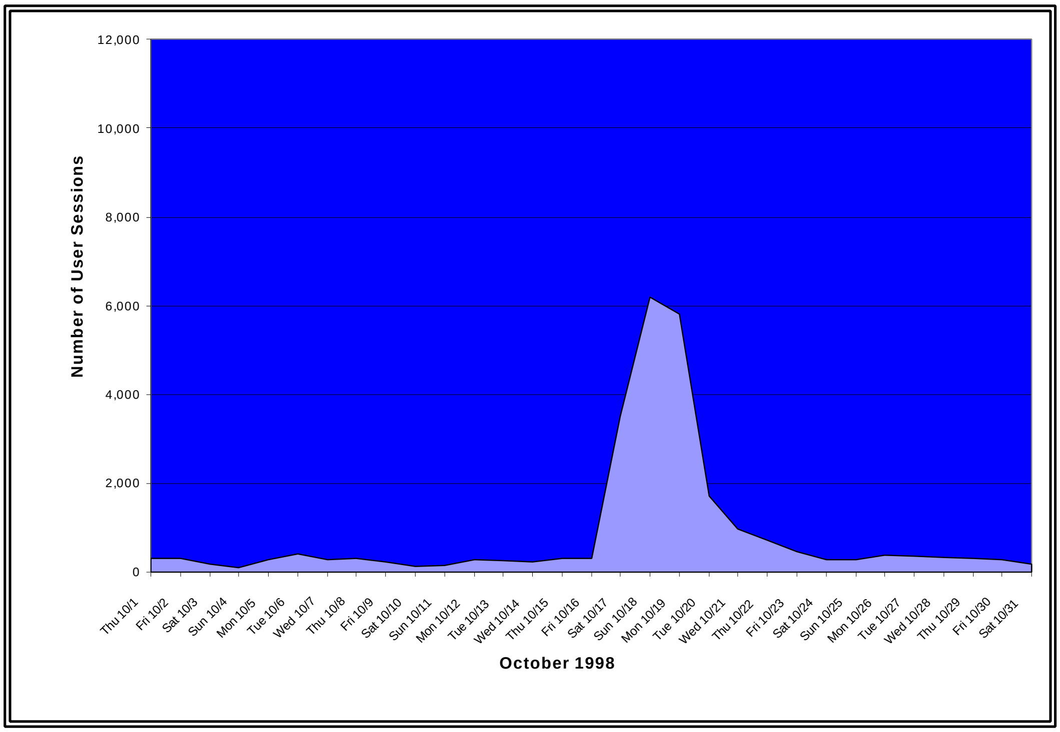

Figure 1. Number of Web User Sessions during Flooding, Oct 1998

Pre-trip ATIS services, such as San Antonio's TransGuide Web sites, can lead to reductions in delay, crash risk, and fuel consumption that are similar to those experienced through traffic management applications.

Even at current low levels of market penetration Web sites, such as San Antonio's, are predicted to offer significant user benefits. While studies across the various MMDI sites suggest that travelers derive significant satisfaction from the sites, the evaluations also suggest that use of the sites may lead to reductions in delay, fuel consumption, and, in some cases, crash risk. For example, as **Table 5** indicates, modeling suggests that travelers through the MCC who check traffic conditions via the Web site before their trips could save as many as 1.8 hours per year in incident-related delays. Similar positive benefits have been predicted for the use of the SmartTrek traffic Web site deployed as part of the Seattle MMDI.

Table 5. Annualized Impacts of the San Antonio Traveler Web Site

Annual Impact	Delay	Safety	Fuel Consumption
Average Network Change	No impact	No impact	No impact
Average User Change	↓ 1.81 hrs / year	Nearly Negligible	↓ 0.3 L / year
Percentage Change	↓ 5.4%	↓ 0.5%	↓ 1.8%

The market for kiosks appears to be much smaller than that for Web pages, while deployment difficulties appear to be greater.

San Antonio's traveler information kiosks program utilizes stand-alone interactive kiosks to provide customized traveler information on current roadway conditions, transit information, navigation instructions capable of accounting for current traffic conditions, and weather information and forecasts. As with the region's Web sites, usage of these kiosks was similarly low. However, unlike the Web sites, the level of usage was not predicted to grow substantially.

Users were initially limited by a number of usability and maintenance issues. During the initial evaluation period, less than half of the systems were found to be operational. In addition, problems existed with the touch-screen interface, including narrow scroll bars and excessively long system response delays.

While these problems have since been corrected, results from other sites, such as Phoenix, suggest that it is unlikely that usage will dramatically increase. In fact, concerns about limited usage have caused some sites to reconsider the deployment of traveler information kiosks at all. For example, the Seattle MMDI program cancelled their kiosk program altogether for fears that such systems were not a cost-effective method for disseminating traveler information.

Overall, while these findings do suggest a limited outlook for kiosk deployment, there may yet be some applications for which traveler information kiosks may be well suited. Suggestions include placement in locations with large numbers of tourists, usage in high pedestrian traffic areas such as transit facilities, or utilization in applications bundling information from multiple sources such as ticket sales.

Public agencies may find benefits in IVN devices. However, proper training, maintenance, and equipment selection is essential to ensuring success of the program.

The IVN units supplied to a cross-section of San Antonio's public sector provide route guidance and real-time traffic information within the San Antonio area and for nearby cities and smaller towns. The units are also capable of helping the motorist avoid traffic congestion.

The units were determined to offer a number of benefits to agencies considered in the study. While the real-time traffic information component experienced relatively little use, both emergency and non-emergency public sector users found the electronic mapping function of the system helpful. Specifically, over 60 percent of the drivers who used the units reported that the IVNs made it easier to locate unfamiliar addresses, saved time, and were perceived safer than paper maps. A number of benefits were also identified that are unique to emergency service use. Specifically, police officers reported using the IVN's mapping function to coordinate pursuits. In one case, an IVN was used to more efficiently direct an air-ambulance to a critically injured victim. Finally, para-transit users have found the units so helpful in navigating unfamiliar areas that many will now refuse to take out a bus not equipped with the system.

However, improvements such as better training, maintenance, installation, and consideration of the time-critical nature of emergency work could increase these benefits. While users of the IVN units were generally satisfied with the system, they had a number of suggestions for improvement. One of the key suggestions was for better maintenance. Over 48 percent of the survey respondents reported problems with their units, and some waited as long as four months for the units to be fixed. Such experiences likely contributed to a lower use of the system. Another suggested improvement was better installation of the unit. This is particularly important for public-agency vehicles because they are often already filled with equipment.

Training is also a key element of successful public-agency IVN deployment. In general, most respondents were dissatisfied with the level of training they received and thought that they could make better use of the IVNs if properly trained. A possible outcome of such training might be an increased awareness of the real-time routing function of the units. If this awareness were translated to increased use of the unit**,** modeling suggests that each user could save over 2.7 hours of delay per year in the MCC alone. This represents the largest potential delay improvement of any of the MMDI treatments considered.

Finally, if IVN units are to be used for emergency situations, there must be a faster method of entering destination addresses. The delays of up to two minutes are unacceptable for emergency response. A possible solution is to create automated links to a computer-aided dispatching system similar to other cities, such as Houston.

Emergency telemedicine has the ability to save lives and reduce treatment and transportation costs. However, a number of institutional and technical issues must be addressed to maximize these benefits.

One of the most innovative aspects of the San Antonio MMDI was the deployment of an emergency tele-medicine project linking emergency medical technicians in the field with doctors in the emergency room. This deployment, known as LifeLink, makes use of the existing TransGuide fiber-optic communications system. In fact, without the cost savings associated with this sharing, the project might not have been feasible. This is an example of how cost savings can be achieved through integration.

An evaluation of LifeLink reveals that the project is currently successful as a proof-of-concept and is predicted to eventually offer benefits. The successful deployment of the LifeLink project is a significant accomplishment, considering the complexity and innovation of the system. This deployment proves that tele-medicine systems are feasible and can be deployed in a fairly cost-effective manner. Furthermore, while no direct benefits have been seen to date, interviews with numerous experts in the field suggest that they are imminent. These benefits are likely to include savings in lives and reductions in recovery time. They may also include substantial treatment and transportation cost savings. Some individuals involved with the deployment feel that these cost savings alone may justify deployment of the system.

However, for these benefits to be fully realized, some institutional issues need to be overcome. Success of the LifeLink project requires the support of both the emergency medical technicians and the hospital community. To date, the hospital community has been unable or unwilling to offer full support. This may be explained by staffing and resource shortages common to many hospitals. However, the lack of support limits the potential benefits of the system.

Furthermore, the system will benefit from improvements such as satellite communications, the addition of an external camera, and the transmission of telemetry. LifeLink is currently deployed in an urban setting, within relatively close proximity to high-class medical facilities, and under the operation of highly skilled emergency medical technicians. Consequently, the potential impacts of the system are limited. This is expected to change once satellite-based communications capabilities are added that will allow LifeLink to be deployed in rural areas. Another improvement will be the addition of an external camera that can be used to transmit images of the patient at the scene. A similar system to this is in development under the Seattle MMDI. Finally, transmission of patient vital signs will greatly enhance the system's effectiveness.

Overall, the LifeLink project is a fairly simple concept that could offer benefits well beyond its deployment and maintenance costs. Once fully developed, the system will likely be transferable to virtually any location throughout the nation.

Institutional issues may impede the development of systems designed to prevent or reduce train to vehicle crashes. However, less intrusive information systems can be developed that have the potential to reduce vehicle-to-vehicle crashes as well as traveler delays.

San Antonio's AWARD project was originally conceived as a safety application that would warn train operators when vehicles were blocking the tracks ahead. However, liability concerns were raised by the railroad industry causing the project to be shifted to a traveler information project. In this final incarnation vehicles in the area are informed about train crossing delays through a combination of VMS and IVN units.

The ultimate deployment of the AWARD project has demonstrated that it is technically and institutionally feasible to field an integrated highway-rail traveler information system. Not only does the system function as designed, but it was also built in a manner that was non-intrusive to the railroads. The latter achievement assisted in the rapid, on-time deployment of the system.

However, while benefits are ultimately expected, the AWARD system is unlikely to have a substantial impact on San Antonio in the near future. The analysis indicates that, at the time of the evaluation, the combination of train delays and traffic demands is too low to warrant re-routing traffic around crossings. Consequently, the system has been rarely, if ever, used.

Nonetheless, with future growth, the system may offer significant benefits. Assuming a 25 percent increase in demand and the adoption of a more aggressive operating strategy, reductions in system travel time as large as 9.2 percent have been predicted for a typical train crossing event when delay information is displayed on surrounding VMS. As with a number of the ITS treatments studied, these mobility benefits are also predicted to be accompanied by similar reductions in crashes and fuel consumption.

Travelers desire a greater level of arterial roadway information. Vehicle probes offer a promising way to deliver this information if a sufficient level of market penetration can be achieved.

Results from the various MMDI sites suggest that travelers desire greater geographic coverage. For example, 59 percent of the Seattle traveler Web site survey respondents suggested the site could be improved by filling in geographic 'gaps' in the coverage, such as arterials. In a separate question, 57 percent specifically suggested improving the site by adding greater arterial coverage. Similar requests were also expressed through focus groups in both Phoenix and San Antonio. Furthermore, modeling results in Seattle suggest that the provision of such arterial data can significantly improve the effectiveness of the traveler information services. In modeled cases in Seattle, provision of arterial and freeway data, as opposed to freeway only data, significantly increased the effectiveness of the region's traveler information services, with delay reductions more than doubling from 1.5 percent to 3.4 percent per year.

Unfortunately, however, such arterial data are often difficult to collect. First, unlike freeway facilities, there has been relatively little instrumentation of arterial networks. Second, the arterial instrumentation that does exist is typically limited to inductive loop detectors. While these detectors are effective in managing traffic signals, they often fall short in providing accurate arterial travel conditions.

One potential solution to this shortcoming is to use vehicles as travel time probes. For example, in San Antonio a system was developed that collects arterial travel time using a combination of voluntarily distributed tags and a series of 53 overhead tag readers deployed along the region's major arterial networks.

In controlled testing, the system was found to be capable of estimating speeds accurate to within 2 percent of actual operating speeds. Unfortunately, however, the market penetration of the tags was too low to consistently predict operating speeds. The typical market penetrations generated by the 40,000 distributed tags averaged only 1 percent, with numerous drops approaching zero.

Consequently, the system is largely being abandoned in San Antonio in favor of point source speed detectors such as radar. Nonetheless, it is reasonable to expect that such a system may perform adequately in areas with a larger penetration of tags. For example, the approach should be more successful in regions with significant electronic tolling facilities such as New York and Florida.

Travelers have a particular affinity for roadway information that is shared through camera images and travel times.

One final observation of the San Antonio MMDI is that while travelers may value many forms of roadway information, they have a particular affinity for two types. The first is the provision of video images from roadside cameras. Such images, whether real-time or static, allow the users to virtually reach out and touch the traffic situation. In fact, travelers are so fond of such video data that camera images are among the most widely accessed pages of both the Seattle and Phoenix traveler Web sites. Furthermore, numerous requests have recently led to a decision by TxDOT to similarly add camera images to San Antonio's traveler Web site.

The second type of data that the public appears to place increased value in are point-to-point travel-time estimates. When asked to suggest possible improvements to Seattle's traveler Web site, over 44 percent suggested adding travel-time estimates. It appears that travel-time information offers improvements over traditional information on average speeds and incident locations, in that it more directly assists the traveler in answering the key question: how long will it take me?

Recognizing the importance of this type of data format, San Antonio undertook the development of an extensive, regional travel data server. This server synthesizes information from the TransGuide freeway management system, the AWARD system rail-crossing information system, and the automatic vehicle identification (AVI) vehicle tag component into a comprehensive set of travel times for the regions major roadways. These data are then disseminated through TransGuide's extensive network of VMS and through San Antonio's traveler information Web site. While much of this deployment took place following the MMDI evaluation period, early indications from the media and Web site user feedback are that the public has been very satisfied with its delivery.

1.4 SUMMARY OF FINDINGS AND RECOMMENDATIONS

Based upon the various results and findings arising from the evaluation of the San Antonio MMDI, a number of recommendations were offered. A brief overview of these recommendations is presented in **Table 6**.

Table 6. Summary of San Antonio MMDI Recommendations

Finding	Recommendations
A strong institutional framework is essential for a successful ITS deployment.	• Get institutional framework in place early • Reach out to and involve non-traditional partners • Encourage stakeholders to think regionally • Keep the public informed and listen to them
While the whole is not always mathematically greater than the sum of its parts, the integration of ITS can offer significantly improved benefits and reduced costs over isolated deployments.	• Consider integration of both new and legacy ITS • Think of ways to share costs through integration • Again, this will require the communication and trust fostered through a strong institutional framework
Integrated freeway / arterial diversion corridors can significantly reduce delay, crash risk, and fuel consumption if operated in a careful, strategic fashion.	• Investigate use of such systems at other sites • Be prepared to pro-actively manage the system • Continue to monitor traffic conditions • May consider adaptive control strategies for parallel arterial management system
While current levels of usage are low, there is a large potential market for Web-based ATIS services.	• Make the investment in traveler Web sites • Develop data sources to populate the sites • Make video data available • Provide point-to-point travel times
Pre-trip ATIS services sites can lead to reductions in delay, crash risk, and fuel consumption that are similar to those experienced through traffic management applications.	• Encourage the deployment of such systems • Provide timely accurate data to take full advantage of these benefits
The market for kiosks appears to be much smaller than that for Web pages, while deployment difficulties appear to be greater.	• Restrict kiosk deployment to high traffic areas such as transit facilities • Rather than dedicated kiosks, consider bundling traffic information with other types of kiosks (e.g., tourism)
Public agencies may find benefits in IVN devices. However, proper training, maintenance, and equipment selection is essential to ensuring success of the program.	• Offer long-term support and training to ITS programs • Be sensitive to needs of users, solicit, and act upon their feedback • If equipping emergency vehicles with IVNs, consider automated address entry, possibly through computer-aided dispatch system
Emergency telemedicine has the ability to save lives and reduce treatment and transportation costs. However, a number of institutional and technical issues must be addressed to maximize these benefits.	• Reach out to non-traditional partners • Be sensitive to their special needs • Involve partners as early as possible in the deployment and planning process • Consider wireless applications of telemedicine • Consider deployments to rural areas
Institutional issues may impede the development of systems designed to prevent or reduce train to vehicle crashes. However, less intrusive information systems can be developed that have the potential to reduce vehicle-to-vehicle crashes as well as traveler delays.	• Reach out to non-traditional partners • Be sensitive to their special needs • Consider liability issues • Involve partners as early as possible in the deployment and planning process

Table 6. Summary of San Antonio MMDI Recommendations (continued)

Finding	Recommendations
Travelers desire a greater level of arterial roadway information. Vehicle probes offer a promising way to deliver this information if a sufficient level of market penetration can be achieved.	• Consider deploying tag-based vehicle probes in areas with high concentration of electronic toll facilities • Other areas may consider emerging wireless cell phone applications or traditional point source speed estimates
Travelers have a particular affinity for roadway information that is shared through camera images and travel times.	• Provide video images wherever feasible • Be sure images are current and provided with spatial referencing clues • Convert available travel speed data to travel time data where feasible

2. SAN ANTONIO MODEL DEPLOYMENT INITIATIVE

2.1 OVERVIEW OF THE NATIONAL MODEL DEPLOYMENT INITIATIVE

On February 26, 1996, the U.S. DOT issued a request for participation in the ITS MMDI, whose goal was to create "model deployments" of ITS that support integrated transportation management systems through strong, regional, multi-modal traveler information services. Successful sites were selected on the strength of their proposals to integrate a combination of existing, new, and expanded ITS services to facilitate reduced traveler delay, costs, and systems emissions; improved safety and customer satisfaction; and enhanced traveler information. On the basis of these criteria, San Antonio, Texas was selected as was one of the four MMDI sites, along with Phoenix, Arizona; Seattle, Washington; and the New York/New Jersey/Connecticut region. Selected characteristics of the MMDI Sites are shown in **Table 7**.

Table 7. Selected Characteristics of MMDI Sites[3]

Site Attribute	Seattle	Phoenix	San Antonio
1990 Population for MSAs/CMSAs	2,559,164	2,122,101	1,302,099
1997 Population Density for MSAs	446.2	194.8	454.3
Rate of Population Growth for MSA/CMSA: 1990-1997	13.4%	26.9%	14.1%
Miles of Instrumented Roadways	120 miles	50 miles	26 miles (plan to increase to 191 miles)
TTI Congestion Index and Rank	1.27 (6th most congested city in US)	1.24 (15th most congested city in US)	0.99 (44th most congested city in US)
VMT per Freeway Lane-mile (1996)	16,870	15,085	12,705
Congested Freeway Travel (%)	80%	65%	45%

2.2 OVERVIEW OF THE SAN ANTONIO METROPOLITAN MODEL DEPLOYMENT INITIATIVE

The San Antonio MMDI is based upon the highly successful TransGuide freeway operations system. This system pre-dates the MMDI and traces its heritage to the Corridor Management Team founded in the 1960s. It has already demonstrated success in performing traffic and incident management functions for the central freeway system in and around the core of the city of San Antonio.

The San Antonio MMDI builds upon the knowledge and infrastructure developed under the TransGuide operation to expand and integrate the system's core operations thereby addressing a broader suite of transportation management goals. This is accomplished through the development and integration of nine individual projects designed to satisfy five different functional goals, as outlined in **Table 8**.

The San Antonio MMDI also presented an excellent opportunity to develop innovative institutional arrangements designed to foster ITS deployment and integration.

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(3) C. Zimmerman, et al "*Phoenix Metropolitan Model Deployment Initiative Evaluation Report*," FHWA, Washington, DC, 2000.

Table 8. San Antonio MMDI Goal Areas, Projects, and Project Deployment Costs

Goal Areas	Projects	Deployment Costs
Improved Traffic Management	Freeway Management System Expansion	$26,575,700
	Medical Center Corridor	$525,000
Improved Traveler Information	In-Vehicle Navigation	$2,388,700
	Kiosks	$1,526,400
	Web site	$3,000
Improved Emergency Services	LifeLink	$3,250,900
Improved Highway Rail Traveler Information	AWARD	$350,800
Improved Travel Speed and Roadway Condition Database	Travel data server	$372,400
	Vehicle Probes	$4,049,000

2.3 EVALUATION APPROACH

Evaluation is a critical component of the San Antonio MMDI and benefits those involved in subsequent deployments and integration of ITS, both in San Antonio and throughout the nation. It also helps to document and identify those approaches that work, those that do not work, and those that show great promise but require refinement. Furthermore, it serves to document the individual benefits and costs associated with many of the approaches taken in the San Antonio MMDI and to promote a discussion of suggested techniques for optimizing these benefits where possible.

A total of six impact measures were considered in the evaluation of the San Antonio MMDI: costs, system efficiency, customer satisfaction, safety, energy consumption, and institutional benefits. Several different methodologies were employed to conduct these evaluations including focus groups, surveys, interviews, traffic simulation, as well as analysis of traffic and usage data.

A detailed benefit/cost analysis is not included in this report, but will be presented in a separate document currently under development. However, deployment and operating costs are included in this report.

2.4 SAN ANTONIO MMDI REPORT OUTLINE

The remainder of this report describes the evaluation that was performed to develop a better understanding of the benefits of the San Antonio MMDI. Section 3 describes the results of San Antonio's successful efforts to develop and expand an institutional framework conducive to ITS integration and deployment. Section 4 presents the traffic management projects implemented as part of the San Antonio MMDI. Section 5 describes the traveler information projects and Section 6 presents the emergency devices projects. Section 7 describes the evaluation of the highway-rail project and Section 8 presents travel speed and roadway condition database evaluations. Finally, Section 9 contains a series of conclusions and recommendations emerging from the evaluation effort.

3. EXPANSION OF SUCCESSFUL INSTITUTIONAL FRAMEWORK

This section describes the results of San Antonio’s successful efforts to develop and expand an institutional framework that is conducive to ITS integration and deployment.

3.1 DESCRIPTION OF EXPANSION OF SUCCESSFUL INSTITUTIONAL FRAMEWORK

Much of the success for the various precursor systems to the San Antonio MMDI, including the TransGuide FMS, can be attributed to the institutional framework that has been established in the San Antonio transportation community over the past 30 years. A primary goal of the San Antonio MMDI is to build upon this successful framework and to extend it to other, non-traditional partners. This framework includes a broad range of formal and informal working relationships, memorandums of understanding, contractual agreements, and multi-agency cooperation.

3.2 EVALUATION APPROACH

The evaluation of institutional benefits entailed a number of one-on-one interviews and the examination of various documents, guidelines, and contractual agreements.

3.3 RESULTS OF THE EXPANSION OF A SUCCESSFUL INSTITUTIONAL FRAMEWORK

In San Antonio, eight actions, which are applicable to other sites deploying ITS projects, were exemplary in facilitating the deployment of the San Antonio MMDI:

- Build on existing relationships,
- Reach non-traditional participants,
- Reach the general public,
- Promote staff involvement,
- Define intra-agency management and staffing requirements,
- Assign intellectual property rights,
- Select the appropriate procurement mechanisms, and
- Develop policies that govern operations.

Build on Existing Relationships

The San Antonio MMDI was the result of activity that started in the 1960s when the Corridor Management Team was organized to deal with current transportation issues and coordinate activities related to construction projects and special events. The team is still in existence and is chaired by the TxDOT District Traffic Engineer and consists of operations staff from Metropolitan Transit Authority, San Antonio Public Works Department, Alamo Dome, San Antonio Police Department, Bexar County Sheriff’s Department, emergency medical services, and county health agency.

In 1988, the San Antonio TxDOT District Engineer charged his staff to get a traffic operations center on-line that would be the best in the nation. A District ITS Committee made up of staff from TxDOT, various city agencies, and transit authority was formed to promote and coordinate ITS and lay the ground work for what would ultimately become TransGuide, the area’s original FMS.

Recently, the San Antonio MMDI participants have taken advantage of both the TransGuide facility and the shared vision that resulted in it to enhance the overall transportation system. Specifically, the San Antonio MMDI effort is building on the TransGuide facility and the services it provides.

The operations center supports the advanced traffic management system, transit and police traffic dispatch, and San Antonio Public Works Department traffic operations. It also houses alternate dispatch centers for the San Antonio Police and Fire Departments. Because agency representatives in the San Antonio area were already comfortable working with one another, the time to develop a trusting relationship and overcome other institutional impediments was reduced. Staff members from most of the agencies involved in the development of the San Antonio MMDI now work at the TransGuide operations center and benefit from increased interaction.

Reach Non-traditional Participants

Several agencies not normally considered to be in the transportation community were asked to participate in the San Antonio MMDI, bringing fresh perspectives and valuable insight to ITS projects. In addition, these representatives are able to provide knowledge, expertise, and information that may otherwise not have been included in the projects.

The San Antonio Fire Department is a participant in the LifeLink Project, which allows emergency medical technicians to consult with emergency room doctors through a video link between the hospital and the ambulance. The trauma centers of three area hospitals were invited to participate in the MMDI LifeLink project.

As a result of participating in the deployments of TransGuide and the MMDI, the San Antonio Police Department management now supports the goal of instrumenting more roadways with ITS. This is significant because Police Department management initially viewed ITS negatively but now see the benefits of improved traffic management that ITS provides.

Reach the General Public

Representatives of the San Antonio agencies believe that the public will not support what they do not understand. Therefore, the management of the TxDOT San Antonio District decided to gain public support through a public relations campaign. This campaign is designed to facilitate visibility and understanding of ITS benefits and to alleviate the public’s privacy concerns.

TxDOT public relations staff have employed as many media as possible in an effort to get the public to understand ITS functionality and realize the benefits. Their public relations program includes radio and television commercials, printed pamphlets and newsletters, real-time video images, and traffic information on local radio and television news. It has been noted that a picture or video image of an icy freeway or traffic incident has a greater impact on the public than the simple reporting of it from the electronic media.

The cost of making the public aware of ITS is primarily in staffing. The TxDOT San Antonio District has dedicated one-and-one-half staff positions to public awareness and outreach. TransGuide has a Public Information Officer and an assistant assigned specifically to the MMDI.

Promote Staff Involvement

Input from staff who will use the new systems is also important to ensure that the systems will be used as intended. Within the San Antonio Fire Department, the Ambulance Committee solicited feedback from personnel concerning the placement of video equipment. Also, operators of the traffic management centers were involved in the upgrade and expansion of the centers.

Within the TxDOT District Office, operations personnel are working more closely with the design and maintenance staff. Design, maintenance, and construction staffs work together when equipment is installed and openly share their knowledge. Staffs with different expertise are housed in the TransGuide facility, which encourages and facilitates interaction.

Within the San Antonio Metropolitan Police Office, consideration of ITS solutions is part of the overall planning process, and the staff incorporates ITS into the day-to-day activities of the agency. ITS and the San Antonio MMDI must be considered in the base case of all planning studies. Metropolitan Police Office staff members knowledgeable of ITS activities have been beneficial in making ITS visible.

Define Intra-agency Management and Staffing Requirements

In TxDOT Headquarters, the Traffic Operations Division staff ensures that ITS programs share information, especially in the six large urban areas with ITS developments. They also provide oversight and coordination, and address policy, procedures, and standards issues. In 1990, the Traffic Management Section was created within the Traffic Operations Division to handle traffic management and process control projects. Both traffic engineers and information systems personnel make up the section. Within the Traffic Management Section, a separate ITS Branch was created in 1991. Later, to make ITS more mainstream within TxDOT and to move ITS from the research and into the field, an ITS Committee was created comprising three TxDOT Headquarters senior managers and the District Engineers from the six metropolitan areas.

Within the TxDOT Traffic Operations Division, four staff members work part-time on the MMDI. Other TxDOT staff, such as legal and procurement, work on the MMDI as needed. At the TxDOT San Antonio District, all ITS activity was consolidated under the Director of Traffic Operations. ITS skills present before the MMDI from previous ITS projects were a benefit to the MMDI.

Operators were hired in 1995 to operate the TransGuide facility. Adequate communications and electronics skills were not available among the existing District staff. Some positions were reallocated within the San Antonio District, while some positions were new. The skills gained from previous ITS experience have been useful in creating a knowledge base that allows operations staff to bring feasible ideas forward.

Due to the MMDI, TxDOT maintenance and automation personnel have new equipment and new applications. Kiosks, automatic vehicle identification readers, and in-vehicle navigation units need to be kept in working order. The San Antonio MMDI has only three maintenance technicians, so maintenance contracts are needed for most systems. Under this approach, the original suppliers will provide the maintenance of the AVI readers and IVN units.

Currently, four San Antonio Public Works Department employees are stationed at the TransGuide operations center. As ITS deployments expand with the MMDI, the Public Works Department may need to hire more operators and engineering technicians. An even greater in-house understanding of system integration and telecommunication is needed. A contractor will provide software development skills in order to integrate various ITS systems.

All San Antonio Police Department dispatchers spend some time at the TransGuide police traffic dispatch position. Skills are required in operating the TransGuide cameras and radio system, which differs from the system at the downtown center. The San Antonio Fire Department staffing levels are not anticipated to change due to LifeLink. However, with LifeLink, the interchange between the emergency medical technicians and the doctors will increase, which may cause units to be out of service longer. This may require additional staffing or repositioning of staff to ensure that appropriate response times are maintained. Verbal skills need to be reemphasized with the increased degree of communications between the doctor and the emergency medical technicians. San Antonio Fire Department officials assume that maintenance responsibility and training will be sought for the LifeLink equipment.

Assign Intellectual Property Rights

The assignment of intellectual property rights (IPR) is an issue that arises in many technology or software development projects. Fortunately, the parties in the MMDI were able to build on an IPR policy that had already been developed by TxDOT management for TransGuide before it became an MMDI project. The specifications for TransGuide software contained language that stated simply that all developed software would be the property of the state of Texas.

TxDOT staff, through their recently established Intellectual Property Committee, have developed procedures that cover intellectual property and address the assignment of all IPR for software created for the MMDI to the TxDOT.

In addition, the TxDOT licenses commercial off-the-shelf software and equipment and does not assume ownership unless it is modified for TxDOT purposes. In that situation, TxDOT will assume full ownership and will copyright the modified software.

Select the Appropriate Procurement Mechanisms

The participants in the San Antonio MMDI took steps to ensure the most appropriate procurement methods were used. These steps included choosing the appropriate lead procurement agency, selecting appropriate procurement instruments, and designing flexibility within contracts.

Choosing the Appropriate Lead Agency

While there were other public sector participants, TxDOT was the logical choice as the lead-procuring agency. Three factors lead to this choice: (1) the short time frame of the MMDI, (2) the need for detailed knowledge of the State Catalog and how it could be used, and (3) the expertise of the TxDOT staff with the existing system already operating in the San Antonio Metropolitan Area. The TransGuide Operations Manager and the TransGuide Automation Administrator, both TxDOT employees, have led the procurement process.

Selecting Appropriate Procurement Instruments

Because time was such a factor in the MMDI projects, parties involved in the MMDI wanted to make the best use of available resources and contracts that they either had in-place or were quickest to initiate. This led to the use of a variety of contracting mechanisms. In addition to the use of the traditional competitive bid process, the San Antonio MMDI participants used two innovative contracting mechanisms: the Texas State Catalog and joint, inter-jurisdictional procurements.

The San Antonio MMDI participants believed that the short deadline for implementation given the MMDI sites precluded the writing of detailed specifications and use of traditional procurement processes. To counteract this short-time frame, the TxDOT staff turned to the Texas State Catalog. The State Catalog of products and services, created by the Texas General Services Commission, was first designed for the rapid purchase of computers because, in the past, procurement procedures were too slow and resulted in the purchase of computer equipment that quickly became obsolete.

The scope of the Catalog has since been expanded to include other technologies and products. It allows for less specification in purchasing computer hardware and software and information services than the traditional construction type procurements. The State pre-qualifies contractors, and the contractors list their products and services on the State's Catalog. The Catalog allows for competition but narrows the field as it operates on a "best" bid rather than low-bid basis.

The advantage of the Catalog process is the reduction of time between the request for offers and selection of the vendor. For most MMDI procurements, the time was 30 days. Because this was their first attempt at using something other than the traditional low-bid process, it took TxDOT officials time to determine if any regulation or law would prevent the use of this new process. TxDOT and VIA staff used the State Catalog to procure products and services for seven San Antonio MMDI components. The MMDI systems integrator was able to use a system similar to the State Catalog to choose pre-qualified vendors to supply the in-vehicle navigational units, information kiosks, and other key supportive equipment.

Officials from the *AZTech* (the Phoenix, Arizona, MMDI) and the San Antonio MMDI worked together on a joint, inter-jurisdictional process for design and procurement. Both *AZTech* and San Antonio MMDI officials procured an open-standard, high-speed sub-carrier transmission and reception infrastructure from a common partner. Arizona DOT staff worked with the TxDOT staff to develop a common protocol for the in-vehicle navigation units.

The *AZTech* contract with the private sector partner includes language that the *AZTech* devices and protocols must be the same as that developed for the TransGuide Traffic Operations Center. Through this action, the *AZTech* public sector participants were able to leverage work already performed by the vendor for the San Antonio MMDI and reduce development costs of the FM sub-carrier interface control document for the communication system. The cooperative design efforts between the Phoenix and San Antonio MMDI projects provide an example that can be duplicated by many other metropolitan areas, especially those within a single state.

Designing Flexibility within Contracts

TxDOT officials have executed a fixed-price contract with their private systems integrator, with variations available on each task. Under this contract, the systems integrator has offered different options that can be completed under different funding levels. The TxDOT administrators allowed the task cost variation provisions to be incorporated into the contract and will transfer funds among the tasks when necessary.

Develop Policies that Govern Operations

Policies regarding how advanced equipment and the data they generate are used are critical components in ensuring that all parties operate under the same manner for regional consistency and effectiveness. In particular, the participants in the San Antonio MMDI developed policies in three areas that can be duplicated by others deploying ITS products and services:

- operation of variable message signs;
- use, distribution, and retention of data; and
- use of new equipment and services.

Public officials for the San Antonio MMDI developed policies outlining what information can be placed on a VMS. Officials found that in San Antonio, non-traffic messages were not well received by the public. TxDOT District officials determined that the only acceptable messages are those related to traffic. However, an exception does exist for messages relating to air quality. In accordance with the policy, TxDOT maintains control over the messages that are displayed on the VMS. Operations staff will issue two messages during an incident. The first message will inform the driver what is going on and the second message will tell the driver what to do. Advertising on the signs is not permitted in any of the areas.

The existing TxDOT transportation data policy is to share as much information as possible. Likewise, in keeping with the Texas Open Records Act, all transit and traffic signal data are readily available to the public, with few restrictions. The TxDOT and other San Antonio MMDI public partners have realized that with the increase in transportation data resulting from the San Antonio MMDI operations, a detailed formal policy to cover the sharing of transportation data is needed. One restriction already placed on data access is that the media are not allowed in the TransGuide control room. Staff from the Texas Transportation Institute have worked with TxDOT staff to create informal procedures whereby traffic data (speeds and counts) and video images can be released over the Internet on the TxDOT Web page and over the telephone.

The Open Records Act set deadlines for record retention, but it is unclear if these guidelines apply to images generated by the cameras. There is no indiscriminate videotaping allowed, and TransGuide images are not used for law enforcement. TxDOT management has set a policy of not retaining recorded video images in order to reduce the risk of liability suits. TransGuide operations will retain videotaped camera images when requested for specific reasons, such as hazardous material spills or special events. These tapes are only used for training and evaluation.

The San Antonio Police Department also has policies that cover the retention of recorded information; usually, records are not retained for longer than 30 days. The San Antonio Fire Department staff are following the Police Department policies, but may develop their own to address retention of video images created in the LifeLink component of the San Antonio MMDI.

Because of the new equipment at TransGuide, San Antonio Police Department management developed procedures that assigned specific responsibilities to the police dispatcher at TransGuide and prescribed how that dispatcher interacted with the Department’s central dispatch center. It took four or five months to adjust to the newly decentralized dispatch position, but this adjustment period could have been longer without the procedures.

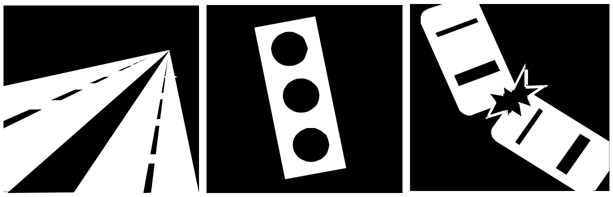
With the advent of the LifeLink project, incident, motor vehicle accident, and hazardous material procedures for the city of San Antonio will be more formalized to ensure that the greatest value is attained from the equipment. The procedural changes will reflect the increased authority of those personnel that are trained on the LifeLink equipment.

3.4 SUMMARY OF RESULTS OF EXPANDING A SUCCESSFUL INSTITUTIONAL FRAMEWORK

The participants in the San Antonio MMDI demonstrated a number of actions that enabled the deployment to move forward to successful implementation. Although the participants faced several obstacles, none of them proved to be insurmountable barriers that would require the public sector to abandon their commitment to ITS deployments. Through the efforts of the MMDI participants, officials from other sites deploying ITS projects can learn from the actions undertaken in San Antonio.

One innovative initiative was the inclusion of non-traditional participants, especially the trauma centers of three area hospitals. A second was the effective use of the Public Information Officer at the TxDOT San Antonio District and a successful media and public outreach campaign. A third positive action was the public partners' use of the Texas State Catalog to shorten the list of pre-qualified contractors that reduced the time-frame necessary to get the private sector involved. These are only a few of the actions highlighted by the San Antonio participants as being instrumental in the success of the San Antonio MMDI.

4. IMPROVED TRAFFIC MANAGEMENT



This section discusses the results of the San Antonio MMDI's traffic management improvement projects. It presents the results of the non-MMDI funded Freeway Management Expansion, the MMDI funded Medical Center Corridor Project, and the integration between the two. Collectively, these two projects are designed to provide integrated management of incident-related traffic delays on both freeway and arterial facilities.

4.1 PROJECT DESCRIPTIONS

4.1.1 Expanded Freeway Management

One of the most popular approaches to improving freeway traffic conditions is the development of an integrated freeway / incident management system. Such systems have been successfully deployed in numerous locations across the nation, including TRANSCOM in New York, CHART in Maryland, and TranStar in Houston.[(4)]

Figure 2. TransGuide Freeway Management Center (TransGuide Design Report)

In July 1995 San Antonio, Texas joined the ranks of these cities with the implementation of TransGuide (**Figure 2**). TransGuide combines traffic, emergency services, and transit resources to offer an advanced system of integrated incident and freeway management. The first phase of the system was evaluated by

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[(4)] "*Freeway Management Handbook*" Federal Highway Administration, Washington, D.C., 1997.

the Texas Transportation Institute[5] and was found to be very successful, with reported reductions in incident response time of 19 percent and in numbers of injury crashes by 16 percent.

Partly as a result of these benefits, a 28.9-mile expansion of the original 26-mile system was undertaken. This expansion adds capabilities along I-10, I-410, and US 281 in San Antonio's northern region and was undertaken during the same timeframes as the MMDI. While neither the expansion nor the original system were funded by MMDI dollars, an evaluation was nonetheless conducted. This decision was made in light of the strategic importance of the TransGuide system in the operations of many of the MMDI funded projects, including the Medical Center Corridor, which could not function without the freeway system.

The evaluation focuses on the 5.44-mile stretch (**Figure 3**), which interacts with the Medical Center Corridor of the I-10 freeway between I-410 and Fredericksburg Road. This section is typical of others along the system and is capable of providing both incident and freeway management. In general, TransGuide utilizes a series of video cameras, loop detectors, and acoustic sensors on the freeway to facilitate traffic monitoring. A combination of lane control signs on the freeways and VMS on the freeway and parallel frontage roads allow traffic management. Finally, both coordination and incident management are supported by a central control facility.

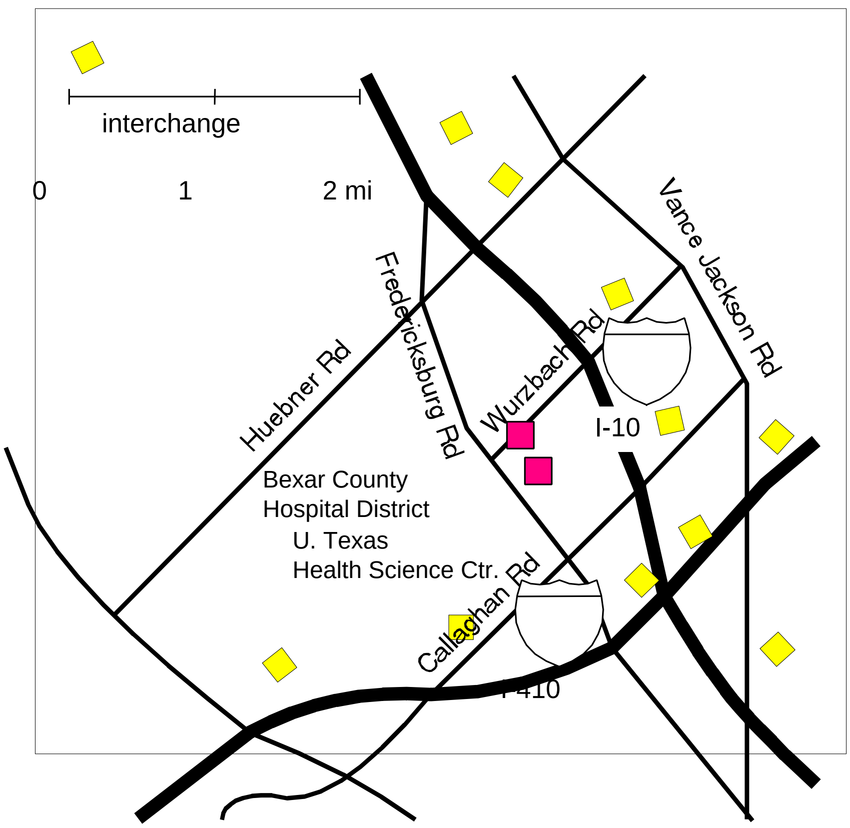

Figure 3. Medical Center Corridor / Freeway Management Expansion

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[5] Henk, Russell H. et al, "*Before-and-After Analysis of the San Antonio TransGuide System*" Texas Transportation Institute, 1997.

At the time of evaluation, the expansion was not yet operational (it subsequently came on line in June 1999). Consequently, the project was evaluated using a traffic simulation model, instead of using a field evaluation.

4.1.2 Medical Center Corridor Project Description

While freeway incident and management systems have experienced fairly widespread popularity, arterial management systems have been relatively slower to catch on. Even rarer has been the integration of these two systems. In this regard, the Medical Center Corridor is a fairly unique arterial traffic management application that, when integrated with portions of the Expanded Freeway Management project, creates the potential for a seamless freeway/arterial management and diversion corridor.

The goal of the project is to have all traffic signals operated by the San Antonio Public Works Department in and around the Medical Center Corridor (**Figure 3**) controlled by a central computer system co-located in the existing TransGuide freeway management facility. An interface to the TransGuide Freeway Management computer then permits the city's Arterial Management computer to receive data on incidents occurring on the surrounding freeway, specifically those covered by the Expanded Freeway Management project.

Information on these freeway incidents is also shared with the traveling public. This is accomplished through the existing TransGuide facility and through nine newly deployed two-line VMS installed as part of the Medical Center Corridor project at the intersections of Fredericksburg Road with Callaghan Road, Wurzbach Road, and Huebner Roads. These VMS are located on the arterials.

In response to the information displayed on the VMS, travelers follow one of three courses of action. Some, if not most, will continue to utilize the affected freeway section. Others, who may be planning to leave Fredericksburg Road for the freeway, may choose to continue on Fredericksburg until they reach an interchange downstream of the incident. Finally, some drivers on the freeway may elect to divert around the incident by taking either the parallel service roads or Fredericksburg Road.

In response to those drivers that do divert to Fredericksburg Road, special, fixed-time, incident response timing plans are implemented in real-time on the arterial to accommodate the increased demand. Additional green-time is given to the vehicles on Fredericksburg Road that are traveling parallel to the Interstate, effectively increasing the throughput of that facility in that direction during the incident period. This increased throughput is essentially borrowed from cross-street traffic along Fredericksburg Road.

As with the Freeway Management Expansion project, the Medical Center Corridor project experienced some deployment delays and was not fully operational at the time of the evaluation. Consequently, the analysis was performed using output from a traffic simulation model instead of field measurements.

4.2 IMPROVED TRAFFIC MANAGEMENT EVALUATION APPROACH

The evaluation of the Freeway Management Expansion and Medical Center Corridor projects considered the impacts of these deployments on system efficiency, safety, energy consumption, customer satisfaction, and cost effectiveness. To address this broad range of measures, a similarly broad range of methodologies was employed, including traffic simulation modeling, interviews, focus groups, and data collection and analysis.

Improved Traffic Management Costs Evaluation Approach

Complete costs for deployment, operations, and maintenance were collected for both the Freeway Management Expansion and Medical Center Corridor Project. These costs were obtained through interviews with project personnel, examination of various contracts, and review of deployment and operations budgets. The results of this process are presented in section 4.3.

Improved Traffic Management Customer Satisfaction Evaluation Approach

Customer satisfaction studies were conducted for both public and private sector users of the Freeway Management Expansion Project. Public sector users were solicited for their opinions on the utility of the video-sharing application of the project's incident management component, while private sector users were queried on their response to the variable message function of the project's freeway management component.

The study of public sector satisfaction with video sharing was accomplished through a series of one-on-one interviews. Interviewees included the TxDOT, VIA Metropolitan Transit Authority, San Antonio Police Department, Texas Transportation Institute, and the local media.

The study of the private sector's satisfaction with variable message signs was facilitated through a series of focus groups. Three 90-minute focus groups were convened with the goal of learning how commuters respond to the messages on VMS. Participants in all three groups were commuters whose work trip took them along at least two of the six instrumented segments of the Freeway Management Expansion. Two groups were recruited from the general public, and one from the "USAA panel" group. The "USAA panel" group is a group of "expert consumers" who work in the area at the USAA Insurance company and who are part of an on-going VMS study being conducted by the Texas Transportation Institute. The purpose of focus groups, a form of qualitative research, is to develop insight, in-depth understanding of attitudes and behavior, and direction for planning or further research.

The Medical Center Corridor was not expressly considered in this study, but it is anticipated that the results of the VMS focus groups should be applicable to the traveler information component of the Corridor project.

Improved Traffic Management System Impacts Evaluation Approach

Evaluation of the system efficiency, safety, and fuel consumption impacts of both traffic management projects was conducted largely through micro-simulation modeling. Micro-simulation modeling was performed because deployment delays and construction on I-10 prevented field measurements from being taken. Use of a model-based approach allowed the evaluation to progress on schedule. The model-based approach also allowed examination of the individual impacts of the separate elements of the traffic management improvements in the corridor.

The following sections provide details on the traffic simulation model used for the evaluation, the confidence of the results, the various experiments that were conducted, and some of the specific details and assumptions that were part of the modeling effort. While extensive, this section is presented here not only for its necessity in understanding the context of the reported values from the Traffic Management improvements analysis, but also for its relevance to the further modeling efforts conducted under the Improved Traveler Information and Integrated Travel data server analyses.

Model Selection

After assessing the capability of several traffic simulation models, the evaluation team selected the INTEGRATION traffic simulation model to conduct this evaluation. INTEGRATION provides a user with an opportunity to evaluate a number of ITS deployment scenarios, including freeway management/arterial management integration, as well as traveler information dissemination.

Model Calibration

A calibrated model is one that reflects the actual site-specific conditions that are being studied. For example, the model should accurately reproduce the demand patterns, travel times, speed profiles, congestion bottlenecks, signal plans, and traffic operations present in the field. An iterative process was undertaken to ensure that the model used for the Improved Traffic Management analysis was properly calibrated. In this process, 1997 traffic volumes, turning movement counts, and observed travel times from the field were compared against the same metrics from the model. Appropriate changes were made in the model until the two sets of values closely approached one another. In this case, the modeled traffic volumes are accurate to within 92 percent of the measured values. Travel times were slightly less accurate and approximately 12 percent higher in the model than observed.

Experiments

A number of experiments were conducted to evaluate system impacts. These experiments examined the individual and collective ability of the incident, freeway, and arterial components of San Antonio's traffic improvement projects in managing several different incident scenarios.

Six representative scenarios identified from a previous study of police incident logs were developed and modeled to represent the entire range of possible incident scenarios.[(6)] The use of this exhaustive set of incident scenarios facilitates two purposes: (1) it allows for an examination of the relative performance of the various ITS treatments under different conditions and (2) it allows the impacts of the various ITS treatments to be normalized to annual results. Impacts of the various shoulder incidents (mild, moderate, and major) were virtually indistinguishable from the non-incident base case. Consequently, ITS could not be reasonably expected to have any substantial impact on these scenarios and was not considered further in the analysis.

Table 9 indicates the relative frequency of each of the representative incident types and presents the normal range of duration and the vehicle hours of delay associated with each category. The table also presents the average delay over base-case (or non-incident) conditions associated with the representative incident scenarios modeled in the San Antonio system for each of these categories. As is evident, for the lane-blocking scenarios each modeled sample falls well within the predicted range of delay for the given incident category.

[(6)] "*Incident Management: Final Report,*" American Trucking Association Foundation, Inc., Alexandria, VA, 1990.

Table 9. Incident Scenarios Used to Determine System Impacts and Base (or no-incident) Conditions

	Incident Blocking Travel Lanes		
	Minor	Moderate	Major
Frequency	16%	3%	4%
Average Duration	15-30 min	30-45 min	45-90+ min
Average Estimated Delay (veh hrs)	500-2000	1000-1500	1200-5000
Total System Delay (veh-hours) No ITS Improvement	1313.3	1437.2	2361.7
Average Stops (per vehicle) No ITS Improvement	3.1	3.1	3.3
Average Speeds (km/hr) No ITS Improvement	51.9	49.8	39.7
Crashes (per million veh-miles) No ITS Improvement	2.3	2.4	2.8
Average Fuel Consumption (L/100 km) No ITS Improvement	13.7	13.8	14.6

Modeling Details and Assumptions

The following sections outline the various assumptions and details of the modeling effort.

Background Traffic

In order to properly evaluate the impact of ITS treatments, information must be known regarding the background traffic demand in the network. For this study, the QUEENSOD[(7)] model was used to generate the traffic demand information required by the INTEGRATION traffic simulation software. QUEENSOD estimates origin-destination traffic demands based on observed link traffic flows, observed link turning movement counts, and link travel times.

In the absence of incidents, travelers in the system follow their most optimal route using the Franke-Wolfe macroscopic user-equilibrium traffic assignment method. During an incident, and in the absence of VMS, most drivers will simply continue to follow their historical non-incident optimum route. However, 10 percent of drivers are considered to be radio users and will thus be made aware of the incident after an average 10-minute delay and may or may not divert based on this new information.

In deciding whether or not to divert, the radio listeners compare the new estimated travel time on the affected route (the sum of the historical or non-incident travel time plus the estimated delay) with the expected, or historical travel time, on the considered diversion route. However, this is not a perfect process since there is no guarantee that an apparently faster diversion route will be faster. First, some error is introduced into the decision-making process. Second, the decision-making driver has no firm idea of how many other vehicles may divert and how that may in turn increase the travel time on the proposed diversion route.

[(7)] Van Aerde and Associates, "*QUEENSOD Rel 2.10 – User's Guide: Estimating Origin-Destination Traffic Demands from Link Flow Counts*," Blacksburg, VA, July 1998.

Incident Management

Incident Management is modeled by reducing the time of the incident. A study of Phase I of the TransGuide system found that incident response times were reduced by 19 to 21 percent.[(8)] However, studies at other sites have shown values as high as 38 percent.[(9)] Consequently, for this evaluation, a value of 25 percent was selected.

Variable Message Signs

VMS are modeled in a similar fashion as radio users discussed above. The only real difference is in the lag time between the incident and notification. For radio users this value is 10 minutes, for VMS it was modeled as 1 minute. The percentage of drivers that respond to the VMS sign is modeled as 10 percent. This value is consistent with findings from other studies, such as the INFORM study in New York. The model considered only VMS, not lane control.

Signal Plans

The incident response signal plans for Fredericksburg Road were acquired from the system developers and inputted directly into the model. In the model, a two-minute delay from the start of the incident to the institution of the plans is assumed.

4.3 DEPLOYMENT COSTS OF IMPROVED TRAFFIC MANAGEMENT

4.3.1 Freeway Management Expansion Costs

Unlike many of the projects examined in San Antonio, the implementation of Phase II of the TransGuide FMS involved very few development costs. This stems largely from the fact that this non-MMDI project is an expansion of an earlier effort involving the development of the initial TransGuide system. The majority of the costs associated with this project are for typical hardware and communications components, with VMS and fiber-optics communications accounting for the bulk of the initial deployment costs.

Another significant cost driver associated with this project stems from the actual implementation expenses. For example, over $1.4 million was spent on mobilization alone. This figure is of particular interest when one considers that these costs were kept from growing even larger by the strategic planning decision to conduct much of the expansion in concert with major highway reconstruction. Planners considering such a deployment at other sites should be aware of the potential impacts of this mitigating factor.

Finally, it may be noted that the total costs associated with the San Antonio expansion amount to approximately $900,000 per mile with annual yearly operations and maintenance costs of around $30,000 per mile.

Table 10 shows the costs for the entire 28.9-mile Freeway Management Expansion project. It was not feasible to separate the costs for the 5.6-mile section considered in the benefits analysis. However, using the costs per mile above, the total costs for the 5.6 miles in the Medical Center Corridor area amount to roughly $5,000,000 for deployment and $168,000 for annual operations and maintenance.

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(8) Henk, et al, 1997.
(9) "Intelligent Transportation Systems Benefits: 1999 Update," U.S. Department of Transportation, 1999.

Table 10. Freeway and Incident Management Expansion Costs

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
Temp. Traffic Barriers and Fences	NA	$ 665,873	
Shafts and Manholes	NA	$ 514,054	
Mobilization	NA	$ 1,424,000	
Permanent Traffic Barriers and Fences	NA	$ 954,153	
Fiber-Optic Cable and Conduits	NA	$ 5,618,487	
Signage	NA	$ 645,275	
Loop Detectors	444	$ 166,857	
Communications Equipment	NA	$ 6,333,171	
Acoustic Sensors	63	$ 279,453	
Digital Detectors	692	$ 267,594	
Variable Message Signs (Large)	23	$ 2,035,257	
Variable Message Signs (Small)	54	$ 2,340,763	
Lane Control Signal Systems	76	$ 2,476,537	
Other Infrastructure	NA	$ 298,009	
Miscellaneous Labor	2	$ 145,133	
CCTV Cameras	33	$ 840,246	
CCTV Field Equipment	NA	$ 1,276,567	
Traffic Signal Software Upgrade	1	$ 1,000	
Planning Software and Management	NA	$ 49,646	
Police Cruisers and Officers	NA	$ 50,063	
Other Planning	NA	$ 179,323	
Workshops	NA	$ 14,264	
Loop detector maintenance	NA		$ 24,601
Video camera maintenance	NA		$ 152,000
Re-lamp LCS and VMS	NA		$ 39,000
Maintain computer hardware	NA		$ 25,000
Maintain communications equipment	NA		$ 129,836
Maintain fiber cable	NA		$ 115,185
48 percent Share of 25 TransGuide Personnel(10)	NA		$ 275,533
48 percent Share of Software Maintenance and Upgrades	NA		$ 78,724
48 percent Share of Hardware Maintenance and Upgrades	NA		$ 12,449
Totals		$ 26,575,724	$ 852,328

4.3.2 Medical Center Corridor Deployment Costs

As with many of the deployments in San Antonio, the Medical Center Corridor involves the customized deployment and systems integration of a number of existing technologies. Deployment costs for the project are split between those for 'off the shelf' products such as the Pentium II workstations and those that are unique to this project such as the development of the innovative traffic management database software. It may be anticipated that future deployments of such systems in the San Antonio area may occur at substantially reduced expense, given the initial investment of the MMDI in this area.

Annual operations and maintenance costs are kept low by housing the operations center within the existing TransGuide operations center and taking advantage of the benefits offered through centralized staffing and maintenance plans. **Table 11** shows the costs of this project.

(10) Share of 25 TransGuide Personnel totals 69 percent. The remaining 31 percent are in existing operations.

Table 11. Medical Center Corridor System Costs

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
Operator Workstation (Pentium II)	1	$ 8,000	
Database Server	1	$ 6,000	
Video Monitor	4	$ 3,000	
Network Hub	1	$ 3,000	
Equipment Rack	2	$ 5,000	
Operator Console	1	$ 8,000	
Variable Message Signs	9	$ 50,000	
CCTV Cameras[11]	3	$ 30,000	
Camera Towers	1	$ 25,000	
Loops - 1 double set with controller	10	$ 35,000	
Windows NT, version 4.0	1	$ 500	
Visual Basic Professional Edition 5.0	1	$ 500	
Precision Mapping Streets, Version 3.0	1	$ 1,000	
SQL Server	1	$ 500	
Custom Database software	1	$ 150,000	
Labor	3,000	$ 170,000	
Other direct costs	NA	$ 30,000	
5% Share of 25 TransGuide Personnel	NA		$ 35,000
5% Share of Software Maintenance and Upgrades	NA		$ 10,000
5% Share of Hardware Maintenance and Upgrades	NA		$ 1,581
Totals		$ 525,500	$ 46,581

4.4 CUSTOMER SATISFACTION WITH IMPROVED TRAFFIC MANAGEMENT

Customer satisfaction with both components of the Freeway Management Expansion plan was considered. Interviews of the public sector examined the sharing of video under the incident management component, and focus groups of private users examined the impacts of the variable message signs deployed under the freeway management component. Customer satisfaction of the Medical Center Corridor was not directly considered, however, the results of the VMS focus groups should be largely transferable.

4.4.1 Public Sector Satisfaction with Video Sharing

This section summarizes the perceived benefits of the public sector regarding the sharing of traffic video from the incident management component of the TransGuide Freeway Management project. It is based on a series of one-on-one interviews with members of the TxDOT staff, the San Antonio Police Department, the local media, and the VIA metropolitan Transit Agency. The results of these interviews are summarized in **Table 12**.

In general, TxDOT staff are pleased with the video sharing component of the TransGuide freeway management project. This is reflected in their commitment to expanding the system through the deployment of the Phase II expansion. They feel that the video allows them to expedite incident management response and to provide accurate traffic information to the public. Furthermore, they believe

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[11] The CCTV cameras for the Medical Center Corridor are less expensive than the CCTV cameras for freeway management because they do not pan.

Table 12. Perceived Benefits Associated with Video Data Sharing

Stakeholder	Perceived Benefits Associated with Video Data Sharing
TxDOT	• Expedites EMS response • Improves accuracy of EMS response • Provides accurate traffic information • Reduces congestion during incidents • Improved relationship between stakeholders, particularly between public agencies
Metropolitan Transit Authority	• Accurate incident response • Accurate traffic data. • Cost savings for Metropolitan Transit Authority. Demand-based response for special events pick-ups • Improved relationship between stakeholders, particularly between public agencies
Local Media	• Accurate weather conditions on freeway • Close coverage of incidents • Exact location of incident • 24-hour real-time freeway video • Improved relationship between stakeholders
Texas Transportation Institute	• Accurate response to incidents • Accurate assessment of prevailing freeway conditions • Cost savings to San Antonio Police Department • Improved relationship between stakeholders, particularly between public agencies
San Antonio Police Department	• Cost savings to San Antonio Police Department • Accurate incident response • Exact location of incident • 24-hour coverage • Improved relationship between stakeholders, particularly between public agencies

that by sharing the data, they improve their relationships with other stakeholders such as the Police Department.

The San Antonio Police Department reports similar satisfaction with the video sharing program. They think that the system helps them help the public by improving the quality of incident response. Video allows the police to determine what type of response is needed at a particular incident scene. A single patrol unit can be dispatched in the case of a minor fender bender. In the case of a more severe incident, the appropriate Emergency Medical Service (EMS) support can be dispatched. This can reduce incident response times and improve emergency responses. In addition, the Police Department believes that the use of TransGuide video has led to significant cost savings by cutting down on the number of false alarms or over-response to minor incidents.

Not surprisingly, the local media have benefited from the TransGuide video sharing program through access to accurate, cost-effective traffic condition information. A less obvious benefit is the use of the video data to provide more accurate weather information. With the traffic video, there is no speculation about prevailing conditions on any one segment. The TransGuide cameras allow operators to verify heavy rain and flooding. The local television networks provide viewers with a real-time picture of weather conditions using video images provided by TransGuide. Live traffic video provides a more accurate account of how weather conditions may be impacting travel than a verbal description. The system was used extensively for this purpose during a recent episode of heavy flooding.

The transit agency thinks that it has also benefited from the video sharing program. There is the benefit of improved traffic information and the unique benefit of direct cost savings. The cost savings are realized by using a demand-based approach for special events rather than using a fixed schedule approach. Since video cameras are installed at key special events locations (the AlamoDome and nearby park-and-rides), transit authority dispatchers can actually see how many people need to be picked up at a particular location at any point in time, rather than simply running routes based on a fixed schedule. The demand-based approach eliminates excess trips and allows the transit authority to optimize individual pickups.

Finally, according to one stakeholder, political infighting and lack of communication and cooperation between various agencies was common before TransGuide. Individual agencies generally followed their own agendas and paid little attention to what other agencies were doing. In some cases, agencies were forced to cooperate, but typically did not do so voluntarily. Although the sharing of video data has not eliminated these problems, it has greatly improved inter-agency cooperation and communication. Individual agencies now tend to be much more aware of what other agencies are doing and voluntarily work together to achieve common goals, rather than working alone to achieve individual goals. Improved cooperation and communication can result in operating cost savings and improve public service.

In summary, the various public sector users of the TransGuide video data are satisfied with the program. The greatest evidence of this is their enthusiastic support for the recent Phase II expansion.

4.4.2 Private Sector Satisfaction with Variable Message Signs

This section describes traveler responses to the freeway variable message and lane control signs that are part of the Freeway Management Expansion Project. Direct responses to the arterial VMS that are included as part of the Medical Center Corridor Project could not be obtained due to project delays.

As described in the evaluation approach, three 90-minute focus groups were convened with the goal of learning how commuters respond to the messages on variable message signs. Participants in all three groups were commuters whose work trip took them along at least two of the six instrumented segments of the freeway management expansion.

General Reactions to the Variable Message Signs

Respondents understood that the VMS are meant to inform them of changing conditions ahead, to help them make a decision about changing routes, to prepare them for a delay, or to assist in traffic flow. They were familiar with the signs from experience with similar Phase I VMS downtown, and they were hopeful that the new Phase II signs would give them information to ease their commute.

Their first reaction to the signs was noting the delay in deployment and operation. They recalled months of blank signs, followed by a period of intermittent testing, and finally working signs, though not working all the time. This initial “stop-and-go” experience has left them somewhat skeptical about the reliability of the signs.

The respondents felt strongly that the information on the signs should be as accurate as possible - they do not want to second-guess the signs, they want to rely on the information. Despite their current uncertainties about the newest signs, respondents consider the VMS to be more useful and reliable than radio or other sources of traffic information because of the signs’ proximity to traffic congestion and their higher level of accuracy.

Respondents want to see messages on the signs all the time. They said that this makes it clear that the signs are working and helps them pay more attention to the signs when they carry an important message about current traffic conditions. While respondents questioned vague or irrelevant messages, such as "Ozone Action Day," they welcomed messages that provided useful information. This meant messages that gave the reasons for congestion or expected delay. They felt that the signs could accommodate more information without compromising driver safety. Respondents also want to see signs on more of the highway network. The area around the airport was cited as an example of a road segment that would benefit from more VMS.

In summary, respondents found the signs very useful, but wished that the information on the signs was more reliable, and wanted signs on more of the highway system.

Changing Routes and the Value of the Signs

The respondents had a few different driving responses when the VMS indicated congestion ahead. One response was to exit the highway and use the access road, or, less commonly, an alternate route (such as Fredericksburg Road in the Medical Center Corridor). Several drivers agreed that it was always a toss-up what to do, and staying on the highway was often the better choice. These drivers were glad to have the advance warning so that they could make the choice, but they said that they felt that they did not necessarily save time or aggravation by switching to the parallel routes. This observation is consistent with the relatively low response rates to VMS noted in such studies as INFORM, which was quoted earlier, and with the logic utilized in this evaluation's traffic simulation modeling efforts.

Respondents took the signs seriously when they reported crashes ahead. Drivers were grateful for the advanced warning (for instance, closed lanes or slowed traffic ahead) when the sign was accurate and perturbed when there was no accident to be found. They assumed that the sign had been left up long after the accident had been cleared.

Another common response to the VMS' congestion ahead message was to move into the marked open lanes, indicated by the lane control signs, and wait it out. These drivers found the value of the signs in knowing what to expect and which lanes were safe for through travel. They found the drive was less stressful when they knew what to expect even if it did not necessarily result in a quicker commute. This is consistent with studies of traveler information at other sites, including other MMDI sites, which suggest that knowledge, even if not acted upon, is valued. This is a situation referred to by some researchers as "serenity."

Others like having the opportunity to decide whether to take another route. While the potential to save time was the obvious reason to switch routes, respondents seemed uncertain that getting off was very effective. Instead, some acknowledged that they preferred to "roll" rather than be stopped, regardless of the time differential. Others said they liked to "explore" or take "shortcuts," even if the result was getting lost.

Conclusions

Respondents are very appreciative of the information provided on the VMS, and also had some suggestions for improvements. They prefer the information on the signs to any other venue for traffic information. They primarily use the information to position themselves on the road safely in accordance with instructions provided by the lane control signals, and sometimes to make the decision to change routes. The most frequently mentioned benefits of the signs are peace of mind, safety, and choice.

The few critical comments made were more in the form of suggestions than complaints. The respondents felt strongly that the information on the signs should be as accurate as possible. They want to rely on the information, and they find it unsettling when a message is out-of-date or blank when they find that it should have provided a warning. They would like more information on the signs when highway conditions ahead warrant it, and they would like more signs.[(12)]

4.5 SYSTEM IMPACTS OF IMPROVED TRAFFIC MANAGEMENT

This final section of the evaluation of the San Antonio traffic management improvements focuses on the impacts of those improvements on the following system level metrics:

- system efficiency,
- safety, and
- energy consumption.

The evaluation examines the impacts of each element of these systems acting in isolation and in an integrated fashion.

4.5.1 System Impacts of Freeway Management Expansion

The TransGuide Freeway Management expansion project seeks to mitigate traffic delays through the integration of incident and freeway management functions. Such systems are becoming increasingly common across the nation, and a number of evaluations have been performed on their operations. However, most of these evaluations tend to address the integrated system as a whole. They do not specifically consider the operations of either the freeway or incident management components on their own. While there are some evaluations of these individual components at other sites where one or the other of the components is absent, these evaluations do not postulate the impact of integrating the missing component at their sites. The net result is a dearth of information on the integration benefits of incident and freeway management.

By means of addressing this situation, this evaluation of the TransGuide Freeway Management expansion considers both the impacts of the incident management and freeway management functions in isolation and the impacts of the systems as integrated in the field. These impacts were modeled, not measured in the field, due to project delays. Also, these results reflect the impact of the various treatments on the arterial and the freeway. The results of all three of these model-based analyses are summarized in **Table 13**.

[(12)] All remaining segments of Phase II Deployment were brought on-line August 2, 1999, and have been in operation continually since then. This includes the segment of Loop 410 around the airport.

Table 13. Impact of Freeway Management Expansion under Various Incident Scenarios on the Freeway and Arterial

Incident Scenario	ITS Improvement	% Change in Total System Delay	% Change in Average Stops	% Change in Average Speeds	% Change in Average Crash Rate	% Change in Average Fuel Consumption
Minor	IM	-2.5	-0.6	1.3	-1.1	0
	VMS	-0.2	0.8	0	0	0.2
	IM & VMS	-1.9	-0.4	0.5	1.0	-0.2
Moderate	IM	-5.6	-1.1	2.3	-1.5	-0.6
	VMS	-3.2	1.0	1.6	-0.7	0.6
	IM & VMS	-7.9	-0.7	3.4	-2.2	-0.2
Major	IM	-16.2	-2.5	8.7	-6.3	-2.5
	VMS	-4.6	2.7	0	-0.9	0.5
	IM & VMS	-18.8	0.9	10.7	-6.4	-1.8

Incident Management Results

Focusing first on incident management, represented in Table 11 as "IM," it is evident why these systems are so popular. For the entire range of incidents examined, the system results in significant savings in delay, crash risk, and fuel consumption. Reductions in corridor-wide delay as high as 16 percent may be achieved when the IM system is applied to the most severe of incident types examined. Furthermore, while the impacts are less dramatic for minor incidents such as disablements, the results are nonetheless positive, with the system affecting a 2.5 percent reduction in delay.

For major incidents, the average number of vehicle stops is also reduced while the average corridor-wide speeds increase by as much as 8.7 percent IM also reduces the crash rate from between 1.1 percent and 6.3 percent depending on the incident scenario. This safety impact is consistent with the hypothesis that IM can be an effective tool for reducing the frequency of secondary crashes by reducing exposure to dangerous traffic queuing conditions.

Freeway Management Results

Freeway management is intended to reduce delay by re-routing vehicles around incidents. This is accomplished by providing information to drivers at some upstream decision point that affords them an opportunity to follow an alternative path to their destination. While such systems can promote more efficient use of roadway system capacity, they cannot increase capacity as IM systems can. Therefore, it is not surprising that the impacts of freeway management systems are typically less beneficial than those attributed to incident management.

Examining the “VMS” entries in Table 14 supports this observation. While freeway management can result in beneficial reductions in delay with reductions as large as 4.6 percent, the impacts are smaller than when incident management is applied to the same range of incident scenarios.

Furthermore, it is instructive to understand that freeway management systems, such as TransGuide, typically operate by diverting traffic away from freeway delays to surrounding surface streets or arterials. As in the Medical Center Corridor, these arterials are most often signalized and are characterized by less smooth traffic flow than the freeway with a larger number of stops and increased crash risk. Examining Table 14, the results of this trade-off are clear. In terms of safety, any reductions in crash risk attributable to avoiding incident induced queuing on the freeway are effectively offset by the increased risk of the lower class and higher potential conflict arterial. Similar tradeoffs impact both average vehicle speeds and fuel consumption, such that the net impact of the ITS treatment on both of these metrics is nearly negligible, according to the model.

Incident management was more effective than freeway management in the Medical Center Corridor, however, both provided benefits. If given the choice between deploying IM or freeway management on its own, IM appears to be the better selection. This is consistent with the thinking of many cities across the country where IM systems have deployed ahead of other ITS treatments such as freeway management. However, this does not mean that freeway management is not a good investment. The real question is whether through integration, freeway management can help make incident management better. To investigate this hypothesis, consideration must be given to the integration of the two systems.

Impacts of Integrated Freeway and Arterial Management

A central focus of the TransGuide Freeway Management Expansion evaluation is to investigate whether the integrated operations of the incident and freeway management functions can produce benefits that are greater than either one of the systems operating on their own. As the “VMS and IM” entries of Table 11 indicate this is typically the case – the whole is greater than either one of the systems acting on its own.

The integration of the two ITS improvements translates into larger benefits. For example, for major incidents, these benefits include:

- delay, as high as 18.8 percent compared to 16.2 percent with IM alone,
- vehicle speeds, as high as 10.7 percent compared to 8.7 percent with IM alone, and
- crash rate, as great as a 6.4 percent reduction compared to 6.3 percent with IM alone.

Nonetheless, there is a corresponding increase in fuel consumption. Another minor trade-off involves the application of the integrated system to relatively minor incidents. As noted previously, traffic management operates by diverting traffic to lower class arterial roadways. For severe and moderate incidents these arterials may prove a better option than the congested freeway. However, for minor incidents, especially where IM has made the incidents impacts even smaller, such diversion is not beneficial to the driver. Nevertheless, the public wishes to be informed even about minor incidents. Information about minor incidents should include whether or not there is any delay.

The optimal application of these ITS improvements involves applying the integrated freeway and IM to moderate and severe incidents, while restricting the treatment for minor incidents to incident management alone.

Annualized Impacts of Freeway Management Expansion

Considering the optimal deployment discussed above, it is possible to estimate the impacts of the Freeway Management Expansion project on the metrics of delay, safety, and fuel consumption over the course of an entire year. These annualized impacts consider the full-breadth of the corridor, including the arterial and freeway facilities and the full range of incident scenarios, where the system was not applied. However, it should be noted, that the resultant values are from models that considered incident-induced congestion only, which represents slightly half of all delay.

Calculation of these annualized impacts is made possible by:

- determining the absolute yearly frequency of major incidents in the Medical Center Corridor,[13]
- scaling each of the other incident types by this value for major incidents according to the relative frequencies of each incident type as outlined in Table 10, and
- multiplying the resultant yearly frequency of each incident type by the modeled ITS impact.

The results of this process on travelers on the freeway and arterial are summarized in **Table 14**. They are consistent with the findings presented earlier. They indicate that over the course of a year, and considering all incident types, the Freeway Management Expansion can be expected to offer improvements in delay, safety, and fuel consumption.

Table 14. Summary of Annual Impacts of Freeway Management Expansion

Annual Impact	Delay	Crashes	Fuel Consumption
Total System Change	↓ 80,883 veh-hrs	↓0.9 crashes/year	↓ 4069 L/year
Average User Change	↓ 1.75 hrs/year	↓.06 crashes/million km	↓ 0.09 L/year
Percentage Change	↓ 5.7%	↓ 2.8%	↓ 1.2%

4.5.2 System Impacts of the Medical Center Corridor

The Medical Center Corridor was conceived to improve corridor-wide traffic flow by integrating with the parallel freeway management system and implementing special incident response signal plans to increase arterial capacity under freeway incident conditions. The deployment is one of the first of its kind anywhere outside of the laboratory. A thorough evaluation was conceived that allows for an examination of the signal response system on its own and as integrated with the freeway management expansion.

Impacts of Medical Center Corridor Signal Response Plan

The first step in the analysis was to consider the application of the incident response signal plans operating on their own. In reality, this response would likely not be undertaken in the absence of an application of the freeway components. However, it is instructive to consider the impacts of this solitary application in order to develop a better understanding of the subsequent integration results.

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[13] Total number of major incidents calculated by multiplying GES database crash rate of 2.3 crashes per million vehicle miles X roadway length of 5.44 miles X AADT of 16,000 vehicles per day X 220 working days per year.

Table 15 shows why it is not wise to deploy incident response signal plans without a freeway component. Few drivers would convert to the arterial unless warned of an incident on the freeway. Consequently, there is little additional traffic demand on the arterial traveling in the direction of the freeway. Therefore, the additional capacity afforded by the incident response signal plans is wasted, and travel conditions for cross-streets can worsen. The result is that traffic conditions are actually made worse for some situations.

This negative impact is evident in the increased delay, crash risk, and fuel consumption associated with isolated application of the signal plan to minor and moderate incidents revealed in the table. The only situation where the isolated application of the signal system makes sense is under conditions of severe incidents. Here, enough radio users divert and the freeway conditions are severe enough to result in delay savings as high as 2.8 percent over the base or do-nothing case.

Integrated Results

Examining the "integrated" entries in Table 13 it is evident that, for limited situations, the integration of the arterial and freeway management components can lead to greater benefits than any of the constituent components deployed on their own. Under severe incident conditions, the integrated system performs better than any element deployed on its own, with reductions in delay as large as 19.9 percent. However, as with the integration of the incident and freeway management systems, a blind application of the integrated arterial and freeway system is not recommended. Under such an application, the system would actually translate into reduced benefits for the moderate and minor incidents.

Table 15. Impacts of Medical Center Corridor under Various Incident Scenarios on the Freeway and Arterial

Incident Scenario	ITS Improvement	% Change in Total System Delay	% Change in Average Stops	% Change in Average Speeds	% Change in Average Crash Rate	% Change in Average Fuel Consumption
Minor	Signal	3.5	-0.6	-7.6	1.8	0.4
	IM&VMS	-1.9	-0.4	0.5	1.0	-0.2
	Integrated	6.3	-0.7	-7.6	3.0	0.2
Moderate	Signal	5.9	-1.4	-11.3	4.0	0.6
	IM & VMS	-7.9	-0.7	3.4	-2.2	-0.2
	Integrated	0	-2.6	-7.3	2.8	0
Major	Signal	-2.8	-2.2	-6.8	1.3	-0.5
	IM&VMS	-18.8	0.9	10.7	-6.4	-1.8
	Integrated	-19.9	-1.4	3.5	-4.4	-1.9

A more optimal solution would be to apply the integrated arterial and freeway system for severe incidents only. For moderate incidents apply the integrated freeway and arterial management systems, and for minor incidents apply only the incident management system as before. The results of applying this solution are summarized in **Table 16**.

Table 16. Impacts of Optimal Operation of Medical Center Corridor on the Arterial and Freeway

Incident Scenario	ITS Improvement	% Change in Total System Delay	% Change in Average Stops	% Change in Average Speeds	% Change in Average Crash Rate	% Change in Average Fuel Consumption
Minor	IM	-2.5	-0.6	1.3	-1.1	0
Moderate	IM&VMS	-7.9	-0.7	3.4	-2.2	-0.2
Major	IM & VMS & Signal	-19.9	-1.4	3.5	-4.4	-1.9

Calculation of Annualized Impact of Medical Center Corridor

In the same fashion that the impacts of the Freeway Management Expansion were annualized, it is possible to determine, through modeling, the annual impacts of the integrated Medical Center Corridor Project under incident conditions. As **Table 17** indicates the project offers annual benefits in delay, safety, and fuel consumption.

Furthermore, for delay at least, these values are greater than could be achieved by deploying any one component of the system on its own. For example, the integrated Medical Center Corridor offers delay savings of 5.9 percent, nearly a full percentage point higher than for IM operating on its own and 0.2 percent higher than the integrated freeway management expansion operating on its own.

Table 17. Annualized Impacts of Medical Center Corridor

Annual Impact	Delay	Crashes	Fuel Consumption
System Change	↓ 84230 veh-hrs	↓0.6 crashes/year	↓ 4469 L/year
User Change	↓ 1.82 hrs/year	↓.05 crashes/million km	↓ 0.1 L/year
Percentage Change	↓ 5.9%	↓ 2.0%	↓ 1.4%

4.6 SUMMARY OF RESULTS FOR IMPROVED TRAFFIC MANAGEMENT

Overall, both the freeway management expansion and the Medical Center Corridor projects successfully demonstrate the benefits of ITS deployment and integration. The following major findings were made:

- **The expansion of the freeway management system in San Antonio offers benefits across a broad range of metrics.** While it has already been established that Phase I of the TransGuide system offers a range of safety and delay savings, it appears that the Phase II expansion will also offer similar savings. The integrated system results in annual savings in delay (-5.7 percent), fuel consumption (-1.2 percent) and crash risk (-2.8 percent) under incident-induced traffic delays.

- **However, the system must be strategically deployed.** The focus groups findings suggest that it is not prudent to operate the system with periods of blank VMS. Such signs tend to erode user's confidence, and ultimately his/her satisfaction and usage of the system. Also, the modeling results suggest that the freeway management function of the system should only be used for moderate and severe incidents. Using the system for minor incidents, such as disablements, actually leads to lower benefits than may be achieved by the incident management function performing on its own.

- **Benefits of the freeway management expansion may be increased through integration with the Medical Center Corridor's arterial management role.** This integration, if employed strategically, can result in even greater delay benefits than could be achieved by the freeway management expansion or by any one of the three integrated components acting on their own. For example, while the freeway management expansion offers 1.75 hours of savings per year per person, the Medical Center Corridor offers 1.82 hours of savings; an increase of 4 percent.

- **The Medical Center Corridor must also be employed strategically.** As with freeway management expansion, it is critical that the integrated corridor system be employed in a strategic fashion. Specifically, only IM should be used for minor incidents, incident and freeway management should be used for moderate incidents, and all three components, including arterial management, should be used for the most severe incidents. If this strategic operation were not followed, then the delay benefits would drop by 80 percent to 0.37 hours per year per person.

5. IMPROVED TRAVELER INFORMATION

A common feature of all four MMDI sites is the presence of improved traveler information services. Such services offer direct benefits to the public and are an excellent resource for promoting the integration of metropolitan ITS components.

In the San Antonio MMDI, three traveler information service projects were undertaken. The first was the deployment of a series of stand-alone traveler information kiosks. The second was an expansion of the existing TransGuide travel conditions Web site. The third was the unique deployment of approximately 500 in-vehicle navigation devices to various public agencies throughout the San Antonio area.

5.1 TRAVELER INFORMATION PROJECT DESCRIPTIONS

5.1.1 Traveler Information Kiosks Project Description

The traveler information kiosk program utilizes stand-alone interactive kiosks such as the one depicted in **Figure 4** to provide customized traveler information to users at 36 indoor and 4 outdoor locations.

Figure 4. San Antonio Kiosk

The systems provided users with:

- current roadway traffic conditions,
- static transit information pertaining to schedule and general service details,
- navigation instructions that are capable of accounting for current traffic conditions, and
- current weather information and forecasts.

There are plans to add additional features to the system including:

- dynamic transit and airport information, with information such as airport flight status and automated parking information;
- telephone numbers for rental car companies; and
- "yellow page" information.

The first of these additional features is expected to be on-line in late 1999.

5.1.2 TransGuide Web Site Expansion Project Description

The TransGuide Web site (http://www.transguide.dot.state.tx.us/) integrates traffic data from a system with three primary data sources. These include:

- loop detectors buried in roadbeds,
- overhead acoustic devices, and
- transponders placed in volunteer probe vehicles that can be picked up by antennae adjacent to the roadways.

The roadbed loop detectors are installed in 26 miles of San Antonio highway (TransGuide's Phase I deployment) and feed data to a high-speed computer network for analysis. The information is supplemented by the acoustic devices and by the Vehicle Tag Program, which consists of volunteers who have placed small transponder tags on the front windshield of their vehicle. These tags emit signals to antennae, which then relay the signals to TransGuide. TransGuide measures the time interval from one antenna to the next, makes time and distance calculations, and advises travelers about how long a planned trip will take.

The data are processed at the TransGuide Operations Center for a variety of uses including the San Antonio Current Traffic Conditions Maps (http://www.transguide.dot.state.tx.us/map/). The maps are images generated from the data for the Web site as each user requests a page. The pages also furnish data-driven information about lane closures and other incidents. **Figure 5** shows a snapshot image of the Traffic Conditions page on the TransGuide Web site. The Traffic Conditions map shows the portions of the San Antonio freeway network that are currently providing Web site viewers with traffic information.

The TransGuide Web site contains an estimated 2,218 individual pages available on the traffic information pages supported by TransGuide. Five of these contain dynamic mapped information. There are 213 other traffic information pages, and about 2,000 non-traffic pages (reports, pdf files, and other documents that users can read on-line or print out in hard copy). Users may access the site from any Internet connection, from anywhere in the world.

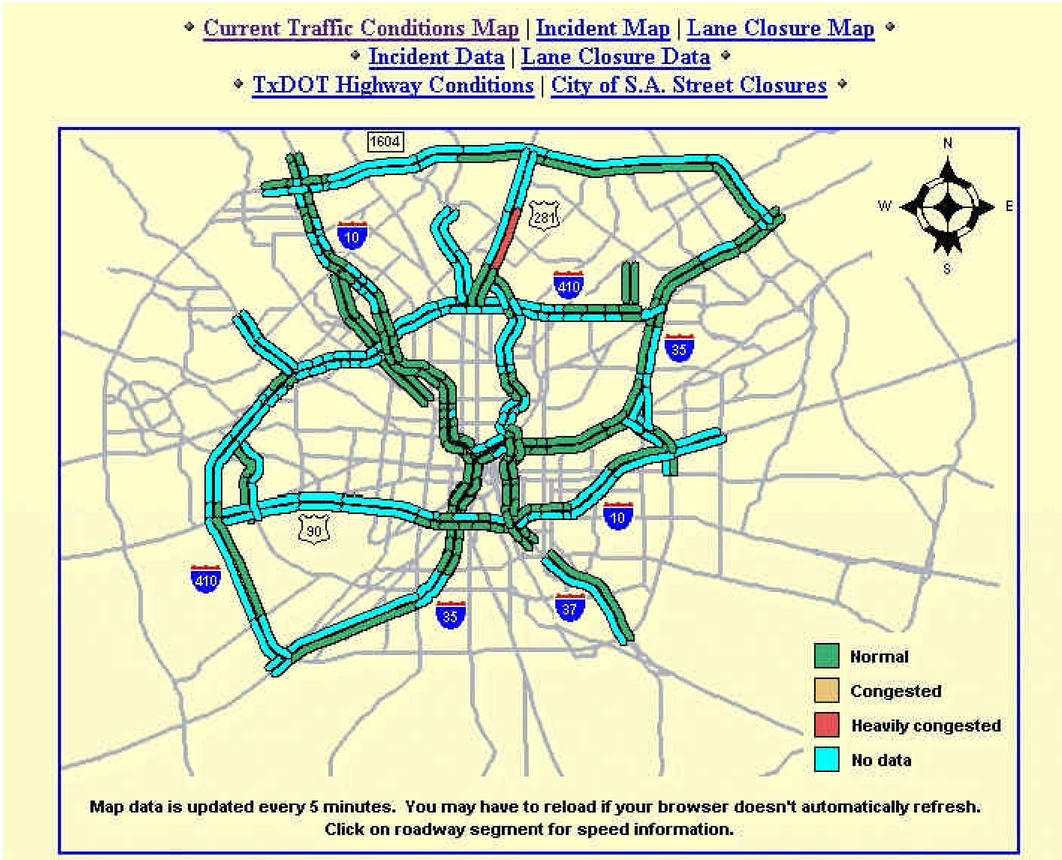

Figure 5. Snapshot of TransGuide Web Site

5.1.3 In-Vehicle Navigation Units for Public Employees Project Description

The purpose of the San Antonio IVN program to distribute real-time and static traffic information to drivers in the greater San Antonio area. The project was originally intended to provide roughly 1000 in-vehicle navigation devices to members of the general public. However, Texas State law prohibits state agencies from providing non-government entities (including private individuals) with state-owned equipment. Consequently, distribution of the units was restricted to public agency-owned vehicles. Furthermore, funding cuts reduced the total number of units from 1000 to the 529 units represented in **Table 18**.

In general, the units provide route guidance within the San Antonio area and for nearby cities and smaller towns. The level of geographic detail and currency of the locational data in this system vary by place, and are influenced by recent changes in roadways, addresses, and road closures that affect the accuracy of the information.

Beginning in June 1998, TransGuide began upgrading the units with a software application that added real-time information on traffic congestion, incidents, and highway-rail intersections (part of the AWARD program).

Table 18. Distribution of IVN Units in San Antonio

Type of Agency	# of IVN Units
Fire Departments	17
Police Departments	77
City of San Antonio	55
Texas Department of Transportation	90
Texas Department of Public Safety	54
Other Agencies	115
Paratransit Vehicles	121
TOTAL	529

As **Table 19** indicates, two different types of IVN units were deployed – an Alpine unit and a Zexel unit. While they both offer route guidance and real-time traffic conditions, their operation and design differ. The most obvious is the difference in user interface. The Zexel is a one-piece unit that provides buttons on the unit for data entry. The Alpine unit comes with a remote control joystick that the driver uses for data entry and programming. The remote control does not have any fixed wires connecting it to the navigation unit, and if lost, the remote control cannot be replaced without purchase of a new unit.

TxDOT currently has no plans to add additional units. However, they are committed to limited repair and maintenance and are encouraging users who do not find the units useful to return them, so that they can be redistributed to other individuals or agencies who will find them useful.

5.2 EVALUATION APPROACH FOR TRAVELER INFORMATION IMPROVEMENTS

Improved Traveler Information Cost Evaluation Approach

Costs for all three of the San Antonio Traveler Information improvement projects were collected in a similar fashion as described in the Improved Traffic Information Section.

Improved Traveler Information: Customer Satisfaction Evaluation Approach

Customer satisfaction evaluations were performed for all three of the Traveler Information Improvement projects. In general, these evaluations attempted to shed light both on the users' acceptance of the given service and on the resultant utilization rates of that service.

Kiosks

The customer satisfaction evaluation of the kiosk project was limited to a single usability study. This study involved an analysis of the functionality of the kiosks conducted by a qualified human factors expert. Based on the results of that analysis, it was concluded that the kiosk usage rates were likely to be very low. Therefore, further analyses, such as intercept surveys, were deemed to be infeasible.

Web Pages

The customer satisfaction evaluation of the San Antonio Web pages focuses on macroscopic usage rates. The analysis is made possible by the fact that Web servers, such as San Antonio's, track activity on their sites by cumulating data minute-by-minute into log files. These files contain information about each visitor to the Web site, including where they are connecting from, what time the visit took place, which

Table 19. In-Vehicle Navigation Unit Characteristics

Characteristic	Alpine NVA-N751A	Zexel NavMate
Picture		
Current vehicle position	Yes	No
Destination Memory Types		
Previously entered destination	Yes	Yes
Editable address book	Yes	No
Multiple destination route planning	Yes	No
Routing guidance methods		
Shortest time route	Yes	Yes
Minimum turns	Yes	No
Maximum freeways	Yes	Yes
Minimum freeways	No	Yes
Minimum toll roads	Yes	No
User-selected road avoidance	Yes	No
Man-machine interface features		
Map display	Allows panning	Centered on vehicle position
Map zoom	7 levels	5 levels
Map orientation	Heading up/North up	Heading up/North up
Guide display	Yes	Yes
Route Maneuver preview	Yes	Yes
Name entry technique	Scroll list / “keyboard”	Scroll list
Brightness adjustment	Yes	Yes
Night/Day setting	Yes	No
Voice Prompting	Max / Normal / Min	On / Off
Volume Control	Yes	Yes
Rerouting	Manual / auto	Manual
Map Data Source	NavTech	NavTech
Hardware		
Display	5.6-in. color LCD	4-in. color LCD
Data storage	CD-ROM	PCMCIA hard disk
User input device	Cordless remote control	Display-mounted keypad
GPS antenna	Yes	Yes
Gyro	Yes	Yes
Wire harness	Yes	Yes
Display cable	Yes	Yes
Display mount	Rigid shaft with ball joint	Flexible shaft with ball joint
STIC interface	External module	External module

pages were viewed, how long the visitor remained at the site, and which browser (and browser version) was used.

These files can become large with some sites generating over 20 Gigabytes of data per month. Consequently, the study of the San Antonio Web site utilizes the commercial software product

WebTrends™ to assist in analyzing these large log files. Using WebTrends™ log analysis software, the customer satisfaction evaluation considers the following indicators of Web usage in San Antonio:

- Number of user sessions, by month, from May 1998 through February 1999;
- Relationship between user sessions, page views, and hits for this Web site;
- Rate of change in use over time;
- Effects of extreme weather events on Web usage;
- Patterns of Web use by day of the week;
- Patterns of Web use by time of day for weekdays, and the weather event days; and
- Number of page views for the most popular pages.

TransGuide conducted a Web site survey to gauge public opinion on the TransGuide project areas, including the Web site. The survey was voluntary and a total of 150 people responded to the questions on Web site use during a three-month period after the initial evaluation.

In-Vehicle Navigation Units

Five focus groups and a project specific questionnaire were used to evaluate the customer satisfaction impacts of the IVN project.

Focus Groups

Five focus groups were held in San Antonio between August 18 – 20, 1998 at the Galloway Research facilities. There were two groups of non-uniformed, general use drivers and one group each of police, firefighters, and paratransit drivers. Respondents were public sector employees whose work vehicles had been equipped with an IVN unit that provides route guidance and real-time traffic information. Participants were identified and recruited by members of the project team. Each group lasted one-and-a-half to two hours and consisted of four to nine respondents. There were 33 respondents in all, 30 men and 3 women, including 12 general drivers, 4 police, 9 firefighters, and 8 paratransit drivers. Participants were offered monetary stipends for their participation, except where prohibited by agency rules.

Participants were recruited to include the different driving purposes of the participating agencies, to achieve a mix of driving locations in the San Antonio area, and a likely mix of IVN use experiences. All participants must have worked at their agencies prior to IVN installation, and all must have had adequate exposure to the use of the IVN. Hence, selection focused on drivers who were assigned full time to an IVN equipped vehicle as opposed to drivers who occasionally used the IVN in a pooled vehicle. Groups were organized by driving purpose and occupation to enable people who were otherwise unacquainted to move quickly through a period of familiarization with one another and focus their discussion on the ways in which they use the unit.

The facilitator worked with the research team to develop a discussion guide that was used to suggest lines of discussion and probes to elicit opinions on all aspects of the IVNs. At the beginning of the sessions, respondents were asked about their initial use and training relating to IVN. As the sessions progressed, respondents discussed ongoing experience with the IVN units, concerns, problems, ideas for improvements, and other possible uses for IVNs. About two-thirds of the way through each session, the facilitator would consult with other members of the research team who were observing to consider any additional topics to include in the discussion.

Questionnaires

The research team used a written survey in order to answer questions about user satisfaction with the IVN devices. Working with a contact person for each agency or department, the team sent the questionnaires to that person for distribution to the IVN drivers from that organization. The survey questions themselves were designed partly in response to the results of the five focus groups conducted with IVN users. The focus group discussions highlighted different areas and particular concerns, such as training and assessment of product features that the surveys pursued further. The questionnaires also address the areas of product awareness, expectations, use, response, and perceived benefits. In all, 995 surveys were distributed and 290 (29 percent) were returned.

Improved Traveler Information: System Impacts Evaluation Approach

System impacts evaluations were performed for both the Web page and IVN projects. As in the traffic improvement study, this analysis focused on the impacts of the traveler information improvements on the metrics of mobility, safety, and fuel consumption. The metrics were considered from both a system-wide and individual user perspective.

Kiosks

There was no consideration of the system impacts of the kiosk project given the observations of limited system functionality and the prediction of low usage rates.

Web Pages

An analysis of the system impacts of Web pages was performed utilizing the same microscopic modeling techniques used in the improved traffic management analysis and described in Section 4.2. For this particular analysis, Web users were modeled in a similar fashion to radio users with the exception that the Web users receive information prior to the start of their trips, not en-route. As with the radio users, the information received by the Web users is also an average of 10 minutes old.

In a slight departure from the improved traffic management analysis, the analysis of Web page users focuses more on individual, as opposed to system-wide benefits. This stems from the fact that the market penetration of the Web page is still very low (less than 0.1 percent) in the San Antonio area.

In-Vehicle Navigation Units

As with Web pages, some micro-simulation modeling was performed for the IVN Units. For this modeling, the IVN users were assumed to operate in a similar fashion to Web and radio users, except that they receive data en-route and that data are only 1 minute old on average.

In addition to simulation modeling, the results of the focus groups and surveys were also culled to provide additional insights into the system impacts of delay and safety on IVN users.

5.3 TRAVELER INFORMATION COSTS

5.3.1 Kiosk Costs

The total costs for the kiosk project are shown in Table 20. The most striking observation is the nearly $761,000 expended on development labor costs, which comes to almost $17,000 per kiosk. Combined

Table 20. Kiosk Costs

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
Indoor Kiosk	36	$ 428,040	
Outdoor Kiosk	4	$ 68,136	
Kiosk Installation	40	$ 48,440	
8-Port Modem Server	1	$ 2,946	
Route Guidance Development Tools	1	$ 5,687	
Map Modification (bus stops)	1	$ 20,000	
Indoor Prototype	1	$ 30,401	
Outdoor Prototype	1	$ 33,650	
Development Labor Costs	1	$ 760,965	
33 percent Share of AWARD/KIOSK/IVN Master computer	1	$ 5,131	
50 percent Share of STIC FM Broadcaster	1	$ 62,978	
Development Labor Costs	NA	$ 60,000	
Kiosk Regular Maintenance	NA		$ 57,403
Kiosk Equipment Updates	NA		$ 9,840
Kiosk Database Updates	NA		$ 9,927
Kiosk Phonelines	NA		$ 24,404
Kiosk Operations	NA		$ 24,601
Kiosk Weather	NA		$ 2,952
4 percent Share of 25 TransGuide Personnel	NA		$ 20,665
4 percent Share of Software Maintenance and Upgrades	NA		$ 5,904
4 percent Share of Hardware Maintenance and Upgrades	NA		$ 934
50 percent Share of FM STIC lease	NA		$ 19,435
Totals		$ 1,526,374	$ 176,065

with the costs of the hardware, this results in a total cost of approximately $29,000 for each indoor unit and $34,000 for each outdoor unit. By comparison, the cost for similar systems in Phoenix was nearly half, at approximately $15,000 per kiosk. The primary difference between the two sites is that the Phoenix costs were off-the-shelf. In San Antonio, the units were essentially designed from scratch. Furthermore, a system integrator conducted the design of the San Antonio kiosks with relatively little direct experience in kiosk design and deployment.

Recurring operations and maintenance costs are 10 percent of the total deployment costs. When the cost of leased phone lines, maintenance, updates, and purchased information is taken into account, it will cost about $150,000 a year to keep the kiosk project running.

5.3.2 Web Site Expansion Costs

The Web page already existed at the beginning of the MMDI project, and was upgraded as part of the deployment. Operation and maintenance costs for the Web page are almost $30,000. The total cost for the Web page project is shown in **Table 21**.

Table 21. Web Page Costs

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
One Time Software Upgrade	NA	$ 3,000	
Software Maintenance	NA		$ 16,401
Communication / Web Interface	NA		$ 12,301
Totals		$ 3,000	$ 28,701

5.3.3 In-Vehicle Navigation Units Costs

The cost of the IVN units was the most significant cost of this project. Both the Alpine and the Zexel units cost approximately $2,800 each. Almost all of the costs not related to purchase of the units was attributable to labor. The maintenance cost for the program, at a little over $100,000 a year, is only a small fraction of the deployment costs. Most of the operations and maintenance costs would go toward maintenance of the database and master computer hardware and software, as well as additional TransGuide personnel. Most of these are fixed overhead costs. The costs for this project are shown in **Table 22**.

Table 22. In-Vehicle Navigation Unit Costs

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
Zexel IVN unit	290	$ 833,460	
Alpine IVN unit	300	$ 855,900	
Navigation System Development Package	NA	$ 94,906	
Development Labor Costs	NA	$ 476,316	
33 percent Share of AWARD/KIOSK/IVN Master computer	NA	$ 5,131	
50 percent Share of STIC FM Broadcaster	NA	$ 62,978	
Development Labor Costs	NA	$ 60,000	
IVN Maintenance	NA		$ 11,919
IVN Database Updates	NA		$ 42,862
IVN Dial Up Phonelines	NA		$ 610
4 percent Share of 25 TransGuide Personnel	NA		$ 20,665
4 percent Share of Software Maintenance and Upgrades	NA		$ 5,904
4 percent Share of Hardware Maintenance and Upgrades	NA		$ 934
50 percent Share of FM STIC lease	NA		$ 19,435
Totals		$ 2,388,691	$ 102,330

5.4 CUSTOMER SATISFACTION OF IMPROVED TRAVELER INFORMATION

5.4.1 Customer Satisfaction with Kiosks

Although some users were observed obtaining information from the TransGuide kiosks, not all kiosks were operational when visited. Data automatically recorded from the kiosk system suggested that perhaps half of the kiosks were not operational. These data suggested that operational kiosks underwent downtime lasting one or two days. A touch control was found that would cause downtime in at least one kiosk, suggesting a possible explanation for the downtime inferred from kiosk use data.

Usability was found to be limited. Features such as route guidance and printing were not functional on all kiosks. Substantial problems were found with the design of the touch interface including scroll bars that were too narrow and system response delays that were too long. Instructions, labels, and map legends were missing in some cases. Use of some touch controls (i.e., buttons) caused system failure. It appears likely that the limitations that were observed would reduce the amount of use and inhibit potential satisfaction with the kiosk system.

While numerous recommendations could be made from the foregoing findings, the following are considered the most valuable to the traveler and transportation system, given the probable cost of making the modifications.

- Use signage and the kiosk screen saver (attraction loop) to communicate kiosk functions.

- Re-design the user interface to permit a wider scroll bar, such as the one that is used on the Transit Authority Information screen, to control all other menus.

- Reduce the size of the alphanumeric and other control buttons on the associated touch keypads to make room for the wider scroll bars and to eliminate, or at least reduce, the incidence of touches on inactive parts of buttons.

- Modify the Find Address screen so that street numbers are entered prior to the street name, valid street numbers can be selected from a menu, and characters can be individually deleted from the entry boxes (e.g., using a backspace control) for both street number and street name.

- Implement a different method of closing the route guidance window.

Finally, converging evidence from this and other evaluations is arising that suggests that even if the numerous usability limitations identified above were addressed, the use of kiosks for dedicated traveler information may have limited utility. For example, the traveler information kiosk project in Seattle was cancelled because the partners did not feel that kiosks provided a cost-effective medium for dissemination of traveler information. Furthermore, the kiosks used in the I-40 corridor and ultimately in the Phoenix MMDI, were found to have very low usability rates even in the absence of many of the functionality limitations identified in San Antonio.

Overall, if kiosks are to continue to be a component of traveler information services, some changes in their deployments must occur. Possible approaches include restricting their deployment to strategic, high-traffic locations, such as truck rest stops or train stations, or the bundling of traffic information with other information, such as tourist activities, etc. This latter approach is supported by the evaluation in San Antonio, where the limited numbers of users who were observed using the system were primarily interested in weather information.

5.4.2 Customer Satisfaction with Web Pages

As discussed in Section 5.2, the customer satisfaction analysis of the Web page project in San Antonio focused on levels of usage, the impacts of unusual events, the temporal patterns of usage, the most popular page views, and the TransGuide Web site survey.

Levels of Usage

The first step in the analysis of the TransGuide Web pages was to quantify both the existing level of usage of the site and the growth, if any, of that usage. As **Figure 6** reveals, determination of these values

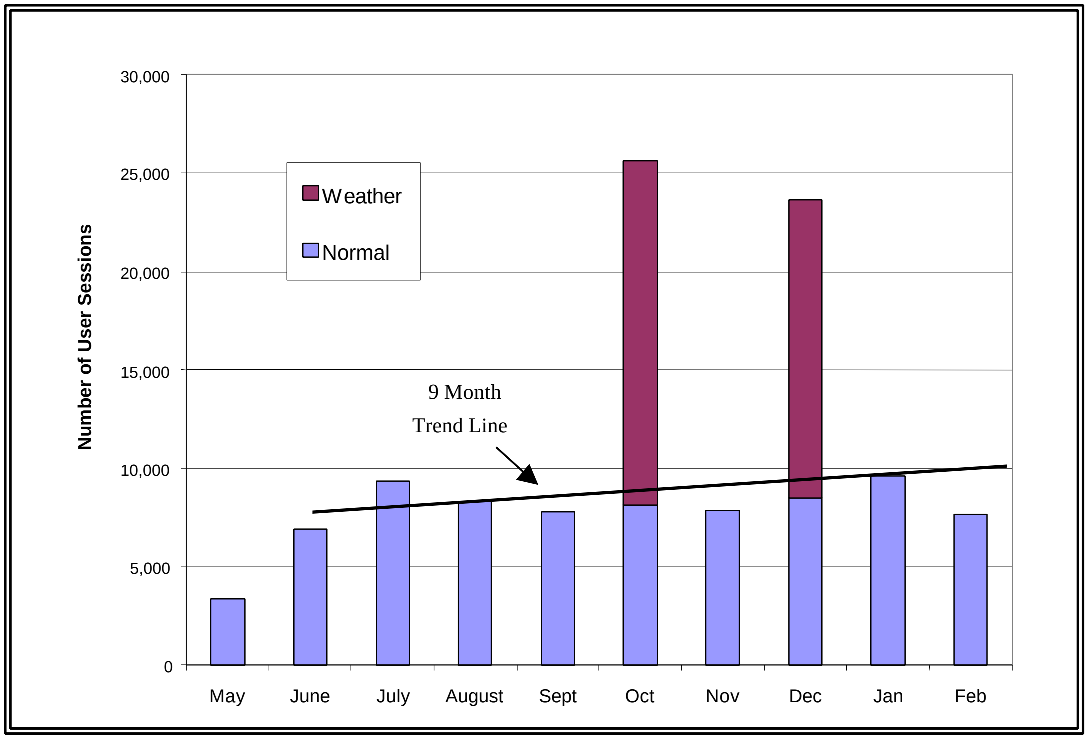

Figure 6. Total Web Page User Sessions from May 1998 to February 1999

was complicated by wide swings in the monthly values of the site's usage. Between May 1998 and February 1999 the usage rates varied from a low of 3,368 user sessions in May 1998 to a high of 25,650 user sessions in October 1998. However, much of this variability can be explained by two factors.

First, an examination of daily use of the Web site reveals that the very heavy use levels experienced in October and December were directly related to severe weather conditions that occurred in San Antonio during these two months. Second, it was revealed that the May 1998 usage was likely to be artificially low due to Internet server problems that were experienced during that month.

In order to estimate the underlying growth in usage of this Web site, a linear regression trend line was calculated for the period from June 1998 through February 1999 based on the number of "normal" user sessions per month. The trend line from this analysis is depicted in the figure and suggests an increase in Web usage of 19 percent per year.

Use Impacts of Unusual Events

Returning to the large spikes in Web page usage evident in Figure 6, it is noted that similar spikes, also attributable to inclement weather, have been observed in the analysis of Seattle's traveler Web pages. These spikes are of great interest in the evaluation of Web page traveler information resources as they indicate both the latent demand that may tapped and the extreme boundaries to which the capacities of the Web site servers must be designed. Spikes in usage levels reflect a response to abnormal or unexpected conditions that indicate that travel conditions may need to exceed a threshold of average, or expected, congestion before users will be motivated to access traveler information.

The first of these events in San Antonio occurred in October of 1998. At that time, Texas experienced a protracted period of severe rain and flooding. This was concentrated in San Antonio between October 17–22, 1998. The first three days of the event alone represented a spike in the use of the TransGuide traffic information Web site of 19 times the average usage level for the other days in the month. However, as **Figure 7** indicates, the level of Web site use soon tapered off to the baseline "normal" level of use as the effects of the flooding subsided.

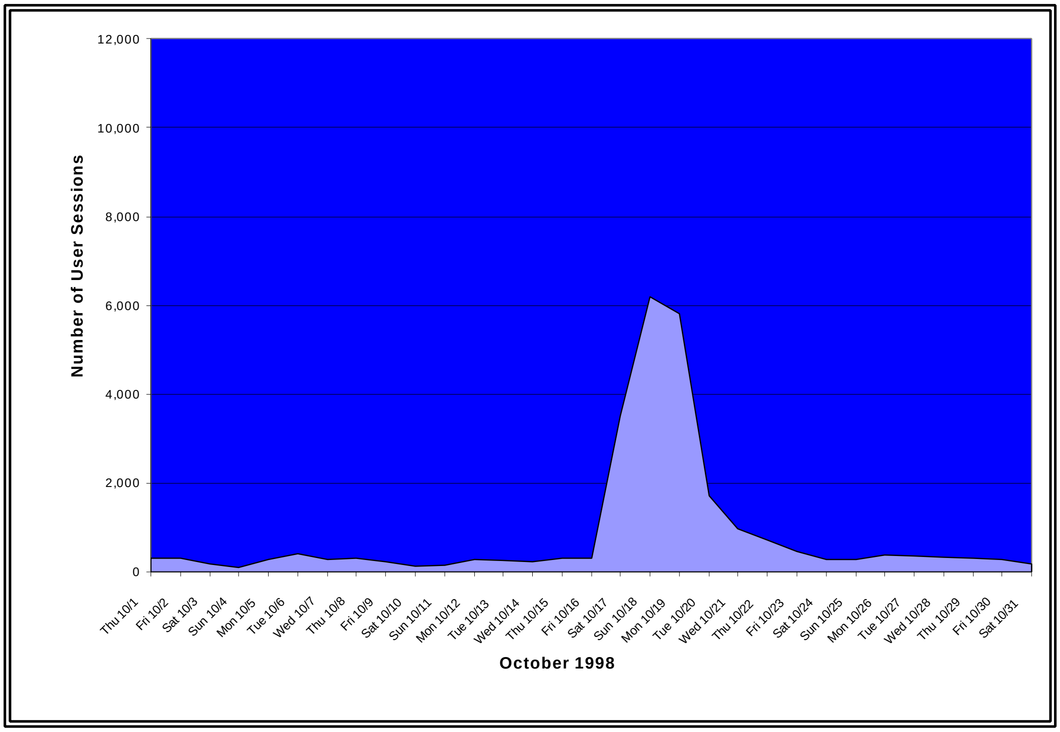

Figure 7. Number of Web User Sessions during Flooding, October 1998

The December event was shorter in duration and its effects on Web use were sharper. However, the volume of Web usage was comparable. At the time, San Antonio experienced an ice storm December 22–24, 1998. Because the impact on the roadways in the area was so severe, TxDOT made a special effort to notify the public over radio and TV of the availability of up-to-date traffic information on the TransGuide Web site. Given the value of this information under such conditions, coupled with heightened awareness on the part of the driving public, the three-day volume of use of the Web site in December also jumped 19 times over the baseline average daily use (with the weather effect removed) for that month. That is, for those three days of most intense Web site use, the level of use was 19 times greater than it would have been if those had been "normal" use days. This again reflects the large potential pool of Web site traffic information users. Within two days, the Web site use had dropped back down to normal levels, as soon as the icing effects had dissipated.

This dramatic impact on Web site use in these two examples suggests that there is significant latent demand for traffic information on the Web site in the San Antonio area that is manifested only when conditions are unusual. There appears to be a core of regular users of the site, along with an additional pool of potential users who are aware of this information source, have access to the Internet, and readily seek out the information when the need for it is especially compelling.

Prior to this analysis, it seemed reasonable to hypothesize that a portion of new users who are drawn to the Web site as a source of traffic information by an unusual event such as this would stay on as more regular users. However, the limited data observed over this 10-month period do not appear to support such a hypothesis. Usage levels dropped after each brief, major spike due to severe weather such as experienced in San Antonio in October and December.

There are several related questions that can be explored with the Web site use data.

- Do unusual events tend to attract new users to the site, or do the regular users use the site differently, engaging in more user sessions per day or perhaps accessing a wider range of traffic information during their user sessions?

- Do the user sessions exhibit different time-of-day patterns of access during these unusual events, compared to normal days?

The relatively crude nature of the Web log data doesn't allow these questions to be answered definitively, but they are suggestive of underlying patterns of use. The following sections look at time-of-day patterns for commuting and non-commuting periods and day-of-week use patterns.

Patterns of Web site Use

Figure 8 shows the pattern in number of user sessions for three weeks in February 1999 by day. This portion of February appears to be relatively unaffected by events that might tend to distort the usage patterns from normal, such as adverse weather, or other disruptions of traffic in the area that would have an impact on usage.

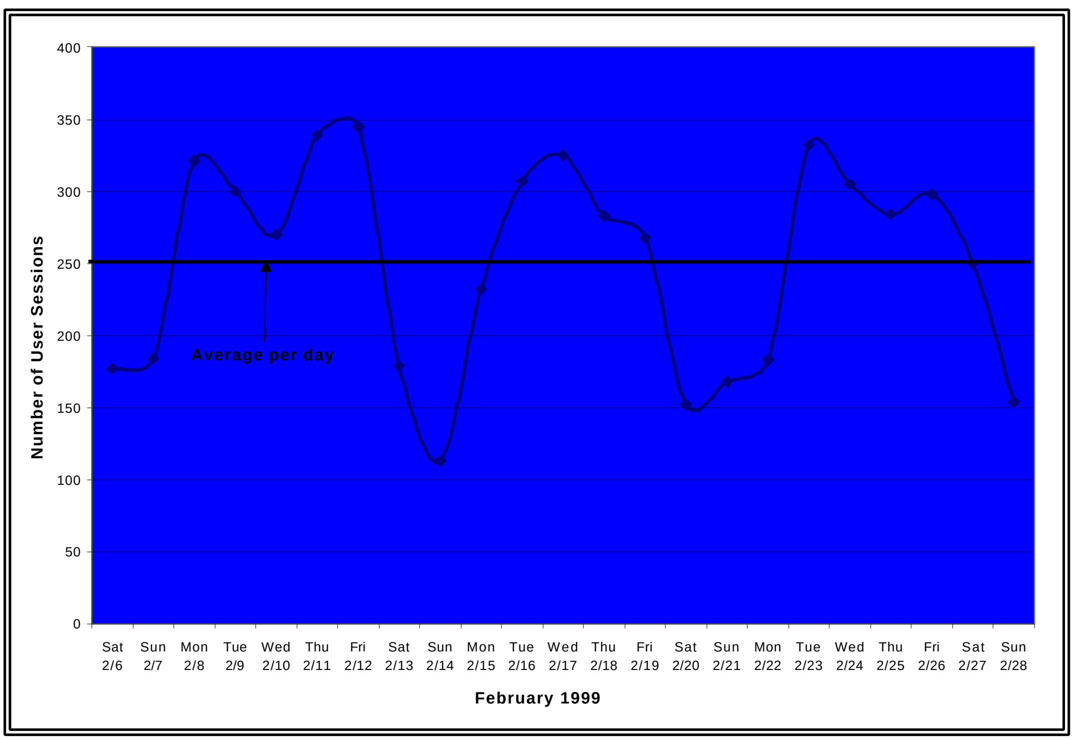

Figure 8. Number of User Sessions Per Day, February 1999

The patterns shown in figure 8 are quite typical of the use of traffic information Web sites. Use is higher during the weekdays and much lower on the weekends. Sundays are typically the lowest use days, but not always. Also characteristic of weekday use is a peak effect on Mondays and Fridays, but as is shown in figure 8, this too is not always true. The higher weekday use of the Web site reflects the higher traffic levels on weekdays associated with commuting, shopping, and other normal driving patterns in urban areas.

Figure 9 explores further the patterns associated with commuting. For this same three-week period in San Antonio in February, it is possible to observe how use of the traffic information Web site varies by time of day for weekdays only. This three-week period shows a pronounced peak in use of the Web site during the afternoon commute period from about 2 PM to 5 PM. Contrary to the bi-modal pattern that can be observed in some cities, there is no evidence of a comparable peak in use during the morning commute. Findings from focus group and survey research suggest that commuters often experience more uncertainty and greater traffic congestion during the afternoon commute compared with the morning commute. Furthermore, demographic data suggest that more people have access to the Internet, and are more likely to use a computer for traffic information, at their office in the afternoon before leaving work than at home prior to departing for the office in the morning. The average number of user sessions per day for this 15-day period of weekdays in February is a little over 290 user sessions per day. While not every month has been analyzed at this level of detail, enough have been sampled to confirm that this general pattern holds up for normal weekdays.

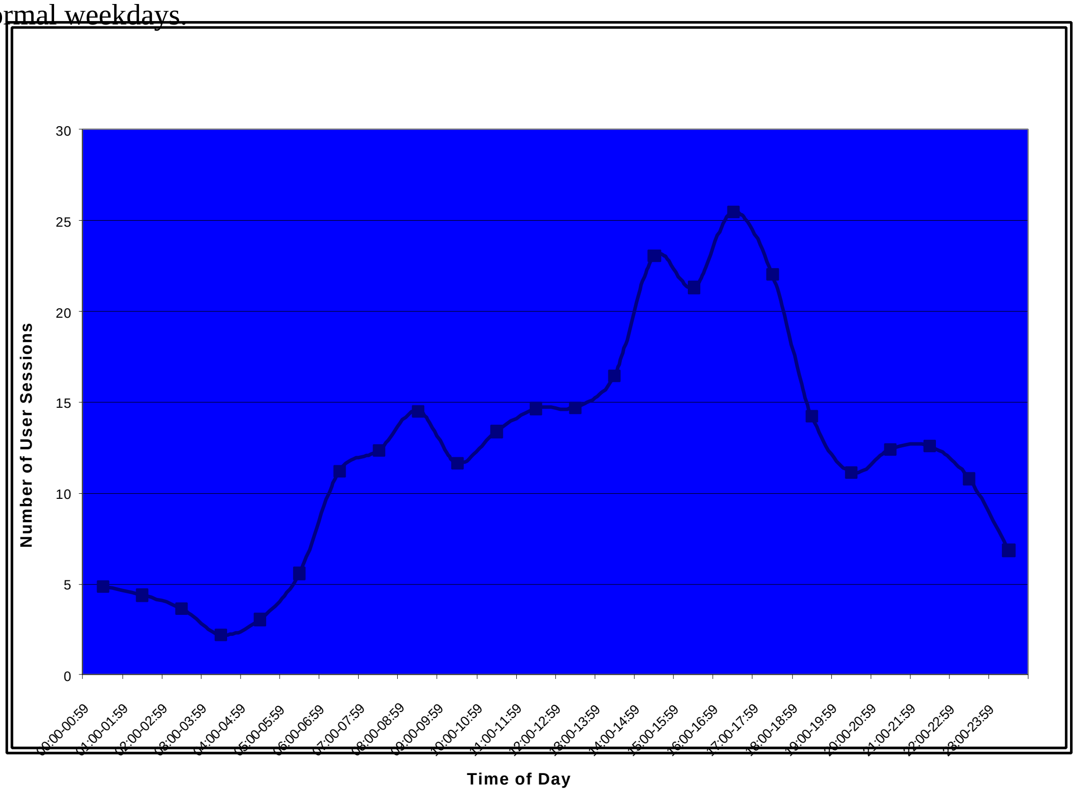

Figure 9. Average Number of Weekday User Sessions Per Hour, February 8–26, 1999

Most Popular Page Views

During a session, a user could view from one to many individual page views. Which pages they tend to view reflects traveler preferences for certain kinds of traffic information, as well as effective ways of presenting and promoting that information. The Web site page content that has the most value for the user will presumably be viewed most frequently. An analysis of the TransGuide Web log files reveals the top 10 page views for the month of February 1999. This is illustrated in **figure 10**.

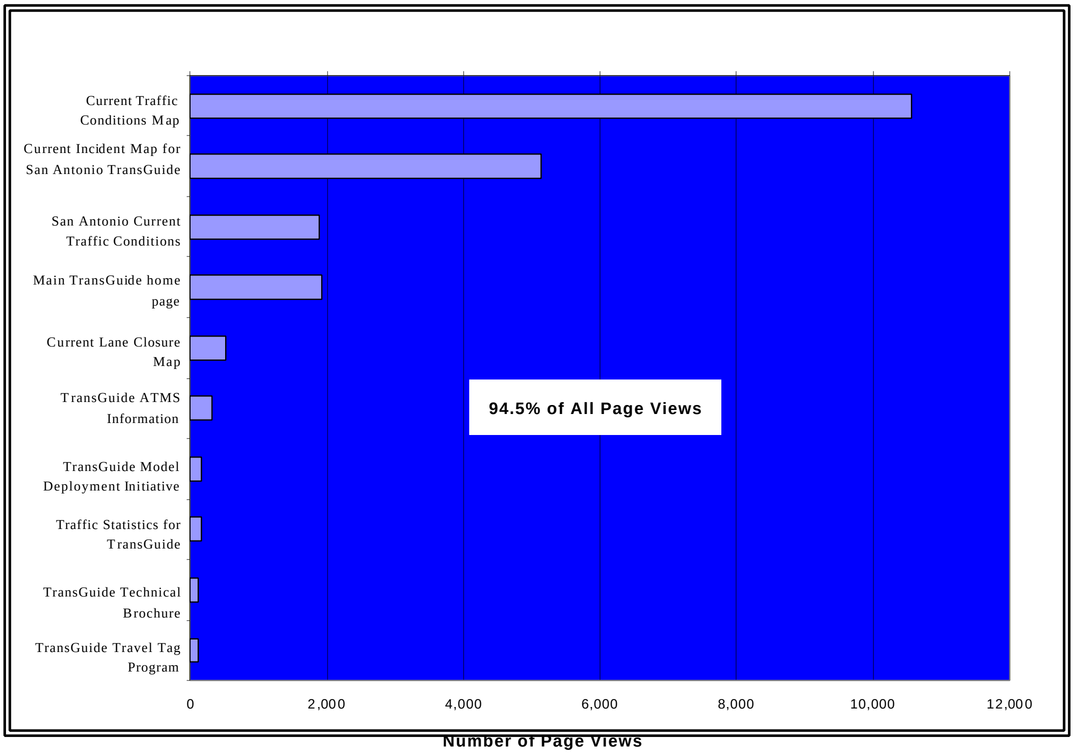

Figure 10. Top Ten Page Views on the TransGuide Web site for February 1999

The strong visual message in figure 10 is that traveler interest in the TransGuide Web site is concentrated in only a few of the traveler information pages. Almost a quarter of all page views in February 1999 (23 percent) were associated with the current traffic conditions map (see figure 5 as well for an image of this map). The top four page views accounted for over 88 percent of all page views during February, and the top 10 page views accounted for 94.5 percent of the activity on the 2,218 available pages. This concentration of interest in the site on these few key traveler information pages is a reflection of what the public in San Antonio is interested in. However, since only five pages carry dynamic traveler information, the options of where travelers can go, assuming they are primarily seeking updated traffic conditions information, is limited to these and a number of other pages. As the site expands and adds more pages, particularly camera image pages, the user interest can be expected to spread more broadly across other such pages on the Web site.

TransGuide Web Site Survey

TransGuide conducted a Web site survey after the initial evaluation period. The survey was displayed on the Web site and responses were voluntary. At time of writing, there were slightly over 150 responses.

Responses to the TransGuide Web survey shows that users generally find the information provided by the Web site useful. On a scale from 1 to 10, with 1 being not useful and 10 being very useful, respondents rated the Web site's usefulness 7.5. Several respondents thought that adding video to the Web site would increase its usefulness. This is consistent with findings in Seattle where 8 of the 10 most popular pages on the Web site were video. In response to these suggestions, San Antonio is planning to capture still images from video and place them on the Web site.

Summary of Customer Satisfaction with Web Pages

A number of tentative conclusions from this Web use analysis can be drawn. However, it must be recognized that Web use data are complicated by measures of use that have no relationship to actual individual travel behavior in San Antonio (e.g., site access from outside the region, agency maintenance uses, server glitches). Furthermore, the software is very limited in its ability to distinguish individual uses of the site from automated processes (e.g., server refresh, proxy caching). Nonetheless, the following conclusions seem plausible, notwithstanding these inherent limitations:

- The level of use appears to be growing slowly over the period of observation and can be expected to continue in that fashion in the future. It is reasonable to anticipate that, as the miles of roadway under surveillance increase over time with the full implementation of Phase II and subsequent phases of the TransGuide program, usage of the Web site also will increase. This will be reinforced by increases in computer use, Internet access, and awareness of the availability of TransGuide's traveler information Web site.

- The dramatic but short-lived jumps in Web usage during periods of extreme weather in San Antonio of 19 times over baseline use demonstrate both the significant latent demand and the growth potential for traveler information provided over the Internet. Prior research has indicated that people seek out traveler information from multiple sources. When the need is great for traffic conditions detail at any time of day, San Antonio travelers will turn to the Web site. But during more "normal" conditions, usage drops back to "normal."

- Commuters are a significant component of the Web site user population. The effect of their use of the site is reflected in a pronounced peak in use during the afternoon commute period on weekdays. This pattern substantiates other data that indicate greater Internet access at the office than at home. The San Antonio use data also suggest that during periods of very bad weather and impaired road conditions, Web site access may be greater during the morning period. Overall, commuters appear to dominate Web site use, as usage levels are more than twice on weekdays what they are on weekends under normal conditions. Of course, the general absence of congestion on weekend days removes most of the motivation for a traveler to seek out traffic information.

- San Antonio travelers have a strong preference for dynamic traveler information over other static forms of information. The main traffic conditions map captured almost a quarter of all usage of the site (February 99 analysis). Almost 95 percent of all activity on this site was associated with only ten pages of information (out of a total 2,218 pages on the site).

Traveler information Web sites are becoming very popular with state DOTs around the country, and San Antonio's Web site is no exception. The infusion of MMDI funding in support of better and more information that can be provided through the Internet is being well received by travelers in the San Antonio area. This is reflected most dramatically in the very large spikes in usage created by the very severe weather events that hit the area in October and December of 1998. San Antonio's TransGuide program is actively developing their Web site and expanding the range of dynamic traveler information offered through the Internet.

5.4.3 Customer Satisfaction with In-Vehicle Navigation Units

The primary objective of this evaluation is to provide insight into public-agency driver experience with real-time traffic-equipped IVN Units. These findings, based on the experience of the San Antonio drivers, suggest recommendations that will help to ensure a productive experience for future IVN placements among agency drivers. These findings may be helpful to TransGuide as they consider possible reassignments of devices within agencies or to other agencies in the San Antonio area. They may also be helpful to agencies in other locations that might be considering a similar agency-based deployment. Finally, these findings may help design modifications and refinements are considered that could make IVNs more effective in an agency context.

- **The driving task is the best predictor of IVN use, satisfaction, and value.**

Results from this evaluation suggest that there are a number of factors that influence and explain agency driver satisfaction with the prototype IVN units deployed during this study. The primary factor is the nature of the driving task, including number of hours per week spent driving. Respondents who drove more than 35 hours a week found the IVN more useful than those who drove fewer hours. Among those drivers, three sets of drivers reported a higher number of reasons for using the IVNs:

(1) those who had dispatchers who gave them different routes with every shift,

(2) those who drive to new or unfamiliar locations regularly, and

(3) those who primarily transport people (regardless of purpose for transport).

Of the drivers who report that they never use the IVN, or used it when first installed but not since, over 98 percent attributed non-use to knowing the area well. Sixty-one percent said the addresses take too long to enter, and 50 percent said the IVN-generated routes were longer. This supports the observation that the unit is most helpful to those who are driving unfamiliar routes.

- **Curiosity, saving time, safety aspects, ease of use, and convenience were frequently cited as reasons for IVN use.**

Drivers who used the IVNs indicated a variety of reasons for using the devices, but five reasons were at the top of the list, each with almost 60 percent of the users listing it as a reason:

- Wanted to see what unit can do
- Saves more time than paper maps
- Spoken directions are safer than paper maps or written directions
- Easier to find unfamiliar destinations
- Easier than asking for directions

People were much less likely to use the IVN as a means to help them avoid traffic congestion, which is not surprising since relatively few people knew about this feature of the devices. Respondents were also less likely to use the IVNs to help them plan a schedule of stops for the day.

Drivers who said they primarily transported people were more likely to give safety reasons for using the IVNs. They were more likely than other drivers to report that they used the devices because IVNs allowed them to avoid traffic congestion and because they were easier to see in the dark. Respondents who transport people include emergency medical technicians, paratransit drivers, school bus drivers, and van drivers. Timing would also be important, as most riders have appointments to keep, and unexpected congestion would create delay. Finally, these drivers are often driving early in the morning and after dark, making map visibility a useful feature.

Respondents who said dispatchers gave them new routes every day were also more likely relative to other drivers to report safety reasons for using the IVNs. They were also more likely to say that the IVNs saved them time relative to paper maps, and that the devices helped them to schedule stops for the day. Because these drivers generally drive alone, the spoken directions would keep them from having to look at a map while they drive. Similarly, drivers who said they drove to new or unfamiliar locations regularly said they used the devices because they liked computers, they saved time relative to paper maps, and they were easier to see in the dark.

- **Formal training may not be a necessary precondition to driver satisfaction, but it is needed for drivers to appreciate the full functionality of the unit, and to dispel drivers' concerns.**

Drivers who received formal training from a trainer outside of their own agency knew more about the functionality of the unit than those who did not. Even including those who received formal training, most respondents were very dissatisfied with the training they received, and felt that they would get better use from the IVN if they understood more about it. Many drivers believed that the units were being used to track their whereabouts. Some had not turned on the unit because they did not want to be traced. Proper training might have dispelled those fears. Even those drivers who reported that they figured out how to use the units on their own thought that a formal training session of some kind would be useful.

- **Management or supervisor support is a useful precondition for IVN use and driver satisfaction.**

In looking at the findings of the focus groups combined with survey responses, several factors appear as preconditions for a good match of driver to IVN. There is greater use of the units when management (or institutional) supports the units, there is proper training, and the units make the job easier.

- **Drivers were generally satisfied with the IVN features, and had many suggestions for improvements.**

People generally seemed quite satisfied with the existing features of the IVNs. Respondents rated clarity of the IVN voice, the screen, and ease of reading the map views quite highly. In fact, one maintenance staff member reported that some drivers often refuse to take vehicles that do not have an IVN unit.

The most popular suggestion for improvement was that the IVNs display traffic incidents on people's routes. Following this, suggestions for improvement tended to focus on entering destinations, such as keyboard or touch entry screens. This suggested improvement was mentioned frequently in respondents' written suggestions: they found the scrolling too time consuming, and the remote control too awkward to use easily in the vehicle. The amount of time required to enter destinations was cited by half of the non-users as the reason they did not use the IVN; they said that it takes them less time to consult paper maps, than to use the IVN. The second most popular suggestion for improvement was that there should be an easy way to change or delete a destination while driving.

- **Too few respondents understood and used the TransGuide real-time traffic information feature to properly assess its value to agencies and their drivers.**

So few drivers made use of the information, it is difficult to present any type of conclusion with regard to the real-time traffic feature.

- **Agency vehicles may not be suited for wireless remote controls for IVN units.**

Discussion in the focus groups and responses to the survey suggest that a wireless remote control is likely to be lost among other work-related equipment in many agency vehicles. Police officers described high-speed emergency situations when the remote went flying across the car. While survey data cannot support this conjecture, focus group respondents said that several of their colleagues “lost” the remote controls, and their units became unusable. People who used the Zexel unit were more likely than Alpine users to say that they found the IVNs to be useful, perhaps because of the difficulty of keeping track of the Alpine handheld remote units.

- **Problems with IVN installation and maintenance interfered with IVN use.**

Just over 48 percent of respondents said that there had been some problem that interfered with the functioning of the IVN since it was installed. Respondents reported waiting for repair for as long as four months. It seems likely that this is a one reason for non-use of the IVNs. When asked to provide comments or suggestions about the installation, operation, or maintenance of the IVN, comments centered on the impact of installation on vehicle and communication systems, poor positioning of the screen in relation to the driver and passenger, and long waits for repair.

- **Finally, IVN use and usefulness are related.**

It appears that people who used the IVNs more frequently came to find that they were more useful to them in their jobs, and people who found the IVNs to be helpful in their jobs were more likely to use the units more frequently.

5.5 SYSTEM IMPACTS OF IMPROVED TRAVELER INFORMATION

The following sections describe the impacts of the various San Antonio traveler information deployments on the system impacts of mobility, safety, fuel consumption, and emissions.

5.5.1 System Impacts of Kiosks

No systems impacts analysis was conducted for the traveler information kiosks owing to their low usage rates. It is likely that if an analysis were performed, the impacts would be small, if not negligible.

5.5.2 System Impacts of Web site

The San Antonio Web site is designed to assist drivers in choosing optimal routes between selected origins and destinations. An evaluation of the success of the site in achieving this goal was conducted using simulation modeling. This evaluation considered the range of conditions under which benefits in terms of delay, safety, and fuel consumption can be achieved and examines both the system-wide and user level magnitudes of these metrics.

User Level Impacts under non-Incident Conditions

In theory, tools such as the San Antonio traffic Web site can be used for the entire range of traffic conditions, including recurring or incident-free situations. However, studies such as those conducted in the Seattle MMDI, suggest that experienced commuters are unlikely to use these services under normal conditions. Using the site under incident-free conditions results in negligible benefits at best and minor negative impacts at worst.

As will be revealed in the subsequent sections, the real benefits of systems such as the San Antonio traffic Web site are achieved under abnormal or incident conditions. This observation reaffirms the importance of the sites containing timely, reliable, and geographically extensive real-time coverage capabilities.

System Level Impacts under Incident Conditions

ITS treatments may be examined at both the user and system level. System level impacts consider the net effect of the ITS treatment on every vehicle in a system. These aggregate results are most likely to occur in situations where ITS treatment affects a large number of users, as in the case of the traffic improvements examined in Section 4.

User level impacts consider the effects of the ITS treatment on individual users within the system. Cases may often occur where substantial user level benefits become lost in the noise of a larger system consideration. These situations most often occur where the number of users of the ITS treatment is very low relative to the total number of travelers in the system. Such is the case with the San Antonio traveler Web site project.

As section 5.4.2 indicates, while the number of Web site users is steadily growing at about 19 percent per year, the total number of users is still quite low – around 10,000 users per month. Assuming that each of these uses were tied to a given trip, this rate of usage suggests a level of market penetration of less than 0.1 percent of the total monthly trips taken in San Antonio in a month. When, an examination of the system-level impacts of the San Antonio Web sites was conducted at a rate of usage even 10 times this value (1 percent) the results could not be detected from the background noise. Therefore, it is safe to assume that, for the foreseeable future anyway, the San Antonio Web site will not have a significant impact on the overall travel conditions or system-level metrics. Nonetheless, as is revealed in the subsequent sections, there remain substantial benefits for individual users.

User Level Impacts under Incident Conditions

Table 23 summarizes the user level impacts that may be expected by a traveler using the San Antonio Web site. The most notable observation is that the Web appears to be very successful in fulfilling its primary purpose of assisting travelers in avoiding delays. These delay savings transcend the entire range of incident types and range as high as 22 percent.

While these delay savings are also accompanied by improvements in average vehicle speed, many of the other metrics do not perform as well. Values for number of stops, crash risk, and fuel consumption are nearly negligible, or just slightly positive.

Overall, these results are not entirely surprising considering that for freeway incidents, such as those examined, the Web pages act to divert vehicles onto lower class, signalized arterials. This operation is similar to that of freeway management and produces similar outcomes.

Table 23. User Impacts of Web Page Usage (Individual Benefits)

Incident Scenario	ITS Improvement	Average User Delay (seconds)	Average Stops (per Vehicle)	Average Speeds (km/hr)	Average Crash Rate (per million vehicle km)	Average Fuel Consumption (L/100 km)
Minor	None	104.3	3.1	51.3	2.3	13.6
	Web	-1.9%	2.4%	0.6%	5.2%	0.8%
Moderate	None	110.9	3.2	49.0	2.4	13.7
	Web	-6.0%	1.8%	2.4%	5.1%	-0.4%
Major	None	185.4	3.3	39.3	2.8	14.7
	Web	-21.8%	-0.7%	11.3%	-8.5%	-2.9%

Calculation of Annualized Impacts

As in previous analyses, it is possible to determine the annual impacts of each of the major evaluation metrics under incident-induced conditions. As **Table 24** indicates, use of the Web pages over the course of an entire year would result in a time savings for each user of approximately 1 hour and 50 minutes. This value is nearly identical to that observed for the impacts of the Medical Center Corridor in Section 4.5.2.

Despite the delay reduction, the impacts on safety and fuel consumption are relatively minor. This is due, in large measure, to the tradeoff involved in rerouting drivers from the incident induced stop-and-go traffic on the freeway to the traffic signal induced stop-and-go traffic on the arterial network.

Table 24. Annualized Impacts of San Antonio Web site

Annual Impact	Delay	Crashes	Fuel Consumption
Avg. System Change	No impact	No impact	No impact
Average User Change	↓ 1.81 hrs/year	Nearly Negligible	↓ 0.3 L/year
Percentage Change	↓ 5.4%	↓ 0.5%	↓ 1.8%

5.5.3 System Impacts of In-Vehicle Navigation Units

This section discusses both the quantitative and qualitative impacts of the public-agency IVN deployment on the system metrics of delay, safety, fuel consumption, and emissions.

Modeled Impacts

IVN units, such as those deployed in San Antonio, can assist drivers in selecting optimal travel routes to avoid unexpected traffic problems. As **Table 25** indicates, such assistance can result in impacts on delay, safety,[14] fuel consumption, and emissions.

Table 25. User Level Impacts of In-Vehicle Navigation Units in San Antonio

Incident Scenario	ITS Improvement	Average User Delay (seconds)	Average Stops (per Vehicle)	Average Speeds (km/hr)	Average Crash Rate (per million vehicle km)	Average Fuel Consumption (L/100 km)
Minor	None	104.3	3.1	51.3	2.3	13.6
	IVN	-1.4%	4.9%	0.4%	0.2%	1.9%
Moderate	None	110.9	3.2	49.0	2.4	13.7
	IVN	-3.4%	3.3%	2.2%	-4.3%	0.6%
Major	None	185.4	3.3	39.3	2.8	14.7
	IVN	-38.2%	3.4%	20.9%	-11.4%	-4.9%

Furthermore, a quick examination of **Table 26** reveals that an IVN unit used to navigate the Medical Center Corridor area over the course of a year could save its owner over two and one-half hours of incident-related delay. This delay benefit significantly exceeds the values for other all other ITS treatments examined in San Antonio and is accompanied by corresponding reductions in fuel consumption and crash risk.

Unfortunately, because of the unique nature of the IVN unit deployment in San Antonio, the units were rarely used for the purposes of avoiding delay. As the results of the focus groups and surveys indicate, many of the public-agency users in the experiment had little or no desire to avoid congestion. Comments were made by police, fire, and ambulance members that they were typically responding to the cause of the incident and did not have option to route around it. Furthermore, most of the participants were not even aware that the system was capable of responding to real-time traffic conditions.

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(14) These safety values represent the change in exposure risk due to re-routing, they do not consider the inherent safety of using the device itself. However, comments from participants do not suggest any negative impacts.

Table 26. Annualized Impacts of In-Vehicle Navigation Units in San Antonio

Annual Impact	Delay	Crashes	Fuel Consumption
System change	No impact	No impact	No impact
Average User change	↓ 2.7 hrs/year	↓ 0.1 crashes/million km	↓ 0.21L/year
Percentage Change	↓ 8.1%	↓ 4.6%	↓ 3%

For these reasons, it is doubtful that a substantial number of public-agency users experienced the systems impacts described above. Furthermore, the net impact of the system at the system level is predicted as being negligible; a prediction confirmed through simulation modeling.

Qualitative Impacts

While the unique nature of the IVN deployment in San Antonio precluded many of the users from experiencing the delay saving component of the devices, the deployment did offer the potential for impacts on public safety. Specifically, the unique placement of the units in vehicles that provide emergency services may allow emergency personnel to perform their duties more effectively. Consequently, the public welfare may be served through potential savings to personal property and even lives. Investigation of the system's potential to offer these benefits was conducted through the focus groups with the police and fire personnel.

Police Officers

Police officers reported mixed results with regards to the public safety benefits of IVN. Two of the officers who had used the device indicated they had used the electronic map function to quickly read off cross-street names to other units during pursuits. They agreed this was much easier, especially in the dark, than looking for street signs. However, the officers agreed that pursuit assistance was not enough, on its own, to justify purchase and use of the system. Furthermore none of the officers reported using the system for route guidance to respond to emergency calls. They consistently reported that it took too much time to enter the destination using the existing interface to justify use of the system for that purpose. They did report that if the interface were improved through addition of a keyboard, or through computer aided dispatching, that IVNs could prove very useful in responding to emergency calls. One officer noted that such an improved system could save lives in a number of situations including drownings and shootings.

Finally, an unsolicited testimonial was submitted to TransGuide on the unit's performance. It speaks to a case where, in the first month of service with one of the area police agencies, an IVN unit was used to direct an AirLife helicopter ambulance to the site of a major vehicle crash. The GPS coordinates determined by the IVN unit were relayed to the helicopter, allowing the pilot to quickly pinpoint the site of the crash. It was estimated that on-scene units were able to reduce the time to the scene of the air ambulance by approximately six minutes. Time savings such as this have the potential to save lives and increase public safety and security.

Fire Fighters

As with the police officers, the fire fighters generally agreed that it takes too long to enter destination information for it to be useful for most first-response emergency calls. However, they did think that the system was helpful for mutual-aid scenarios. These are situations where a fire crew is placed on standby for a brief period of time, and then asked to assist a fire crew in another jurisdiction that has already responded and is on the scene. Under these situations there is time to enter destination information. The crews thought the IVNs would be helpful in these situations since these calls typically require them to respond to fires in areas with which they are less familiar. At least two examples were cited where the use of the IVN unit in mutual-aid scenarios had been effective in reducing response times. Even in situations where they did not use the route guidance capabilities of the system, the fire fighters felt that the system's positioning and mapping capabilities were useful for emergency response. A number of them reported the effectiveness of the system in indicating what street they were on and what the cross-streets were, especially when street-signs were not present or readily visible.

Overall, the fire fighters thought the IVN system was effective as it exists now, but could be very effective if improved. None of them found the system to significantly reduce operator safety, while they all thought that, even with its limited capabilities, the system was somewhat effective in emergency response. As with the police officers, the fire fighters thought the addition of a keyboard or a computer aided dispatching function would make the IVN a valuable tool in fire fighting, and could increase public safety.

5.6 SUMMARY OF IMPROVED TRAVELER INFORMATION IMPACTS

In summary, the San Antonio MMDI provides insights into the relative strengths and weaknesses of a variety of traveler information platforms. The following section discusses the major findings of the analysis of these traveler information projects.

Interactive kiosks may not be the best medium for traveler information. In San Antonio, the kiosks had a number of usability and maintenance issues. For example, it appears that as little as half of the systems were operational during the usability study period. In addition, there were problems with the touch-screen interface including scroll bars that were too narrow and system response delays that were excessively long. Taken together, these findings suggest the potential to negatively impact customer satisfaction and use of the systems. Furthermore, findings from other sites suggest that even if the San Antonio kiosks did not experience these shortcomings, it is unlikely that they would have experienced a high-degree of usage or acceptance. For example, a similar deployment along the I-40 corridor in Arizona resulted in very low usage rates, while the entire traffic kiosk project was cancelled in Seattle for fears the systems were not a good investment. While the prognosis for stand-alone, interactive traveler information kiosks is poor, the systems may offer some benefits if bundled with other services such as ticket sales, for example.

In-vehicle navigation units may offer benefits to public agencies. While the real-time traffic information component experienced relatively little use, both emergency and non-emergency public sector users found the electronic mapping function of the system helpful. Over 60 percent of the drivers who used the units reported that they found the IVNs made it easier to locate unfamiliar addresses, saved more time, were safer than paper maps, and were easier than asking for directions. In addition, a number of benefits were identified that are unique to emergency service use. Specifically, police officers reported using the IVN's mapping function to coordinate pursuits, and, in one case, to more efficiently direct an air-ambulance to a critically injured victim.

Improvements such as better training, maintenance, installation, and consideration of the time critical nature of emergency work could increase these benefits. While users of the IVN units were generally satisfied with the system, they had a number of suggestions for improvements. One of these suggestions was a call for better maintenance. Over 48 percent of the respondents to the survey reported there had been some problem with their unit, and some reported waiting as long as four months for the unit to be fixed. Such experiences likely contributed to a lower utility of the system than may otherwise have occurred. Another suggested improvement was for better installation of the unit. This is particularly important for public-agency use since such vehicles are often already full with a great deal of additional equipment. Training also appears to be a key element of successful public-agency IVN deployment. In general, most respondents were dissatisfied with the level of training they received and felt that with improved training they could make better use of the IVN units. Finally, it is clear that if IVN units are to be used for emergency usage there must be a faster way of entering destination addresses. The delays of up to two minutes experienced are unacceptable for emergency response. Possible solutions include automated links to a computer aided dispatching system.

Current use of traveler Web sites is quite low, however, there is a large potential market. Currently, the San Antonio Web site is only used about 10,000 times per month. This represents less than 0.1 percent of all the trips in the area. Use of the Web site is growing, though not as rapidly as in Seattle and Phoenix. One reason for this is that San Antonio does not have congestion as severe as the other two cities. However, spikes in usage as high as 19 times normal during situations such as heavy flooding indicate large latent demand for the service and support predictions of growth.

Even at current low levels of market penetration, the Web sites are predicted to offer substantial user benefits. While the level of market penetration is too low to have a significant impact on the overall transportation system, individual users of the Web site may be expected to experience benefits by using the service. For example, modeling predictions suggests that travelers through the Medical Center Corridor area could save as much as 1 hour and 48 minutes per year in incident-related delay. Similar benefits have been predicted for the use of the SmartTrek traffic Web site deployed as part of the Seattle MMDI.

6. IMPROVED EMERGENCY SERVICES

A further functional goal of the San Antonio MMDI was to improve the operation and provision of emergency services in the region. Previous sections of this analysis have examined how emergency services may be improved under the umbrella of other applications. For example, incident clearance times may be reduced through the Freeway Management Expansion project and police, fire, and paramedic services may benefit from IVN Units. This section examines the impacts of the LifeLink deployment – a project solely devoted to improving emergency services.

6.1 LIFELINK PROJECT DESCRIPTION

LifeLink is a unique project that allows doctors to be virtually transported from the hospital emergency room into the ambulance and by the patient's side. As deployed, the project allows video and voice teleconferencing capabilities between University Hospital and ten ambulances in the San Antonio Fire Department fleet. The system facilitates near-constant two-way audio and video communication between the attending emergency medical technician (EMT) in the ambulance and the doctor in the hospital's emergency room.

The LifeLink system uses the San Antonio TransGuide fiber-optic network for transmission of data. Radio antennas, or beacons, have been placed at 1.6 km or less intervals along the lengths of the TransGuide freeway management network. While the beacons can only receive transmission from one ambulance at a time, it is common for a single ambulance to be able to 'see' two or more communication beacons. Ambulance software is designed to look for, and connect to the hospital through, the closest of these beacons that is not being used by another EMT conference. The hospital is connected to the fiber-optic network through a fiber-optic line.

There are several pieces of equipment installed in each ambulance that is part of LifeLink. The ambulance system consists of the following five major components:

- **Video Camera**: Points toward the patient's torso while in its default position. It can be panned, tilted, and zoomed as needed by the EMT through the use of a handheld remote control.

- **Two Video Monitors**: One of the monitors displays the incoming image from the hospital and can be seen by both the patient and the EMT. The other displays the outgoing image of the patient and can be seen only by the attending EMT, to avoid having the patient view his/her own wounds.

- **Intercom**: A microphone is available that can transmit noises in the ambulance as well as the patient's voice, and that allows the monitoring doctor to communicate with the patient through a speaker located near the outgoing video monitor.

- **Wireless Headset**: A headset with headphones and a microphone is provided for conversations between the EMT and the ER doctor. Use of the headset overrides the intercom system.

- **Ambulance Computer**: The computer controls all data flows into and out of the ambulance. The boot-up procedure takes approximately 90 seconds. Consequently, EMTs have been advised to start the process before they leave the ambulance to attend to the patient at the scene (**Figure 11**).

Figure 11. EMT's view of Doctor (l) and of Outgoing Image of Patient (r)

Figure 12. In-Hospital Computer (l) and Display (r)

The LifeLink hospital "node" is simpler than the ambulance system, in that all equipment takes up no more space than a standard personal computer (**Figure 12**). The hospital system consists of the following components:

- **Hospital Computer:** A standard PC is used to control data flows from the ambulance. The monitor displays the patient's image transmitted from the ambulance, while a picture-within-picture image displays the outgoing view from the hospital camera.

- **Video Camera:** This camera, which sits on top of the computer monitor, displays the image of the doctor. The doctor can also pan, tilt, and zoom the image from the camera through the use of a remote control.

- **Headset:** The headset consists of two headphones and a microphone.

The initial deployment has been limited to some extent by financial constraints, institutional issues, and simple delays.

On the financial side, a number of cuts in the program were made necessary by cuts to the overall MMDI funding. The number of ambulances was reduced from a proposed 25 to 20. This number was further reduced to the 10 studied, by a subsequent decision to only deploy the system in newly acquired vehicles. In addition, funding issues also reduced the coverage area of the Phase I system by causing the number of receiver sites on the freeway to be scaled back from 92 to 59. Finally, two proposals for additional functionality were cut entirely from this first phase. The first was a proposal for an external camera on the ambulance that would allow doctors to examine an incident scene. The second was a proposal for the transmission of telemetry, or patient's vital signs such as blood pressure, temperature, and heart rate, that would provide a greater wealth of information to the doctors. It is anticipated that both of these systems will be provided in the future.

On the institutional side, the number of participating hospitals was reduced from an anticipated three to one. This reduction was a result of the management of two delayed hospitals requesting a more in-depth medical evaluation of LifeLink before joining the program.

Finally, as with any new, complex undertaking, there were technological delays in bringing the system to full deployment. At the time of the evaluation, a combination of technical and hospital workload issues resulted in the system only being used three times.

The combination of these factors does have an impact on the evaluation. It makes it infeasible to perform a controlled impact analysis study. Nonetheless, the evaluation proceeded because of the system's potential and the valuable lessons that can be learned even without full deployment.

6.2 LIFELINK EVALUATION APPROACH

As noted above, a controlled thorough study of the system's impacts was not possible for the level of deployment and usage at the time of the evaluation. Nonetheless, an evaluation of the system's costs, a limited investigation of user's satisfaction, and a discussion of potential benefits and suggestions for realizing these benefits was possible and was performed.

Improved Emergency Services Costs Evaluation Approach

Complete costs for deployment, operations, and maintenance were collected for the LifeLink project. These costs were obtained through interviews with project personnel, examination of various contracts, and review of deployment and operations budgets. The results of this process are presented in Section 6.3.

Improved Emergency Services Customer Satisfaction Evaluation Approach

Given the low usage of the system, the investigation of user's customer satisfaction was largely limited to an observation of the EMT's training session and discussions with the system integrators and emergency medicine directors.

Improved Emergency Services System and User Benefits Evaluation Approach

This evaluation focused on reviewing the operation of the system, researching relevant literature, and conducting interviews to hypothesize the potential impacts of the system. This same research also assisted in identifying the institutional and technological considerations that must be addressed to ensure that these potential benefits are fully realized.

6.3 LIFELINK PROJECT COSTS

LifeLink has been described as one of the most advanced applications of tele-medicine ever fielded. Consequently, it is not surprising that the deployment costs for this project are characterized by substantial investments in research and development. In fact, the expenses associated with this research and development account for over 56 percent of the total deployment cost, or over $1.8 million of the $3.2 million total.

Communications are another major cost driver of the LifeLink project. For example, the costs involved in transmitting the audio / video data from the ambulance to the roadside fiber optic network are over $1.1 million, or nearly 36 percent of the total non-recurring deployment costs. As high as these costs are, they would have been substantially higher had the system integrators not been able to take advantage of the existing TransGuide fiber optic network to transmit between the roadside and the appropriate hospital free of charge. The costs for this project are shown in **Table 27**.

Given these large actual and potential communications costs, it is doubtful that the project would have been deployed as it was had it not been for the availability of the TransGuide cable. In fact, future plans for the project involve moving from the current configuration entirely and toward a satellite-based system.

Table 27. LifeLink Costs

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
Ambulance Node	10	$ 215,410	
Hospital Node (w/fiber)	1	$ 44,320	
Fiber Hub Install	51	$ 1,033,413	
Fiber Hub Install - Kits only	8	$ 121,064	
Lab Development Materials	NA	$ 53,995	
Mobile Development Materials	NA	$ 79,445	
Development Labor Costs	NA	$ 1,643,275	
SWRI Development Labor Costs	NA	$ 60,000	
Ambulance Equipment Maintenance	NA		$ 6,331
EMS Communication Maintenance	NA		$ 18,994
Totals		$ 3,250,922	$ 25,325

6.4 CUSTOMER SATISFACTION WITH LIFELINK

Early observations of customer, or user, satisfaction of the LifeLink system offer mixed results. The EMTs generally responded positively to the system, while the reception by emergency physicians was less enthusiastic.

EMTs reactions were largely gauged from observations made at the LifeLink training session that was held at TransGuide in August of 1998. Most of the EMTs using the system seemed positive about the technology and interested in seeing it work. While there were some evident difficulties, such as audio and video that cut-out periodically due to coverage issues, the EMTs appeared very willing to forgive these annoyances and seemed eager to begin applying the technology to practice. The evident pride and professionalism of the San Antonio Fire Department staff may explain part of this enthusiasm. These EMTs are among the best trained in the nation and are very receptive to any new techniques or technologies that may help them in their core business of saving lives.

The reception from area physicians was not as positive. While many feel that the system has the potential to offer benefits, they have not yet embraced it as the EMTs have. This likely has little to do with their actual satisfaction with LifeLink operations. More likely, their negative reaction is linked to concerns about the increased time and effort that is required to operate the system. While EMTs are already present in the ambulance whether or not they are using the system, emergency room physicians must leave some other task unfilled in order to be in front of their LifeLink terminal.

6.5 SYSTEM IMPACTS OF LIFELINK

This section describes the potential impacts of the LifeLink system on human health and the cost-effectiveness of emergency operations. It also discusses the various institutional and technological considerations that will need to be addressed to ensure that these hypothesized benefits are fully realized.

Potential Benefits of the LifeLink System

As described previously, a direct empirical examination of the impacts of the LifeLink system was not possible due to delays in the project and limited usage at the time of the evaluation. However, through a series of interviews and the examination of both literature sources and similar applications, it was possible to develop an overview of the likely impacts of the system, once the deployment matures.

When the LifeLink system is used, several results may occur: the patient may be released instead of being carried to a hospital, the most suitable hospital facility may be selected sooner, and potentially for those cases where the emergency is a traffic accident, the accident scene may be cleared sooner. These actions in turn may translate into one or more of a number of benefits including:

- reduced emergency treatment costs,
- improved patient survivability and recovery,
- reduced litigation and claims, and
- reduced delay and secondary crashes.

Figure 13 represents the path by which these potential benefits may accrue. It should be noted that for any given case, none of these impacts may be realized, or one or more of these impacts may occur.

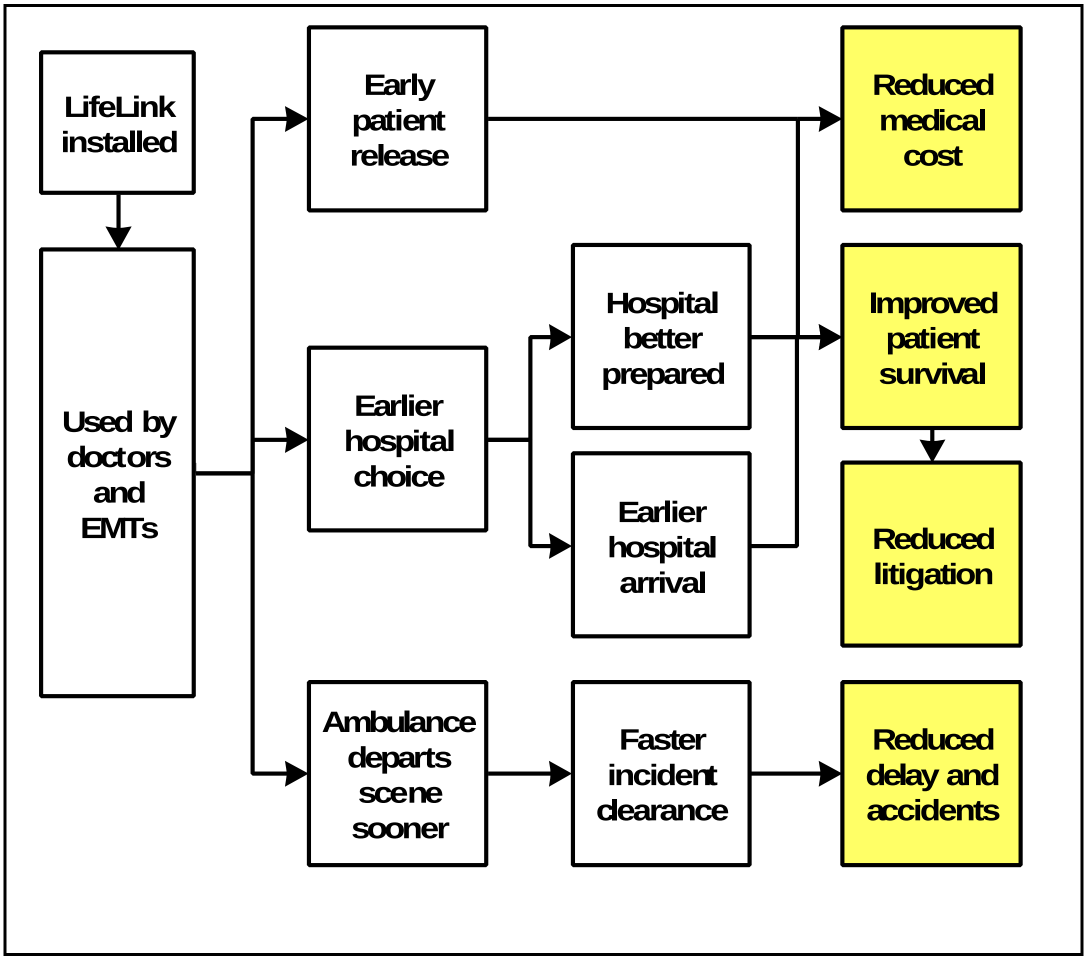


Figure 13. Potential Impact Linkages of the LifeLink Project

Improved Patient Survival and Recovery

The LifeLink system allows physicians to see, hear, and monitor a patient almost as soon as the patient is in the ambulance. Because of this, physicians using LifeLink may be able to diagnose injuries and other medical problems and to advise the ambulance EMTs on proper treatment while en-route to the hospital. In certain circumstances, this early intervention may improve the patient's chances for a full recovery. **Figure 14** provides a hypothetical representation of this impact.

The LifeLink system may save time in the emergency room by providing visual information on incoming patients that helps physicians and medical staff prepare to treat them as soon as they arrive, rather than taking time to determine the course of treatment. This "advance notice" for the emergency room may improve patient survival, especially in cases where specialized treatment methods or equipment may be required.

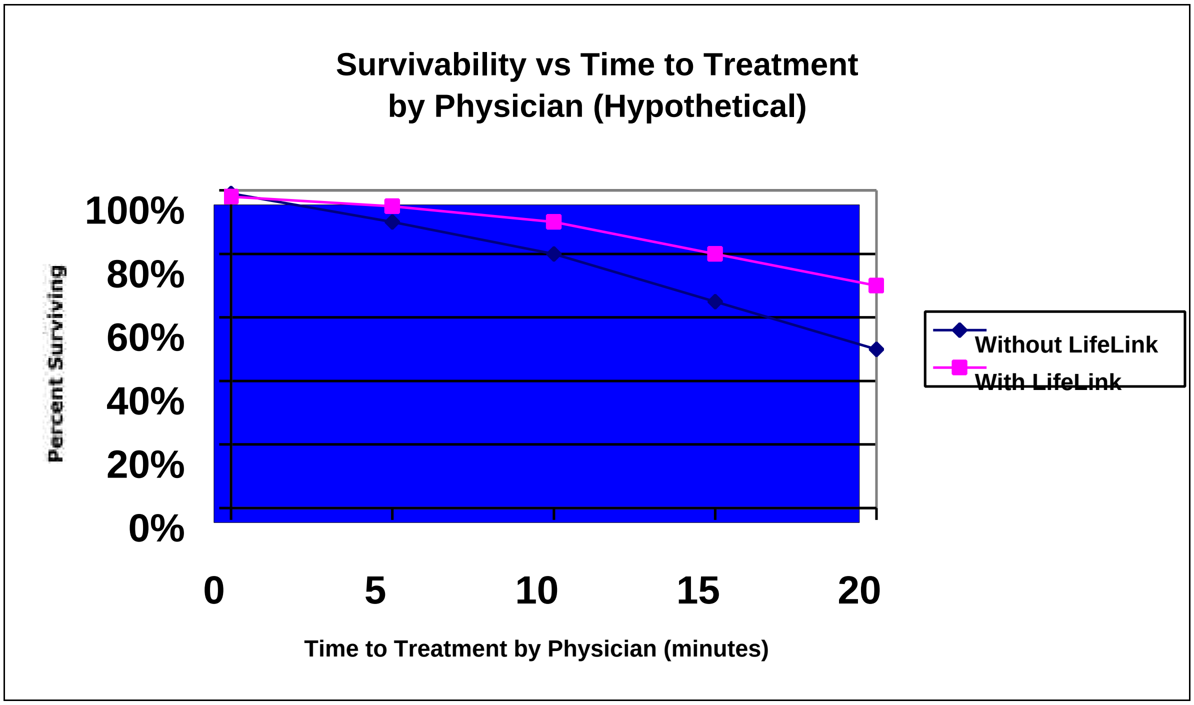


Figure 14. Hypothetical Impact of LifeLink System on Patient Survivability

Reduced Cost of Emergency

Because the doctor can see, hear, and monitor a patient almost as soon as that patient is in the ambulance, there may be times when the doctor will release the patient at the scene instead of transporting the patient to an emergency room. This procedure, known as triage, can afford savings and place much-needed ambulance equipment back into service sooner. Also, because hospitals can be better prepared for patients, factors such as equipment, supplies, and medical personnel's time can potentially be reduced. Finally, earlier patient treatment usually leads to faster recovery and results in less hospital time and further reduces costs.

Reduced Litigation Claims

Because of better information and earlier, more extensive treatment leading to improved patient survival and recovery, there should be a reduction in claims and litigation against medical personnel and hospitals. Better information to document decisions made will reduce the amount of litigation by limiting ambiguity and uncertainty with respect to treatment choices. This leads to benefits in reduced legal time, court time, and time of other parties involved in the conflict. The monetary settlement is a transfer and does not enter into social benefit.

Reduced Delay and Secondary Crashes

Because the determination of appropriate treatment can be made more quickly, it is possible the ambulance might leave the scene earlier. For roadway accidents, this may allow for faster incident clearance, which in turn should result in reduced delay and occurrence of secondary crashes caused by queuing. Alternatively, the use of LifeLink might entail additional time at the scene rather than less. Because even the direction of impact cannot be estimated reliably, a zero effect is assumed until additional information can be obtained.

Institutional and Technological Recommendations for Realizing Full LifeLink Benefits

In order that the potential benefits described above may be fully realized, a number of institutional and technological recommendations should be addressed. Many of these issues were actually put forth by the system integrators. Therefore, there is a high probability that they will be instituted in subsequent deployments of the system.

Institutional – Deploy LifeLink in Environment Conducive to Experimental Technology

A key finding of the LifeLink evaluation is that, in order for systems like LifeLink to succeed, they must be deployed in areas where the medical community is receptive to and has the resources to employ experimental technologies. As was noted earlier, the EMT community was very receptive to the LifeLink deployment. This was a key factor in the successful physical implementation and initial proof-of-concept of the system.

The hospital community, on the other hand, was notably less receptive to LifeLink. Two of the three hospitals initially proposed as Phase I deployment sites were unwilling to participate in the program at all. While the directors of these two hospital facilities recognized the potential for LifeLink benefits, they were unwilling to take the risk of disrupting operational procedures in their facilities to experiment with an unproven technology.

University Hospital, which was willing to participate in the program, did so at a reduced level of commitment than was first anticipated. As with the other two hospitals, the directors of University Hospital were concerned with the potentially unknown impacts of the system on the daily routine of the emergency room. Concern was also expressed about the system altering physician / EMT roles in unpredictable ways. Furthermore, constrained budgets have left emergency room staff busier and less inclined to participate in the testing of a new technology. When LifeLink was first deployed, the Chief of the Emergency Room at University Hospital gave instructions to EMTs not to operate the LifeLink system more than two or three times a week, as any greater usage would put undue strain upon his emergency room physicians. Taken together, these institutional concerns contributed in part to the very low usage of the system in this initial phase of deployment.

Technological - Add Patient Telemetry

In addition to providing a more receptive institutional environment, a number of technological improvements may assist LifeLink in realizing its full potential. This is not to say that the system as deployed is faulty, because it is not. Rather the evaluators, with the assistance of external experts, system implementers, and system practitioners, have identified a number of technical improvements that may increase the magnitude of any potential benefits.

The first of these that was mentioned by most everyone involved in the program was the addition of telemetry capabilities. The system is currently designed to transmit patient vital signs, or telemetry, from one of two special stretchers to the hospital LifeLink terminal. Unfortunately, budget cuts forced the elimination of the telemetry-transmitting stretchers from the project. Dr. Davis, Chief of the Emergency Room at University Hospital, and many other tele-medicine experts expressed their belief that a good portion, possibly as high as 90 percent, of the benefits of LifeLink would come from doctors being able to view patient’s life signs.

Technological – Add an External Camera

Another potentially beneficial component of the LifeLink project that was delayed due to budget cuts was the addition of an external camera that could capture and transmit images from outside the ambulance to the emergency room. This would be particularly useful in allowing physicians to remotely view crash scenes. Research conducted by Dr. Richard Hunt has demonstrated that providing photographs of patients involved in crashes significantly improves emergency room preparedness and ultimately patient treatment and survivability.

Technological – Expand to Rural Coverage

Finally, many people spoken to by the LifeLink evaluation team thought that LifeLink would have its greatest impact in rural areas where it may only be needed a few times each year. In Europe, for example, physicians staff ambulances while in the urban areas of the United States, they are staffed by highly trained paramedics. In rural areas, in contrast, volunteers who may only see a serious crash once or twice a year staff ambulances. Having a physician or experienced EMT who sees these types of injuries very frequently "on board" with the volunteer could immeasurably improve patient treatment. Consequently, the system implementers are currently planning for a Phase II rural deployment using satellite communications.

Note that the presence of these recommendations does not mean that the LifeLink system was by any means a failure as deployed. On the contrary, it was highly successful as a proof of concept and perhaps even in terms of direct impacts, though for reasons discussed earlier this latter hypothesis is difficult to investigate.

6.6 SUMMARY OF LIFELINK EVALUATION RESULTS

An evaluation of LifeLink reveals that while it may not currently offer significant benefits, it is certainly predicted to do so with continued development. The following sections discuss the major findings from this evaluation.

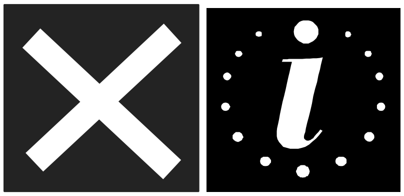
LifeLink has been a successful proof-of-concept for mobile emergency tele-medicine, and it is predicted to offer benefits. Considering the complexity and innovation of the LifeLink project, the successful deployment of the system is a significant accomplishment on its own. This deployment has proven that tele-medicine systems are feasible and can be deployed in a fairly cost-effective manner. Furthermore, while no direct benefits have been accrued to date, interviews with numerous experts in the field suggest that they are imminent. They are likely to include savings in lives and reductions in recovery time and may include cost savings that are large enough to justify the LifeLink deployment on their own.

Institutional issues need to be overcome to fully realize these benefits. Success of the LifeLink project requires the support of both the emergency medical technician and hospital community. To date, however, the hospital community has been unable or unwilling to offer full support. This may be easily explained by staffing and resource shortages common to many hospitals; however, it has had the effect of limiting potential benefits of the system.

The system will benefit from improvements such as satellite communications, addition of an external camera, and transmission of telemetry. LifeLink is currently deployed in an urban setting, within relatively close proximity to high-class medical facilities, and under the operation of highly skilled emergency medical technicians. Consequently, the potential for impacts of the system is limited. This is expected to change dramatically, once satellite-based communications capabilities are added that will allow LifeLink to be deployed in rural areas. Another improvement that is expected to assist in maximizing the benefits of the LifeLink system is the addition of an external camera that will be used to transmit images of the patient at the scene. A similar system to this is also under development under the Seattle MMDI. Finally, nearly everyone consulted thought that the transmission of patient vital signs will greatly enhance the system's effectiveness.

Finally, LifeLink has demonstrated that there may be economic benefits from integration. As indicated in the cost analysis, the LifeLink project would likely not have been feasible as deployed without the significant savings offered through the use of the existing TransGuide communications network.

7. IMPROVED HIGHWAY RAIL INFORMATION



At-grade highway-railroad crossings give rise to traffic control problems that affect not only on traffic safety, but also traffic flow performance. Railroad crossings near freeway exits can cause problems, since passing trains can lead to significantly long blockages of traffic movements on freeway frontage roads and possible blockages of nearby freeway exits. This can lead to congestion on the freeway. In an effort to alleviate these problems, the San Antonio MMDI has adopted a program, AWARD, of integrating highway-rail interfaces with various forms of traveler information.

7.1 AWARD PROJECT DESCRIPTION

The original San Antonio MMDI proposal called for a rail-crossing system focused on safety. This system was designed to use sensors and cameras at the railroad crossing to detect the presence of vehicles blocking the railroad tracks as trains were approaching. Wireless communication was then to be employed to transmit a warning and image of the situation directly to the cab of the on-coming train in time to allow the locomotive engineer to stop and thus avoid striking the vehicle.

Unfortunately, the railroads were slow to participate in this program. While they have a strong commitment to safety, they were concerned that the utilization of the system would shift liability from the vehicle blocking the tracks, as it currently stands in most cases, to the railroad itself. This concern was further exacerbated by the fact that the proposed system was essentially untested and could not be guaranteed as failsafe.

In the face of these concerns, the San Antonio MMDI project team revisited the proposed project and decided to pursue a slightly different course with a focus more on traveler information than safety.

The revised AWARD project is a non-intrusive system. As depicted in **Figure 15**, this system was implemented using detectors located on poles mounted on city or state right-of-way so that it would not intrude on railroad right-of-way. Because the equipment does not interface with any railroad equipment or the actual rail lines, no agreements with the railroad operators were required, thus allowing for the rapid deployment of the AWARD system.

The system has been designed to help motorists and emergency response vehicles avoid delays due to railroad operations on tracks crossing freeway frontage access roads. It has been deployed at three highway-rail intersections in the vicinity of Fredericksburg Road and I-10.

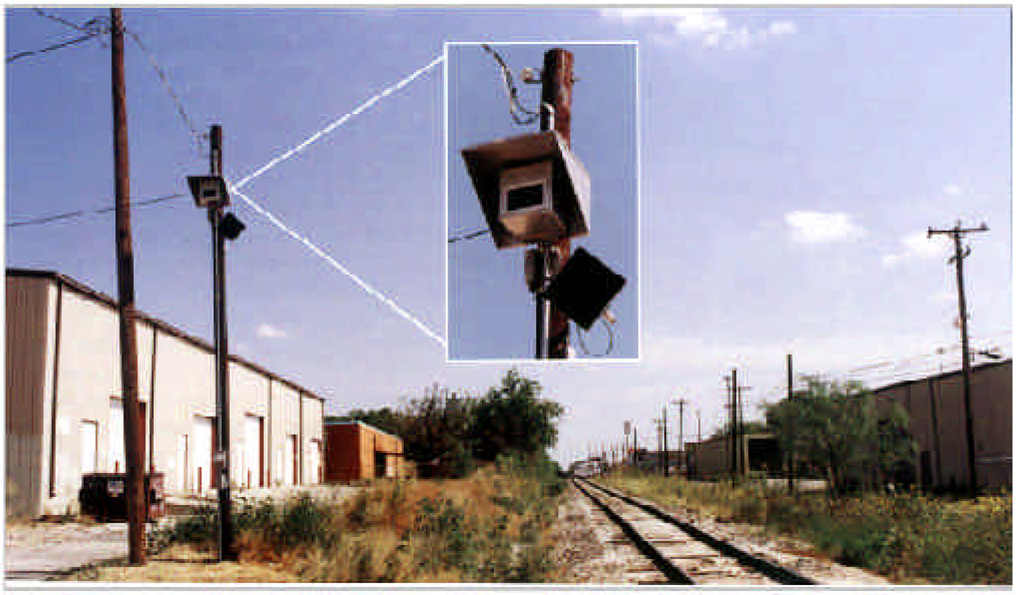


Figure 15. AWARD Site Installation (TransGuide MMDI Design Report)

[**Figure 16**]() presents a conceptual view of the AWARD system for the Fredericksburg Road and Woodlawn Avenue crossing. The system includes Doppler radar and acoustic sensors placed at selected locations along the railroad tracks to detect the presence, speed, and length of trains before they approach the grade crossings.

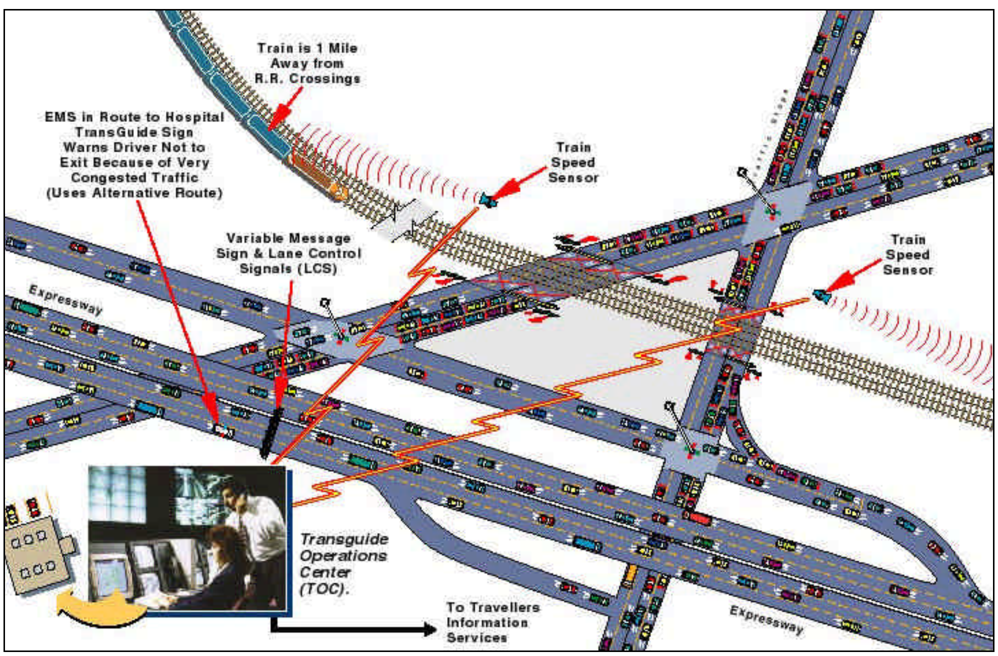


Figure 16. AWARD System for Fredericksburg Road and Woodlawn Avenue Railroad Crossing (TransGuide MMDI Design Report)

Each time a train is detected, data are transmitted to the master computer located at the TransGuide Operations Center where speed measurements are analyzed to calculate the length and acceleration/deceleration of the train. From this information, the master computer calculates the expected time of arrival of the first element of the train at the grade crossing. Information can be communicated to drivers using existing VMS that are part of the TransGuide freeway management system. Railroad delay information is also disseminated to other traveler information services, such as IVN units, through the integrated travel data server (Section 9). **Figure 17** illustrates the information flows for the AWARD project.

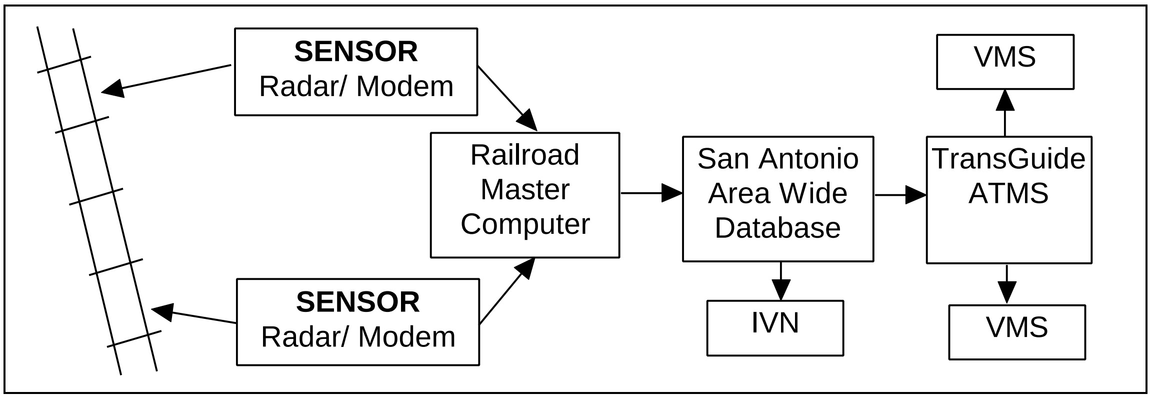


Figure 17. AWARD Information Flows

7.2 EVALUATION APPROACH FOR IMPROVED HIGHWAY RAIL INFORMATION

Improved Highway Rail Information Cost Collection Evaluation Approach

Costs for the AWARD project were collected in a similar fashion as described in the Improved Traffic Information Section (Section 5.3).

Improved Highway Rail Information Customer Satisfaction Evaluation Approach

Customer Satisfaction with the AWARD system was observed in focus groups described in previous analyses. Participants in the VMS focus group were asked about their experiences, if any, with AWARD's VMS. Similarly, participants in the IVN focus group were queried about their reactions to the train crossing information available through the IVN units.

Improved Highway Rail Information System Impacts Evaluation Approach

The investigation of the potential impacts of the AWARD system on delay, safety, and fuel consumption was constrained to the Woodlawn Avenue and Fredericksburg Road crossing and followed two courses of action.

First, field interviews were conducted. These interviews investigated both the frequency and duration of train blockages and the frequency of postings to AWARD's VMS.

Second, an INTEGRATION micro-simulation model was constructed that examined the railroad crossings of Fredericksburg Road and Woodlawn Avenue as in **Figure 18**. This network covers approximately 1 square mile and is enclosed by I-10 on the west, Woodlawn Avenue on the north, Blanco Road on the east, and Culebra Road on the south. The network also includes 15 origin and destination nodes, all located at the boundaries of the network where roadways carry traffic either in or out of the study area.

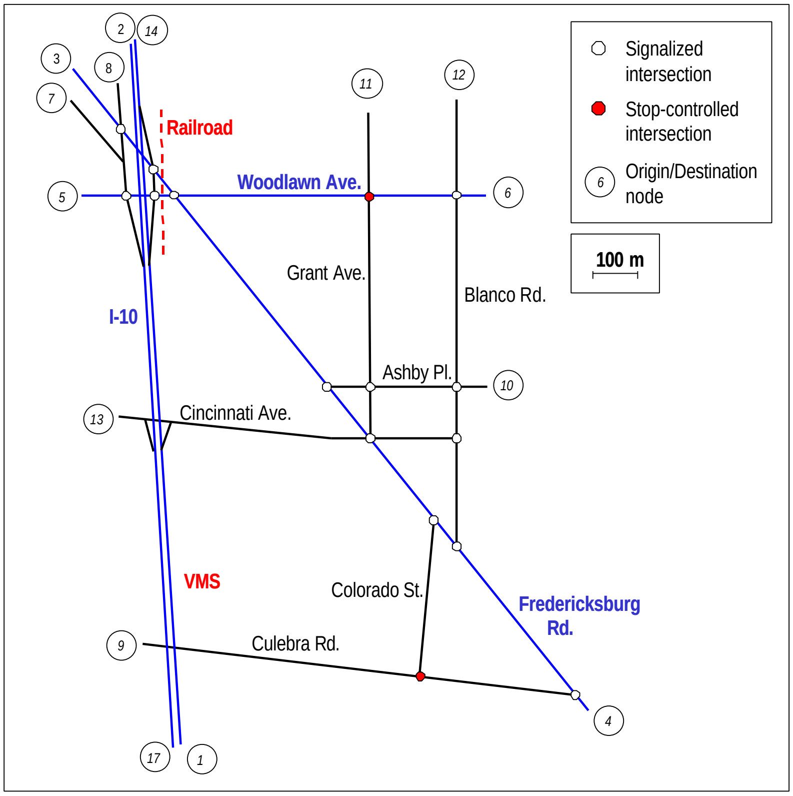


Figure 18. AWARD Simulation Network

The preemptive warning of train blockage to vehicles traveling on I-10 West was simulated through the use of a VMS system installed upstream of the Fredericksburg Road exit. The system was located in such way that vehicles intending to exit I-10 at the Fredericksburg Road could be rerouted through the preceding exit. The compliance of each vehicle to the VMS system was further modeled through features of the INTEGRATION software that allow the user to specify various response levels to advance information.

7.3 AWARD PROJECT COSTS

The most significant deployment cost of the AWARD project was the development labor costs. These costs accounted for over 80 percent of the total project budget. For the equipment costs, the use of off-the-shelf acoustic and Doppler radar sensors reduced the cost of the sensors. Increased TransGuide personnel is the largest recurring cost, accounting for just under 60 percent of the total operations and maintenance budget. In contrast, the remaining hardware, software, and operation and maintenance costs are quite low at under $15,000 a year for the AWARD system at the three crossings. The costs for this project are shown in **Table 28**.

Table 28. AWARD Project Costs

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
AWARD Train Sensors	6	$ 55,164	
Development Labor Costs	NA	$ 230,490	
33 percent Share of AWARD/KIOSK/IVN Master computer	NA	$ 5,131	
SWRI Development Labor Costs	NA	$ 60,000	
AWARD Sensor Maintenance	NA		$ 2,753
AWARD Leased Phone Lines	NA		$ 3,552
4 percent Share of 25 TransGuide Personnel	NA		$ 20,665
4 percent Share of Software Maintenance and Upgrades	NA		$ 5,904
4 percent Share of Hardware Maintenance and Upgrades	NA		$ 934
Totals		$ 350,785	$ 33,808

7.4 AWARD CUSTOMER SATISFACTION RESULTS

The results of the IVN and VMS focus groups suggest that travelers are not aware of and likely not being exposed to the AWARD system.

Although respondents in the VMS focus groups were selected based on their commute along segments of the freeway north and west of the AWARD signs, it seemed possible that other trips might bring them into contact with the AWARD VMSs posted closer to downtown San Antonio. Unfortunately for this study, only one respondent had any recollection of having seen VMSs at a railroad crossing. Respondents had trouble remembering very much at all about their experiences at railroad crossings, which seemed to be few and unremarkable.

The IVN's real-time data includes information on the AWARD system. When a train is blocking selected intersections on arterial roads and creating traffic backup onto the freeway system, AWARD sends a warning signal that is transmitted to drivers on their IVNs. There was little discussion about this capability among the focus group participants. Some were aware that this was a component of the real-time information, but they had no direct experience with it themselves.

7.5 AWARD SYSTEM IMPACTS

Frequency of Train Blockages and Use of AWARD System

Interviews concerning the operation of the system's VMS confirm what the focus groups suggest - that the AWARD system is seldom used. Under TxDOT operating procedures, messages are only posted to freeway message signs when traffic conditions exist that directly affect freeway operations.

Under current traffic conditions, queues of vehicles often form on the freeway exit from I-10 when passing trains halt traffic movements on both Fredericksburg Road and Woodlawn Avenue. However, these queues rarely grow to such extent as to spill onto freeway lanes and affect freeway operations.

This situation is attributed to the fact that there are typically only two to three trains passing the Fredericksburg Road and Woodlawn Avenue crossing on a given day (though numbers as high as seven are possible). Furthermore, the duration of each crossing usually varies between only three and seven minutes. Thus, while traffic blockage for periods of over five minutes and delays of up to 10 minutes are often reported by motorists, the queues of vehicles that form during the passage of a train rarely spill onto freeway lanes.

These findings are consistent with simulation results. In simulation runs using the estimated current demands, the queues of vehicles that formed on the Fredericksburg Road Exit never affected freeway operations. In most cases, it remained better for a motorist to stand in the queue that formed during the passage of a train than to detour across less familiar streets.

Taken together, these results show why the VMS system installed on I-10 is rarely used to warn freeway traffic about traffic blockages on and near the Fredericksburg Road Exit. As indicated, the signs installed on I-10 are only intended to be used when a queue of vehicles forming on the Fredericksburg Road Exit threatens to spill back onto freeway lanes and negatively affect freeway operations. Consequently, under current conditions, train delay messages are rarely, if ever, posted to AWARD's freeway signs. Nonetheless, there may be situations where the system would be used and would offer benefits. Such potential situations are examined in the following sections.

Modeling the Potential Impacts of More Aggressive Operating Procedure

While it is doubtful that AWARD has any system impacts under current conditions, an argument could be made that benefits may accrue by adopting a more aggressive operating procedure. Specifically, this revised operating procedure would use the VMS to inform drivers of train crossing blockages as soon as they occur, rather than waiting for the queues to spill-back to the freeway facility. Such a system may assist drivers in avoiding even the small queues that currently occur at the crossings.

Unfortunately, the model suggests that as long as traffic demands stay as they are now, the adoption of such a system would likely not result in any improvement in system or individual travel times. Rather, the model suggests that the current delays are too minor to justify re-routing.

Modeling the Potential Impacts of AWARD under Increased Demands and More Aggressive Operating Procedure

The final situation by which AWARD may offer system benefits is if the existing traffic conditions were to change. The system may become beneficial in the future if significantly higher traffic demands were experienced. Higher demands may be a function of either:

- overall growth in traffic in the San Antonio area (recall that San Antonio is one of the fast-growing areas in the country), or
- a large temporary increase in demand due to a special event or incident somewhere in the traffic system.

Assuming a growth of 25 percent and the adoption of the more aggressive operating procedure described above, a series of simulation runs were conducted for an assumed train crossing delay of six minutes and for a variety of levels of driver compliance to the variable message signs. The system-wide results of these simulations are presented in **Figure 19**. **Figure 20** presents the results for the drivers most directly affected by the system. These are drivers who are traversing the network from origin-destination (O-D) pairs 1-6, 1-11, and 1-12 in Figure 18.

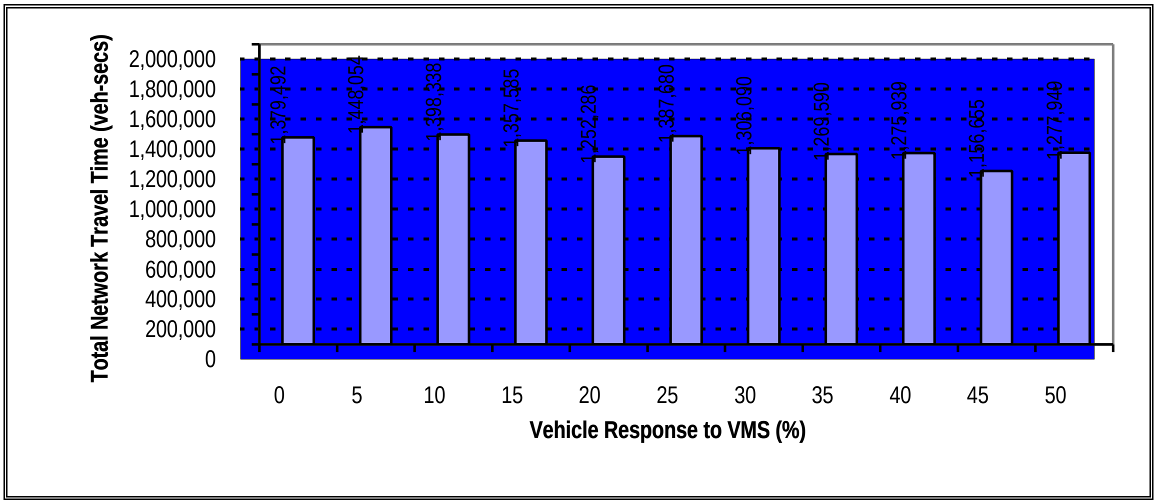


Figure 19. Travel Time Impacts of AWARD for All Vehicles in Network

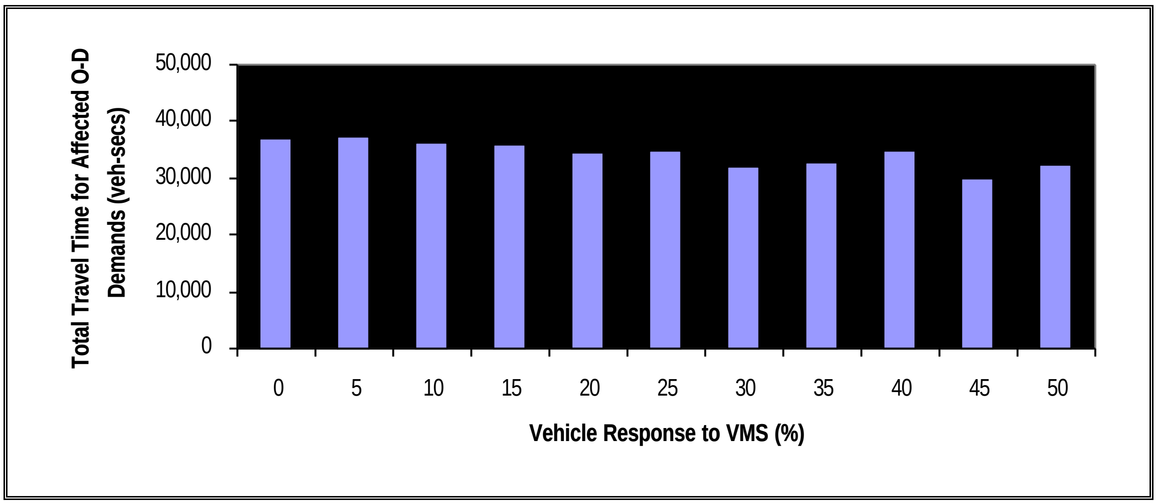


Figure 20. Travel Time Impacts of AWARD for Affected ODs

As is evident from the figures, travel time benefits can be achieved under these specific situations. However, these travel time benefits are highly dependent on the degree of driver compliance with the variable message signs.

For example, the assumption of 10 percent compliance rate adopted in the examination resulted in small travel time savings of 2.1 percent for the affected O-D pairs described above. However, these results are lost when the impact on all vehicles in the network is considered.

It is only when compliance rates are beyond 15 percent that travel time savings are accrued for both the affected O-D pairs and the network as a whole. For instance, the use of VMS messaging caused a 6.7 percent reduction in total travel time for O-D flows directly affected by the train operations under a 20-percent response level, and a 19.0 percent reduction at the 45 percent level. From a system point of view, the same vehicle response levels resulted in reductions of total system travel time of 9.2 percent and 16.2 percent, respectively.

While it is unclear whether compliance rates as high as 45 percent can be achieved, the 20 percent value is likely reasonable. This level of compliance is only 10 percent greater than has been observed for response to more general freeway based message signs.

Finally, assuming a 20 percent compliance rate, it is possible to examine the predicted future impacts of the AWARD system on metrics beyond travel time savings. As **Table 29** indicates, small decreases were predicted for crash risk and fuel consumption.

Table 29. System Level Impacts of AWARD at a 20 percent Compliance Rate and Assuming a 6 minute Train and 25 percent Increase in Demand

Impact/Six minute train	Total System Travel Time	Crashes per Million km	Total Fuel Consumption
No VMS	10.2 veh-hrs	3.016	2109 L
20% VMS Response	9.6 veh-hrs	2.753	Slight increase
Percentage Change	↓ 6.7%	↓ 8.7%	↓ Slightly

7.6 SUMMARY OF AWARD EVALUATION RESULTS

Overall, the AWARD project was found to be another deployment that did not offer substantial immediate benefits, but may in the future. The major findings from the AWARD analysis are summarized.

The AWARD project has demonstrated that it is technically and institutionally feasible to deploy an integrated highway-rail traveler information system. Not only does the system function as designed, but it was also built in a manner that was non-intrusive to the railroads. This latter achievement assisted in the rapid, on-time deployment of the system.

As deployed, the AWARD system is unlikely to have a substantial impact on San Antonio. As the analysis indicated, the current combination of train delays and traffic demands is too low to offset the increased travel costs of rerouting. Consequently, the system has been rarely used.

However, with future growth the system may offer benefits. Assuming a 25 percent increase in demand and the adoption of a more aggressive operating strategy, reductions in system travel time savings as large as 9.2 percent were predicted for a typical train crossing event and a 20 percent compliance to the VMS.

These benefits are sensitive to driver compliance. If the compliance rate drops to 10 percent then the system travel time benefits are lost entirely. Conversely, if compliance were to increase to 45 percent, then the system travel time savings would nearly double to 19.2 percent. However, it remains to be seen whether such rates can be achieved in the field.

8. IMPROVED TRAVEL SPEED AND ROADWAY CONDITION DATABASE

8.1 AREA-WIDE TRAVEL DATA SERVER PROJECT DESCRIPTIONS

The final goal of the San Antonio MMDI was the development of an extensive, real-time travel speed and roadway condition database. This database, known as the Travel data server, synthesizes information from a variety of data sources including the TransGuide freeway management system, the AWARD system, and the AVI Vehicle Tag component. The following sections describe the elements of this goal.

8.1.1 Travel data server Project Description

As **Figure 21** indicates, the Travel data server project takes traffic data from a broad range of sources both within the MMDI and outside of it. These data are then fused into a single real-time database for dissemination to a wide variety of users. These users include TransGuide and Medical Center Corridor operators, highway advisory radio listeners, and users of IVN devices, kiosks, and Web sites. Data available include static information on transit and airline operations, dynamic information about incidents and road closings, and real-time estimates of link specific travel speeds or times.

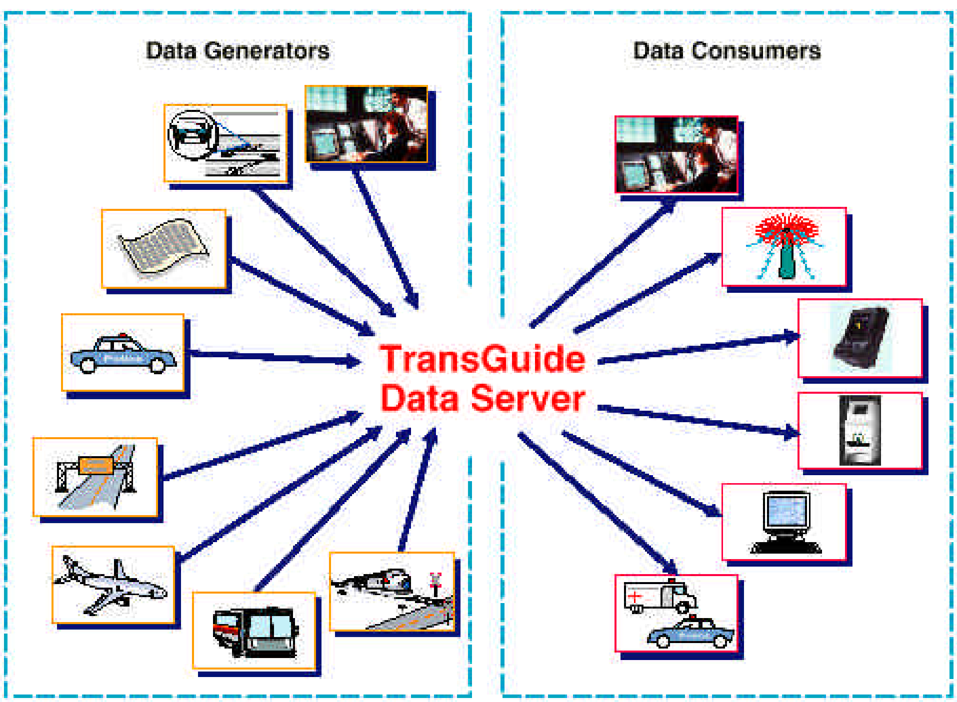


Figure 21. Data Server Conceptual Design (TransGuide Design Report)

The static information regarding transit and airline operations is provided directly by those services and is primarily made available to kiosk users. The police, maintenance personnel, and the AWARD train crossing system supply the information regarding road closures and incidents.

The most complicated data element is the estimation of travel speeds and times. There are four primary sources of data being used to perform this function. They include:

- theoretical data from sources such as traffic simulation models,
- floating cars equipped with Global Positioning System (GPS) technologies,
- inductance loop and acoustic detectors from the TransGuide system, and
- vehicle probe data from the tag reader project.

Together these sources provide data on historical travel behavior and the current conditions of link travel speeds and travel times.

Theoretical Speed Estimates

Theoretical travel speeds/travel times for 300 miles of lower class roadways are estimated using historical travel times based on posted speed limits and in some cases simulation modeling. Adjustments are made to accommodate delay at traffic signals, the impact of the number of lanes, and the presence of a median.

Floating GPS-Equipped Vehicle Readings

Travel speeds from 150 miles of slightly higher-class roadways are estimated using floating car GPS runs. The GPS travel times are based on field runs that are correlated to a NavTech GIS-based map. These maps, which are proprietary, use some form of segmentation definition (i.e., divide the network into a number of segments or links).

Currently TTI is conducting a minimum of three travel time runs using the GPS equipment, per 15-minute time interval, during peak conditions under recurrent conditions for each segment. These test runs are being conducted along portions of the network that are not covered by the AVI and ATMS technology.

Initial findings have indicated that the variance between travel times within a 15-minute interval are in the range of 2 mph on the routes that data have been collected. Data were collected and saved as 15-minute averages during the peak periods. These data are stored as the default values in the database. Adjustment factors for incidents, rain, construction, and/or lane closures due to maintenance activities were then computed and may be applied to the default values where and when appropriate.

TransGuide Freeway and Incident Management System

As discussed previously, the TransGuide system has a vast array of detection technologies that facilitate the estimation of current speeds on freeway segments within the systems coverage area. At the time of the evaluation only the first 26 miles of the TransGuide system were operational and being shared with the travel data server. However, it is anticipated that the additional 28 miles examined, as the Freeway Management Expansion project, will soon also be available. Furthermore, plans exist to ultimately expand the system and make travel times available from over 190 miles of freeway in the San Antonio area.

AVI Traffic Probes

The final source of travel speed data in San Antonio is the 98 miles of major arterials and minor expressways that are covered by the AVI tag component. As part of the MMDI, 38,000 vehicles were voluntarily equipped with passive AVI "tags" that are read as the vehicles pass under an electronic interrogator mounted on an overhead structure (see **Figure 22**). The 53 reading locations were placed at selected points on major arterials and minor expressways, and were spaced a mile to several miles apart. The reader data were transmitted to a central computer that matches vehicles from different reading locations to estimate average speed. The expectation was that this system could estimate travel speeds on the arterials and expressways and transmit this information to the travel data server.

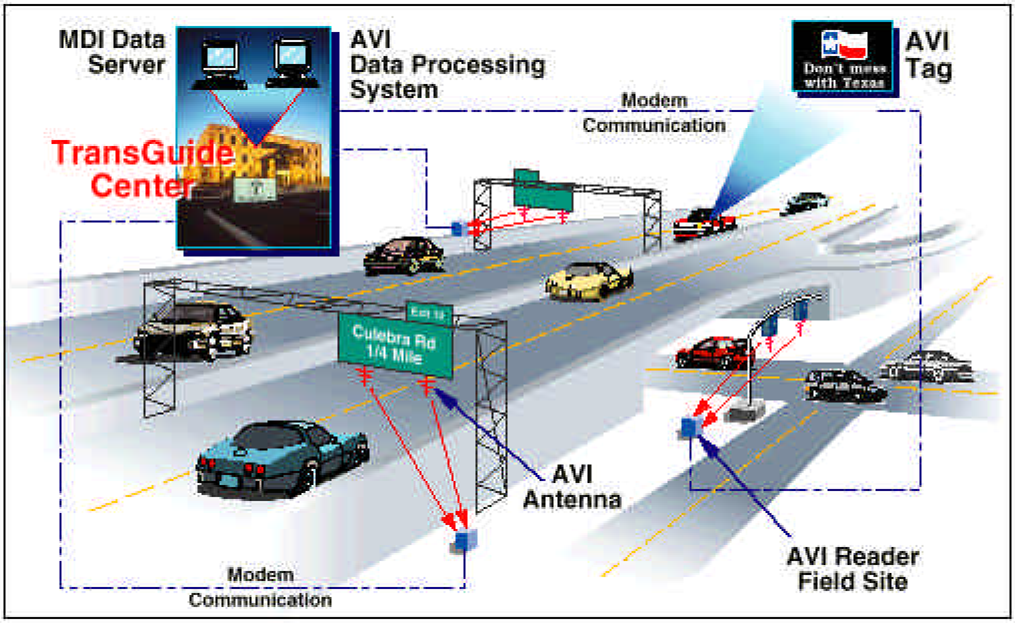


Figure 22. Automated Vehicle Identification Conceptual Design (TransGuide Design Report)

8.2 AREA-WIDE TRAVEL DATA SERVER COSTS

Costs for the database were collected through interviews with the program partners and the review of budgeting documents. The costs of the travel data server are presented in **Table 30**. As with most of San Antonio's MMDI projects, development labor costs were a major cost driver. In fact, almost all of the costs related to the data served were related to development, which is not surprising given the experimental nature of the server.

Table 30. Costs of Travel Data Server

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
Data Server	1	$ 15,547	
Development Labor Costs	NA	$ 296,882	
SWRI Development Labor Costs	NA	$ 60,000	
2% Share of 25 TransGuide Personnel	NA		$ 10,332
2% Share of Software Maintenance and Upgrades	NA		$ 2,952
2% Share of Hardware Maintenance and Upgrades	NA		$ 467
Totals		$ 372,429	$ 13,751

Costs for the AVI component were also collected through interviews with the program partners and the review of budgeting documents. **Table 31** presents the costs related to the vehicle tags and the readers deployed across the region. The tags, which were distributed free of charge, are low-priced passive tags and cost about $15 each. The readers cost about $50,000 each, compared to about $10,000 plus installation for a set of two loop detectors per lane for a six-lane road. With installation costs taken into account, the costs of the tag readers are still slightly more expensive than standard loop detectors. Finally, development costs for the vehicle tag project were very low, with a little over 10 percent of the cost for the tag readers.

Table 31. Costs of AVI Probe Surveillance

Equipment Description	Units	Deployment Cost	Yearly O&M Costs
Data Server	1	$ 15,547	
64 Port Modem Server	1	$ 20,122	
TTI Subcontract	NA	$ 56,925	
Probe Readers	53	$ 2,364,222	
AVI tags	78000	$ 1,129,780	
SWRI Development Labor Costs	NA	$ 282,500	
GPS runs	NA	$ 120,000	
Development Labor Costs	NA	$ 60,000	
AVI Maintenance	NA		$ 32,213
AVI Phone lines	NA		$ 27,726
2% Share of 25 TransGuide Personnel	NA		$ 10,332
2% Share of Software Maintenance and Upgrades	NA		$ 2,952
2% Share of Hardware Maintenance and Upgrades	NA		$ 467
		$ 4,049,096	$ 73,691

8.3 ANALYSIS OF THE AVI TAG COMPONENT OF THE DATABASE

As was mentioned in the evaluation section, the analysis of the AVI tag component focuses on the sufficiency of the deployment for the purposes of generating accurate travel time estimates. To make this determination, an analysis was performed of the reliability, fidelity, and level of market penetration of the system.

Overall Reliability Study

The overall system reliability was determined by acquiring and filtering 30 days worth of tag reader log data to find which sites failed to report tags at any time. The one-month study spanned from June 11 to July 10, 1998.

During the study period, 6 of the 53 sites (11.3 percent) experienced down time for at least one day. The shortest period of non-functionality for any reader during the test period was one day (Site 53, July 9). The longest period of non-functionality was 25 days. A site downtime-day is defined as one tag reader site being non-functional for a period of one day. The total number of site downtime-days for the system during the test period was 87 out of 1,590 (5.5 percent). The tag reader functionality fluctuated between 90 percent and 100 percent during the 30-day test period. The minimum percentage was 90.6 percent (June 27–28) while the highest percentage was 98.1 percent (July 6–8, 10).

Controlled Reliability Study

A controlled reliability test was also conducted to evaluate the ability of the tag readers to capture a specific tagged vehicle. In this test, a number of cars equipped with GPS location recorders drove routes along which tag readers were installed. The travel time data collected from these runs were compared to the data collected by the tag readers to see if the control vehicle had been accurately detected.

The study looked into a number of factors that could impact the system reliability. These factors include the facility type (arterial vs. freeway), the geometric configuration of the tag reader antenna (vertical vs. oblique mounting), weather conditions, and vehicle speed under the antenna. Based on the test runs that were conducted, there appeared to be a difference in system reliability between arterial and freeway readers. The arterial reader's failure ranged from 17 to 50 percent, while the freeway failure rate ranged from 5 to 21 percent. The mounting of the antenna, vertical vs. oblique, did not appear to impact the reliability of the tag reader. Fortunately, a thunderstorm occurred during one of the data collection days and no impact on the reliability of the tag reader system was detected. The test runs indicate a reduction in system reliability as the vehicle speed increased. This information is presented in **Table 32**.

Table 32. Tag Capture by Vehicle Speed

Speed (mph)	Correct Reads	Missed Reads	TOTAL	% Correct
0-15	3	0	3	100%
16-25	2	1	3	67%
26-35	9	1	10	90%
36-45	13	3	16	81%
46-55	35	1	36	97%
56-65	81	9	90	90%
TOTAL	143	15	158	91%

AVI Travel Time Fidelity Analysis

The AVI fidelity test was conducted as part of the controlled reliability study. It involved comparing the travel times recorded from the control GPS vehicle and the travel times computed by the AVI system for that vehicle.

The AVI system was found to estimate travel times to within 2 percent of the GPS estimated travel times in controlled testing. An analysis of various levels of data collection indicated that the level of aggregation had little impact on the accuracy of the travel time estimates.

Level of Market Penetration Analysis

The level of market penetration (LMP) of the tags was computed by counting the number of tags read at a specific reader over a time period, then dividing that number by the total number of vehicles that passed the reader in the same period.

Of the 3,300,000 tag reads recorded by the system through August 3, 1998 at site 53, 26 percent were Amtech tags from out-of-town drivers. Tag reader administrators from Southwest Research Institute noted that numerous 'hits' were received from Amtech-manufactured toll tags distributed by toll authorities in Houston, Dallas, Oklahoma, and Kansas, in order of decreasing frequency. It should be noted that such toll tags function slightly differently from the tags distributed under San Antonio's incident detection program. Because toll tags require an extremely high reliability (> 99 percent), they contain small batteries that actively emit a signal. Such 'active' tags are more visible to tag equipment because of the signal emitted, and hence they are extremely readable. San Antonio's tags, on the other hand, do not contain a signal-emitting battery. Instead they are passive, which reduces tag manufacturing and maintenance costs. The LMP varied from 0 to 8.5 percent over a typical day, with the average LMP at 1 percent or less. **Figure 23** shows the average LMP for the vehicle tags. The maximum LMP occurring between 4:00 and 5:00 AM when the total flow was low and the number of trucks was high (trucks are typically equipped with toll tags).

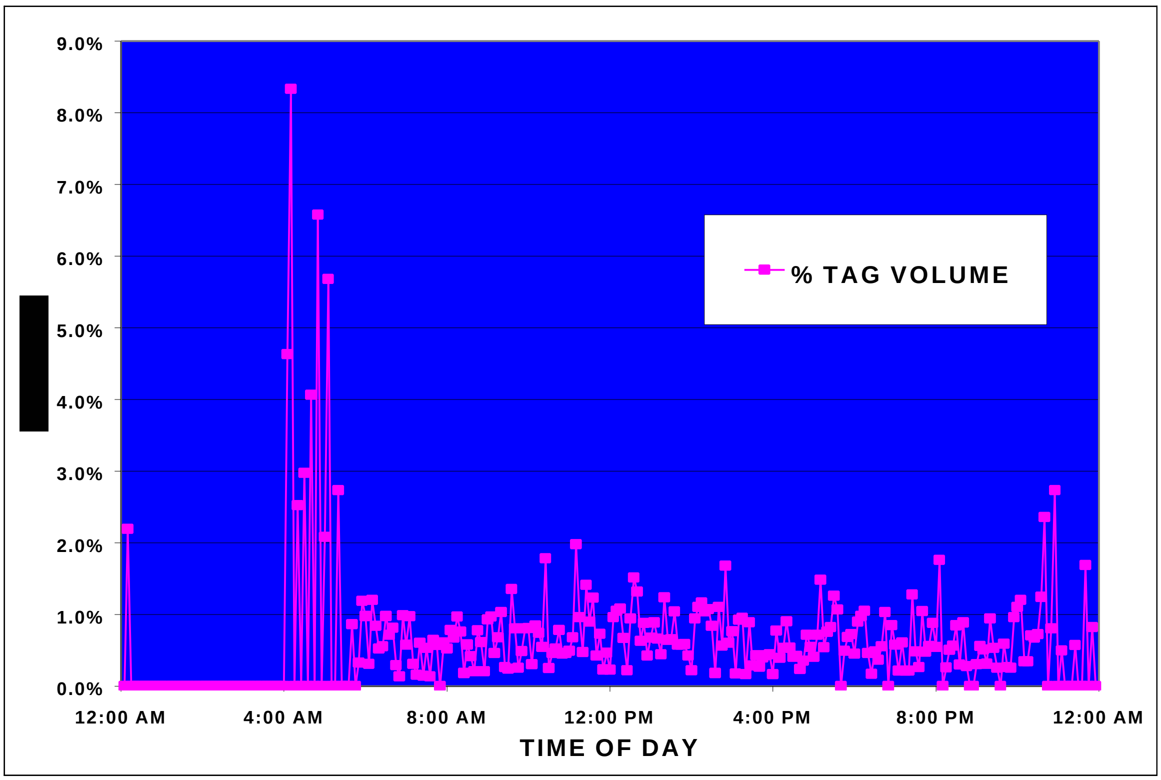


Figure 23. Level of Market Penetration for Vehicle Tags Based on Time of Day

The AVI tags were found to be reliable and to accurately measure travel times in a controlled testing situation. However, the level of market penetration was found to be insufficient. LMP averaged 1 percent or less for most periods of the day, and over a quarter of the tags read were from other cities. The low LMP makes it difficult to measure travel times consistently throughout the day.

Since the evaluation, San Antonio has decided to use inductive loop detectors and point source detectors to capture speeds on arterials and minor expressways, instead of AVI tags. This decision stems from the AVI tag's requirement of a high LMP.

8.4 CUSTOMER SATISFACTION EVALUATION

Conclusions on customer satisfaction with the database can be drawn from other MMDI sites and from the TransGuide Web survey. Other MMDI sites used focus groups to measure customer satisfaction with traveler. The Web survey was voluntary, located on the TransGuide Web site, and totaled 154 responses.

The results of the Seattle Web site focus groups provide some insights. Specifically, users of the SmartTrek Web pages indicated that that adding surveillance on important arterials would increase the utility of the site. Similar findings were recorded in Phoenix, where Web page focus group users also requested additional coverage area. While perhaps not directly transferable, it is likely that these views also belong to travelers in San Antonio. This supposition may be supported by the number of travelers (40,000) who have voluntarily enrolled in the travel tag program for arterial surveillance. Since travel times on arterials may increase utility of the Web site and VMS, San Antonio plans to install inductive loop and point source detectors to capture arterial speeds since the AVI tags failed to gain enough market penetration.

Since the evaluation period, TransGuide began providing freeway travel time information to the Web site and the VMS (see **Figures 24** and **25**). Responses to the TransGuide Web survey show that most respondents think that the travel time information provided by TransGuide is accurate. When asked how accurate the TransGuide travel time information is on a scale of 1 to 10, with 10 being very accurate and 1 being not accurate, the average score was 7.6. **Figure 26** shows the range of responses to this question.

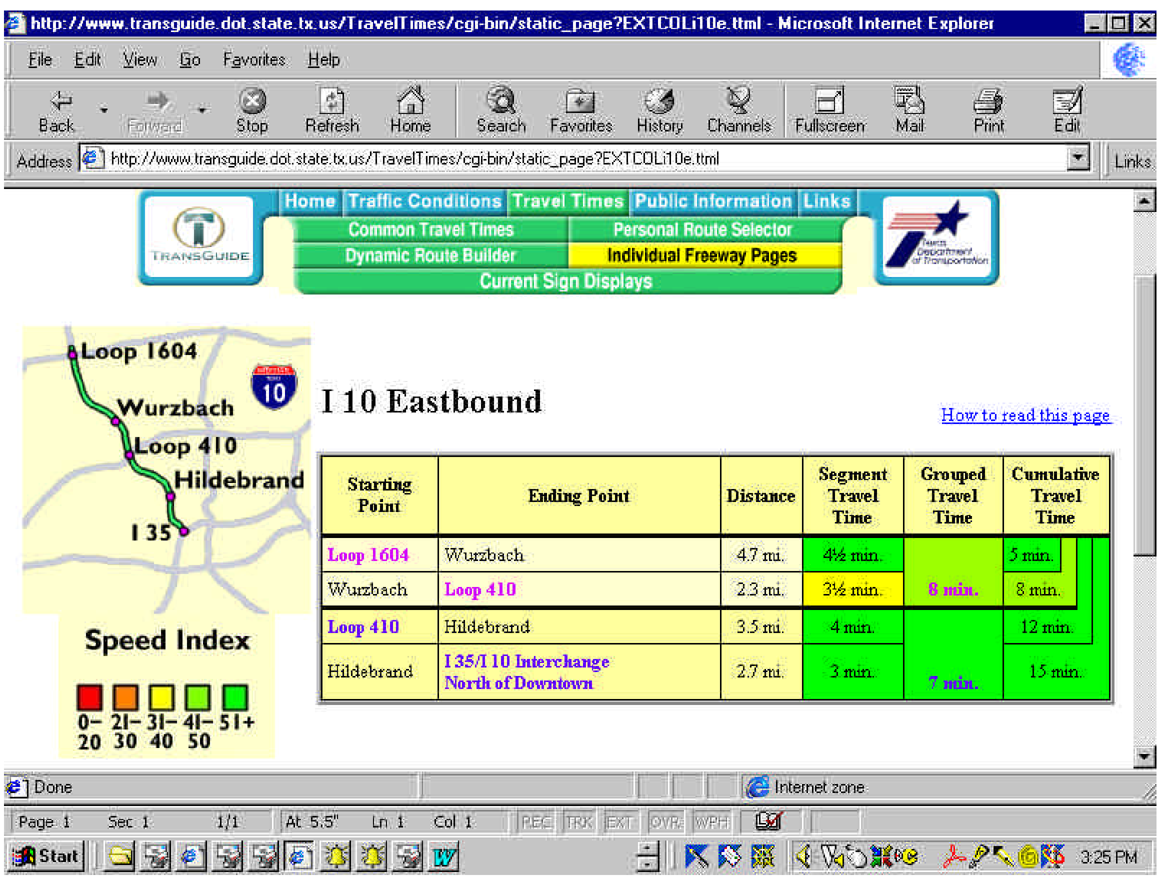


Figure 24. Freeway Travel Times as Presented on TransGuide Web Site

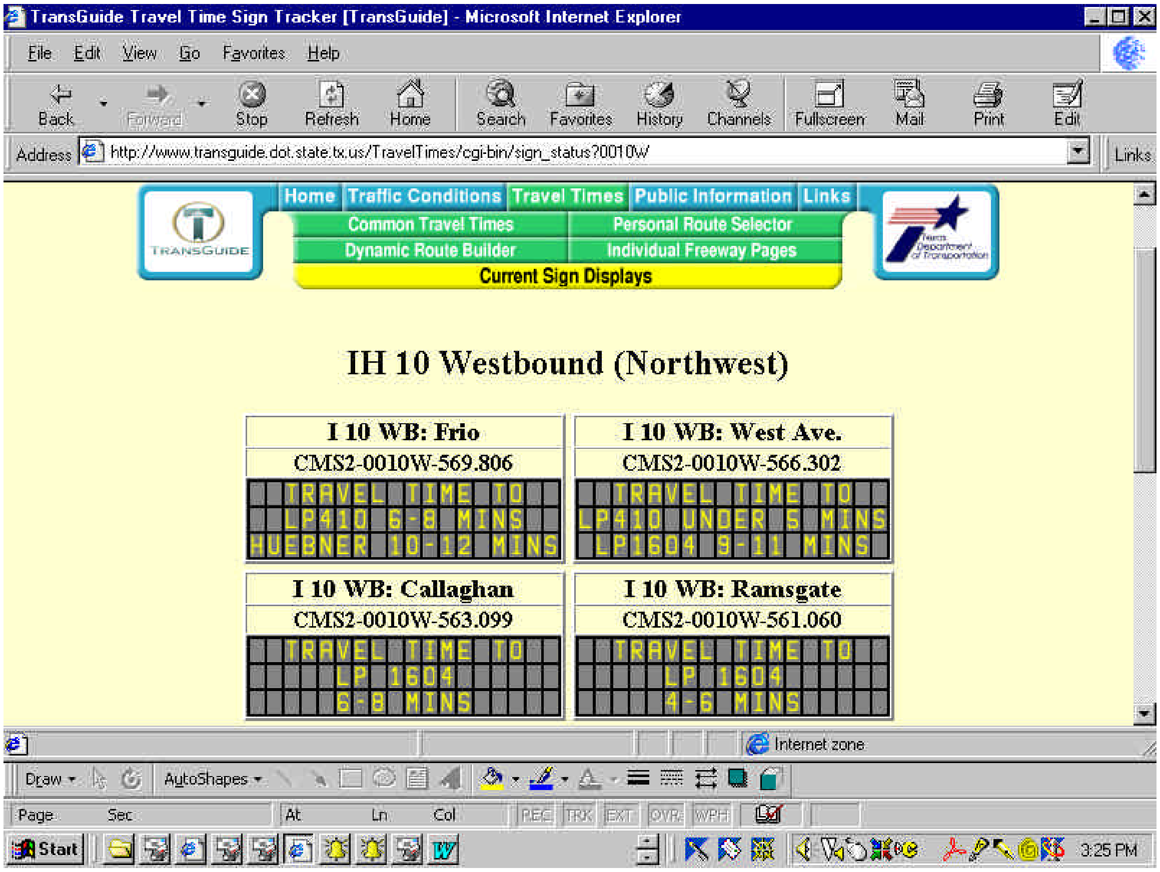


Figure 25. Travel Times as Presented on Variable Message Signs (TransGuide Web Site)

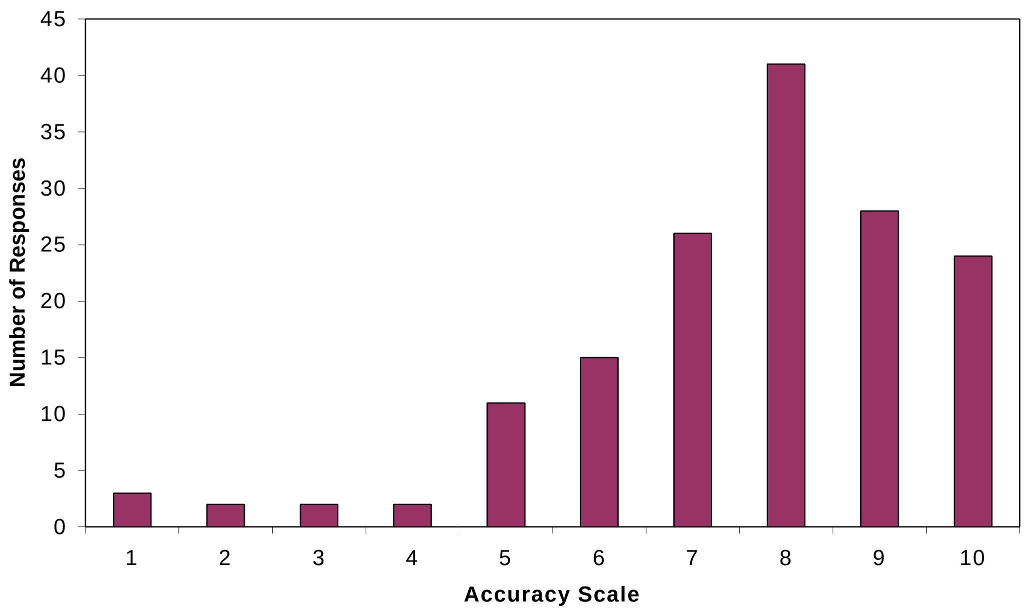


Figure 26. Perceived Accuracy of TransGuide Travel Time Information

Travel time information appears to be popular among the traveling public in San Antonio. When TransGuide began providing travel time information on the VMS and Web site, the event made front-page news in the paper. The event was also a popular topic for local call-in talk shows.

8.5 SUMMARY OF RESULTS

Vehicle probes are an effective means of collecting travel speed data if the level of market penetration is adequate. The AVI tags were reliable when tested in a controlled environment to within 2 percent of the actual vehicle speed. However, tag reliability was not the limiting factor in collecting arterial travel speeds. The level of market penetration was, on average, 1 percent or less for most of the day. This led to large gaps in speed data. San Antonio is now looking toward other means of collecting speed data on arterials, such as point source detectors and/or loop detectors.

Travel time information on VMS and on the Internet is popular among the traveling public in San Antonio. When travel time information debuted in San Antonio, the media covered gave attention to the event. In addition, most respondents thought that the travel time information provided was accurate, according to the TransGuide Web site survey.

The public thinks that integrated arterial and freeway data will offer greater benefits. They are correct. Focus groups in Seattle and Phoenix have both suggested that the traveling public think they would get even greater utility from traveler information that considered a wider range of roadways, including major arterials.

9. CONCLUSIONS AND RECOMMENDATIONS

The major conclusions and recommendations of the evaluation of the San Antonio MMDI may be summarized as follows:

- The deployment and integration of ITS in a metropolitan setting may offer substantial benefits. However, these benefits are not guaranteed. Some approaches will prove successful, some will not, and some will only prove successful with substantial improvements.

- In order to ensure the greatest ratio of successful to unsuccessful projects, those considering ITS deployment and integration must approach the process in a strategic fashion and must be willing to make a long-term commitment to the project's success.

Substantial Benefits Offered by ITS

The major results from the San Antonio MMDI are summarized in **Table 33**. The results range from projects that were clearly successful, to projects that were not successful, to those that, while they did not show immediate benefits, have potential for future success.

These projects were evaluated to be successful and offer benefits as deployed:

- The Freeway Management Expansion offers reductions in delay and improvements in safety and fuel consumption.

- The Medical Center Corridor offers similar benefits, with delay reductions as large as 6.3 percent.

- The San Antonio Traffic Web Pages offer user delay reductions as high as 6.3 percent and are growing in usage by as much as 19 percent per year.

- The Integrated Travel data server offers improvements in nearly all metrics over traditional freeway-only surveillance data sources.

Only one project was identified as being unsuccessful as deployed:

- The Kiosk projects were hampered by functionality and low usage problems.

Finally, three projects did not offer immediate impacts, but are likely to offer benefits in the future:

- LifeLink was proven as a concept and is likely to save lives when deployed rurally with telemetry data.

- In-Vehicle Navigation Units for public agencies may become more useful with additional training and reallocation to agencies that can truly benefit from them.

- The integrated Travel data server is successful in providing freeway travel speeds, however, it continued to lack arterial speeds at the time of evaluation. The vehicle tag component never attained adequate market penetration to consistently monitor conditions on the arterials. San Antonio has plans to implement other systems to collect arterial speeds.

- The AWARD project may offer delay reductions if traffic demands increase.

Table 33. Summary of San Antonio Evaluation Results

Project	Cost	System Efficiency	Customer Satisfaction	Safety	Energy Consumption
FMS Expansion	Deployment $26,575,724 O&M $852,328	Incident delay reduced 5.7% for all travelers	Travelers satisfied with VMS, but have suggestions for improvements	Secondary crash risk reduced 2.8% for all travelers	For all: Fuel reduced 1.2%
Medical Center Corridor	Deployment $525,000 O&M $46,581	Incident delay reduced 5.9% for all travelers	No chance to gauge public opinion yet. TTI is studying issue.	Secondary crash risk reduced 2% for all travelers	For all: Fuel reduced 1.4%
In-Vehicle Navigation	Deployment $2,388,691 O&M $102,330	Potential incident delay reduction of 8.1% for users, no system impact	Para-transit, satisfied, other agencies desire improvements, all need training	Potential for non-traditional safety impacts such as quicker fire response	Fuel reduced 3%
Kiosks	Deployment $1,526,374 O&M $176,065	No impact	Limited usage, needs to be bundled with other information	No Impact	No Impact
Web Page	Deployment $3,000 O&M $28,701	Incident delay reduction of 5.4% for users, no system impact	Growing at 19% per year, large latent demand as high as 19X	Secondary crash risk reduced 0.5% for users, no system impact	Fuel reduced 1.8%
LifeLink	Deployment $3,250,922 O&M $25,325	No impact	EMTs like system, area hospitals not ready	No impact, but great benefits predicted for rural application	No impact
AWARD	Deployment $350,785 O&M $33,808	None currently, but potential for 6.7% system travel time reduction per train	Users are not aware of system due to low utilization of VMS and ATIS platforms	None currently, but potential for 8.7% system crash reduction per train	None currently, but prediction of small future fuel reduction
Travel Data Server	Deployment $372,429 O&M $13,751	None currently	Travelers requesting even more arterial data	None currently	None currently
Vehicle Probes	Deployment $4,049,096 O&M $73,691	No direct impact, capable of estimating travel time within 2%	40,000 have volunteered to use tags	No direct safety implications	No direct impacts

Approach ITS Deployment and Integration in a Strategic Fashion

According to the results of this MMDI evaluation, deployment and integration of ITS projects must be performed in a strategic fashion. It is not enough to blindly put an ITS solution in the field and hope that it will offer benefits. Rather, consideration must be given as to what specific treatment to deploy, where and when to best deploy it, who else to work with to ensure success, and how to best deploy and manage it once a decision has been made to proceed. The following sections discuss the implications of each of these considerations using examples from the San Antonio MMDI.

Need to Consider What ITS Treatment to Deploy

One of the most important considerations in addressing a given problem using ITS is the question of which is the most appropriate ITS technology to deploy. While on the surface there may appear to be multiple solutions to a given problem, on further examination, many of these potential solutions are in fact inappropriate.

For example, as part of the effort to more widely disseminate traveler information, the San Antonio MMDI adopted the deployment of over 40 traveler information kiosks. While kiosks have been successfully deployed as information resources for a variety of non-traveler-related purposes, it is becoming clear that they may not be the best solution for sharing traveler information.

The advice to others considering ITS deployment is to do some basic research. Develop a careful understanding of the particular problem or goal being addressed and get to know the strengths and weaknesses of the available options.

Need to Consider Where and When to Deploy ITS – Is it Really Needed?

When San Antonio was faced with not being able to deploy a safety-based highway-rail system, they transformed the project to an information-based device. The system was deployed at a location where traffic demands were very low and the system was rarely used, if ever. However, the system may have proven beneficial had there been serious traffic congestion due to train crossings at that location.

While the ITS Award project has some current value as a proof-of-concept and is predicted to offer benefits in the future, the short-term return on investment is very low. Consequently, when considering ITS deployments, an analysis of proposed sites is recommended to ensure that a problem does in fact exist and that ITS is the appropriate solution and is capable of having an impact.

Consider Whom to Work With to Ensure Success – Identifying Appropriate Partners

Another important consideration in the deployment and especially the integration of ITS is to be strategic about whom to work with to ensure the project's success. Often, transportation officials have operated in what is essentially a vacuum. While other groups, such as police or the media, may have operated on the periphery, they have rarely been equal partners in solving transportation problems. The introduction of ITS both facilitates and requires changes in this paradigm.

In San Antonio, a great deal of the success of the MMDI and of the area's overall ITS program may be traced to TxDOT's ability to involve non-traditional partners in the effort to combat congestion. For example, by offering free or subsidized sharing of traffic video and the use of the TransGuide facilities, TxDOT has managed to secure the support and cooperation of police, fire, transit, and media groups that had not directly participated in transportation management in the past. This cooperation has resulted in benefits for the partners and the traveling public.

Others are encouraged to follow this example and to strategically think about who best can assist in addressing growing transportation concerns in their areas of the nation. This process may involve approaching non-traditional partners and may require incentives to begin the process as in San Antonio. However, in the end everyone is likely to experience benefits, especially the traveling public.

Need to Consider How to Best Deploy and Operate ITS – Developing the Optimal System

The final consideration in ITS deployment is to undertake a strategic approach to the deployment and operation of the selected solution. While a given transportation problem will often exhibit a number of characteristics common to other sites, it is likely that there will also be a number of unique properties to the problem. Furthermore, within a given ITS solution such as incident management, for example, there are often a number of different ways in which to deploy the solution. The challenge for those implementing ITS is to best match the unique characteristics of their particular problems or sites with the most appropriate operating parameters of the selected ITS solutions.

An example of why this is important can be found in the deployment and implementation of the Medical Center Corridor in San Antonio. This corridor serves to integrate separate freeway, incident, and arterial management components into a seamless freeway / arterial diversion corridor. However, as **Table 34** indicates, blindly applying all three of these components to a given incident situation often results in a sub-optimal solution and negative impacts, such as for minor accidents.

The most optimal operating procedure for the Medical Center Corridor project is to invoke:

- incident management ("IM" in the table) for minor incidents,
- incident and freeway management ("IM & VMS" in the table) for moderate incidents, and
- all three systems including arterial management ("Integrated" in the table) for only the most severe incidents.

The optimal deployment would result in an annual incident-induced delay of 5.9 percent. This compares very favorably to the 1.1 percent reduction that would be accrued by blind deployment of all three components for every incident type. Overall, this example should encourage others considering ITS deployment to carefully consider the best operating procedures for their particular sites.

Need to Undertake a Long-Term Commitment to Ensure Project's Success

The final recommendation from the San Antonio MMDI evaluation is that it is necessary to make a long-term commitment to ensure and to maintain an ITS deployment's success. Even with a strategic deployment, it is often not enough to walk away and hope that full benefits will be achieved or that benefits will continue unaided. More likely, the project will require oversight well into the future.

There are a variety of commitments that may be necessary to ensure a project's success. Specifically, there is often a need to provide continued support and training, continued development, continued financial support, or more time investments. Examples of each of these types of commitment may be illustrated with examples from the San Antonio MMDI.

Table 34. The Impacts of Different Applications of the Medical Center Corridor in Various Incident Scenarios

Incident Scenario	ITS Improvement	% Change in Total System Delay	% Change in Average Stops	% Change in Average Speeds	% Change in Average Crash Rate	% Change in Average Fuel Consumption
Minor	IM	-2.5	-0.6	1.3	-1.1	0
	IM&VMS	-1.9	-0.4	0.5	1.0	-0.2
	Integrated	6.3	-0.7	-7.6	3.0	0.2
Moderate	IM	-5.6	-1.1	2.3	-1.5	-0.6
	IM & VMS	-7.9	-0.7	3.4	-2.2	-0.2
	Integrated	0.1	-2.6	-7.3	2.8	0.0
Major	IM	-16.2	-2.5	8.7	-6.3	-2.5
	IM&VMS	-18.8	0.9	10.7	-6.4	-1.8
	Integrated	-19.9	-1.4	3.5	-4.4	-1.9

Need for On-Going Support and Training – Public Agency IVN Users

Continued support and training are often necessary to bring an ITS deployment to full or increased utility. The IVN units for public agencies in San Antonio support this observation. First, real-time access of traffic conditions was added to the units after their initial installation in the vehicles. Unfortunately, most of the drivers were apparently not made aware of the upgrade or provided adequate training in its use. Consequently, few users were able to take advantage of this key capability. Some form of short training session or communication could have easily addressed this situation.

Second, maintenance problems significantly interfered with IVN usage. In fact, 48 percent of the respondents to an IVN usage survey reported that there had been some problem that interfered with the functioning of the IVN since it was installed. This situation might have been easy to address with an aggressive maintenance program. However, many respondents reported waiting up to four months for repairs to be made. Not only did this put the units out of service for the period of inactivity, but it is also likely that the delay caused some users to lose interests in the unit altogether.

Third, while many of the IVN users had suggestions for improvements, such as allowing faster destination entry, there were no deployment resources available for instituting these changes. Without these types of resources, it is likely that the San Antonio IVN deployment will not reach its full potential, at least among the region's emergency service providers.

Finally, despite financial limitations, the San Antonio MMDI did make one long-term commitment to the success of the IVN deployment. They are planning to facilitate the reallocation of the various IVN units to drivers and agencies that can make best use of them in their current configurations. This should help to maximize the benefits of the project at a low cost.

Need for Continued Development – LifeLink Project

ITS often employ complicated, cutting-edge technology. Consequently, their development may take a number of years. Over the course of that time, there are likely to be benefits in field testing the product. However, there must be a commitment to learning from these field tests and to integrating that knowledge into subsequent development of the product.

The LifeLink project in San Antonio is one case where this recommendation is being followed. The project involves an innovative application of remote communication techniques to facilitate improved patient care in ambulances. As currently deployed within San Antonio, the system has been a successful proof of concept. However, the developers recognize that the true benefits of the system will come with further development. For example, the application of technology that allows for rural operations and the transmission of patient telemetry data will greatly enhance the system and is actively being pursued. It is likely that with continued support this system will translate into life-saving benefits.

Need for Waiting – Traveler Information Web Site

The first two types of commitments described above are active. Sometimes, there is very little to do but wait and perhaps make some minor improvements to ensure the success of an ITS deployment. An example of this is the San Antonio traffic Web site. As **Table 35** indicates, the current Web site offers benefits to its users. However, the current average demand for the system is quite low. The site is consulted for less than 0.1 percent of the total trips in San Antonio.

Table 35. Annualized Impacts of San Antonio Web Site

Annual Impact	Delay	Crashes	Fuel Consumption
System change	No impact	No impact	No impact
User change	↓ 1.81 hrs/year	Nearly negligible	↓ 0.3 L/year
Percentage Change	↓ 5.4%	↓ 0.5%	↓ 1.8 %

Demand for the site has been steadily increasing, possibly as high as 19 percent per year. Furthermore, as **Figure 27** indicates, there is a large latent demand in the system. During an abnormal period of flood-induced traffic delays in October 1998, usage of the system increased nearly 19 times above its average. The usage soon dropped back to normal, but this spike gives an indication of the potential number of users that may use the system in the future as traffic conditions worsen.

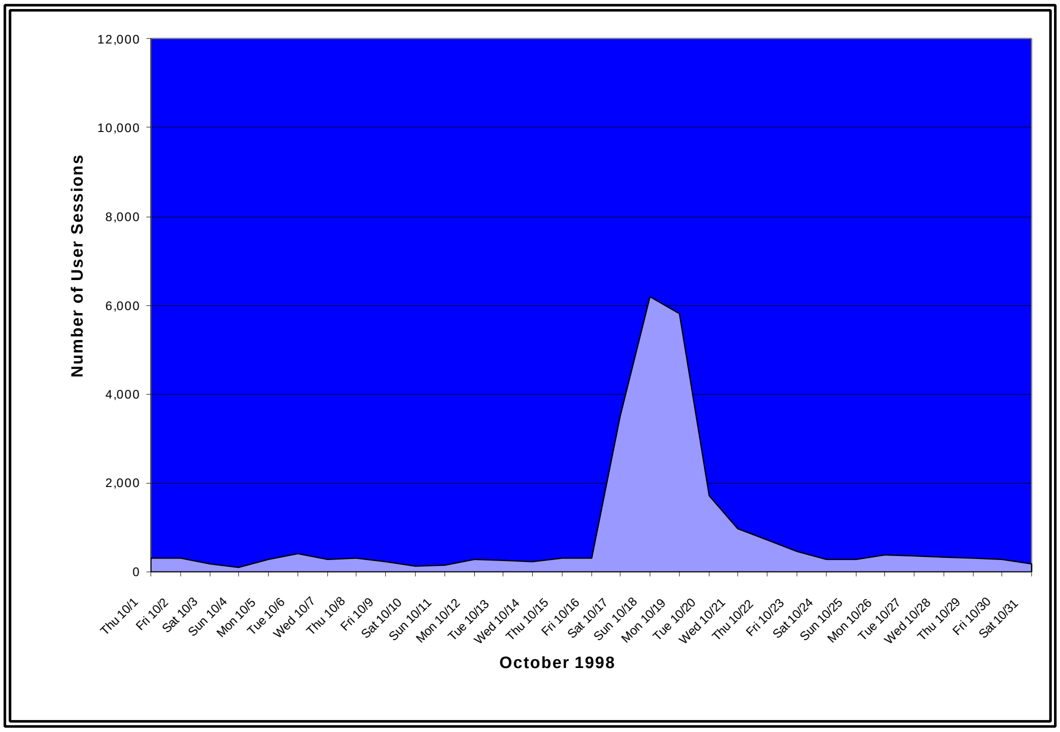


Figure 27. Number of Web User Sessions during Flooding, October 1998

Need for Long Term Financial Commitment

Continued financial support is the final long-term commitment necessary to ensure successful ITS deployment. As **Figure 28** indicates, the annual costs of ITS projects should not be underestimated. In San Antonio, these operations and maintenance costs are expected to run at over $1.3 million per year. They include substantial investments in staffing and hardware maintenance with smaller budgets for software maintenance and communication costs.

Furthermore, the values presented in Figure 28 include the additional deployment costs discussed in some of the other long-term commitments above. For example, the costs of the future development of the LifeLink system are not included in these estimates.

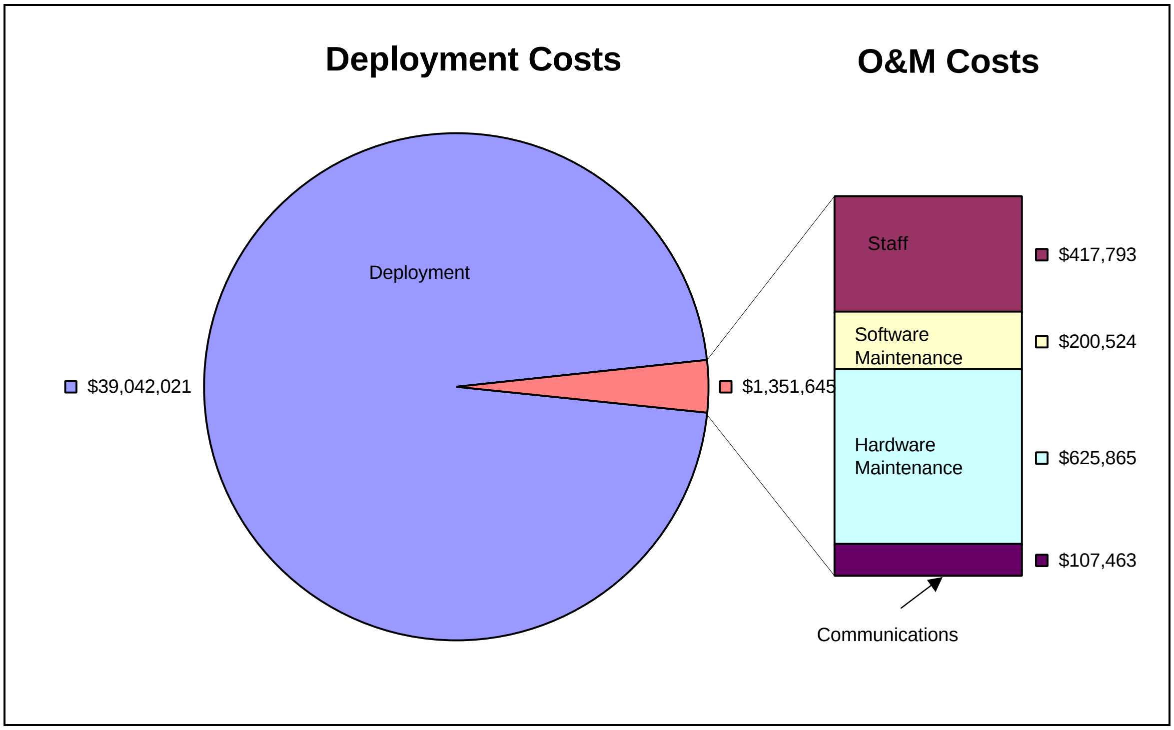


Figure 28. Summary of San Antonio MMDI Deployment / Operations and Maintenance Costs

Summary

Overall, the San Antonio MMDI has provided a valuable roadmap for ITS deployment and integration. It has provided examples of many successful practices and recommendations to follow and has undoubtedly been valuable to the people of San Antonio. It is hoped that others can also learn from the San Antonio experience and bring the benefits of ITS integration to the traveling public in their local areas of the nation.

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