Driver Information Services: The Feasibility of Using Local Access Cable TV

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DRIVER INFORMATION SERVICES: THE FEASIBILITY OF USING LOCAL ACCESS CABLE TV

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16. ABSTRACT

The feasibility of using local access cable TV as a driver information tool is explored. A literature review and a series of interviews were conducted and are described in the report. A survey of commuters in the Seattle metropolitan area was also conducted and is described. Analysis included developing a probabilistic model and using a computer-based model developed by the Federal Highway Administration. An implementation plan and evaluation strategies are provided. Conclusions include recommendations for further research.

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SUMMARY

The purpose of this research was to determine the feasibility of using local access cable TV as a driver information tool. Specifically, the investigation focused on the possibility of transmitting a computer-generated graphic of traffic conditions on Seattle area freeways.

The research began by establishing the extent of the traffic congestion problem. Urban traffic congestion is clearly a problem of national significance, and the conditions in the Seattle area are considerably worse than average.

Because major new freeways are not going to be constructed in the immediate future, transportation system management strategies have been evolving to cope with the problem. Low cost projects to marginally increase existing capacity or change consumer demand have been developed. Driver information services are tools designed to influence the pattern of demand. Three key variables -- route selection, departure time, and modal choice -- are the principal targets.

A literature search was done to identify relevant research and experiences. Driver information services include a broad range of programs, from the familiar road map to sophisticated, advanced electronics. The proposed project fell generally in the class of traffic advisories. Very little activity was noted specific to the proposed project.

The analysis of the data collected covered three broad categories: feasibility, behavior and benefits. The proposed project was determined to be quite feasible. Two practical methods were identified and costs estimated for their implementation.

A survey was done to determine if the public would use the services and what characteristics these users might have. Finally, a computer simulation was run to determine potential benefits. The simulations were based upon a traffic incident condition, and the impact of the service appeared to be positive.

CONCLUSIONS

The following recommendations are based upon the completed research and analysis:

1. Consideration should be given to implementing the proposed driver information service. While commuters already have available a number of information sources, none of them are truly real-time and available before they leave their houses. This information might prevent them from committing to a particular route and being unable to change upon learning of a problem. They could also make decisions about their departure times that would not be possible if they were already enroute. Radio stations might also prove to be consumers of the service. If the radio stations elected to receive the cable signal, they could supplement their existing information services. It might also assist them in developing news stories when major traffic incidents occurred.

2. Consideration should be given to the microwave option. It appears to be the easiest to implement and its cost is comparable to the coaxial cable option. Further analysis might be needed to decide how to relay the signal from the Viacom tower to the TCI station. Cost might be the final determinant, and a bid process would be needed. A brief implementation and evaluation plan is provided in Appendix C.

3. The Washington State Department of Transportation should consider involving Seattle METRO and others in the design of the new surveillance and control and driver information system. Output to the public should be an important factor and given proper consideration. The Seattle METRO staff might be able to contribute useful suggestions to help increase modal split for transit. The proposed service could also benefit the Seattle METRO dispatcher operation. Real-time information about traffic conditions on the freeways could facilitate re-routing buses to avoid delays. An interactive link with Seattle METRO might also improve information about conditions on the major arterials.

4. Consideration should be given to committing resources for research into advanced technology applications. Technology may not solve the problems, but it can help control them. Japan and some European countries are doing considerable work in this area, but nothing similar seems to be developing in this country. The Seattle area would be an excellent test area, particularly given its traffic problems. Research directed at coordinating all the driver information sources would help focus their impacts.

5. Consideration should be given to further research in behavior modeling and analysis. Supply and demand management are the two major thrusts for dealing with traffic congestion. As has been noted, additional capacity is unlikely in the near future. Other supply-side strategies may gain some positive results, but demand-side activities seem to hold greater promise. Behavior modeling may prove a significant tool because it is necessary to identify the key elements affecting behavior before it is possible to leverage that behavior. It may become possible to target key subgroups and direct their commute patterns through driver information services and other tools.

6. Consideration should be given to researching the impacts of driver advisories. Because commuters operate with free choice regarding their trip decisions, they must be able to make the best decisions. The nature and delivery of the necessary information needs to be further refined and developed.

CHAPTER 1
INTRODUCTION

PURPOSE

The purpose of this report is to determine the feasibility of using local access, cable TV as a driver information tool. The need for this analysis is driven by the increasingly serious problem of urban congestion. The report is a case study of the Puget Sound area specifically focused on potential applications in King County. This report has no ambition to "solve" the existing or future congestion problem, rather it analyzes whether real time information presented on local cable TV might have a positive impact on mitigating traffic conditions. At best, the TV application is offered as only a piece of the solution puzzle.

METHODOLOGY

This report will provide some background information regarding the congestion problem and the reasons for pursuing improved driver information. Figure 1 represents the steps that were taken to accomplish this project. The problem was identified as congestion resulting from too much demand for available capacity. The proposed solution is to affect the parameters of that demand (i.e., departure time, route selection, mode choice) by providing improved driver information. The proposed driver information service improvement will provide a picture of real-time traffic conditions on the area's major freeways (I-5, I-90, I-405, and SR 520). This picture will be a computer-generated graphic that would be televised over the local access cable TV channel.

The first step of this project was collecting data relevant to the problem. This was done several ways. First, a literature review was undertaken, beginning with a computerized bibliographic search. Those references were then screened for relevance and additional sources. Next, a series of interviews were conducted. Those interviewed included local cable networks and other local media, representatives from the Washington State Department of Transportation, other local government officials, and the local transit system. These interviews helped to determine the technical feasibility of implementing a local cable TV connection.

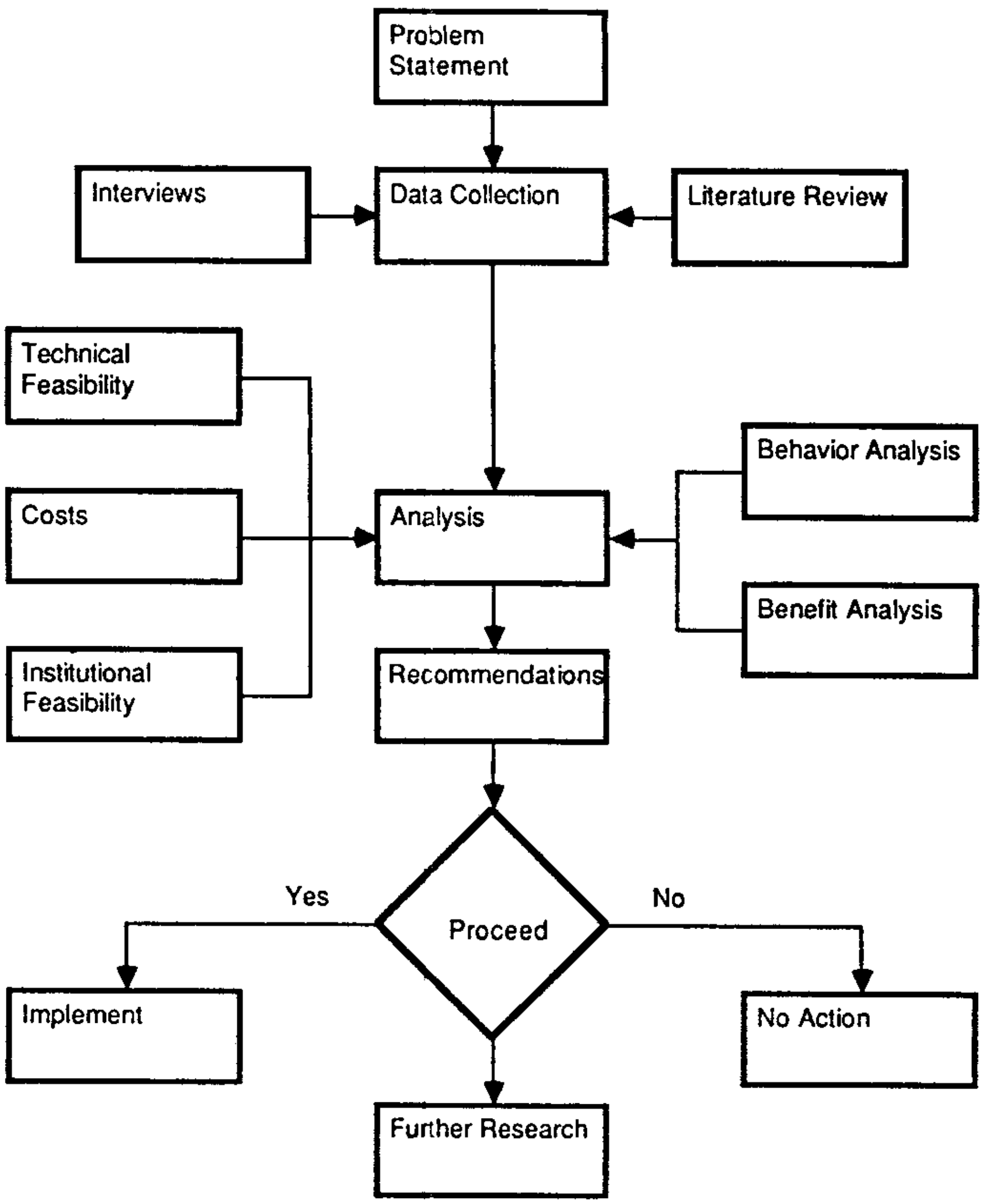


Figure 1. Project Methodology

Further information was collected through the use of a telephone survey. This survey provided data to construct a LOGIT model to estimate the likelihood that local residents would use the service if it was available.

The information collected was used for accomplishing the next steps. The data were analyzed, cost estimates were generated, and a determination was made of technical and institutional feasibility.

The data analysis process led to the development of recommendations. If the project is determined infeasible, no further work will take place. If the proposal seems reasonable, the next step will be to develop an implementation plan. This plan will time-line the necessary phases for operation and identify the key steps, the organizations that will be involved, the equipment that will be needed, and the contracts that will support the project.

The final step involves developing an evaluation plan. Consideration will be given to several methods, including the use of surveys and trip diaries. A list of possible measures of effectiveness will also be developed.

BACKGROUND

Congestion

Urban congestion has become a significant national and local problem. Traffic engineering professionals have developed a technical scale for appraising congestion, but it is best defined by describing what it causes. "Congestion is typified by slower-than-desired travel speeds, erratic stop-and-go driving, unpredictable travel times, increased operating costs, higher accident frequencies, energy waste, air pollution and many other frustrating conditions. It is attributed to overloaded facilities when traffic demand exceeds capacity; in other words, when too much traffic is attempting to use the same facility. Undesired delay, increased pollutants, and a waste of scarce resources are the resulting impacts" (1). Undesired stress for the motorist is an additional impact, the extent of which is difficult to measure.

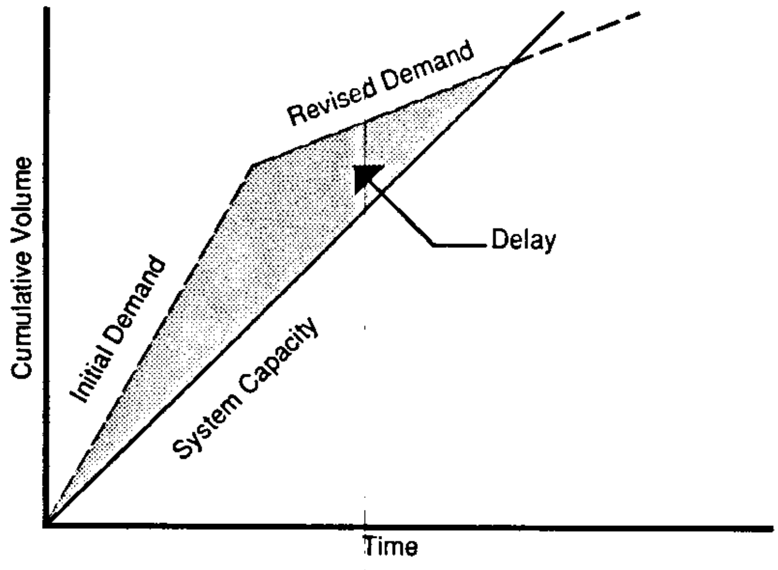
There are three typical kinds of congestion. Congestion that routinely occurs at particular times and locations is described as "recurring excessive demand." When congestion occurs because of deficiencies or shortcomings in the design of the highway facility, it is labeled a "recurring geometric deficiency." "Incident delay" describes unusual circumstances such as accidents, disabled vehicles, minor construction, and gawking motorists that create travel delays. Figure 2 is a generalized representation of two typical congestion conditions. The first corresponds to excessive demand for existing capacity or design conditions, and the second corresponds to reduced capacity because of an incident. The shaded areas represent delay, and the goal of this project is to reduce the amount of delay.

Urban freeways are a good barometer for estimating the scale of the problem. Urban freeways carry nearly 30 percent of all traffic in urban areas. In 1983, about 55 percent of peak hour urban freeway travel occurred under congested conditions. This is an increase from 41 percent in 1975. Approximately 12 percent of all urban freeway travel occurs under recurring congested conditions. This percentage is expected to rise to about 24 percent by the year 2005. Incident delay is currently responsible for about 61 percent of all urban freeway delay and this percentage may increase to 70 percent by the year 2005 (2).

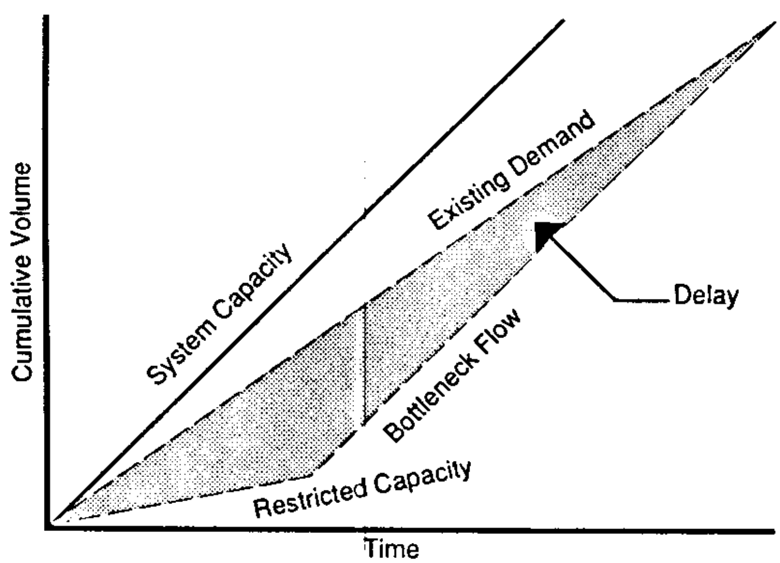
What these numbers represent are approximately 1.2 billion vehicle-hours of delay, 1.3 billion gallons of wasted fuel, and over $9 billion in user costs per year. By the year 2005, these numbers could rise to 6.9 billion vehicle-hours of delay, 7.3 billion gallons of wasted fuel, and over $50 billion in user costs (2). This is clearly a national problem of immense proportions.

Conditions in Seattle appear to be worse than average. A recent analysis done by the Federal Highway Administration (FHWA) ranked Seattle as the sixth worst major metropolitan area in the country using a congestion severity index. Table 1 provides a comparison of the top urban centers in the country (2). While this index is open to challenge (i.e., it does not fully account for traffic mitigation measures), conditions are worsening.

A recent study done by the Puget Sound Council of Governments (PSCOG) reinforces the seriousness of the local problem (3). The report predicts an increase of 42 percent in the number of vehicle trips in the region on freeways and arterials between the years 1980 to 2000. Another 42 percent increase is predicted for the year 2020. The report also predicts an increase in vehicle miles traveled of 72 percent by the year 2000 and another 52 percent by 2020. Table 2 provides a summary of



Example 1: Excessive Demand



Example 2: Traffic Incident

Figure 2. Typical Delay Conditions

Table 1. Congestion Severity Index

Urban Area	Index* 1984	Index* 2005	Ranking 1984	Ranking 2005
Houston	11,112	54,810	1	2
New Orleans	10,576	27,641	2	7
New York	8,168	12,282	3	14
Detroit	7,757	42,394	4	3
San Francisco	7,634	18,734	5	10
Seattle	7,406	27,523	6	8
Los Angeles	6,376	12,139	7	15
Boston	5,538	21,237	8	9
Charlotte	5,263	76,393	9	1
Atlanta	5,034	11,205	10	18
Minneapolis	4,704	9,529	11	21
Dallas	4,630	36,938	12	5
Norfolk	4,505	9,258	13	23
Chicago	4,501	10,700	14	19
Denver	4,454	9,828	15	20
Washington	4,188	15,160	16	11
Hartford	4,111	7,043	17	26
San Antonio	3,938	37,831	18	4
Pittsburg	3,216	7,243	19	25
San Diego	2,823	5,958	20	28
Cincinnati	2,590	6,223	21	27
Baltimore	2,441	15,037	22	12
Philadelphia	2,421	11,376	23	17
Kansas City	2,347	4,302	24	34
Salt Lake City	2,132	5,811	25	29
Columbus	2,099	4,652	26	33
Cleveland	2,061	4,099	27	35
Sacramento	1,803	8,037	28	24
Milwaukee	1,724	5,653	29	30
Portland	1,696	9,372	30	22
St. Louis	1,612	4,938	31	32
Phoenix	987	12,717	32	13
Providence	660	2,617	33	37
Miami	609	28,549	34	6
Buffalo	577	3,983	35	36
Tampa	575	11,870	36	16
Indianapolis	89	5,148	37	31

* Congestion Severity Index=Total Delay/million veh-miles of travel

Source: Lindley, Jeffery A.,"Urban Freeway Congestion: Quantifications of the Problem and Effectiveness of Potential Solutions," ITE Journal, January 1987, p. 30.

Table 2. Regional Highway System Statistics

	1980	2000	2020
Total Vehicle Trips	5,000,000	7,100,000	10,100,000
20 year increase:		42%	42%
Vehicle Miles of Travel (VMT)	32,300,000	55,400,000	84,000,000
VMT on freeways	16,000,000	27,600,000	36,600,000
Percent total VMT on freeways	50%	50%	44%
VMT on arterials	16,300,000	27,800,000	47,400,000
Percent total VMT on arterials	50%	50%	56%
20-year increase:			
total VMT	72%	52%	
freeway VMT	73%	33%	
arterial VMT	71%	71%	
Average trip length (mi)	6.5	7.9	8.3
Average travel time (min)	14	20	36
Average speed (mph)	28	24	14

Source: Puget Sound Council of Governments and the Municipality of Metropolitan Seattle, "Summary Report: Multi-Corridor Project," November 1986,page 60.

the anticipated growth impacts. The implications of the data from Table 2 are that future trips will be longer, take more time, and operate at slower speeds. All of this implies increased congestion levels.

Congestion will increase because no new highways are currently planned, and travel demand will continue to increase. Without additional capacity, the increasing demands for service will put significant stress on existing facilities with an anticipated decline in service levels. Major construction activities include the completion of Interstate 90 (I-90) across Lake Washington and into Seattle, a number of geometric improvements, and the development of additional high occupancy vehicle (HOV) lanes. Historically, the building of new major freeways has been politically sensitive. The I-90 project was delayed in court for many years and the proposed R.H. Thomson freeway was abandoned because of public reaction. As conditions become more intolerable, resistance to new facilities will probably decline, but most likely few capacity increases will be made.

TSM

Because capacity will not increase, the problem becomes one of better management. It is essential that the existing system operate as efficiently as possible. The response has been a series of strategies generally labelled as Transportation System Management (TSM). These strategies are relatively low-cost options that are implemented singly or in concert with others that mitigate existing transportation conditions. The strategies can be divided into three broad classes: supply management, demand management, and incident management. A more detailed explanation is provided in Chapter 3.

Driver Information

The proposed driver information improvement is a strategy that falls both into demand and incident management. The hypothesis of this research project is that three key variables impact the service level of the system.

The first is departure time. If the times that commuters are on the road can be spread, then the system may provide a higher level of service. The second is route selection. Some routes, most notably the freeways, draw a disproportionate share of the demand. If motorists can be encouraged to consider alternative routes during congested periods, the system again may be able to deliver a higher level of service. Third is modal choice. Currently, the average vehicle occupancy rate in the Seattle area is 1.2 to 1.4 (Henry, 1987 unpublished data, and Secrist, 1987 unpublished data). The promotion of ridesharing and transit alternatives could increase this average and perhaps remove some vehicles from the system.

Driver information services can have a positive impact on departure time, route selection, and modal choice. Historically, driver information services have existed for centuries. In primitive times, people marked trails and roads in a variety of ways and even were able to provide estimates for distances. In Europe, villages sprang up at convenient distances that marked approximate one day journeys. Besides room and board, travel information about conditions on the trip ahead were obtained. Maps were also an early information tool.

Eventually signs were developed and posted along the routes. These signs provided everything from street names to warnings about poisoned water. Each contributed information that the traveller could use in planning his trip.

With the advent of the automobile, the intensity of travel created a demand for more information. Initially, the concern was safety and traffic control. The use of signs expanded beyond just information about routes and distances. Controlling traffic became the next level of concern. The level of intensity has now reached the point in urban centers where congestion has become a monumental problem and the need for more sophisticated information has developed.

Today the world is in the throes of an electronic revolution that has permitted the development of more sophisticated traffic control and driver information tools. Traffic can now be electronically monitored and surveyed using a variety of detectors, including television. In addition, traffic flows can be metered to mitigate congestion.

Driver information services, including electronic variable-message signs, highway advisory radio transmissions, and commercial radio broadcasts, are in common usage. Electronic variable-message signs can provide a variety of short messages advising motorists of current conditions on the road ahead. Each sign has a message board consisting of a pattern of lights that can be controlled to send the desired advisories. Highway advisory radio (HAR) transmissions are messages sent at prescribed frequencies (usually at either end of the car radio AM frequency range) over a very short distance. Commercial radio stations often transmit traffic information as a public service. The source of the information varies and can include an "eye-in-the-sky" reporter in an aircraft, local transit system reports, or local police reports.

In Seattle, all of the above services are used. Typically, the variable-message signs and HAR services have been used when construction projects or other similar events have been anticipated. New, permanent variable-message signs are being constructed by the Washington State Department of Transportation and will soon be operational. Commercial broadcasts are available, but generally on a random basis. One radio station (KING-AM) has begun transmitting information every seven minutes during rush hour, but the information is not always current. A potential problem is that information received by existing media often comes after motorists have committed to specific routes. The use of cable TV may minimize this problem by providing useful information to commuters before they get into their cars.

SUMMARY

Congestion has become a problem of major significance nationally and in the Puget Sound area. Because of political and practical constraints, congestion will probably not be reduced by the development of increased system capacity. The system will have to be managed as efficiently as possible, and tools will be needed to aid in the process.

This report analyzes the feasibility of implementing a specific, improved, driver information service that may impact three key variables: departure time, route selection, and modal split. Chapter 2 describes the data collection process. Chapter 3 includes an analysis of the information collected and a model for estimating the public response to implementation. Chapter 4 includes summary remarks and recommendations. The appendices include an implementation plan and possible evaluation strategies.

CHAPTER 2
DATA COLLECTION

INTRODUCTION

Several sources of data were investigated pursuant to analysis and report preparation. A literature review was the starting point and this material was supplemented by interviews, letters and a survey. This chapter provides a brief discussion of the process and a summary of the findings. A description of the survey can be found in Chapter 3.

LITERATURE REVIEW

The first step taken was a computer-based bibliographic search using the Transportation Research Information Service (TRIS). This was accomplished with the assistance of the Washington State Department of Transportation (WSDOT) Library. The key phrase "driver information systems" located over thirty titles and produced written abstracts. These abstracts were screened and specific reports pursued. The reports can be grouped into three categories: general transportation system management (TSM), driver information, and advanced technologies. A brief summary of each category is provided.

General TSM

Transportation system management (TSM) is the general heading for most traffic mitigation efforts. TSM includes activities such as ridesharing, parking management, variable work hours, transit, high occupancy vehicle treatments, and surveillance and control systems. It also encompasses driver information systems. A significant amount of research and study has already been done on TSM issues. One early report (1) provides a useful overview and summary of options. Others are more specific and look at corridor and activity center management (4) and general HOV activities (5) (6).

Traffic management activities are a subset of TSM. Much analysis has occurred concerning congestion, and the problem is usually divided into demand and supply issues. This leads naturally to efforts to manage supply and demand. As discussed in Chapter 1, there are several kinds of congestion problems: recurring geometric deficiencies, recurring excessive demand, and nonrecurring hazards (incidents). The development of supply and demand strategies helps to organize a variety of responses to the problem of congestion (7).

There were few specific references to the use of television. Those found focused on the more traditional use for surveillance and control that was introduced in the late 1950s in Detroit (8). Early research on the John C. Lodge Freeway in Detroit established the use of closed-circuit television as an effective tool to respond to congestion causing incidents on roadways. This concept was quickly adopted and applied to many urban freeway management efforts. Figure 3 is a generalized representation of the early application of this technology.

No effort was made to exhaustively review all the literature on TSM activities. However, a key overall element of TSM applications is the synergistic effect of applying a variety of measures in coordination with each other. This will be important when researchers attempt to determine the benefit of implementing this proposed local access cable TV project.

Driver Information Systems

Several reports were identified that addressed driver information systems more directly. A brief history of the development of driver information systems was presented in Chapter 1. This is noted because a great deal of attention is still being given to enroute services, most specifically advisory signs and advisory radio (9) (10). Highway advisory radio is being further developed, particularly in Europe (11), and more will be mentioned as a part of the advanced technology discussion.

The literature review found very little specific research done on pretrip, driver advisory services. That which was found can be divided into three classes: advisory systems, integrated information systems, and motorist behavior. Each will be briefly described.

Advisory Systems. A great deal of research has been done in Europe, much of it within the Euro-Cost 30 project sponsored by the Commission of the European Communities. It has been determined that a small reduction in unnecessary travel can have a significant impact on congested conditions (12).

In this country, two recent studies merit mention. The first involved the use of a telephone service that allowed motorists to call a number and receive taped messages on current traffic conditions (13). The system did not work well, the principal reason cited being a lack of knowledge about the

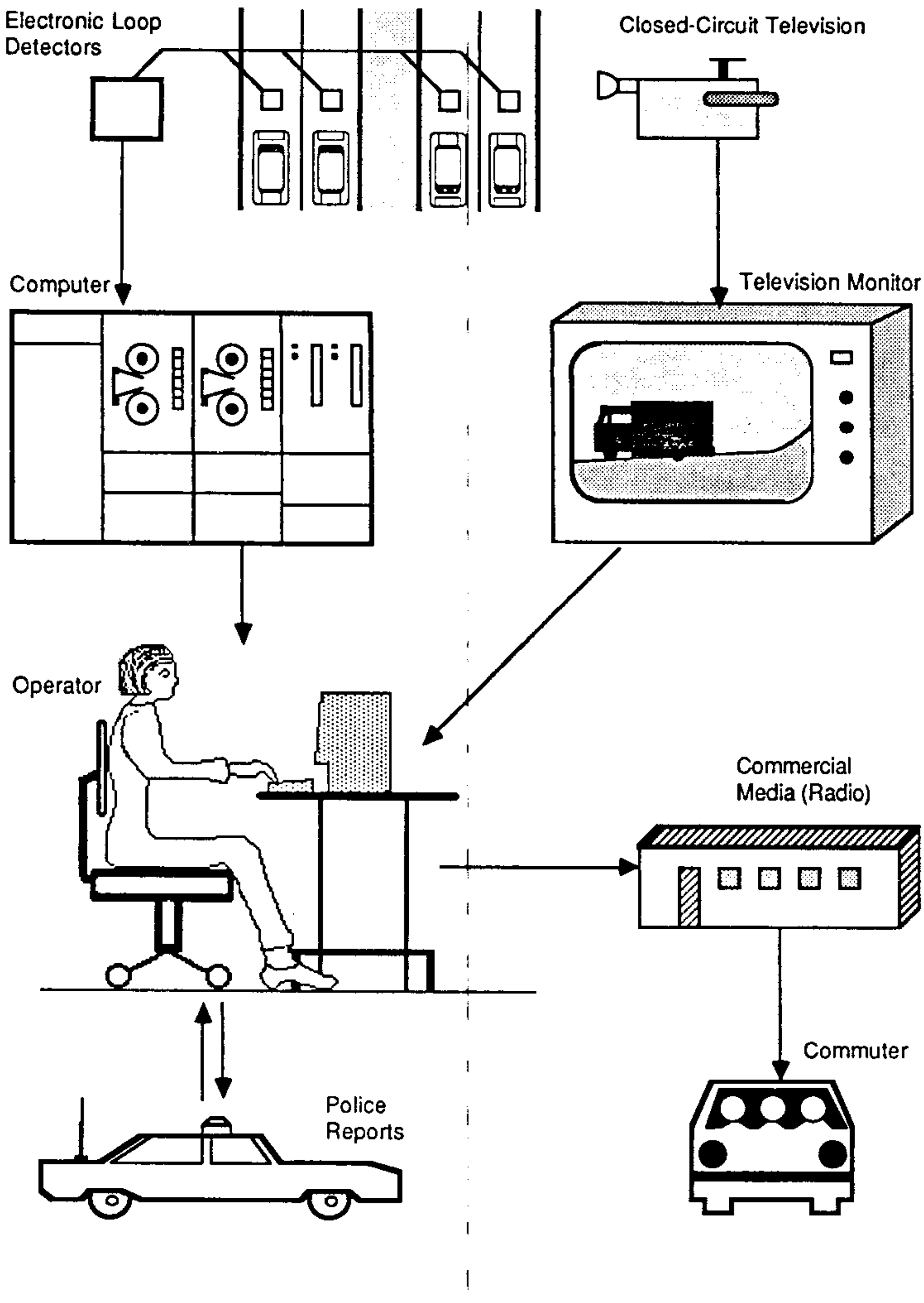


Figure 3. Surveillance and Control Elements, John C. Lodge Freeway

service. Another reason cited was that conditions would change between the time the motorist made the telephone call and the time the motorist reached the freeway. The second reason bears directly on the use of television because vehicles do not currently have TVs on board.

The second study was done to determine the potential impact of radio advisories on traffic conditions (14). The authors simulated part of the Indianapolis highway network with a model and used data from local sources. The model was run with an incident introduced, and the results were analyzed. A second run was made with the same data, except that a traffic advisory was introduced. Assumptions were made about motorists responding to the advisory, and the results were analyzed. Additional assumptions regarding average vehicle occupancy and the value of time were made, and the compared results showed a positive benefit resulting from the advisory. This has potential application for this project.

Integrated Information Systems. As noted earlier, the coordination of several separate TSM activities can have a synergistic impact on traffic congestion. Conventional wisdom suggests that the coordination or integration of a variety of driver information services might also provide increased benefits. This assumption has led to efforts to accomplish this. The most celebrated example is on Long Island, New York. The Integrated Motorist Information System (IMIS) project was started by the state of New York over ten years ago, and it has generated interest and expectation ever since. Slightly misnamed, IMIS is really a comprehensive effort at freeway management with special attention given to driver information services. It was designed to optimize traffic flow through a heavily travelled, 35-mile corridor, on northwest Long Island. The intent was to integrate a variety of traffic management measures into a comprehensive system using a common database. Figure 4 is a representation of the IMIS project (15).

The original IMIS plan was to build the whole system before putting it into operation. Significant problems and delays have caused its designers to rethink their approach. The problems encountered have been institutional (i.e., skepticism by senior management), psychological (i.e., confusion due to equipment malfunctions), and others (i.e., problems burying cable). Construction costs, originally estimated at $29.2 million, may eventually be as high as $35 million (15).

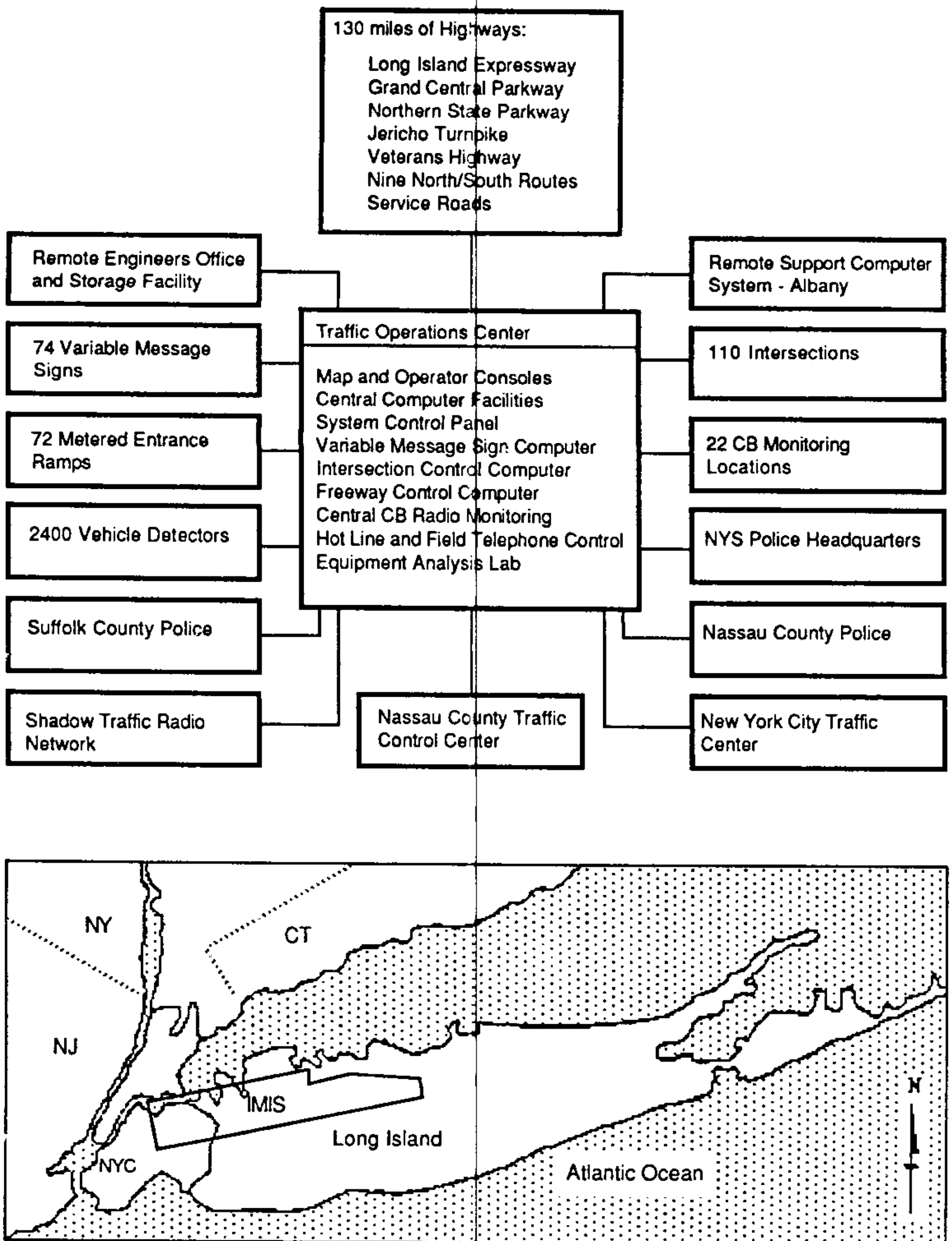


Figure 4. The IMIS Project*

* Bayster, Daniel; Werner, Thomas; Gardeski, Raymond; "The Integrated Motorist Information System: The Ideal and the Real," Presented to the National Conference on Strategies to Alleviate Congestion, March, 1987, p.3.

The resulting difficulties experienced by the IMIS team have resulted in reduced expectations and reorganization. Rather than build the entire system and implement it as a whole, the project will be phased; each phase will be properly tested and able to stand on its own. A number of reports have been published detailing the design and development of the project (15) (16) (17).

Motorist Behavior. This is a relatively new area of transportation research. The general strategy has been to collect information from individuals regarding their personal characteristics and decision-making choices. This information is then statistically analyzed to determine if relationships exist between the personal characteristics and the decisions being made. The results seem to indicate that patterns do exist that may be helpful to transportation system planners (18) (Abu-Eisheh and Mannering, 1987 unpublished data, and Mannering, 1987 unpublished data). One research project demonstrated that it may be possible to affect existing equilibrium conditions by providing enhanced traffic information (19). The results indicated that convergence to equilibrium took longer, but the state ultimately reached was superior to that occurring without the additional information.

Another research effort surveyed motorists in the Dallas area to determine their route selection criteria (20). The study found that drivers are not committed to a single route. While drivers indicated they would divert upon hearing an advisory, few could recall doing so. Key issues appeared to be information credibility and previous driving experiences.

Advanced Technology

Advancements in electronics have promoted the development of more sophisticated information systems. These advancements have come in several areas. The particular relevance of this research to this project is the need to plan current developments so as not to preclude the future implementation of new technologies.

One area of advancement has come from developments in navigation systems (21). Self-contained computer packages relying on dead reckoning techniques are already available for installation in automobiles. These systems generally use CRT map displays and, once calibrated, can identify for drivers their position on the map. This method, however, does not have an interactive capability and is unable to identify the best routes to take based upon traffic considerations. One of the first commercially available systems based on this map-matching technology is the ETAK Navigator available in this country (21). Navigation has evolved from dead reckoning techniques to more sophisticated Loran positioning and satellite communication technologies. These navigational tools make it possible to determine position more precisely.

The development of electronic variable message signs has been mentioned earlier. This technology permits the motorist to obtain real-time information, although the quality of that information is necessarily limited because of space and time constraints.

Advancements in traditional Highway Advisory Radio technology are also being pursued. West Germany and other European countries are adopting a new system called Autofahrer Rundfunk Information, more commonly referred to as ARI (22). This system alerts the driver to imminent information broadcasts that are tied to designated zones in the service area. Vehicles are equipped with special radios. These are modified AM/FM radios. The area is divided into traffic zones, each of which is keyed to a specific transmitter. When traffic conditions dictate it, the transmitter activates and overrides the special car radios. Messages are tailored to the individual zones.

The next significant plateau is the development of interactive systems that permit individual vehicles to communicate with a central computer. The communication consists of origin and destination information and real-time experiential data from the vehicle to the central computer. The central computer analyzes the experiential data along with other data inputs (i.e., loop detectors), determines the existing conditions on the network, and transmits route selection information back to the vehicle. Systems such as ALI (Autofahrer Leit- and Information system), ADRIANE (Automatic Route Indicator, Delft University, Netherlands), and AUTO-SCOUT employ various versions of this concept (23) (24). The use of computer CRTs in vehicles may lead to the eventual transmission of data, such as is being proposed in this project, directly to drivers in their vehicles.

INTERVIEWS

Direct interviews were held with representatives of the Washington State Department of Transportation (WSDOT), Metro Traffic Control (a private company headquartered in Houston, Texas), local cable TV representatives and one local commercial TV station, and the Municipality of

Metropolitan Seattle (METRO), the local transit agency. The following is a brief summary of the results of those interviews.

WSDOT

The WSDOT operates the Traffic Systems Management Center (TSMC), which monitors conditions on the major freeways in the greater Seattle area. The I-5, I-90, I-405, and SR 520 routes are monitored with 17 cameras and approximately 900 loop detectors. The cameras have been in place since the mid 1960s and the loop detectors first were installed in the late 1970s.

In 1981, WSDOT started the FLOW system, a series of ramp meters on I-5 and SR 520. Currently the system consists of 24 ramp meters and 71 data stations.

The data collected are fed into two Concurrent Computer Corporation 732 computers. The data are cycled through once each minute. A RAMTEK graphics package is used to display the current situation as a schematic on a CRT display. It is this representation that is proposed for transmission on local TV (see Figure 5).

The graphic display reproduces conditions on the major freeways. The graphic is in color and monitors one-mile segments of the freeways. Freeflow traffic conditions are shown as green segments on the freeway. Moderate traffic flows are shown as yellow segments and heavy traffic flows are shown as red segments. A flashing red segment indicates a blockage or severe congestion problem.

The WSDOT is currently involved with a major construction effort to complete I-90. As part of this project, the existing systems at the traffic control center will be upgraded. The upgrading will include new cameras, new computers, an increased density of loop detectors, and more ramp meters and data stations. This will include an expansion into more freeway miles in and around Seattle (Henry, 1987 unpublished data).

Metro Traffic Control

Metro Traffic Control is the largest traffic reporting service in the country. Currently it operates in 18 major metropolitan areas, and it is planning to develop the Seattle market.

Metro Traffic Control operates out of a studio and uses full-time, on-the-scene reporters and an engineering staff. It relies on eye-in-the-sky and on the ground reports that are fed to the studio. These reports are then provided to local radio stations through negotiated contracts.

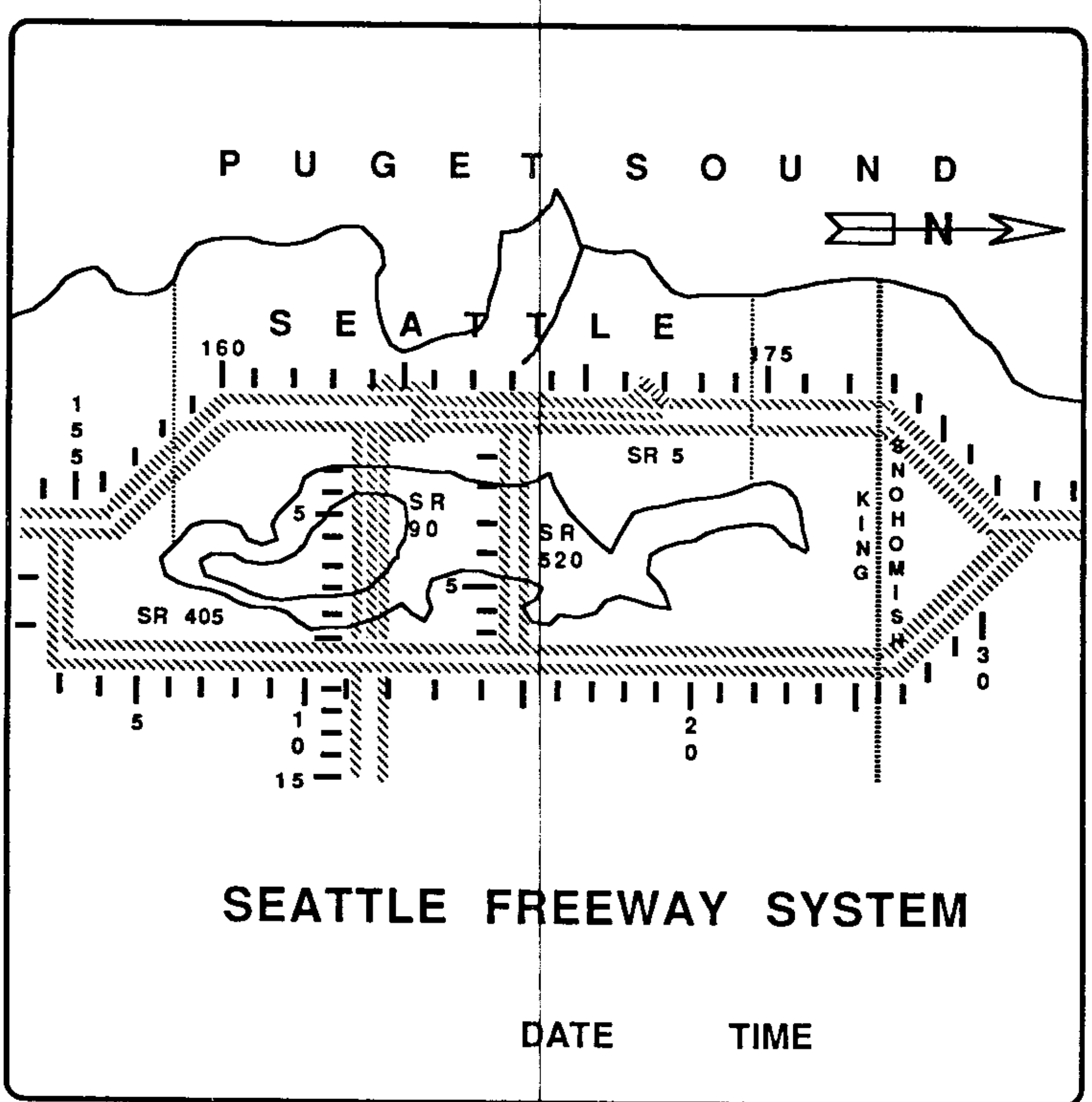


Figure 5. The Computer-Generated Graphic

The company is a for-profit enterprise, the principal source of revenue being advertisements sold to sponsor the traffic reports.

Several of the markets served receive television reports. A graphic package is generated at the studio using a computer. The data are provided by the on-the-scene reporters, who call in the status of current conditions. The information available includes the current status on the system, average speeds, and travel times. The information, however, is not truly real-time; it is supplied by reports received from the reporting staff.

Discussions with the company indicate a desire to move into the Seattle market. The company has indicated no interest in the cable TV industry. Television reports would be brief and would not be available upon demand. The company also expressed interest in working with the staff at the TSMC (Saperstein, 1987 unpublished data).

<u>Local Cable TV</u>

The King County area is served by three local cable companies: TCI, Viacom, and Seacom. Currently, cable penetration reaches about 48 percent of local households, and the current subscription rate is 250,000 to 300,000 households. Local public access programming is monitored by the Office of Cable Communication, an office of the City of Seattle. The programming originates from the TCI station.

Local public access programming does not start until the afternoon. Morning programming consists of a readerboard service. All three cable companies have expressed an interest in providing the proposed traffic information service subject to approval by the City of Seattle (Lee, Giamberso, Swift, 1987 unpublished data). The Office of Cable Communications was contacted, and interest in the service has been expressed subject to the understanding that other local access programming would have priority should the demand arise (See Appendix B).

<u>Commercial TV</u>

One local commercial TV station has expressed an interest and begun negotiations for the use of the graphic information. Discussions with this station produced concern about competition with the cable networks, and the discussions seem to have precipitated action by this station, as a contract with WSDOT was signed shortly afterward.

The commercial station intends to broadcast the graphic information two to three times during its 6:00 to 7:00 a.m. local news show and also during its afternoon news show. The cost for arranging the signal transmission will be borne by the station (Robertson, 1987 unpublished data).

Local Transit

The possible use of cable TV by local transit was also explored. Several national examples were reviewed, including the Central Ohio Transit Authority (Ahlstrom, 1987 unpublished data and Simonetta, 1987 unpublished data), Houston METRO (Boudreaux, 1987 unpublished data) and Seattle METRO (Nine, 1987 unpublished data). In these cases, a magazine format was used and shows were generally produced only once a month.

The staff at Seattle METRO was contacted regarding the specific project. METRO staff agreed that the potential for significant impact on modal choice was small given the immediate proposed application. The potential increases, however, when an upgrade of the existing system is considered. Efforts will be made to participate in the development of the new system to accommodate transit and ridesharing applications (Roach and Wraith, 1987).

Seattle METRO currently provides traffic information to the local media. Bus operators and line supervisors radio in traffic reports to the dispatch office, where the information is available to the media.

CHAPTER 3
ANALYSIS

PURPOSE

The purpose of this chapter is to verify the feasibility of transmitting a computer graphic like that shown in Figure 5 over local access Cable TV. Though not the mainstream purpose of this research, it is also necessary to address the impacts of general traffic advisory information services.

Puget Sound commuters already have access to substantial information. This information can be broadly divided into two classes (Mannering, 1987 unpublished data). The first is experience-based, that is, the result of past commuting experiences and information exchanged with other commuters. The second is real-time, that is, relatively current information usually generated by the media from "eye-in-the-sky" or local transit sources.

Commuters tend to have a preferred route based upon past experience. Departure times are also determined in this fashion. Commuters learn what their average commute times are and then adjust their schedules accordingly. Traffic system constraints such as distance, average congestion conditions, and alternative route availability directly affect these commute decisions.

Individual characteristics such as age, sex, and marital status can also impact commute decisions. These characteristics can shape an individual's valuation of time and willingness to take risks (i.e., change routes or departure times) during the commute trip. Those individuals impatient about lost time and willing to take risks are the principal market for driver information services.

This chapter will establish the feasibility of providing the proposed driver information service. In addition, mathematical models will be estimated to provide insight on the market segments likely to be receptive to the proposed service. A computer model will then be used to demonstrate how the driver information service could alter demand patterns to improve congested conditions. Finally, additional discussion is provided about implementation issues, including a more detailed description of the computer-generated graphic.

FEASIBILITY

The question of feasibility has been subdivided into three parts: technical, cost, and institutional feasibility. Each is a critical element and each is discussed below.

Technical Feasibility

The key question was how it could be done. Conventional wisdom indicates that anything can be done with the necessary resources. For this study, however, only three alternative approaches were outlined. Each relied on a different medium for transmitting the signal. The first would depend on telephone lines, the second on coaxial cable lines, and the third on microwave transmissions.

The telephone line option appeared to be the most practical and was explored first. It would involve the use of appropriate modems and the leasing of a telephone line. This option, however, was eliminated early. The reason was that the telephone line connection required a digital signal and the computer graphic output was analog. The incompatibility was correctable, but it would require a significant restructuring of the computer graphic package. This was considered unreasonable because of the planned upgrade of the entire computer system.

The coaxial cable option was then investigated and found to be feasible. This alternative involved backsending a low frequency FM signal along the existing WSDOT cable lines already in place in the I-5 corridor. The WSDOT cable could be tapped into the TV cable head-end at a convenient point (located where 80th Street crosses the I-5 corridor). The signal would then travel to the cable TV station, where it could then be broadcast. Figure 6 represents what this system might look like. A more detailed description of the equipment needed is provided below in the cost section and in Appendix A.

The microwave option was also explored. Microwave technology has one significant constraint that bears directly on this problem. It requires a direct line-of-sight to work. Buildings, trees, hills, and other obstructions can block signal transmissions. It is possible to relay the signal through a series of transmissions, but each transmitter/receiver pair increases the cost, as noted below.

A review of the terrain and existing antenna locations revealed that a clear line-of-sight exists between an existing antenna sight adjacent to the TSMC and the Viacom TV tower located in northeast Seattle. The microwave transmission from the antenna site to the tower would put the computer graphic signal into the cable TV system. The signal could then be relayed to the TCI station

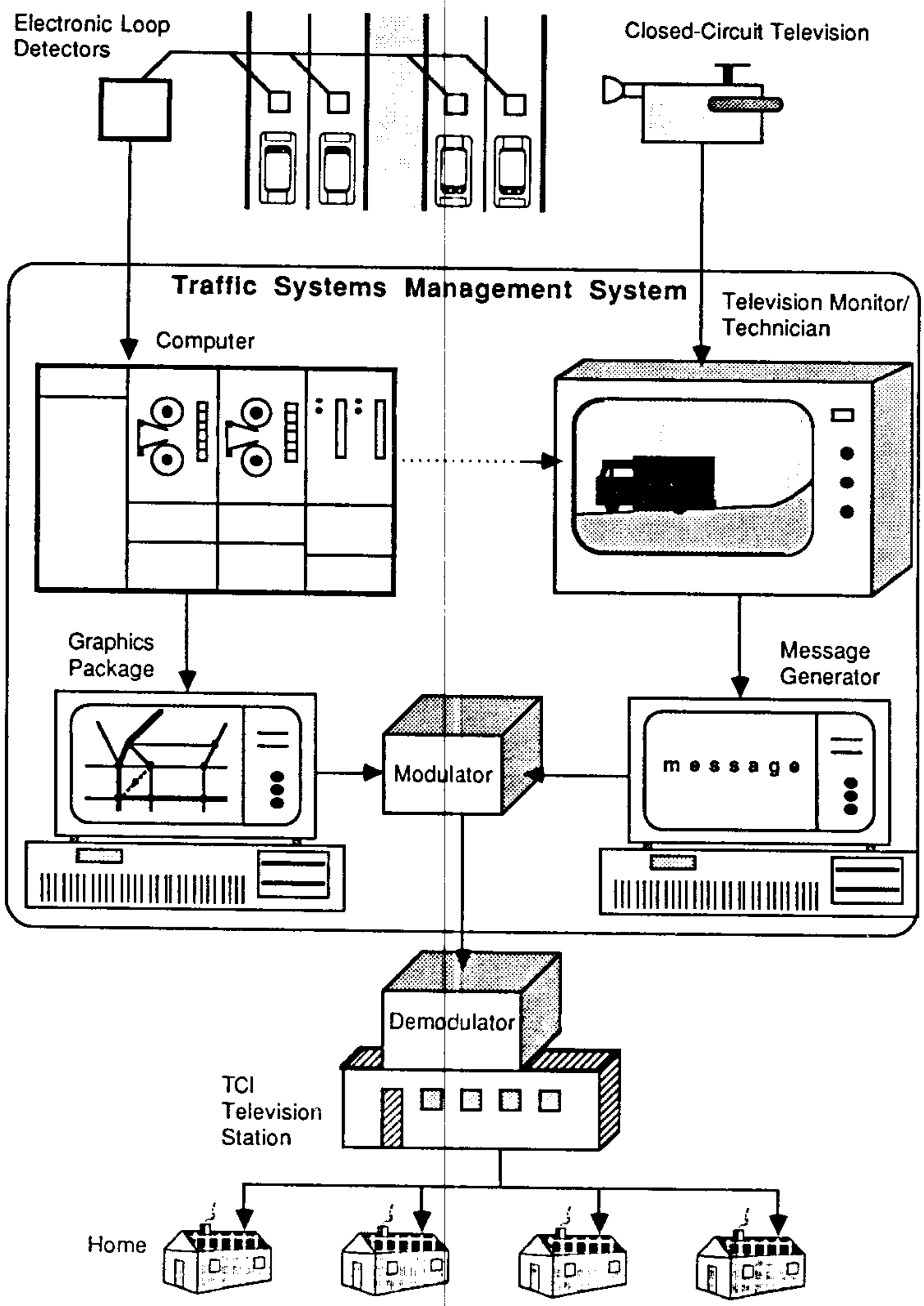


Figure 6. The Coaxial Cable Option

by existing coaxial cable or short-distance microwave. Figure 7 is a representation of how this alternative might look. A more detailed explanation is provided in Appendix A.

The result of this analysis is the conclusion that transmitting the computer graphic on local access cable TV is technically feasible.

Cost Feasibility

Cost feasibility is relative to the resources available. This research presumes limited resources and is therefore interested in low-cost alternatives. The costs of the two feasible options are described below.

Coaxial Cable Option. A detailed description of the elements of this option is contained in Appendix A. Table 3 includes a list of the equipment and labor costs associated with implementing the coaxial cable option. Equipment costs would be approximately $15,290 and labor costs would be about $2,200. Actual costs would be determined through a bid process. Some care was taken to develop representative costs (Henry and Meldrum, 1987 unpublished data).

Microwave Option. A detailed description of the elements of this option are also included in Appendix A. Table 4 includes a list of the labor and equipment costs associated with the microwave option.

As noted above, two alternatives exist for implementing the microwave option. Both alternatives involve a microwave transmission from the TSMC to the Viacom TV tower. Alternative 1 could then convert the microwave transmission to coaxial cable and transmit the signal directly to the TCI station. As shown in Table 4, the equipment costs would be $19,000 and the labor costs would be $880.

Alternative 2 would take the original microwave signal and relay it via another microwave transmitter/receiver pair to the TCI station. Equipment costs would be $500 less and labor costs would be the same.

Both options could be implemented for less than $20,000. As noted above, cost feasibility is determined by resource availability. The project would need to be programmed into the list of annual projects, but the cost does not appear to be prohibitive. Therefore, the project appears to be cost feasible.

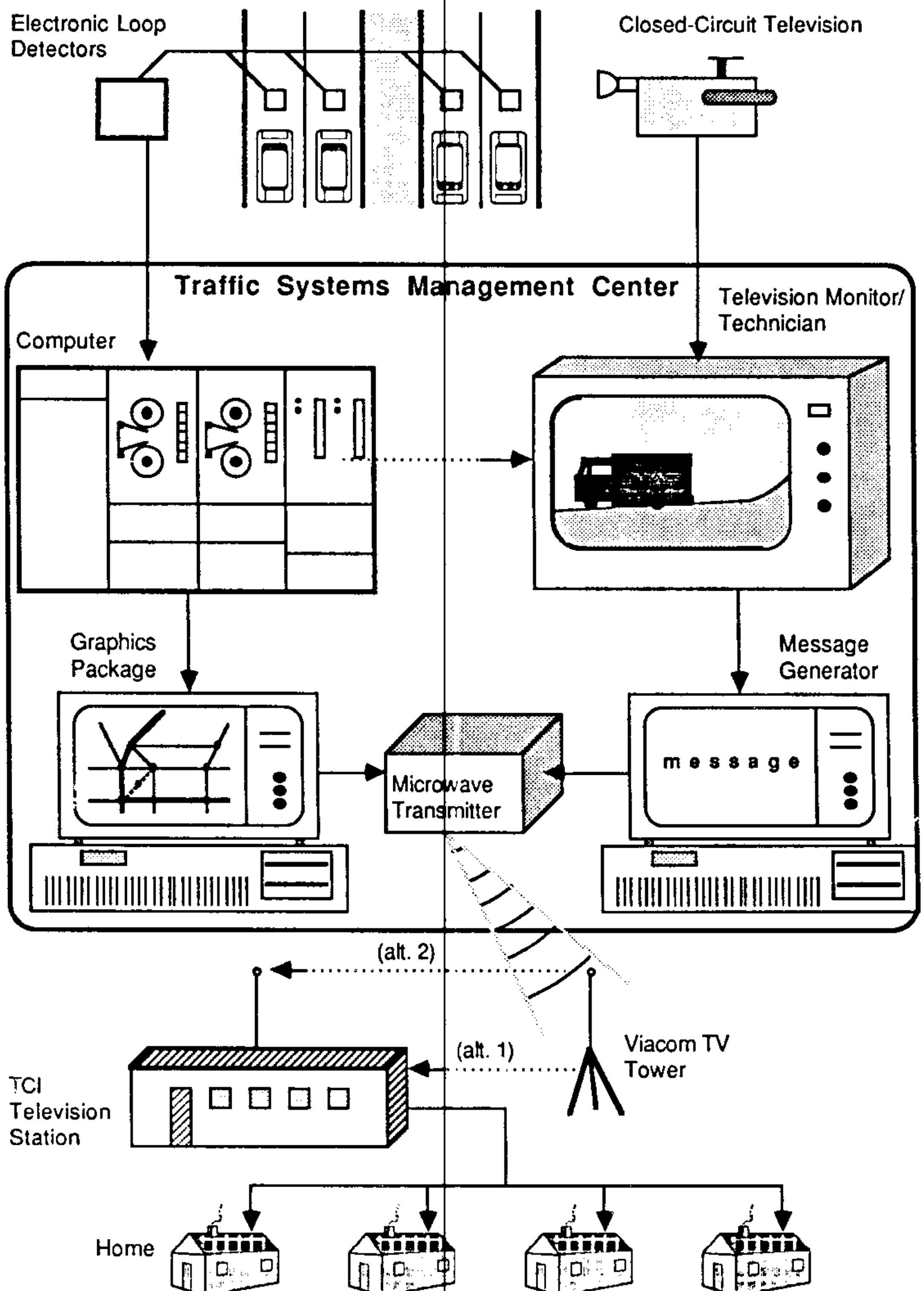


Figure 7. The Microwave Option

Table 3. Coaxial Cable Cost Estimates

Item Description	Cost
Character Generator	$3,000
Video Switch	$500
Audio Source	$1,000
FM Modulator	$3,500
Subchannel Multiplexer (2)	$100
Junction Boxes (4)	$200
Coaxial Cable (1000 ft @ $1.50/ft)	$1,500
2" Conduit Pipe (300 ft @ $2.10/ft)	$630
Unistrut Mounts (150 ft @ $240/100ft)	$360
FM Demodulator	$3,500
Electrical Switch, A-B	$1,000
Total Equipment Costs	$15,290
Labor Costs (40 man-hours @ $55/hr)	$2,200
Total Costs	$17,490

Table 4. Microwave Cost Estimates

Item Description	Cost
Character Generator	$3,000
Video Switch	$500
Audio Source	$1,000
FM Modulator	$3,500
Microwave Transmitter/Receiver Pair, 23GHz	$6,500
FM Demodulator	$3,500
Electrical Switch, A-B	$1,000
Total Equipment Costs	$19,000
Labor Costs (16 man-hours @ $55/hr)	$880
Total Costs	$19,880

Institutional Feasibility

Two issues bear directly on the institutional feasibility question. Would the proposed service be regulated, and are there licenses required? Are the cable TV companies interested in the service and would it conflict with other existing services?

The coaxial cable option would not require any licenses. The only issue would be available space within the cable itself. This appears not to be an issue because sufficient capacity would be available on the cable (Henry, 1987 unpublished data).

The microwave option would require a license from the Federal Communications Commission (FCC). The FCC does not charge a fee for the license, but a frequency coordination search must be done prior to applying. This search costs about $250, but the WSDOT could do it internally with existing staff, thereby saving that amount. The license takes about two weeks to obtain.

Local access programming is monitored by the Office of Cable Communications (OCC), an agency of the City of Seattle. Initial contact with the OCC indicated an interest in the service, although no formal response had been provided pending a formal request (see Appendix B). Two local access channels would be available (public and local government), and this project would be initially directed toward the public access channel (Channel #29). The OCC also indicated that priority would be given to local, public programming, but there appears to be no current demand for this.

The three cable stations all indicated interest in the project (Lee, Giamberso, Swift, 1987 unpublished data). None offer programming during the 6:00 a.m. to 9:00 a.m. time slot. Currently each operates an automatic readerboard service with announcements of public interest.

Both the coaxial cable and microwave transmission options appear to be institutionally feasible.

BEHAVIOR ANALYSIS

As noted above, two types of variables influence commuters when they make trip decisions. The first are external transportation constraints (deterministic) such as distance, general traffic conditions, traffic information, and the availability of alternatives. The second are individual characteristics (behavioral) such as income, sex, and marital status. Historically, investigators have given more weight to deterministic variables in the decision-making process. As noted in Chapter 2, much work has been done recently to estimate the influence of behavioral variables.

It seems intuitive that real-time traffic advisories would have a positive impact on traffic conditions if commuters would respond to the information. What factors might influence the sensitivity of an individual commuter to the proposed driver information service? Can those commuters most likely to respond be profiled? A survey was developed to generate some data for input into some mathematical models to determine whether those questions could be answered. The results are highlighted below.

Survey

The purpose of the survey was to gather data about individual commuters that might permit researchers to estimate the probability that they would use the proposed driver information service. Figure 8 is a sample of the survey instrument. The survey was administered by telephone in the greater Seattle area with particular emphasis given to the suburban commuter. (This emphasis resulted from the selection of telephone prefixes). Interviewers were given specific telephone prefixes and instructed to randomly select households from the telephone book. The intent of the survey was to collect data to permit an illustrative analysis of existing commuter behavior patterns. As such, it is not intended to provide an exhaustive description of all possible market segments.

The survey resulted in 117 valid responses. Table 5 includes a summary of the key variables generated by the survey. The analyses of the results and the modeling efforts were done using the SST Statistical Software Package.

Probability Models

The purpose of the modeling effort was to determine the mathematical probabilities of whether the service would be used and whether individuals would likely act on the information. The models would help profile the deterministic and behavioral characteristics of those individuals who were information-seekers and risk-takers. Information-seekers are those commuters already sensitive to the availability of real-time information; they already listen to the radio and TV services that are available. Risk-takers are those commuters willing to make changes to their routine patterns for commuting. This effort focused on those individuals who indicated that they changed their routes or

COMMUTER SURVEY

We are conducting a traffic survey for the University of Washington with the objective of reducing traffic congestion in the Seattle area. The survey focuses on the morning commute to work and the use of traffic information by commuters. Do you have a few minutes to participate in this survey?

1. How long does your average morning work trip take?
2. Do you normally take a carpool or vanpool to work?
3. Do you think traffic is a serious problem in the Seattle area?
4. What is the zip code or approximate location of your work place?
5. Do you need to be at work at a specific time or do you have flexible work hours?
6. Do you ever commute by transit? If so, how often per month by transit?
7. Do you listen to the radio or local TV for information about traffic condition before planning your morning trip to work?
8. Do you ever change your departure time to work because of traffic congestion? If yes, about how many times per month do you choose a departure time that is different from your normal departure time?
9. Do you ever change your route to work because of traffic congestion? If yes, about how many times per month do you choose a route that is different from your normal route?
10. Do you ever take transit or carpool because of traffic congestion?
11. If offered on local TV, would you use traffic congestion information in your route, departure the or mode selection?

GENERAL QUESTIONS

1. What route do you usually take to work? I-90; I-405; I-5; SR 520; other.
2. What is your age?
3. What is your marital status? Single Married
4. How many people reside in your household?
5. Do you subscribe to cable TV?
6. How many cars are owned by your household?
7. Which of these categories best approximates your household income?
   less than $20,000 $20,000 - $40,000 $40,000 - $60,000 $60,000+
8. Is the respondent male or female?

Figure 8. Commuter Survey

Table 5. Sample Summary Statistics*

	Averages*	Standard Deviation
Total travel time most frequently used route (minutes)	30.49	10.29
Most frequently used route congested at level of service D or worse (percent)	89.70	
Estimated additional trip travel time on the shortest time alternate route (minutes)	7.84	2.95
Number of departure time changes per month	2.32	3.44
Percent changing departure time	45.30	
Number of route changes per month	2.81	4.16
Percent changing route	48.70	
Think traffic congestion is a serious problem in the Seattle area (percent)	85.60	
Listen to the radio or TV for traffic advisories (percent)	61.58	
Flexible work starting time (percent)	68.38	
Age (years)	37.81	12.17
Percent married/single	65/35	
Percent male/female	60/40	
Number of household members	2.71	1.54
Number of household cars	2.22	0.37
Household income (dollars)	36,200	17,800
Percent residing on the eastside	40.17	
Percent using transit	25.64	
Number of transit trips per month	3.45	8.47

* Averages unless otherwise noted.

their departure times. The issue of modal change was set aside because it was determined that longer-term and more elaborate issues (i.e. organizing carpools and acquiring transit schedules) were involved (Mannering, 1987 unpublished data). This issue is discussed further later in this chapter.

The binary LOGIT model was selected for accomplishing these purposes. The calculation of the choice probabilities was based upon the following formula (Mannering, Bottiger, and Black, 1987 unpublished data):

$$P_i = \frac{1}{1 + e^{-V_i}} \qquad (1)$$

where P_i is the probability of selecting choice i.

To calculate equation (1), the utility equation V_i had to be solved. Because the choice situation is binary, the utility function for the second choice option is implicitly set equal to zero. The first choice ($_i$) utility function could therefore be defined as follows:

$$V_i = A + BX + C \qquad (2)$$

where A, B, and C are vectors of estimable parameters, "X" is a vector of transportation system variables, and "Y" is a vector of individual characteristic variables.

The LOGIT models are estimated by standard maximum likelihood methods. A standard t-statistic evaluation method is also used to test for the significance of the coefficients. A full description of these methods is available elsewhere (25).

The first model was designed to identify information-seekers. The dependent variable was whether respondents listened to the radio for traffic advisory information. Specifically, the model would identify the key variables affecting the utility of seeking information and the weights (coefficients) given to those variables. The likelihood of those surveyed using the service was estimated to be 61.5 percent.

The results of the first model are presented in Table 6. The table identifies the key variables, with their estimable coefficients, and the utility function (V_i). Some interpretation of these results is warranted. The constant term captures mean observables and provides for statistical consistency. The negative number implies some general resistance to the information service, which may represent

Table 6. Information Service Usage Probability Estimates

Variable	Estimated Coefficient	t-Statistic
Constant	-3.104	-2.196
Additional trip travel time on shortest time alternative route (minutes)[dt]	-.356	-3.596
Age variable(years)[ag]	.058	2.517
Congestion level on most frequently used route indicator (1 if level of service D or worse, 0 otherwise)[ls]	1.041	1.320
Total travel time most frequently used route (minutes)[tt]	.041	1.575
Traffic problem recognition (1 if problem, 0 otherwise)[tp]	1.336	2.053
Television variable (1 would use if available, 0 otherwise)[tv]	1.353	2.729
Marital status variable (1 if single, 0 otherwise)[ms]	1.108	1.946
Number of observations	117	
Log likelihood at zero	-81.098	
Log likelihood at convergence	-57.082	

Utility function

$$V(i)= -3.104-.356*dt+.058*ag+1.041*ls+.041*tt+1.336*tp+1.353*tv+1.108*ms$$

negative sentiment about existing conditions as well as some resistance to change. The first variable is travel time (tt) and the positive coefficient indicates greater utility as travel time increases. This is logical: time has value and commuters would want to be aware of delays that might cause longer commutes. Those with longer commutes likely would be more sensitive and therefore more interested. The next variable (dt) represents the travel time differences between the best alternative route and the next best one. The negative coefficient indicates that as the difference between routes increases, the commuter receives less utility from the information service. This is also logical, because commuters would gain less from the service when their alternative choices were not attractive.

The level of service variable (ls) is a surrogate measure for general traffic conditions. If traffic conditions are generally worse, then the commuter would likely be more sensitive to possible changes and might expect those changes to occur more often. If the usual level of service is generally good, the commuter has less inclination to check out conditions. The positive coefficient supports this conclusion.

If commuters already use existing information services, it is reasonable to assume they might be interested in a new, proposed service (tv). The positive coefficient supports this analysis.

The age (ag) of the commuter appears to be related to the utility of the service. The older the commuter, the more utility is gained from using an information service. This might mean that older people are more experienced and rational in their approach. Younger commuters may be more stubborn about getting to their destinations or they may simply use the radio for other purposes, such as entertainment.

Marital status (ms) also appears related. Single people appear to gain greater utility. This seems counter-intuitive, except that marital and familial obligations may provide constraints that weaken the utility of an information service.

The last variable is perhaps the most intuitively obvious. Those individuals who perceive that traffic conditions are a problem (tp) are more likely to utilize a driver information service than those who do not. If there is no perception of a problem, then there is no motivation to seek a remedy.

The next two models were designed to profile risk-takers, those commuters willing to make changes in their commute patterns. The second model looked at the willingness to change departure times. Table 7 displays the results. The estimated likelihood for changing departure times for those surveyed was 45.3 percent. An interpretation of the utility function will help verify its logic.

The need for the constant term was explained earlier. The negative sign represents a general resistance to making departure time changes. Departure change affects the entire morning routine, and some resistance would seem reasonable. As travel time (tt) increases there appears to be an increasing utility in making departure time changes. Read differently, the shorter the trip, the less benefit is gained from changing the departure time. Delays that may have a significant percentage impact may in fact be only several minutes. This may be acceptable to the short-time commuter, but percentage delays for those with a longer commute may represent significant time commitments. The longer the alternative routes (dt) are relative to the preferred route, however, the less utility is gained. Departure time change has two elements. The first may simply be an earlier or later departure using the same route. The second may result from changing the route and adjusting for the longer travel time. As alternative travel time gets longer, that element becomes less attractive. A zone identifier was used for this model (es). It represents the utility gained by commuters living east of Seattle. These commuters have a unique commute problem as they have only two major route choices over Lake Washington. Both bridge options tend to be severely congested. There seems to be a negative relationship to making departure time changes. The unique commute problems may be one factor, as the individuals may have adjusted to existing conditions and learned "to live" with them. Eastside residents, however, also tend to have higher incomes. The income variable (in) is structured for low income respondents and indicates that lower income commuters gain more utility from changing departure times. Lower income jobs often have fixed start times that would encourage changing departure times to compensate for existing conditions.

As noted earlier, those who perceive traffic conditions as being a major problem (tp) are more likely to respond to counter the problem. The variables and coefficients in this model all seem logical and appropriate.

The third model examined circumstances affecting the willingness of commuters to change their routes. The results of this model are displayed in Table 8. The likelihood was calculated to be 48.7 percent. Again, some explanation of the utility function is necessary.

Table 7. Departure Time Change Probability Estimates

Variable	Estimated Coefficient	t-Statistic
Constant	-.853	-.903
Additional trip travel time on shortest time alternative route (minutes)[dt]	-.291	-3.397
Zone indicator (1 if eastside commuter, 0 otherwise)[es]	-.476	-1.057
Income level(1 if <$40k, 0 otherwise)[in]	1.071	2.459
Total travel time most frequently used route (minutes)[tt]	.054	2.211
Traffic problem recognition (1 if problem, 0 otherwise)[tp]	1.016	1.578
Number of observations	117	
Log likelihood at zero	-81.098	
Log likelihood at convergence	-68.345	

Utility function

$$V(d) = -.853 - .291*dt - .476*es + 1.071*in + .054*tt + 1.016*tp$$

Table 8. Route Change Probability Estimates

Variable	Estimated Coefficient	t-Statistic
Constant	10.711	3.273
Additional trip travel time on shortest time alternative route (minutes)[dt]	-1.659	-4.386
Gender indicator(1 if male, 0 otherwise)[sx]	1.500	1.975
Income level(1=<$20k, 2=$20k-$40k, 3=$40k-$60k, 4=$60k+)[in]	-1.097	-2.403
Total travel time most frequently used route (minutes)[tt]	.071	1.651
Traffic problem recognition (1 if problem, 0 otherwise)[tp]	2.207	2.176
Number of observations	117	
Log likelihood at zero	-81.098	
Log likelihood at convergence	-27.907	

Utility function

$$V(r)= 10.711-1.659*dt+1.5*sx-1.097*in+.071*tt+2.207*tp$$

The constant term is positive for route changes. This might indicate a utility beyond a simple response to congestion. The need to accomplish other tasks like personal errands or interest in a change of scenery could explain the positive constant term. As travel time (tt) increases, the utility of a route change also increases. The individual may be more willing to find a better alternative. This is counter-acted, however, if the next best alternative travel time increases more (dt), and the utility would then be decreased.

Males (sx) appear to be more willing to change routes. Males may tend to be more aggressive and greater risk-takers than females; they may be more comfortable pursuing unfamiliar routes.

Income (in) is also a factor. As income increases, there appears to be less utility to changing routes. Age may be an indirect factor as incomes tend to rise with age. Older people may be less willing to change their familiar pattern. Also, higher income jobs may not have strictly enforced start times, so there is less pressure to be at work on time. Reviewed in the context of departure time changes, lower income people may simply be greater risk-takers.

Finally, if people perceive traffic conditions as a problem (tp), they are more apt to react to them. This has already been described earlier. Again, the variables and coefficients appear logical.

<u>Elasticity Models</u>

Some additional insight can be gained from reviewing the elasticities of the variables. The calculation of probability elasticities with respect to the model variables may be useful in defining a marketing campaign to make the proposed service more effective. To calculate the probability elasticities (E_{ik}), the following formulas are defined (Mannering, Bottiger, and Black, 1987 unpublished data):

$$E_{ik} = b_k x_k (1 - P_i) \tag{3}$$

$$E_{ik} = c_k y_k (1 - P_i) \tag{4}$$

where E_{ik} is the elasticity of choice "i" for independent variable k,

b_k, c_k are estimable coefficients from the vectors defined in Equation (2),

x_k, y_k are independent variables from the vectors "X" and "Y" defined in Equation (2), and

P_i is the probability of choice "i" as defined in Equation (1).

The average elasticities were determined by using equations (3) and (4) and enumerating through the survey sample. The results of this process are displayed in Tables 9, 10, and 11 for the three models previously developed. An absolute value greater than one (1.0) implies elastic behavior, an absolute value less than one (1.0) implies inelastic behavior.

For information service and departure time change, only the additional trip travel time on the shortest time alternative route variable (dt) is elastic. This means any change in the other variables will result only in a minor change in the dependent variable. The relationship between the "dt" variable and the dependent variables does not at first seem helpful. To the extent that "dt" represents a perceived value rather than a real one, however, there may be some benefit. A marketing campaign that encourages commuters to seek and use viable alternative routes might be helpful.

Three independent variables have an elastic relationship to the dependent route change variable. The alternative route travel time difference (dt) variable has an inverse relationship that could benefit from the above described recommendation. If alternative routes could be shown to be viable and competitive, more route changes might occur.

Income also has an inverse relationship. A marketing campaign targeted at higher income, professional people might have some benefit.

Finally, if travel time on the preferred route were increased, commuters would quickly look for alternatives. It would be counterproductive to introduce conditions that would increase travel times on particular routes, but a marketing campaign that emphasized the time spent in commuting and that suggested shorter alternatives (e.g., HOV lanes) might be helpful.

While age is not a direct variable in any of these models, less successful models did indicate some relationship to the dependent variables. A marketing campaign aimed at an older population might also have some benefits.

BENEFITS ANALYSIS

The previous sections established the feasibility of the proposed project and the likelihood the new service would be used. Whether the implementation of the new service would provide any measurable benefits to the existing system remains to be determined.

Table 9. Information Service Usage Elasticity Estimates

Elasticity with respect to:	Value
Additional trip travel time on shortest time alternative route (minutes)	-1.230
Age	.791
Congestion level on most frequently used route	.320
Total travel time most frequently used route (minutes)	.461
Traffic problem recognition	.377
TV usage	.162
Marital status	.151

Table 10. Departure Time Change Elasticity Estimates

Elasticity with respect to:	Value
Additional trip travel time on shortest time alternative route (minutes)	-1.371
Origin of trip	-.122
Income level	.256
Total travel time most frequently used route (minutes)	.886
Traffic problem recognition	.443

Table 11. Route Change Elasticity Estimates

Elasticity with respect to:	Value
Additional trip travel time on shortest time alternative route (minutes)	-8.478
Male indicator	.436
Income level	-1.462
Total travel time most frequently used route (minutes)	1.170
Traffic problem recognition	.924

In the absence of an operational model, it is necessary to simulate the possible impacts of the proposed service. Very little analysis has been done regarding the impacts of traffic advisory services. One key study (14) was done to evaluate the impact of the advisory service on a simulated freeway model.

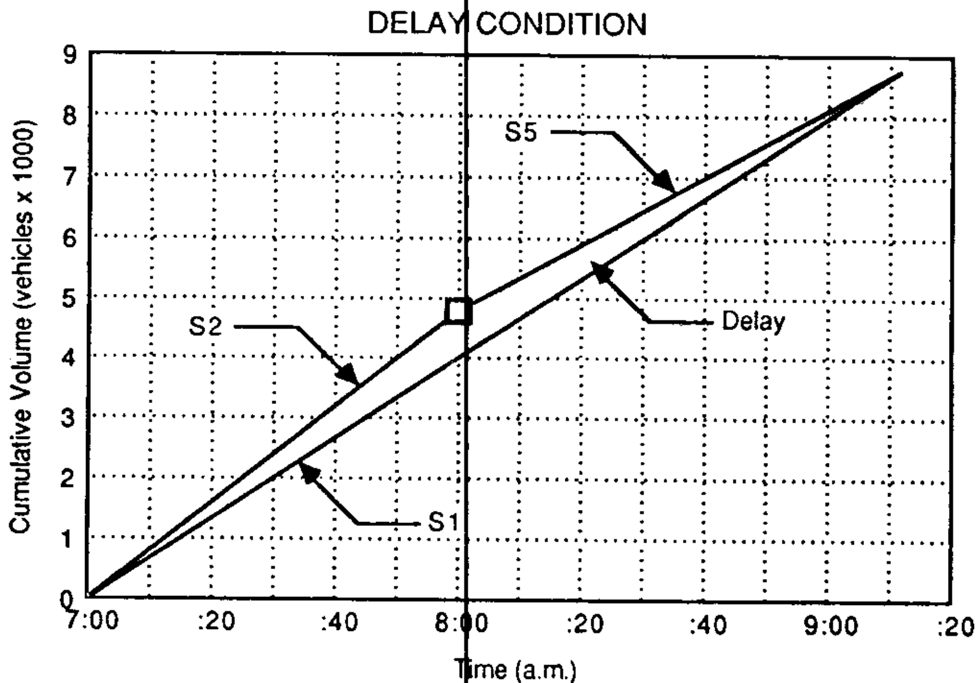
First, normal conditions were measured, then an incident was introduced and measured. Finally, the incident was rerun with assumptions reflecting the existence of the advisory service. The results were compared to the incident situations run without the advisory service. The analysis demonstrated a significant improvement in traffic flow when the advisory service was available.

FHWA Model

To measure potential benefits provided by the proposed service, a copy of a computer model developed by the Federal Highway Administration (FHWA) was acquired. This computer package uses formulas developed in the 1970s and LOTUS 123 to estimate the amount of delay resulting from traffic conditions (26). Two situations were evaluated. The first comprised normal, recurring traffic conditions and the second involved introducing an incident. The conditions tested were a simulation of traffic flows on the Evergreen Floating Bridge and the Interstate-90 Floating Bridge in Seattle.

Peak hours for both bridges in the morning are 6:00 a.m. to 9:00 a.m.. Demand for the Evergreen Floating Bridge usually results in a four-mile queue about 8:00 a.m. (Henry, 1987 unpublished data). Figure 9 is a representation of this condition. The Interstate-90 (I-90) Floating Bridge usually has a 3.4 mile queue formed by 7:45 a.m. (Henry, 1987 unpublished data). This queue actually forms west of the bridge and backs onto the bridge. The bridge has two directional lanes and a reversible lane for westbound commuter traffic. Figure 10 is a representation of the morning commute conditions (see Table 12). Note that conditions vary every day and these descriptions are offered only as examples (27).

Traffic conditions have built up over the years and commuters have adjusted to the normal conditions. Conditions appear to have reached an equilibrium, and commuters are assumed to be less likely to change without some stimulus. The occurrence of an incident that impacts traffic conditions, however, could result in commuters adjusting their routines. Figure 11 represents an incident condition occurring on the Evergreen Floating Bridge. The resulting delay assumes no advisory

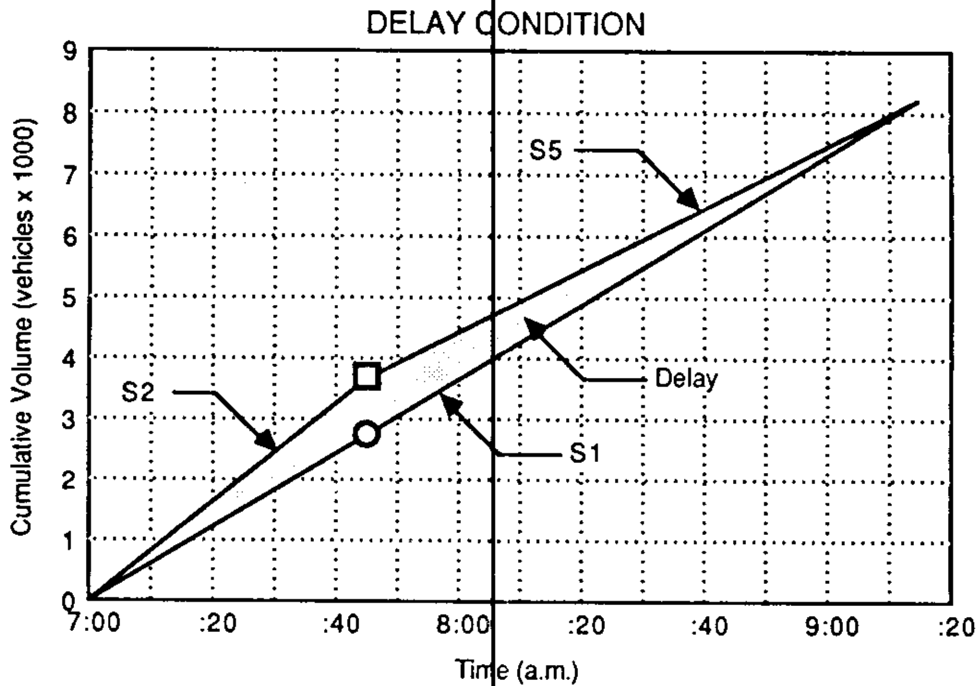


Evergreen Floating Bridge

Number of Lanes:		2
Capacity flow rate of the facility, veh/hr	S1 =	4000
Initial demand flow rate, veh/hr	S2 =	4000
Initial bottleneck flow rate, veh/hr	S3 =	4850
Adjusted bottleneck flow rate, veh/hr	S4 =	4000
Revised demand flow rate, veh/hr	S5 =	3282
Incident duration until first change, min	T1 =	0
Duration of total closure, min	T2 =	0
Incident duration under adjusted flow, min	T3 =	0
Elapsed time under initial demand, min	T4 =	60

Total Delay, veh-hrs =	928.1
Time to Normal Flow (TNF), min =	131.0
Maximum extent of queue, veh =	850
Maximum length of queue, miles =	2.41

Figure 9. Evergreen Floating Bridge Normal Conditions



I-90 Floating Bridge

Number of Lanes:		2
Capacity flow rate of the facility, veh/hr	S1 =	3600
Initial demand flow rate, veh/hr	S2 =	4925
Initial bottleneck flow rate, veh/hr	S3 =	3600
Adjusted bottleneck flow rate, veh/hr	S4 =	3600
Revised demand flow rate, veh/hr	S5 =	2936
Incident duration until first change, min	T1 =	0
Duration of total closure, min	T2 =	0
Incident duration under adjusted flow, min	T3 =	0
Elapsed time under initial demand, min	T4 =	45
Total Delay, veh-hrs =		1116.3
Time to Normal Flow (TNF), min =		134.8
Maximum extent of queue, veh =		994
Maximum length of queue, miles =		2.82

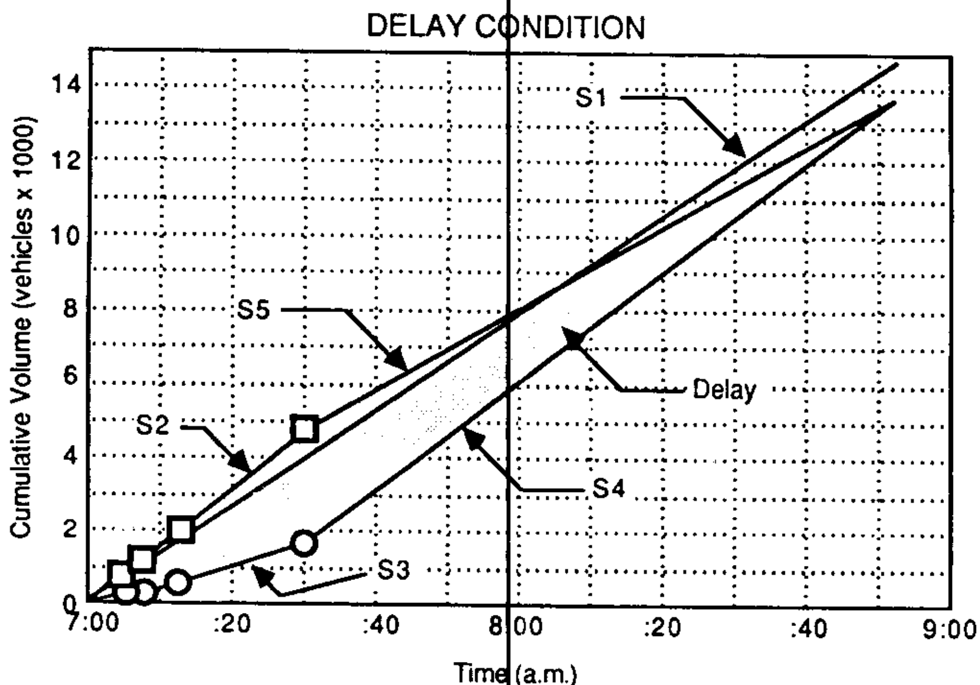
Figure 10. I-90 Floating Bridge Normal Conditions

Table 12. Conversion Worksheet

Evergreen Floating Bridge (SR 520)	
ACTUAL ESTIMATES	
Peak hour backup=	4 miles
Spacing assumption=	50 ft/veh
Conversion method	
5280 ft/mi * 4 mi= 21,120 ft	
21,120 ft/ 50 ft/veh= 422 veh	
422 veh * 30 ft/veh= 12,660 ft	
12660 ft/ 5280 ft/mi= 2.4 mi	
MODEL ASSUMPTIONS	
Peak hour backup=	2.4 miles
Spacing assumption=	30 ft/veh
Interstate 90 Floating Bridge (I-90)	
ACTUAL ESTIMATES	
Peak hour backup=	4.7 miles
Spacing assumption=	50 ft/veh
BACKUP CALCULATIONS**	
2 lanes=	0.8 mi
3 lanes=	2.6 mi
Total lane miles=	9.4 mi
2-lane equivalent miles=	4.7 mi
Conversion method	
5280 ft/mi * 4.7 mi= 24,816 ft	
24,816 ft/ 50 ft/veh= 496 veh	
496 veh * 30 ft/veh= 14,880 ft	
14,880 ft/ 5280 ft/mi= 2.82 mi	
MODEL ASSUMPTIONS	
Peak hour backup=	2.82 miles
Spacing assumption=	30 ft/veh

* The models assume a 30 foot spacing for vehicles, while actual conditions indicate a 50 foot spacing. The numbers have been adjusted to compensate for this. An adjustment was also made for the reversible lane on I-90 (see Table 12)

** Part of the backup is on a 2 lane facility and part is on a 3 lane facility. This calculation converted everything to 2 lanes.



Evergreen Floating Bridge

Number of Lanes: 2

Capacity flow rate of the facility, veh/hr	S1 =	4000
Initial demand flow rate, veh/hr	S2 =	4850
Initial bottleneck flow rate, veh/hr	S3 =	1400
Adjusted bottleneck flow rate, veh/hr	S4 =	2000
Revised demand flow rate, veh/hr	S5 =	3282
Incident duration until first change, min	T1 =	10
Duration of total closure, min	T2 =	5
Incident duration under adjusted flow, min	T3 =	10
Elapsed time under initial demand, min	T4 =	60

Total Delay, veh-hrs =	3956.3
Time to Normal Flow (TNF), min =	223.0
Maximum extent of queue, veh =	3117
Maximum length of queue, miles =	8.85

Figure 11. Evergreen Floating Bridge Incident Condition

information service. The incident would create an additional 3028 vehicle-hours of delay over normal conditions (see Table 13). Would the proposed driver information service reduce the amount of additional delay?

It seems intuitive that the new service would have a positive impact. Two separate examples were run to test that assumption. The first assumed ten percent of the commuters would change routes upon learning of the incident. Ten percent is an arbitrary assumption based upon the earlier analysis that 48.7 percent of the surveyed commuters changed routes due to congestion at least once a month. Figure 12 represents the impacts this diversion would have on conditions on the Evergreen Floating Bridge. Because of limited options, this shift would probably move to the I-90 Floating Bridge where conditions were already congested. What would the impact be on I-90 and would there be a net benefit to the system?

Figure 13 represents the impact of the route shift to the I-90 Floating Bridge. As expected, the shift created additional delay. An analysis of both bridges, however, indicated a positive benefit (see Table 13). The route change condition could mean a savings of 615.5 vehicle-hours for the system.

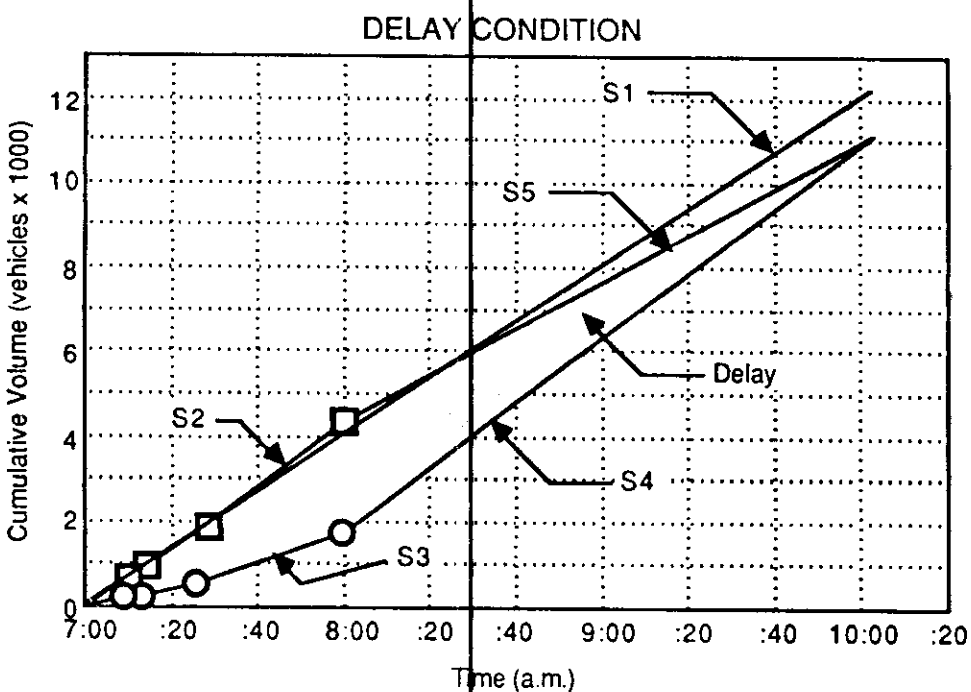
The second test involved a change in departure time. Again, ten percent of the commuters were assumed to delay their departure. For this exercise, the impact of this action resulted in a ten minute extension of the slightly reduced initial demand flow rate. Figure 14 is a representation of this example. It was also assumed that I-90 was not affected by these changes. The result was a savings of 1019.9 vehicle-hours for the system (see Table 13).

A variety of departure and route change combinations could be run, but it is clear that the driver information service could have a positive impact. If vehicle occupancy is assumed to be 1.2 persons per vehicle, then the vehicle-hours of delay can be translated into people-hours, and a value can be assigned to estimate actual savings. Table 13 includes a conversion of vehicle-hours to people-hours. The value of time is difficult to assess and arguments can be made for a range from minimum wage to average salaries of commuters. For purposes of illustration, the value of a people-hour was assumed to be $6.00. Again, Table 13 provides the result of this calculation for the two examples.

The magnitudes and frequencies of incidents that occur on Seattle-area freeways are random and unpredictable. Predicting annual benefits resulting from the proposed driver information service is

Table 13. Benefit Calculations Worksheet

	Delay
Normal Condition [NC]	
Evergreen Floating Bridge=	928.1 hrs
I-90 Floating Bridge=	1116.3 hrs
Total Delay=	2044.4 hrs
Incident Condition (Evergreen Bridge) [IC]	Delay
Evergreen Floating Bridge=	3956.3 hrs
I-90 Floating Bridge=	1116.3 hrs
Total Delay=	5072.6 hrs
Route Change Condition [RC]	Delay
Evergreen Floating Bridge=	2560.4 hrs
I-90 Floating Bridge=	1896.7 hrs
Total Delay=	4457.1 hrs
Departure Change Condition [DC]	Delay
Evergreen Floating Bridge=	2936.4 hrs
I-90 Floating Bridge=	1116.3 hrs
Total Delay=	4052.7 hrs
Differences	Delay
[IC]-[NC]=	3028.2 hrs
[IC]-[RC]=	615.5 hrs
[IC]-[DC]=	1019.9 hrs
Cost Savings Estimates	
Assumed average vehicle occupancy=1.2 pers/veh	
People hours=vehicle hours/1.2	
Person hour= $6.00	
Route change savings=	$3,078
Departure change savings=	$5,100

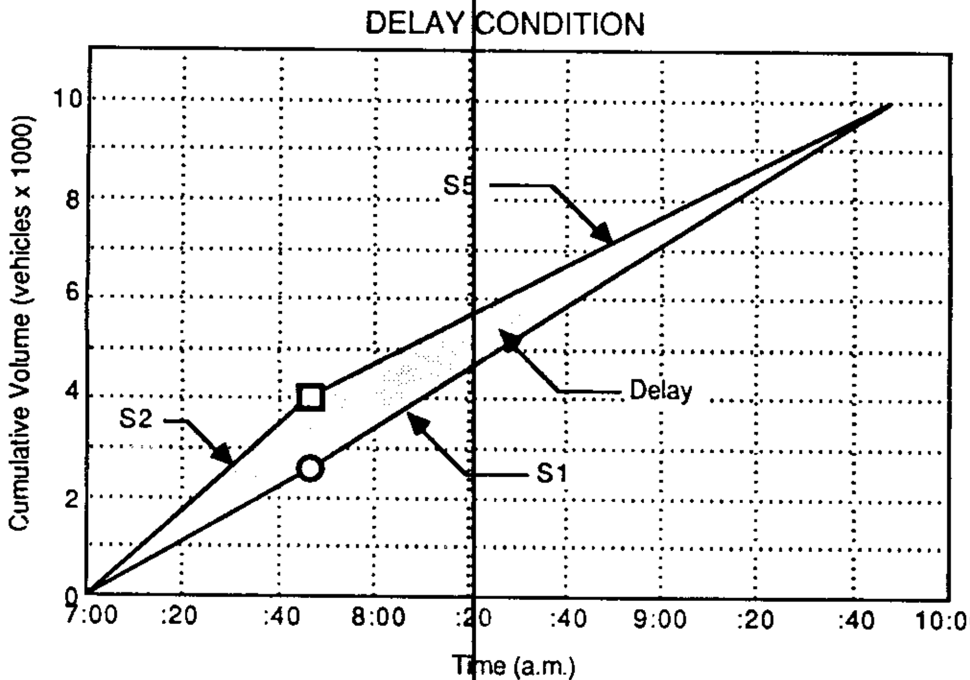


Evergreen Floating Bridge

Number of Lanes:		2
Capacity flow rate of the facility, veh/hr	S1 =	4000
Initial demand flow rate, veh/hr	S2 =	4365
Initial bottleneck flow rate, veh/hr	S3 =	1400
Adjusted bottleneck flow rate, veh/hr	S4 =	2000
Revised demand flow rate, veh/hr	S5 =	3282
Incident duration until first change, min	T1 =	10
Duration of total closure, min	T2 =	5
Incident duration under adjusted flow, min	T3 =	10
Elapsed time under initial demand, min	T4 =	60

Total Delay, veh-hrs =	2560.4
Time to Normal Flow (TNF), min =	182.4
Maximum extent of queue, veh =	2632
Maximum length of queue, miles =	7.48

Figure 12. Evergreen Floating Bridge Route Change Condition



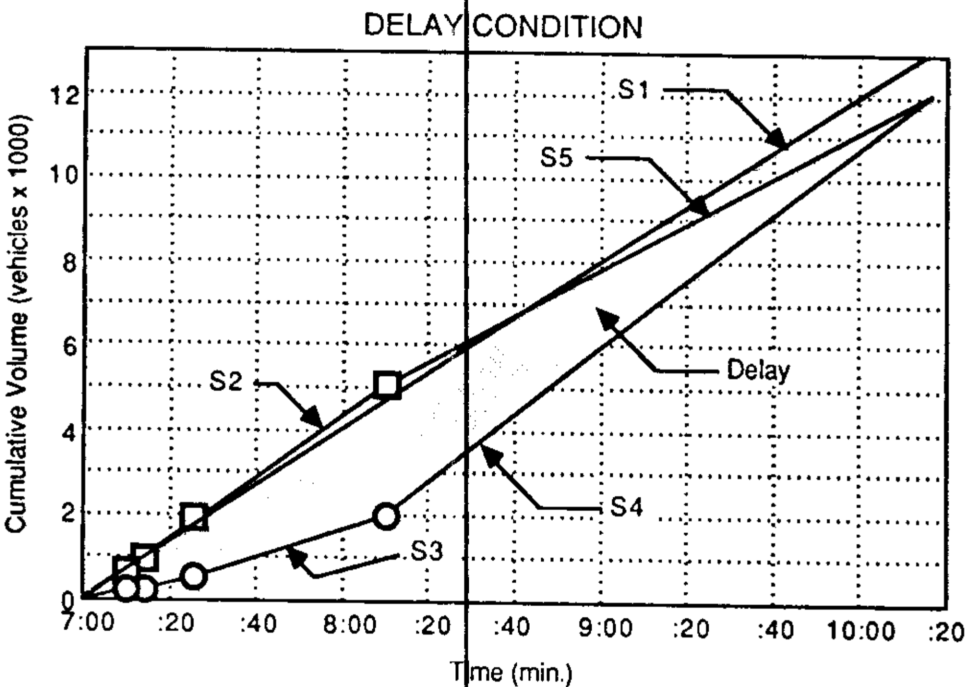
I-90 Floating Bridge

Number of Lanes: 2

Capacity flow rate of the facility, veh/hr	S1 =	3600
Initial demand flow rate, veh/hr	S2 =	5410
Initial bottleneck flow rate, veh/hr	S3 =	3600
Adjusted bottleneck flow rate, veh/hr	S4 =	3600
Revised demand flow rate, veh/hr	S5 =	2936
Incident duration until first change, min	T1 =	0
Duration of total closure, min	T2 =	0
Incident duration under adjusted flow, min	T3 =	0
Elapsed time under initial demand, min	T4 =	45

Total Delay, veh-hrs =	1896.7
Time to Normal Flow (TNF), min =	167.7
Maximum extent of queue, veh =	1358
Maximum length of queue, miles =	3.86

Figure 13. I-90 Floating Bridge Route Change Condition



Evergreen Floating Bridge

Number of Lanes:		2
Capacity flow rate of the facility, veh/hr	S1 =	4000
Initial demand flow rate, veh/hr	S2 =	4365
Initial bottleneck flow rate, veh/hr	S3 =	1400
Adjusted bottleneck flow rate, veh/hr	S4 =	2000
Revised demand flow rate, veh/hr	S5 =	3282
Incident duration until first change, min	T1 =	10
Duration of total closure, min	T2 =	5
Incident duration under adjusted flow, min	T3 =	10
Elapsed time under initial demand, min	T4 =	70
Total Delay, veh-hrs =		2936.4
Time to Normal Flow (TNF), min =		197.5
Maximum extent of queue, veh =		3026
Maximum length of queue, miles =		8.60

Figure 14. Evergreen Floating Bridge Departure Change Condition

therefore extremely difficult and arbitrary. It does appear, however, that the proposed service would be cost effective.

DISCUSSION

"A small reduction in unnecessary flow can achieve a much larger saving in journey time in congested conditions" (12). This fact is the reason for investigating better driver information services. It is important to reiterate that the proposed new service is only a part of a larger strategy to improve travel conditions. As a source of driver information, the new service would supplement existing services already in place. The analysis to this point has been positive, but it is also necessary to discuss further considerations that bear more on the goals of the proposed service than the feasibility of it.

TSM

Transportation Systems Management (TSM) strategies were introduced in Chapter 1. Those strategies were grouped under demand, supply and incident management approaches. Demand management strategies are targeted at three key variables. Those variables are route selection, departure time and modal choice, and each has a significant impact on demand patterns. These strategies include alternative work schedules, high occupancy vehicle lanes, park-and-ride lots, and driver information services.

Supply management strategies are aimed at expanding or constraining capacity. Examples include changing lane widths, ramp metering, and additional lane construction.

Incident management strategies are often considered as parts of the previous options. They are cited here because of their importance. Incidents are those events that restrict the ability of the system to provide appropriate service levels. Incidents generally are classed as accidents, disabled vehicles, construction activities, adverse weather, and gawking motorists. The strategies include traffic surveillance, quick response teams, and driver information services.

The application of individual TSM strategies may have only a marginal impact on the ability of the system to deliver an acceptable level of service. The development of a number of coordinated programs could have a synergistic impact. The proposed driver information service should be evaluated in that context.

An earlier study of a telephone-based driver information service was previously cited (13). It serves as a good argument for coordinating TSM activities. A telephone service was established that provided a recorded message describing traffic conditions. It was not successful because people did not use it. Many did not know about its availability, but many who did cited the fact that conditions changed between making the call and driving in traffic.

By itself, the proposed new service would be vulnerable to the same arguments. Cars are not equipped with televisions. The service, however, is not suggested in isolation, rather it is proposed as a supplement to existing information sources. One other advantage is that the proposed service would be current, not subject to being revised, so it would be more credible than a taped message.

Mode Choice

Modal choice is also an important consideration in the analysis of the proposed service. Attention was focused on departure time and route selection because of the factors that affect modal choice decisions. Decisions to carpool, vanpool, or take the bus are complex and involve a number of issues. Individuals familiar and experienced with local transit services are more apt to consider the transit option when a serious congestion problem occurs. These people are familiar with existing routes, schedules, fares and procedures. Those inexperienced with transit are unlikely to choose that mode in response to an isolated incident.

The carpool and vanpool option is even less likely. With the possible exception of severe weather, individuals are unlikely to try and arrange carpools and vanpools, on short notice, in response to existing traffic conditions. Even the weather situation is usually the result of prior arrangements made in anticipation of treacherous conditions. Both carpools and vanpools generally require advanced arrangements that are not always flexible to existing traffic conditions.

Finally, TSM strategies must be coordinated. Inherent to transit, carpools and vanpools are barriers (i.e., loss of privacy and independence, transfer requirements and general inconveniences) that work against their natural selection. If individuals gain nothing by changing modes, they are unlikely to do so. If the travel times of all modes are similarly impacted by the existing traffic conditions, then mode choice will continue to be a less viable variable. The existence of park-and-ride lots and high occupancy vehicle (HOV) lanes contribute significantly to encouraging modal change. In the example of the Evergreen Floating Bridge traffic incident, the absence of HOV lanes to by-pass the problem leaves route selection and departure time as the two major options left, because transit and carpools will encounter the same delays. This has become a serious problem because the major freeways are already operating at capacity. As demand continues to grow, the departure time and route selection variable benefits will become increasingly marginal, making modal choice more important.

However, some opportunities exist that may benefit modal choice. The most obvious example would be to show "snow routes" on those days when the weather encouraged more people to take transit. The system could be set up to provide that information, supplemented by information about how to use the service. The supplementary information could be provided by voice-overs or character-generated messages. The emergency information could be provided on a readerboard that would have to be kept up-to-date.

In the same fashion, a readerboard service could provide periodic rider alert information about normal route and schedule adjustments. This information could be provided during times when traffic conditions were normal or on a scheduled basis.

The planned system upgrade might provide additional opportunities, but the current retrofit situation does not seem promising for impacting modal choice. The use of the magazine format, cited earlier, appears to have more potential.

The cable companies are interested in upgrading the level and quality of local access programming. Transit systems have found the use of cable TV to be very productive. One television show can have greater impact than a host of mailings and other techniques.

The cost of programming can be surprisingly low. Equipment can be provided by the cable companies and volunteers can be found to do many of the associated tasks. It might be reasonable to work with students at the University of Washington. Interest has grown, and momentum is building for a national cooperative network (Ahlstrom, 1987 unpublished data). Television is much extolled for its virtues and condemned for its faults. It is, however, a powerful tool for shaping public opinion and tastes.

The Graphic

The discussion to this point has centered on the feasibility of transmitting the computer-generated graphic produced at the TSMC. It is important to describe that graphic in more detail and to speculate on what modifications could be made to it.

The graphic is generated by a RAMTEK package. Data are provided by 900 loop detectors, 24 ramp meters, and 70 additional data stations. It is a simple schematic of the major freeways in the greater Seattle area. Figure 5 is a reproduction of the graphic. It covers the area from the junction of I-5 and I-405 in the south to the junction of the same routes in the north. It also includes SR 520 between I-5 and I-405 and I-90 bounded by I-5 and extending a few miles east of I-405.

It is a color graphic. Traffic conditions are represented by different colors. Green represents freeflow, and yellow and red represent increasingly congested conditions. Flashing red represents a serious problem, usually an incident of some sort that has temporarily halted traffic flow.

There is no explanatory key or other source of explanatory information. By itself, and unadorned, the graphic would be of little use to the general public. To make it more useful, some changes are suggested.

The first change would be to move some of the titles around to make space for messages. These messages would operate much like a readerboard only they would revolve through the picture at the bottom of the screen. When conditions were normal, the messages could promote the use of transit and ridesharing by providing informational phone numbers to call. Advertising is not permitted on local access cable channels, so the messages would be in the form of public service announcements.

When conditions deteriorated on the freeways, the message could be changed. They would have to be kept simple, and it might be possible to have several stored in memory. The message generator could be a character generator like the types commonly used for readerboard services, or it could be a computer with additional capabilities. The next level of messages might identify where conditions were bad and warn commuters about possible delays along those routes.

If conditions became bad enough, the message might identify the problem (i.e., "truck overturned on I-90 Floating Bridge") and suggest a solution (i.e., "recommend take alternative routes"). Messages, in general, should include information about the location and degree of congestion, the reason for the congestion, whether or not a lane is blocked, and alternative routes (if appropriate) (13). Figure 15 represents how the revised graphic might look.

Another level of sophistication might be a split-screen format. The graphic could be shown as an inset with other images or information shown on the rest of the screen. This might permit more complex messages or pictures (i.e., from the surveillance cameras) of the relevant problem. The difficulty with this is that reducing the graphic image in size would lose a lot of resolution. This could be confusing to the viewer, particularly if the service were still new and unfamiliar.

One interesting alternative may develop with the arrival of Metro Traffic Control in the Seattle market. Metro Traffic Control is interested in accessing the closed-circuit television surveillance system operated by the WSDOT. It has some interesting graphics packages that are not as accurate as the proposed WSDOT graphic image. These additional graphic images could be excellent supplemental information services, however, with the WSDOT image as the principal information source. Access to the closed-circuit television system could be provided in exchange for access to the additional graphics packages.

Attention has been focused principally on the video transmission. An audio signal is possible to include, as well. Several options are possible.

First, the audio signal could provide entertainment only. This would involve using music from a local FM radio station. The music might draw more people to the channel, but it would not enrich the quality of the information.

A second option would be to provide an information service. Again, a local radio signal would be used, but this would use a news show format radio station. The listener could be updated on current events and perhaps additional traffic information. This might encourage listeners to continue tuning in once they were in their cars.

The third option would be educational. Rather than depending upon outside sources, specific messages would be prepared and played on an audio cassette. These messages could include information about transit and ridesharing or about regional transportation issues. Music could also be provided between the messages.

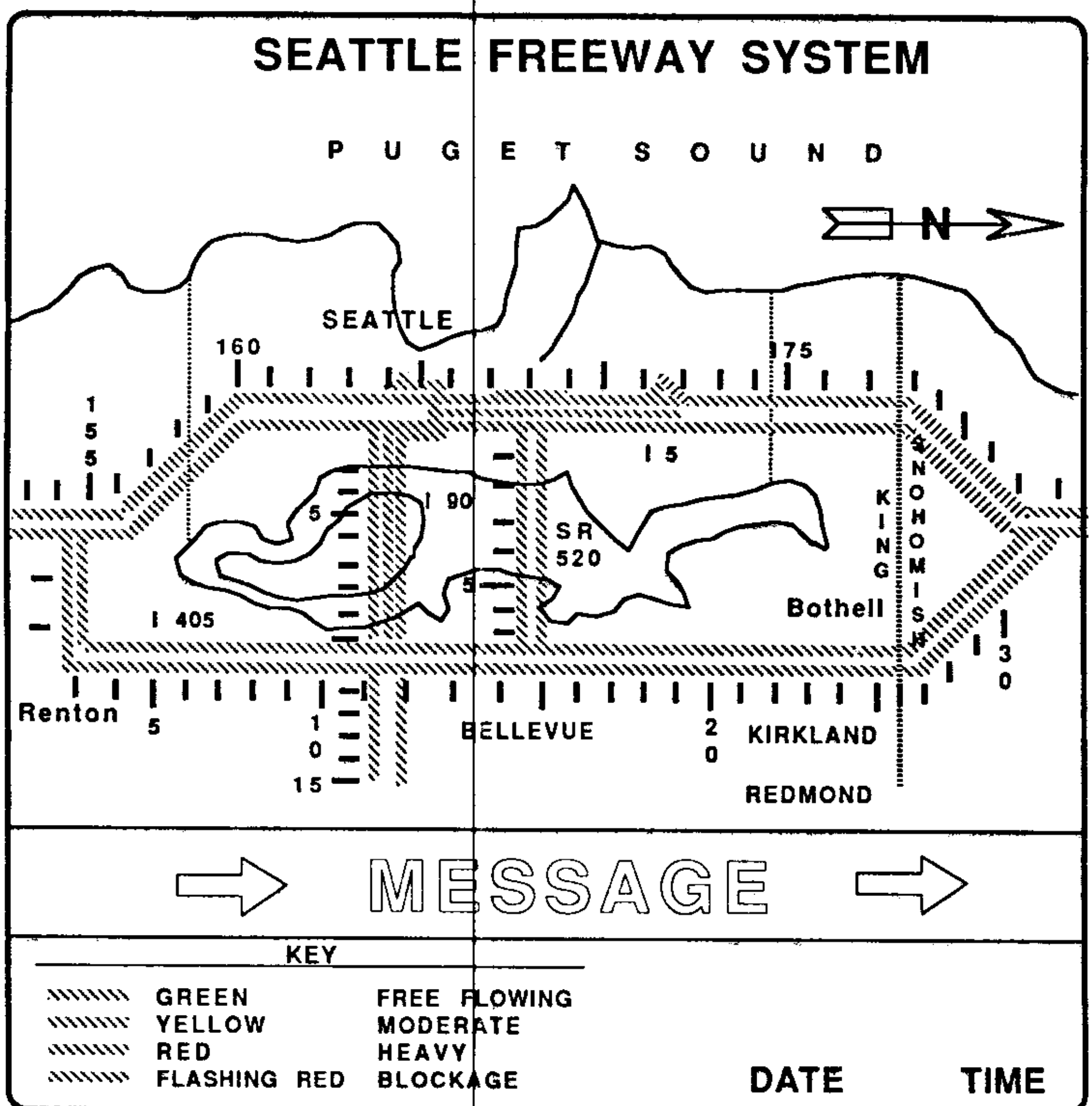


Figure 15. The Revised Computer Graphic

As a final point, the proposed service should be properly marketed. Advertising its availability will not be an issue; the cable companies will handle that in an effort to attract more customers. What will be important is providing information about how to use the service. Brochures mailed to cable subscribers would probably be effective. These brochures would also offer an opportunity to provide some context; to explain why the service was available and how it could be used to proper advantage. Other modes like transit could be promoted, as could concepts such as alternative work schedules. The marketing program would also provide a good educational opportunity. Information about HOV lanes, park and ride lots, and other TSM programs could be provided. The cost of implementing a marketing campaign would depend on the level of commitment desired. A good initial mailing to 300,000 households could cost as much as $12,000 (Rasmussen, 1987 unpublished data). An on-going campaign could also be considered.

SUMMARY

The purpose of this research is to determine the feasibility of transmitting a computer-generated graphic display of real-time traffic conditions on local access, cable television. This was analyzed to determine its feasibility, the probability it would be used, and the benefits it might provide. The analysis determined the project was technically, financially, and institutionally feasible; there was a strong probability that consumers would use the service; and the service would provide significant benefits. Finally, the graphic display was analyzed and several modifications were considered.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The purpose of this research was to determine the feasibility of using local access cable TV as a driver information tool. Specifically, the investigation focused on the possibility of transmitting a computer-generated graphic of traffic conditions on Seattle area freeways.

The research began by establishing the extent of the traffic congestion problem. Urban traffic congestion is clearly a problem of national significance, and the conditions in the Seattle area are considerably worse than average.

Because major new freeways are not going to be constructed in the immediate future, transportation system management strategies have been evolving to cope with the problem. Low cost projects to marginally increase existing capacity or change consumer demand have been developed. Driver information services are tools designed to influence the pattern of demand. Three key variables - route selection, departure time, and modal choice - are the principal targets.

A literature search was done to identify relevant research and experiences. Driver information services include a broad range of programs from the familiar road map to sophisticated, advanced electronics. The proposed project falls generally in the class of traffic advisories. Very little activity was noted specific to the proposed project.

The analysis of the data collected covered three broad categories: feasibility, behavior and benefits. The proposed project was determined to be quite feasible. Two practical methods were identified and costs estimated for their implementation.

A survey was done to determine if the public would use the services and what characteristics these users might have. Finally, a computer simulation was run to determine potential benefits. The simulations were based upon a traffic incident condition, and the impact of the service appeared to be positive.

At this time it is important to make some key observations. Traffic conditions in Seattle are already severe. Impacts on route selection and departure time will provide only marginal benefits. The peak morning period is defined as 6:00 a.m. to 9:00 a.m. Demand varies within the peak period and departure time changes may provide a more uniform distribution of that demand. Further, these departure time changes may extend the peak period beyond the existing limits. Most major freeways and arterials are operating at or above capacity. Route changes may shift the demand to available capacity. The results may be the more efficient use of the transportation system. The proposed project will assist only in managing additional demand; it will not eliminate existing demand.

Implementation of this project could have an important impact, however. When the new system is designed and specifications are drawn up, special features could be included that would assist in increasing the average vehicle occupancy rate. The implementation of the proposed project puts the technology in place and begins the development of a market for the service.

Equilibrium describes the condition of a stable traffic system. The basic theory is that commuters will seek out their best solutions and traffic will settle into predictable patterns. If a change in the system occurs, the pattern will change and a new equilibrium will develop.

This research identifies two types of commuters: information-seekers and risk-takers. Information seekers are those individuals likely to use the proposed service. They are commuters interested in determining conditions confronting their commute. Risk-takers are those willing to change the patterns of their commutes, often in response to information provided about those commute trips. The research indicated a significant probability that average commuters might change the route or departure time of their usual trips. This may have some implication on the concept of equilibrium and the importance of traffic advisories.

The traffic patterns in Seattle may appear stable, but significant activity may be occurring below the surface. If these trends can be identified, and if they can be leveraged, it may be possible to direct segments of the demand to benefit the overall system. The new research in behavioral modeling may provide some useful insights. Research has shown that traffic advisories may have a significant impact on traffic equilibrium (19).

Finally, the graphic proposed for transmission on cable TV requires some enhancements. These are needed to attract viewers and to make the information comprehensible. Several ideas were considered.

RECOMMENDATIONS

The following recommendations are based upon the completed research and analysis:

1. Consideration should be given to implementing the proposed driver information service. While commuters already have available a number of information sources, none of them are truly real-time and available before they leave their houses. This information might prevent them from committing themselves to a particular route and being unable to change upon learning of a problem. They could also make decisions about their departure times that would not be possible if they were already enroute. Radio stations might also prove to be consumers of the service. If the radio stations elect to receive the cable signal, they could supplement their existing information services. It might also assist in developing news stories when major traffic incidents occur.

2. Consideration should be given to the microwave option. It appears to be the easiest to implement and its cost is comparable to the coaxial cable option. Further analysis might be needed to decide how to relay the signal from the Viacom tower to the TCI station. Cost might be the final determinant, and a bid process would be needed. A brief implementation and evaluation plan is provided in Appendix C.

3. The Washington State Department of Transportation should consider involving Seattle METRO and others in the design of the new surveillance and control and driver information system. Output to the public should be an important factor and given proper consideration. The Seattle METRO staff might be able to contribute useful suggestions to help increase modal split for transit. The proposed service could also benefit the Seattle METRO dispatcher operation. Real-time information about traffic conditions on the freeways could facilitate re-routing buses to avoid delays. An interactive link with Seattle METRO might also improve information about conditions on the major arterials.

4. Consideration should be given to committing research into advanced technology applications. Technology may not solve the problems, but it can help control them.

Japan and some European countries are doing considerable work in this area, but nothing similar seems to be developing in this country. The Seattle area would be an excellent test area, particularly given its traffic problems. Research directed at coordinating all the driver information sources would help focus their impacts.

5. Consideration should be given to further research in behavior modeling and analysis. Supply and demand management are the two major thrusts for dealing with traffic congestion. As has been noted, additional capacity is unlikely in the near future. Other supply-side strategies may gain some positive results, but demand-side activities seem to hold greater promise. Behavior modeling may prove a significant tool because it is necessary to identify the key elements affecting behavior before it is possible to leverage that behavior. It may become possible to target key subgroups and direct their commute patterns through driver information services and other tools.

6. Consideration should be given to researching the impacts of driver advisories. Because commuters operate with free choice regarding their trip decisions, they must be able to make the best decisions. The nature and delivery of the necessary information needs to be further refined and developed.

SUMMARY

To conclude, it is necessary to return to the beginning. Congestion is the result of too much demand for existing capacity. To minimize congestion demand, supply, or both must be changed. Transportation System Management strategies have been developed to do this and they have had marginal success.

A new driver information service has been proposed and analyzed. It is offered in an environment in which consumers are able to make choices about their trips freely. Market forces (i.e., supply and demand factors) will have an impact on those individual choices. The new service will provide additional information to assist consumers in making their decisions.

As stated at the beginning, the new service will not solve the congestion problem. It will, like other TSM activities, have a marginal, positive impact. Provided in concert with other TSM activities it will enable the existing transportation system to deliver the best level of service possible.

BIBLIOGRAPHY

1. Capelle, Donald, G., "Freeway Traffic Management," National Cooperative Highway Research Program, Project No. 20-3D, 1979.

2. Lindley, Jeffrey A., "Urban Freeway Congestion" Quantification of the Problem and Effectiveness of Potential Solutions," ITE Journal, January 1987, pp. 27-32.

3. Puget Sound Council of Governments and Municipality of Metropolitan Seattle, "Summary Report: Multi-Corridor Project," November 1986.

4. Federal Highway Administration, "Transportation Management for Corridors and Activity Centers: Opportunities and Experiences," DOT-I-86-21, May 1986.

5. Transportation Research Board, "Urban Traffic Management," Transportation Research Record No. 1081, 1986.

6. Brittle, Chris and McConnell, Natalie and O'Hare, Shanna; "Traffic Mitigation Reference Guide," Metropolitan Transportation Commission, December 1984.

7. Ahmed, Samir A., "Urban Freeway Management Technology," Transportation Engineering Journal, American Society of Civil Engineers, Vol. 112, July 1986, pp. 369-379.

8. Taragin, Asriel, "A Summary of the John C. Lodge Freeway Research," NCHRP Project 20-3C, July 1976.

9. Dudek, C.L., Huchingson, R.D., Stockton, W.R., Koppa, R.J., Richards, S.H., Mast, T.M.; "Human Factors Requirements for Real-Time Motorist Information Displays," Vol. 1, September 1978.

10. Dudek, Conrad and Huchingson, R. Dale, "Manual on Real-Time Motorist and Information Displays," FHWA-IP-86-16, August 1986.

11. David, Y. and Portal, M.L., "Electronic Traffic Aids on Major Roads: COST 30 bis," 1985.

12. Russam, K. and Jeffery, D.J., "Route Guidance and Driver Information Systems-An Overview," Proceedings from the Second International Conference on Road Traffic, 1986, pp. 1-5.

13. Carvell, James D. Jr. and Hatcher, Donald R.; "Dial-In Freeway-Traffic Information System," Transportation Research Record No. 643, 1977, pp. 37-40.

14. Fricker, Jon D. and Tsay, Huel-Sheng; "Airborne Traffic Advisories: Their Impact and Value," Transportation Research Record No. 996, 1984, pp. 20-24.

15. Baxster, Daniel H., Werner, Thomas C., Gardeski, Raymond M.; "The Integrated Motorist Information System: The Ideal and the Real," Presented to the National Conference on Strategies to Alleviate Traffic Congestion, Sponsored by the Institute of Transportation Engineers, San Diego, California, March 1987.

16. Zove, P. and Berger, C., "Integrated Motorist Information System Feasibility and Design Study: Generalized Methodology for IMIS Feasibility Studies," Vol 1 & 2, May 1978.

17. Zove, P., Gordon, R., Scott, J., Berger, C., Domjan, W., and Soccoli, F.; "Integrated Motorist Information System Feasibility and Design Study," Vols. 1, 2, & 3, April 1977.

18. Abu-Eisheh, Sameer A. and Mannering, Fred L., "A Discrete-Continuous Analysis of Commuters' Route and Departure Time Choice," Presented at the 66th Annual Transportation Research Board Meeting, Washington, D.C., January 1987.

19. Mahmassani, Hani S., and Tong, Chee Chung, "Availability of Information and Dynamics of Departure Time Choice: Experimental Investigation," Transportation Research Record #1085, 1986.

20. Huchingson, R. Dale, McNees, R.W., Dudek, Conrad L.; "Survey of Motorist Route-Selection Criteria," Transportation Research Record No. 643, 1977, pp. 45-48.

21. French, Robert L., "Historical Overview of Automobile Navigation Technology," Presented at the 36th IEEE Vehicular Technology Conference, May 1986.

22. Jeffery, D.J., "Ways and Means for Improving Driver Route Guidance," Transport and Road Research Laboratory Report No. 1016, 1981.

23. Jeffery, David, "Route Guidance and In-Vehicle Information Systems," Information Technology Applications in Transport, ed. by Bonsall and Michael Bell, 1987, pp. 319-351.

24. Oei, H.L., "Route Information Systems," from Man and Information Technology: Towards Friendlier Systems, edited by J.H.F. van Apeldoorn, Delft University Press, 1983, pp. 19-25.

25. Ben-Akiva, Moshe and Lerman, Steven, "Discrete Choice Analysis: Theory and Application to Travel Demand," M.I.T. Press, Cambridge, Massachusetts, 1985.

26. Morales, Juan M., "Analytical Procedures for Estimating Freeway Traffic Congestion," Public Roads, September 1986, pp. 56-61.

27. Washington State Department of Transportation, "Ramp and Roadway Traffic Volumes," June 1986.

28. Nihan, Nancy, "Impacts of Freeway Surveillance and Control on Eastbound SR 520," Washington State Department of Transportation Report No. WA-RD-99.1, February 1987.

APPENDIX A
THE COAXIAL CABLE AND MICROWAVE OPTIONS

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The purpose of this appendix is to provide more details about the two options described in Chapter 3. Included is a description of the equipment, the path of the signal, and the labor activities involved.

COAXIAL CABLE OPTION

The coaxial cable option would begin with the generation of the graphic signal from the computer. The signal would be transmitted to a video switch where it would be mixed with the signal from the message generating device (i.e., a computer or character generator). The signal would then be sent to an FM modulator where it would be joined with the output from the audio source (i.e., FM tuner or cassette player). The output from the FM modulator would be processed through a subchannel multiplexer before it was sent out over the main coaxial trunk cable. The signal would be sent at a low frequency so it would not interfere with the high frequency signals coming in to the TSMC.

The trunk cable would then be tapped at a point near the existing cable TV company line. The likely point for the tap would be a junction box located on the I-5 median between the Fifth Avenue Northeast and the Northeast 80th Street overpasses. The junction box would hold amplifier T-N10 and would be about 600 feet south of the Northeast 80th Street overpass. This overpass is used by the cable TV companies to cross the freeway.

When the tap was made, a subchannel multiplexer would be installed in the junction box to separate the desired signal from the trunk cable. Additional cable would have to be buried to carry the signal out of the I-5 right of way.

To do this, the conduit carrying the trunk wire would have to be entered at the base of the Northeast 80th Street overpass. New cable would then be pulled from the T-N10 amplifier/junction box through the existing conduit. Another junction box would be installed. Then, 2-inch conduit would be attached to the overpass using unistrut mounts placed every 5 feet. One additional junction box would be needed. The conduit would be directed to the west side of the freeway right of way.

At the end of the overpass structure the conduit would feed into a junction box and the cable would then be directed into the ground. A trench 6 inches wide, 18 inches deep and about 120 feet long would be needed to reach the cable TV head-end. One junction box would also be required in the trench. The new cable would then be spliced into the cable TV line.

When the signal reached the TCI station it would then be processed through an FM demodulator and passed through an electric switch. The switch would be used to turn the signal on and off at the prescribed times. The signal could then be sent over the cable TV network.

MICROWAVE OPTION

The microwave option would begin with the computer-generated graphic signal, which would be sent to a video switch where it would be mixed with the output from the message generating device (i.e., computer or character generator). The signal would then be sent to the microwave transmitter where it would be combined with the audio signal from the audio source (i.e., FM tuner or cassette player). The microwave transmitter would then send the signal to the microwave receiver located on the Viacom tower. This would require the transmitter and receiver to be properly aligned. At this point, two alternatives would be possible.

Alternative 1

When the microwave signal was received it would next be sent to an FM modulator located at the Viacom tower. The signal would then be transmitted over the existing cable TV line to the TCI station. At the station, the signal would be processed through an FM demodulator and passed through an electric switch. It would then be sent out over the cable TV network.

Alternative 2

When the microwave signal was received, it would be relayed to a second microwave transmitter and then sent to the TCI station where it would pass through an electric switch before it would be sent out over the cable TV network.

SUMMARY

The cost for both options is about the same, but the amount of labor and disruption involved with the microwave option is less than for the coaxial cable option.

Once TCI has the signal, it would be sent out over their cable network. Both Viacom and Seacom are connected to the network, and they would simply activate their own switches.

APPENDIX B
CORRESPONDENCE

APPENDIX B
CORRESPONDENCE

Included in this appendix are copies of correspondence with the Seattle Office of Cable Communications (OCC). This correspondence, supplemented by interviews and telephone conversations, indicates a willingness by the OCC to develop the proposed service.

TRAC

WASHINGTON STATE TRANSPORTATION CENTER

July 29, 1987

Mr. David Arnesen
King Co. Office of Cable Communications
516 - 3rd Ave., Room 401
Seattle, WA 98104

Dear Mr. Arnesen:

I am writing to confirm the interest of the Washington State Department of Transportation (WSDOT) and Washington State Transportation Center (TRAC) in using cable TV to broadcast local traffic conditions.

I enjoyed discussing the proposal with you on the phone, and I appreciate your initial support and willingness to pursue the project. I want to briefly outline the proposal.

The WSDOT currently operates a control center that monitors traffic flow on local freeways including I-5, I-90, I-405 and SR 520. The monitoring is done with closed circuit TV and electronic sensing devices located in the pavement. Signals from the electronic devices are fed to a computer for analysis, and a graphic display is produced. It is this display we wish to televise.

The display is in color and is only a schematic of the system. It would be supplemented with character generated messages that would interpret the display. The messages would be generated by WSDOT personnel and would include recommendations to potential commuters. The display would be shown during the morning commute only.

The WSDOT has contracted with TRAC to determine the feasibility of the project. If the project is approved, the WSDOT would be responsible for the implementation costs and would market the service.

I believe the project will be a significant benefit to the community. It will help advertise the existence of local access programming, it will aid commuters, and it will assist us in managing our transportation facilities.

If you have further questions, I can be reached at 543-7310 in Seattle or (206) 586-2483 in Olympia. I look forward to working with you further.

Sincerely,

Gordon Kirkemo

GK/alk

121 More Hall FX-10 University of Washington, Seattle, Washington 98195 Telephone (206) 543-8690

University of Washington   Washington State University   Washington State Department of Transportation

City of Seattle

Office of Cable Communications

Charles Royer, Mayor

July 15, 1987

Mr. Gordon Kirkemo
TRAC
121 More Hall, FX-10
University of Washington
Seattle, WA 98195

Dear Gordon:

I enjoyed meeting with you yesterday and discussing the proposed plan to use cable television to broadcast local traffic conditions. It is an exciting proposal and is one that would assist in further developing the use of cable television for purposes other than entertainment programming. I would like to be kept imformed about the progress of this plan and also offer my assistance where necessary. The proposal sounds like a solid idea and could be very useful in the community for helping relieve some of the growing traffic congestion. Please call me at 684-0438 if I may be of assistance.

Sincerely,

Debbie

Debra L. Lewis
Acting Director

DLL:dmr

Office of Cable Communications 4th Floor 400 Yesler Seattle Washington 98104 (206) [illegible]

APPENDIX C
IMPLEMENTATION AND EVALUATION PLAN

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IMPLEMENTATION

The implementation of the local access cable TV driver information service project will require approximately six months. Implementation assumes the project has been approved and programmed by the Washington State Department of Transportation (WSDOT). That approval will require some additional engineering and accounting work in keeping with established WSDOT procedures. Consideration could be given to funding the project from the I-90 program or from energy rebate funds passed back to the state.

Overall program responsibility will be assigned to the manager of the TSMC. Table C-1 contains the timelines for accomplishing the key steps. A brief description of those steps is provided based upon the timeline.

First Month

A bid package would be drawn up and advertised. Specifications for all the equipment would be identified. The equipment is standard, off-the-shelf technology, and previous bid documents could be referenced.

Negotiations would be undertaken with the three cable companies and the Seattle Office of Cable Communications (OCC). The OCC would have to approve the project before the cable companies could participate. This approval appears likely, based upon previous correspondence (Appendix B). The specific roles and responsibilities of the cable companies and WSDOT would be formally agreed upon.

The graphic package would need to be modified. This would require assigning appropriate personnel to the task. The refinements would be minor, and sufficient time would exist to permit the work to be done when the time was available.

Table C-1. Proposed Project Timelines

Activity	Month 1	2	3	4	5	6	7	Later
Bid preparation and advertisement	////////							
Bid award and equipment order		////////	////////					
Installation and tests				////////	////////			
Develop advertising campaign	////////	////////	////////	////////				
Implement advertising campaign					////////	////////	////////	
Negotiate with cable TV companies	////////							
Negotiate with Houston MTC		////////	////////	////////				
Modify graphics package	////////	////////						
Frequency search and license	////////							
Implementation							////////	////////
Evaluation								////////

Appropriate WSDOT personnel would conduct the frequency coordination check. The results would be forwarded to the Federal Communications Commission (FCC) to acquire the necessary license for the microwave transmissions. The FCC license takes about two weeks to acquire and there is no license fee.

The Public Affairs Office would be assigned the responsibility for developing an appropriate advertising campaign. The campaign would involve more than alerting people to the new service. It would explain how to effectively utilize the service and provide background information about traffic problems. This would be a key element to a successful project.

<u>Second Month</u>

Bids would be awarded and contracts signed for the work and the equipment. Standard WSDOT procedures would be used to accomplish this. With the awarding of the contracts, the equipment could be ordered. The equipment should be available in 4 to 6 weeks.

Negotiations with Metro Traffic Control of Houston should be undertaken. Metro Traffic Control (MTC) will be expanding into the Seattle market. Arrangements could be made to share video signals. MTC is interested in the closed circuit TV surveillance available at the TSMC. The variety of graphic packages produced by MTC would be of interest to the project.

MTC has offered to provide a person at the TSMC. That person could coordinate the transmissions and relieve existing TSMC personnel of that duty.

The development of the advertising campaign and the modification of the computer graphic would be continuing during this period.

<u>Third Month</u>

Successful negotiations with MTC could result in the installation of additional equipment at the TSMC. That might begin during this time period.

The equipment ordered to support the project would be arriving, and some installation might already be taking place.

The advertising campaign would be designed and ready for production.

Fourth Month

Installation of the project equipment would be in full swing. The advertising material would be in full production.

The modifications needed to cooperate with MTC would be completed during this time frame.

Fifth Month

Installation of the equipment would be complete and testing would have begun.

The advertising program would be activated. Mailings would be sent and any video productions done would begin showing on the air. All mailings could be done as inserts into the cable billings.

Sixth Month

Advertising would continue and any problems that had surfaced would be corrected.

Seventh Month

The project would be implemented.

Later Months

Monitoring and evaluation of the project would begin.

EVALUATION

Direct evaluation of the project would be difficult to do. The principal goal of the project is to facilitate the flow of commuters to work. Measures of effectiveness would include travel time, delay, energy consumption, average travel speeds and modal split. It would be difficult to measure the isolated benefits provided by the new service as so many other activities also have impacts. Discussions with MTC personnel regarding the evaluation of their services indicates they really do not know (Saperstein, 1987 unpublished data).

Two strategies can be suggested for monitoring the project. The first would be to survey the market to determine reactions to the service. This would be done because the market is finite and easily defined (i.e., cable TV subscribers). The survey could determine how many subscribers used the service, how many made decisions based upon the service, and how many believed the service to be credible.

The survey could also seek ideas for refining the service by asking what information the viewers would like to see provided.

The first survey should be done no sooner than six months after the service was initiated. This would give viewers a chance to learn about it and to gather some experience. Sample surveys could then be done periodically to measure trends (i.e., Are more people using it?)

The second strategy involves seeking volunteers to keep trip diaries. The diaries could be daily logs of what each commuter was confronted with in the morning. The diarist could track the information provided by the service, the decisions made and why, and the conditions found during the commute trip.

These logs would help determine the usefulness and accuracy of the information provided by the service. It would also be helpful for planning adjustments or for developing the new, upgraded system.

To accurately measure the impact of the proposed service, data would have to be collected before and after the project was implemented. Several methodologies could be applied.

One technique would involve collecting volume and lane occupancy data for specific stations on the freeway. The data would be collected over a prescribed time period prior to program implementation and again after start up. A methodology called times series intervention analysis could be applied to evaluate the impact (28).

Another technique would be a floating car study. Representative commute runs could be made before and after implementation. Travel times, delays, average speeds, and queue lengths could be logged and compared.

Another method would be to obtain manual queue length counts before and after implementation to assess the impact. Assistance from eye-in-the-sky reporters might be possible, or roving automobiles might be used. Appropriate statistical tests would be applied to measure impacts.

The methods chosen might depend upon time and resources available.