

Chapter 2 – Literature Review

2.1 - Introduction

A review of existing literature was performed to support the study undertaken in this thesis. A general survey was first performed to chronicle past research efforts in developing traffic surveillance technologies used for ATIS purposes. Next, the potential advantages of AVI technology versus loop detection and GPS technologies are discussed. Lastly, a discussion of literature associated with AVI field studies is performed along with a discussion of AVI issues to be addressed in this thesis.

2.2 – Survey of Research in Traffic Surveillance Technology

In the recent past, researchers have tested a wide array of technologies in an attempt to find improved methods of monitoring traffic conditions. This research in traffic surveillance has ranged from studies of traditional loop detection methods to the use of anti-submarine warfare technology. AVI comprises one of but many of the areas of current research. A brief survey of technologies explored during the past decade and a half is given below to provide an understanding of the level of research interest in traffic surveillance technologies.

Bohnke and Pfannerstill acknowledged a need for more reliable traffic data acquisition than localized data collection generated by traditional loop detectors (1986). The pair introduced a pattern recognition algorithm which could utilize unique vehicle presence signatures generated by successive series of inductance loop detectors. By identifying and reidentifying platoons of vehicles traveling across links bounded by loop detection equipment, vehicle travel times could be obtained.

Ju and Maze performed simulations on incident detection strategies using the *FREQ8PE* simulation model (1989). Their research evaluated a comparison of incident detection strategies using police patrol versus the use of motorist call boxes at 1 km spacing. The motorist call boxes formed the backbone of the modeled freeway surveillance and control system (FSCS). This FSCS yielded a benefit-to-cost ratio of 2.69 as it generated benefits from travel-time reduction and reduced fuel consumption. These benefits were brought about by reduced incident detection time afforded by the motorist call boxes.

AT&T experimented with the use of applied acoustic and digital signal processing technology to produce a vehicular traffic surveillance system (Nordwall, 1994). Labeled the SmartSonic Traffic Surveillance System (SmartSonic TSS-1), the project was intended by AT&T to replace buried magnetic loop

detection systems. This technology was originally developed from research used by the U.S. Navy for submarine detection purposes. Mounted above passing vehicles, the SmartSonic TSS-1 listens to the acoustic signals of vehicles and is capable of distinguishing between larger trucks or buses and smaller vehicles. Applications were to include traffic monitoring and vehicle counting, with the potential for incident detection being an area for further research.

Prior to the installation of an AVI system in Houston, a cellular phone demonstration project was performed (Levine and McCasland, 1994). Researchers recruited 200 volunteers to participate in the program, which required them to call a traffic information office when they passed specific freeway locations during their morning and evening commutes. The lessons learned from the cell phone project aided in the development of the data analysis, processing and dissemination techniques used for the AVI system that was later constructed. In a similar scenario, prior to installing a large-scale AVI system in the Puget Sound area, a small-scale test of AVI was performed (Butterfield et. al., 1994). In this test, AVI was “piggy-backed” with existing loop detectors. Results yielded an AVI detection rate of about 80% for a fleet of tag-equipped buses.

In a 1996 report by Turner, a variety of techniques for travel time data collection were discussed, along with the advantages and disadvantages of each. These data collection techniques included Electronic distance measuring instruments (DMI's), License plate matching, Cellular phone tracking, Automatic vehicle location (AVL), Automatic vehicle identification (AVI) and Video imaging. Turner specifically noted that travel time information was of particular importance for applications including congestion measurement and real-time travel information.

In their discussion of video-based surveillance, Berka and Lall continue the discussion of improving upon the use of loop detection to gather traffic data (1998). The authors claim that loop detection reliability is low, and that maintenance and repair of such a pavement-based system creates safety risks for repair crews. Berka and Lall maintain that non-intrusive technologies such as video surveillance provides reduced traffic disruption during installation or repair. In addition, video surveillance is capable of detecting incidents on the sides of roadways, outside of the detection range of loop detectors.

In this brief survey, more than ten distinct traffic surveillance technologies have been identified as the subject of research efforts since 1986. The amount of attention given to the research field of traffic surveillance clearly suggests that a surveillance system that can provide reliable and accurate travel time

data would have great potential. The research community’s interest in developing reliable and accurate surveillance systems is a primary motivation for the evaluation of San Antonio’s AVI system.

2.3 – Potential Advantages of AVI Over Inductance Loop Detection and GPS

One of the driving factors in research is the desire to improve upon what already exists. The use of AVI to replace conventional loop detection for traffic monitoring is no exception. One advantage AVI offers over loop detection is its ability to provide *space mean speed* information. Loop detectors monitor traffic conditions at single-point locations where the detector is located. These loops are capable of generating *spot mean speed* data at various points along a traffic facility. The spot mean speeds must then be processed to estimate the speeds of vehicles between the detector location points. Given that loop detector spacing is often ½-mile or greater, there can be significant uncertainty in attempting to estimate the speed of vehicles between loops. Turner further attests to the advantages of AVI in acquiring travel time data. He reports that a study by NCHRP showed that travel time data generated from space mean speed measurements are rigorous enough for technical analyses while being simple enough to be understood by non-technical audiences.

Ford notes that inaccurate results can be generated by loops because they do not easily identify congestion that occurs between loop stations (1998). He specifically reports that previous research has found loops to be inaccurate in both congested and high speed conditions, with expected error measurements ranging from 5-10 mph. In addition, loop detectors are prone to failure. AVI, meanwhile, can monitor the progress of vehicles across links of traffic, giving travel time information more accurate than that derived from loop detector measurements. In a comprehensive comparison of loop detection and AVI technologies for the collection of travel times, Ford makes the assessments given in Table 2.1.

Table 2.1 - Comparison of Loop Detector & AVI Travel Time Collection Technologies

Data Collection Technology	Costs			Data Accuracy	Constraints
	Capital	Installation	Data Collection		
Loop Detector Systems	Low	Moderate	Low	Low	High failure rate and inaccurate estimations
AVI Systems	High	High	Low	High	Probe density and antenna sites

In spite of higher costs, Ford concludes that the reliability and accuracy of AVI equipment makes it a better option than loop detection for Advanced Traveler Information Systems (ATIS).

Parkany & Bernstein discuss the potential advantages that vehicle-to-roadside communications (VRC) such as AVI could have in incident detection (1995). Compared to spot speed, occupancy and flow data provided by loop detectors, AVI can provide transportation officials with more useful traffic data. This data can include lane-specific and station-specific headways, the volume of tag-equipped vehicles on a section of a facility at any time, and the number of tagged vehicles that switch lanes between readers. Preliminary conclusions from Parkany and Bernstein's research indicated that a VRC incident detection system using headway, lane-switch and lane-monitoring algorithms could perform better than the California algorithm typically used with loop detectors.

In addition to its advantages over loop detector surveillance, AVI also has a distinct advantage over the use of GPS. Moore presents the case of downtown "canyons" created by skyscrapers (1999). In such cases, GPS communications can be blocked by the presence of large buildings. In these downtown locations where improved efficiency is often needed, terrestrial-based AVI systems can perform very capably.

In recent years, researchers have also been looking to AVI to help improve incident detection on freeways and arterials. Historically, incident detection has been performed by algorithms which analyze loop detector data. Ivan and Chen compared several algorithms using both fixed and vehicle-based surveillance methods (1997). Their results indicated that a combination of the two types of surveillance methods yielded the best incident detection results. Petty et. al. concluded that a probe-vehicle based algorithm for incident detection is feasible, and it avoids certain infrastructure-related problems facing loop-based algorithms (1997). Similarly, Marshall and Batz noted that AVI equipment used in the electronic toll and traffic management (ETTM) system constructed in the Greater New York/New Jersey Metropolitan Area offered more reliable potential for incident detection (1994). This reliability stemmed from the individual vehicle travel times gathered by the system. Lastly, Carlin gathered travel time data from Houston's AVI system in order to establish a suitable database from which to develop an automated incident detection algorithm (1996).

In addition to AVI's reported ability to provide reliable travel time information and potential to improve incident detection methods, AVI offers more flexibility in its potential uses in transportation management

programs than traditional loop detection systems. Inherent to the use of AVI technology is its ability to track individual vehicles, a capability that loop detection does not possess. Turner mentions that, in addition to its ability to provide real time travel information, AVI is even more valuable because of its use in electronic toll collection and fleet management applications. In addition, travel-time information is fast becoming an integral part of real-time travel information systems used in such applications as in-vehicle navigation.

Dorrance notes that the real-time data provided by AVI can be used to evaluate the effects of traffic management strategies as well as to help develop new management programs. In addition, such information can be used to market HOV lanes, given that comparisons of HOV-lane speeds vs. non-HOV-lane speeds can be provided to travelers. By relaying such up-to-the-second speed data to commuters, HOV lanes could become more attractive to the potential traveler if he receives a quantifiable report indicating that HOV traffic is moving faster than non-HOV traffic. Such information could lead to more drivers deciding to car pool, thus reducing the amount of traffic on the road. Incident assessment, emergency vehicle routing and traffic flow pattern monitoring are other potential advantages of AVI cited by Dorrance. As a final note, Levin and McCasland report that AVI programs hold unique potential for improving relationships between transportation management officials and the general public. The use of travel tags provides a physical connection between the two groups, which can help foster support for future traffic management projects.

Without question, AVI holds substantial promise in improving upon traffic surveillance capabilities currently offered by inductance loop detection technology as well as GPS systems.

2.4 – Issues in AVI Probe Systems

The research focus of this thesis is to assess the reliability and accuracy of San Antonio's AVI system. In addition, a level of market penetration analysis is performed as well as a study of how well the system predicts travel times for a single probe vehicle based on travel times calculated at three aggregation levels: 2-, 5- and 15-minutes.

A thorough literature search revealed no other studies performed on the San Antonio AVI system since its installation. Numerous other AVI systems exist in the United States and abroad as mentioned by Ford. Those used for traffic management purposes apart from electronic toll collection include the

Transtar Traffic Monitoring System in Houston, TX, the New York/New Jersey TRANSMIT system, and the AVI system in Oslo, Norway. In addition, aside from preliminary testing reports, no field evaluation studies were found for any of these systems.

Two important issues in the performance of an AVI system are the system's ability to read "foreign" or out-of-town tags, as well as the percent-correct read rate of each AVI antenna. Both of these issues are discussed in this thesis. While the literature review did not locate any large-scale AVI field studies, it did give some insight into the importance of out-of-town tags and correct read rates for AVI systems.

The acquisition of tag-derived travel time data within a city can be aided greatly by the presence of compatible tags worn by out-of-town vehicles. Dorrance addresses the importance of compatibility issues, noting that out-of-town traffic from New York, Oklahoma, Louisiana and California aid in the collection of AVI data in Houston, TX (1994). By being compatible with out-of-town tags, the Houston AVI system's traffic monitoring capabilities are greatly enhanced. AVI tags worn by commercial vehicles as part of fleet management operations also contribute to the travel time database in Houston.

Regardless of the proliferation of tags on the roadways, if the AVI antennas fail to read the passing tags, tag distribution efforts are wasted. AVI systems used exclusively for travel time data collection do not need to operate under the strict tolerances found in electronic toll collection (ETC) systems. Since revenues are not lost with each missed tag, transportation management officials using AVI for ATIS purposes can afford to operate their system at a reduced tag capture rate. While ETC systems strive for a 99.95% correct read rate per antenna, AVI used for ATIS purposes can provide adequate travel time data while operating at a reduced rate compared to ETC. In the San Antonio case, the minimum tag capture tolerance for each of the 93 antennas installed was set at 80% (Miller and Dignazio, 1999). Each antenna was tested to meet this tolerance level prior to acceptance.

In light of the apparent absence of field studies of existing full-scale AVI systems, the work in this thesis covers relatively new ground in AVI research.

2.5 – Summary of Literature Review

In recent decades, researchers have been actively investigating numerous technologies, ranging from sensitive acoustic devices to pattern recognition algorithms, in an effort to improve upon existing traffic surveillance methods. Given that it is a relatively young technology with many potential uses, AVI

continues to be one of these technologies researched in academia. In light of recent research efforts, AVI appears to show more promise as a more reliable and accurate method of predicting travel time information than other technologies, particularly loop detectors.

This work serves as an independent evaluation of the existing AVI system in San Antonio, TX. Several issues addressed in this literature review will be discussed in more detail, including out-of-town influence of tag-equipped vehicles and tag read rates of antennas. The numerous references cited in this literature review also indicate that AVI technology likely possesses untapped potential in other ATIS applications, particularly incident detection. This field study appears to be the first of its kind in evaluating an in-place, full-scale AVI system. It is hoped that this work will serve as a first step in quantifying the efficacy and reliability of such a system.