Potential Applications of Video Technology for Traffic Management and Safety in Alabama

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UTCA Theme: Management and Safety of Transportation Systems

Prepared by

UTCA

University Transportation Center for Alabama
The University of Alabama, The University of Alabama at Birmingham, and
The University of Alabama in Huntsville

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University Transportation Center for Alabama

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16. Abstract

Throughout the country, and in the state of Alabama, agencies are beginning to implement video technology for traffic management without a complete understanding of the costs and benefits associated with these systems. Video systems require substantial investments associated with purchasing, installing, and maintaining equipment along with training personnel. Offsetting these costs are the benefits such as automated enforcement programs, which have reduced violations and crashes related to red-light running, speed, railroad crossing, and aggressive driving. Video systems can be configured to solve various traffic management problems; therefore, each traffic issue requires specific hardware, software, and management techniques. To insure successful implementation of video technology in Alabama, several steps were completed: a detailed review of current capabilites was performed, how to implement a video system was investigated , and where in Alabama these video systems can most improve traffic management and safety was determined. In summary, this research project proved that video technology for traffic management and safety can, if implemented correctly, reduce crashes and violations.

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List of Acronyms

1.	FCC	Federal Communications Commission
2.	FMCW	Frequency Modulated Continuous Wave
3.	GDOT	Georgia Department of Transportation
4.	ITS	Intelligent Transportation System
5.	VMS	Variable Message Sign
6.	TMC	Transportation Management Center
7.	TCC	Transportation Control Centers
8.	MARTA	Metropolitan Atlanta Rapid Transit Authority
9.	VDS	Video Detection System
10.	HEROS	Highway Emergency Response Operators
11.	MOVER	Motor Vehicle Emergency Response
12.	TDM	Travel Demand Management
13.	TIS	Traveler Information Services
14.	TOCC	Transportation Operations and Communication Centers
15.	VTOC	Virtual Transportation Operations Center
16.	MTM	Motorway Traffic Management
17.	IDSV	Immediate Detection of Stopped Vehicles
18.	CCTV	Closed-Caption Television
19.	ALDOT	Alabama Department of Transportation
20.	EMS	Emergency Management Systems
21.	CMAQ	Congestion Mitigation and Air Quality
22.	ASAP	Alabama Service and Assistance Patrol
23.	LACMTA	Los Angeles County Metropolitan Transportation Authority
24.	ITSA	Intelligent Transportation
25.	FOIA	Freedom of Information Act
26.	CARE	Crash Analysis Reporting Environment
27.	VMT	Vehicle Miles Traveled
28.	ARTS	Advanced Rural Transportation Systems

Executive Summary

Throughout the country, and in the state of Alabama, agencies are beginning to implement video technology for traffic management without a complete understanding of the costs and benefits associated with these systems. Video systems require substantial investments associated with purchasing, installing, and maintaining equipment along with training personnel. Offsetting these costs are the benefits such as automated enforcement programs, which have reduced violations and crashes related to red-light running, speed, railroad crossing, and aggressive driving. Video systems can be configured to solve various traffic management problems; therefore, each traffic issue requires specific hardware, software, and management techniques. To insure successful implementation of video technology in Alabama, several steps were completed: a detailed review of current capabilities was performed, how to implement a video system was investigated, and where in Alabama these video systems can most improve traffic management and safety was determined. In summary, this research project proved that video technology for traffic management and safety can, if implemented correctly, reduce crashes and violations.

Section 1
Introduction

The goal of this research was to perform a comprehensive review of the current and potential use of video technology for traffic management and safety in the state of Alabama. This final report includes:

- Literature Review
- Data Collection/Site Visits
- Evaluation of Alabama's Needs Related to Traffic Management and Safety
- Recommendations for Video Technology Applications in Alabama
- Implementation Strategies for Video Technology Applications
- Conclusions

To insure successful implementation of video technology in Alabama, this research provided a detailed review of the current capabilities, how to implement a system, and where in Alabama these video systems can most improve traffic management and safety.

Throughout the United States and Alabama, agencies are starting to implement video technology for traffic management purposes without a complete understanding of the cost and benefits associated with these systems. This report identifies instances where video applications have been used successfully and notes the benefits of these systems. Additionally, cases where video applications were unsuccessfully implemented or operated are discussed.

Based upon the lessons learned during the literature review process along with data collection relevant to crashes in Alabama, recommendations have been developed in order to suggest potential applications of video technology in traffic management and safety roles for the State of Alabama.

Section 2
Traffic/Incident Management and Relevant Technologies

In order to effectively execute traffic and incident management functions, reliable, accurate, and timely traffic information must be available. This information includes (but is not limited to) the following:

- Traffic Performance
- Traffic Congestion
- Incident Detection and Confirmation
- Incident Assessment
- Vehicle Speed and Direction
- Vehicle Occupancy
- Vehicle Location

This information is used to detect and verify traffic incidents and congestion, initiate incident response, implement traffic control strategies, and monitor network flows. The necessity of such a massive volume of real-time data requires that surveillance technologies be employed in an information-gathering role.

Perhaps the most "proven" of all traffic surveillance technologies are inductive loop detectors. Loop detectors are placed in the subsurface of the roadway and when utilized can provide real-time traffic data. However, it has been noted that the cost of installation and maintenance of loop detectors can be prohibitively high. Thus, other technologies must be examined in order to provide a more cost-effective alternative.

These alternative technologies provide not only cost-savings but also have the ability to obtain a greater variety of traffic and incident-related data. Each alternative is presented along with theory relevant to its use and the technology's advantages and disadvantages.

Microwave Radar

Microwave radars that are used in the United States in vehicle detection applications transmit energy at 10.525 GHz as regulated by the Federal Communications Commission (FCC). Two types of microwave radars are used in the United States in traffic monitoring applications. The first type of radar measures vehicle speed by emitting electromagnetic energy at a constant frequency. The Doppler principle is used to calculate the velocity of a passing vehicle by evaluating the difference in frequency between the transmitted and received signals. However, the downfall of the constant-frequency microwave radar is its inability to detect a stopped vehicle. Thus this technology cannot be used in a number of important traffic and incident management roles. The second type of microwave radar commonly used in traffic applications emits what is referred to as a "frequency-modulated continuous wave" or FMCW, which varies in frequency with time. Unlike the constant-frequency microwave radar, FMCW emitting radars are capable of detecting the presence of a stopped vehicle as well as vehicle speed.

The ability to determine vehicle speed and presence allows the second type of microwave radar (sometimes referred to as a "true presence" radar) to be utilized in a number of applications ranging from signalized intersection control to vehicle counting. This technology is, however, not without its limits. A major disadvantage of the microwave radar technology is the lack of suitable locations for its installation. Because the radar device must be placed beside or above the road, an overhead structure must be constructed. The erection of separate support structures for individual devices is not cost-effective, thereby limiting the placement of devices to pre-existing structures.

Passive Infrared Detectors

Passive infrared devices are sensors that detect the infrared energy emitted by objects that are within the detection range of the device. They operate by measuring changes in energy emissions within the sensor's field-of-view, in that "the change in energy is proportional to the absolute temperature of the vehicle and the emissivity of the vehicle's metal surface (emissivity is equal to the ratio of the energy actually emitted by a material to the energy emitted by a perfect radiator of energy at the same temperature)" (Loral AeroSys, 1995).

The primary advantage of the passive infrared sensor is that it is capable of detecting vehicles at a greater range that sensors that depend on visible wavelengths, however, the accuracy of the detector can be degraded by heavy rain or snow. Passive infrared detectors are also limited by their inability to collect speed data (only vehicle presence data is obtainable).

Active Infrared Detectors

Active infrared detectors operate in much the same manner as microwave radar devices, in that energy from the sensor is reflected off of the vehicle in order to obtain data. These detectors are capable of measuring vehicle presence as well as vehicle speed; however, atmospheric and placement concerns (a suitable structure must be constructed, as in the case of the microwave radar) prevent this technology from being cost-effective.

Ultrasonic Detectors

Ultrasonic detectors operate by transmitting sound at the 25-50 KHz range. While more expensive detectors can measure Doppler speed, the most widely used (and low-cost) detectors provide only vehicle presence data. Ultrasonic devices are commonly compact in size and easy to install, however their practical traffic management use is restricted by the limited amount of data obtainable in a cost-effective manner.

Video Cameras and Image Processors

Video image processors function by analyzing the images supplied by a video camera. While video cameras and processors are typically more expensive than other surveillance mechanisms, their flexibility is an incredible strength. Video cameras can be used to obtain vehicle presence, speed, length, and lane change data for multiple lanes of traffic with a single detector. Additionally video surveillance allows for rapid incident detection and verification. The primary disadvantage inherent with video technology is operation in poor lighting situations (night or heavy weather, for example).

The flexibility of the video camera and processor has prompted agencies to pursue the widespread use of the technology as a cost-effective means of obtaining traffic information. Despite the cost-effectiveness and diverse information derivable from video technology applications, the use of these technologies may not be affordable enough to warrant installation in every community. The implementation of video technology is limited based upon the existing infrastructure. Communities must have sufficient computing technology and manpower to operate a video system, as well as an adequate network of wiring to transmit video data. The transmission of video images can be prohibitive because of the size of the data involved, thus partnership with wiring providers is vital.

Section 3
Review of Traffic Management Case Studies
(Outside Alabama)

Atlanta, Georgia

The State of Georgia's Department of Transportation (GDOT) began planning a statewide Intelligent Transportation System (ITS) in 1991, later named NAVIGATOR. The first phase of the system implementation called for development in the Atlanta metropolitan area. According to GDOT the plan for development in Atlanta fell into four major categories: surveillance and detection, incident management, traveler information, and traffic control strategies. The first phase of Atlanta's ITS development was completed in 1996.

The NAVIGATOR system is an integrated system that allows rapid updating of elements of the established ITS infrastructure. For example, signal timings and Variable Message Signs (VMS) can be updated by operators via computer. Traffic information is also available in real-time on the Internet. Figure 3-1 shows the presentation of real-time data on the Internet.

The nerve center of the Atlanta intelligent transportation system is the Transportation Management Center (TMC). The TMC is linked via fiber-optic cable to seven satellite Transportation Control Centers (TCC). A TCC has been established for five metropolitan counties, the City of Atlanta itself, and the Metropolitan Atlanta Rapid Transit Authority (MARTA). A comprehensive freeway management center, used by the TMC consists of:

- 66 color Pan/Zoom/Tilt surveillance cameras
- Over 300 fixed black and white cameras
- 41 VMSs
- 318 video detection system (VDS) cameras
- Five ramp meters

Along with the above technologies an incident management program was established consisting of the following:

- 26 Highway Emergency Response Operators (HEROS)
- Over 100 accident investigation sites
- A Motor Vehicle Emergency Response (MOVER) team
- A Metro-wide incident management task force

As a result of the implementation of the NAVIGATOR system, studies have revealed a 23-minute reduction in incident duration in 1997, resulting in cost savings of $44.6 million due to reductions in delay time. Based upon an investment of $72 million (over the course of the system's development) for freeway and incident management components, a benefit-cost ratio of

2.3 for 1997 is obtained. However, an actual benefit-cost ratio for the NAVIGATOR system is purported to be much higher, based upon the conservative manner in which the benefit-cost ratio was calculated.

I-95 Corridor

For ITS development to continue to be successful in the United States, there must be an integration of systems covering both urban and rural areas. One such development is taking place along the I-95 Corridor spanning over 13 states and the District of Columbia. Implementing a complex system of surveillance, the I-95 Corridor Coalition seeks to encourage the development of traffic management systems, Travel Demand Management (TDM), and Traveler Information Services (TIS). The summary of an eight-month surveillance requirements/technology project conducted for the I-95 Corridor Coalition (1).

A survey was performed to identify the goals of the I-95 surveillance system and the eight goals listed below were recommended:

1. Enhance traffic incident management
2. Enhance real-time traffic control operations
3. Enhance traffic management during snow storms and other emergencies
4. Improve multimodal and intermodal transportation operations
5. Support TIS
6. Enhance the transportation systems planning database
7. Facilitate TDM strategy implementation
8. Support traffic law and regulation enforcement

The total mileage of the corridor was estimated at 5600 miles. After the corridor's current status was surveyed, it was discovered that about 4000 traffic detection devices covered approximately 630 miles of Corridor roads. In addition, 2700 traffic detection devices were counted but the mileage covered by these devices is unknown. Also, 504 miles will be covered in the immediate future after 3400 new traffic detection devices are deployed.

The conceptual surveillance system was designed for both urban as well as rural roads. Because the system is so land intensive, design must focus on the integration of information from multiple sources and use of multiple technology types. Surveillance technologies must gather data for traffic management, TDM, intermodal transportation, traveler advisory information, and transportation facility planning. It is recommended that for locations known for having a high incidence of traffic crashes, stand-alone incident detection systems should be installed. Other means for incident detection may originate from human surveillance, aerial surveillance, and in-vehicle Mayday devices. These other forms of notification should be implemented to the fullest in rural areas. The implementation of surveillance technologies may not only be beneficial in acquiring traffic data, but may also be used to gather data concerning pavement conditions, weather, and environmental conditions.

In order for the I-95 Corridor surveillance system to function properly, careful consideration is taken in regards to the choice of technologies and the needs of the coalition. The technologies chosen for the corridor have region-wide application and impact. To test the usefulness of new technologies, Field Operation Tests are conducted. The surveillance Field Operation Tests have the following objectives:

- The feasibility of integrating surveillance information from multiple sources is assessed.
- Identify and formulate institutional arrangements that enhance cooperation of agencies and organizations that are gathering surveillance information.
- Determine the best technology or technologies that can be implemented throughout the entire I-95 Corridor.
- Gather the necessary information for the coalition to prepare a Corridor-wide Surveillance System Deployment Plan.

After the Field Operation Tests are conducted, preparation for deployment begins. First, a traffic study is performed to determine areas along the Corridor that require surveillance. Next, monitoring and regular updating of the surveillance technologies used at each particular point along the Corridor occurs. Finally, the cost database is updated periodically. While the development of the surveillance system is an ongoing process; the design and deployment of technologies are important steps in the success of the Corridor Surveillance System.

Minnesota

The Minnesota Department of Transportation has made a concerted effort to provide innovative, technology-based traffic information in rural and small urban areas in that state. Such areas are experiencing a growth in traffic volume; subsequently, an increased need for reliable and real-time traffic and weather data has arisen. Because the transportation and information needs of rural and small urban areas are rapidly evolving, it has become necessary to develop solutions to these needs that are both flexible and upgradeable.

A major portion of the solution involved the emplacement of Transportation Operations and Communication Centers (TOCC) in the St. Cloud and Duluth areas. These centers serve as the precursors to a large development that will place TOCCs in seven more Minnesota cities. In addition the TOCC development, Virtual Transportation Operations Center (VTOC) software developed by ADDCO Inc. is used.

The VTOC software allows a user to monitor and control the various ITS components operated by the TOCCS. Each individual component is integrated into a network that is accessible from the Internet, thus allowing a user to operate the component from a remote location. The VTOC software provides the following features:

- Responsive - Local needs and concerns were addressed as part of the design and deployment processes
- Innovative - The VTOC solutions utilize new and emerging technologies linked to field proven devices
- User Friendly - The current staff, with training, operates and maintains the systems
- Uses existing infrastructure - The new systems are designed to interface with existing systems and existing technology
- Fault Tolerant - The VTOC system in one region can provide backup for another region since the operator can be located virtually anywhere
- Transferable - The VTOC concepts are readily transferable and usable state and nationwide
- Flexible - The systems are designed for flexibility and expansion in order to accommodate new products and technologies

Of particular interest to this research, the VTOC software allows for the transmission of video data through conventional or wireless means. Thus, a user can view traffic video feeds from a variety of locations via a personal computer connected to the Internet.

Europe

A junket to Europe studied the innovations in traffic control in place on that continent (PIARRC, 2000). The researchers noted a number of differences between American and European systems. These contrasts were both of a cultural and engineering nature (PIAARC, 2000). Of importance to ITS is the observation that Europeans appear to have a generally greater respect for authority. From this respect comes a higher level of compliance with traffic control regulation and devices.

From an engineering perspective, it was noted that Europeans were utilizing new technologies faster than their counterparts in the United States. Additionally, European transportation agencies appeared to be more progressive in the testing and implementation of new technologies and applications of traffic control devices. In the ITS field, the use of advanced technological solutions seemed more readily accepted by European engineers. The example of Sweden is noted in that Swedish engineers often integrate ITS solutions directly into their operation and do not call special attention to their use. This policy seems to reduce the likelihood that the innovative practices will be questioned for budgetary or other nontechnical reasons.

One of the primary innovations in use in Europe is the use of Variable Speed Control. This system allows transportation authorities to achieve traffic flow and safety improvements by dynamically changing the speed limit. This practice has been closely integrated with congestion and incident detection programs. Using loop detectors and video cameras, Sweden's Motorway

Traffic Management (MTM) program has been employed in the Lundby Tunnel. The system is able to measure traffic volumes and speeds, classify vehicles, detect incidents, wrong-way vehicles, disabled vehicles, and pedestrians. The MTM system has resulted in a 23 percent reduction in overall accident rates and a 35 percent reduction in serious crashes.

Another innovation is the Immediate Detection of Stopped Vehicles (IDSV) system in France used for the automatic detection of incidents through video processing. A private toll road company (COFIROUTE) employs the system. Cameras are placed at intervals along the roadway and then are connected to the toll road operations center by fiber-optic cable. Through the use of digital image processing, images are automatically detected and then verified by operators. The company claims a 99 percent detection rate in tunnels and a 90 percent detection rate on open highways.

Many of these systems, particularly Variable Speed Control, utilize photographic automated enforcement in order to maintain speed limits. Figure 3-2 illustrates a photograph taken by a photo-radar system in the United Kingdom.

The use of automated enforcement for speed control has resulted in a five-ten percent increase in roadway capacity and a 25-30 percent decrease in the number of rear-end crashes on the approaches to freeway congestion.

In addition to the widespread use of photo enforcement of speeds, the use of decoy camera housing units with a simple flash bulb and no camera has resulted in the perception of a greater presence of video enforcement units.

Section 4
Traffic Management Programs In-Place in Alabama

Mobile

The City of Mobile provides an example of taking ITS from its infancy to full deployment. The first ITS application implemented in Mobile was VMS technology. The VMS is used in Mobile's Bankhead Tunnel to relay lane closings, maintenance work, and crashes information to drivers. Video detection is also used at various intersections and interstate ramps throughout the city.

Perhaps the most widely recognizable ITS application implemented in Mobile is the city's Fog Warning System Project. This was developed following a multiple vehicle accident that took place on the I-10 Bayway Bridge, on March 20, 1995. The incident resulted in one fatality and 91 injuries and involved a total of 193 vehicles. The cause was determined to be the excessive vehicle speed during a major fog event. The warning system was developed in order to detect fog, provide adequate warning motorists, inform motorists of detours, and reduce vehicle speed. The system includes the following:

- Weather monitoring station (Condition Detection)
- Visiometer (Measures Visibility)
- VMS - Provides motorists with information and pre-programmed messages.
- Changeable Speed Limit Signs- Used for slowly reducing vehicle speeds.
- VDS - Alerts motorists to congestion
- Tunnel Control Room Operation Center - Operational 24 hours per day, 7 days per week, and 365 days per year. Monitoring equipment, quad screen monitors, and alarms.
- Closed Caption Television (CCTV) - Traffic congestion and incident verification.

The majority of the ITS projects implemented throughout the City of Mobile are funded by ITS funding appropriated through Congress. Figure 4-1 illustrates warning signage typical of the Mobile fog detection system.

Montgomery

In the State capital of Montgomery, a simple plan has been developed for the deployment of ITS technologies. The first phase included a closed loop along I-65 service roads and ramps in downtown Montgomery and installation of CCTV and VDS cameras as well as microwave radar equipment for traffic detection. Initial fiber-optic cable construction was included in Phase I. Currently the city is in Phase II of ITS deployment. This phase includes the laying of fiber-optic cable along the Montgomery bypass. The newly installed fiber-optic cable should create a ring around the city and the closed loop system will provide communications to the Alabama Department of Transportation (ALDOT) 6th Division office and to the Montgomery Traffic Engineering Department.

The next two phases, Phases III and IV will include the deployment of more fiber-optic cable throughout the city along major arterials. Additionally, CCTV Cameras will be installed at a number of intersections for the role of incident and congestion management. The use of VMS in outlying areas is also planned. Finally, the construction of a TMC at the 6th Division Office is planned. Also, the system in Montgomery is designed as an open system, which will be linked with the agencies such as transit, fire, police, and Emergency Management Systems (EMS). Funding for Montgomery ITS projects has come mainly from funds provided by Congress.

Tuscaloosa

The City of Tuscaloosa has taken a different approach from other cities in its implementation of ITS technology. The city has developed its own ITS network with funding coming predominately from the City of Tuscaloosa itself using City equipment and labor resources. The construction of Tuscaloosa's ITS network has included the expansion of the City's traffic control center and installation of CCTV cameras at various locations throughout the city. Figure 4-2 illustrates a CCTV camera located in Tuscaloosa. Further expansion of the network will include the installation of additional fiber-optic cable, VMS, and upgrading the traffic control center with features like the BARCO system and an active status map deployment for TMC operations. Also, the City plans to get other stakeholders such as Tuscaloosa Police and Fire Departments, and the City of Northport directly involved.

Birmingham

The metropolitan area of Jefferson and Shelby Counties, which includes both the City of Birmingham and City of Hoover, has transportation problems and issues that are unique to large urban areas. For instance, Birmingham must contend with Congestion Mitigation and Air Quality (CMAQ) funding all of which involves the issue of air quality standards.

The first action taken to provide a base for ITS deployment was the creation of the Alabama Service & Assistance Patrol Program (ASAP). The ASAP vehicles locate problems on the highway and clear the roadway as quickly as possible. The ASAP Program is a partnership between the DOT and Department of Public Safety.

The next phase of Birmingham's ITS implementation was the deployment of fiber-optic cable throughout downtown. This phase was critical because it connected all stakeholders including: City Fire Department, City Police, EMS, City Engineers, and Department of Transportation staff. The fiber will connect CCTV cameras and VMS in the future. Cameras will provide overlapping coverage of freeway routes. The cameras are mounted at high exposure locations on existing poles. The next phases of ITS implementation in Birmingham will be the installation of additional fiber-optic cable and CCTV, VDS units, and microwave radar units throughout the metro area extending south of the city into Shelby County. Finally, the City of Birmingham plans to begin work on a Regional Transportation Management Center. The center is to be staffed and operated for approximately 16 hours per day. An operations manual for the TMC is presently being constructed. It should be mentioned that the City also plans for Internet connections with map display giving drivers access to real-time traffic data. The densely populated City of Hoover, a smaller municipality south of Birmingham, is currently constructing a CCTV surveillance system long US 31 and presently has a TCC in their City Engineering office.

An on-site visit was conducted for Birmingham's Traffic Management Center. Figure 4-3 presents an interior view of the Traffic Management Center. The purpose of Birmingham's implementation of video technology was to efficiently monitor arterials and interchanges and to achieve signal optimization. Officials claim that using video technology saves time and money for the City by becoming the "eyes" for transportation officials and other government agencies. Video saves time by allowing quicker incident management and saves money by reducing the manpower necessary for overall traffic observation. The City of Birmingham uses its video network for safety and transportation management only. There are no plans to use the technology for enforcement purposes. In addition to the traffic applications of video technology, the network is set-up to be accessible by the Birmingham Police Department, Fire Department, and EMS. It should be noted that by providing the Fire Department access to the camera images not only allows fire officials to be able to gain instant fire verification and severity, but also the City gains 24-hour monitoring of the system without requiring the center itself to be manned around the clock.

The video network in Birmingham is predominately fiber-optic in nature however there is some use of wireless technology. A Birmingham official interviewed for this report claims that the future of video applications will move more toward digital technology because the fiber deployment can be reduced to a four-fiber connection sonic network.

Officials claim that a reasonable cost expectation for each camera location is approximately $24,000 for each camera-unit and unit installation. While much of Birmingham's video deployment is in the developmental stages, officials have already begun to look toward the future. The hopes of city traffic engineers for the future are to move from being restricted to "sight in the field and control in the office operation" to create the ability to "control from the field and see from the office" using mobile data terminals. The City is currently planning the deployment of 30 more cameras in the downtown area and 40 cameras along vital arterials throughout the city. It was also recommended, that for the ITS systems of any metropolitan area to become compatible with other nearby cities the hardware must be similar and the system architecture must be nonproprietary in nature. If ITS systems throughout the state lack these two things then compatibility will be difficult. Birmingham's deployment of video technology is a good example of how peripheral benefits may be achieved through the proper identification of stakeholders and providing the appropriate agencies with access to the video technologies.

The Future of ITS in Alabama

In the years to come not only will ITS technologies be utilized in the above-mentioned metropolitan areas, but also in other cities across the state with transportation needs that may call for ITS applications. One example is the City of Huntsville. Officials in Huntsville are currently developing a strategic plan for the implementation of ITS technologies. First, the city plans to identify user services such as Freeway Management and Incident Management. Then, the city will determine who the stakeholders are such as the fire department, police department, and EMS. The next course of action to be taken will be to install a fiber-optic cable network along major arterials for connection to traffic signals and cameras. Then officials plan to add, as necessary, traveler information services and VMS displays.

Another metropolitan region that plans to implement ITS technologies is the Muscle Shoals area. Plans are in the works to develop a fiber network with CCTV Cameras, monitoring stations, and VMS as well. A warning system has been proposed similar to the Mobile Bayway Bridge Project for the O'Neal Bridge crossing the Tennessee River. As transportation problems develop across the state, the need for ITS technologies will intensify causing the preceding projects to become a benchmark for ITS implementation strategies in the future. Transportation officials will need to know what works and what does not work to better address their ITS needs.

Section 5
Automated Enforcement and Relevant Technologies

Estimates indicate that about one-third of crashes and two-thirds of resulting fatalities in the United States can be linked to aggressive driving behaviors. In order to combat aggressive driving, increased enforcement of traffic laws has been suggested, however, the costs of enforcement can often limit an entity's ability to perform this task. Thus, automated enforcement has been suggested as a potential solution. Automated enforcement is defined as: "The use of image capture technology to monitor and enforce traffic control laws, regulations, or restrictions" (Turner and Polk, 1998). Automated enforcement technologies can be applied to the following enforcement challenges:

- Red-Light Running
- Speed Limit
- Rail-Highway Grade Crossing
- High-Occupancy Vehicle Lane
- Electronic Toll Collection
- Vehicle Inspection and Weigh-In-Motion Stations

The application of automated enforcement to red-light running, speed limit violation, and rail-highway grade crossing violation will be examined in this review. An overview of the relevant technologies used in these automated enforcement technologies will also be presented.

Red-Light Running

Red-light running has been found to be a significant source of traffic crashes and fatalities. Roughly 260,000 crashes per year result from red-light running. Red-light running incidents claim approximately 750 lives per year. In one study, occupant injuries occurred in 45 percent of red-light running crashes, compared with 30 percent for other crash types.

Various researchers have studied the frequency of red-light running incidents. A violation rate of roughly 13 violations per 10,000 vehicles was observed at 12 intersections in California. Research conducted in Arlington, Virginia between 1994 and 1995 at two intersections yielded 8,121 red-light running violations over a period of 2,694 hours. This yields a frequency of slightly more than three violations per hour. Violations during peak traffic hours are claimed to be at a rate of approximately 12 per hour.

Because the resources of law enforcement agencies are limited, the enforcement of traffic signals is difficult to accomplish (particularly in urban areas where a large number of signals are concentrated). In cases where a law enforcement officer witnesses a violation, the apprehension of the violator can be highly dangerous as the officer must often follow the violator through the red signal and pursue the vehicle through areas that may be highly congested. Thus, the question arises as to what can be done to combat the red-light running problem?

Several potential countermeasures are presented:

- Removal of unwarranted traffic signals - Remove signals from low traffic volume locations.
- Signal Timing - Provide adequate clearance or change signal intervals. Studies have shown that the presence of inadequate signal change intervals can be correlated with increased crash rates.
- Enforcement - Utilize innovative and advanced technologies to assist in the monitoring of red-light running violations.

Red-Light Running Technology

The fundamental technology associated with automated red-light running enforcement is a photo detection system. This system consists of electromagnetic loops buried in the road surface, a terminal block housing a microprocessor, and a camera mounted on a pole. Cables connect the elements of the system. The system operates by monitoring the traffic signal and triggering the camera when a vehicle passes over the loops after a predetermined period of time. Commonly, red-light running camera systems also take an additional photograph of the violating vehicle while it is in the intersection. The system records the date, time, time elapsed since the beginning of the red signal, and the speed of the vehicle.

Typical requirements and considerations for a red-light running system are:

- The ability to capture, transmit, process, store, and recover captured images so that data may be managed in an efficient manner.
- Sufficient resolution to satisfy court standards for the image reading of vehicle license plates and clear detail of the vehicle and identification of the vehicle operator (if necessary).
- The capability to prevent the spreading of overexposed portions of an image (anti-blooming) that may result from vehicle headlights or sunlight from reflective surfaces.
- Adequate differentiation of light to dark areas within an image to provide necessary details (also referred to as contrast latitude).
- The ability to provide clear images of moving vehicles.
- The ability to detect violators at varying levels of light.
- Image enhancement circuitry to eliminate major sensor defects such as bright or dark columns, which detract from the visible presentation of the image.
- Continuous readout of images to support monitoring along with single frame capture capability for recognizing several successive vehicles committing a violation.
- The ability to be moved to different locations or to be mounted into a permanent position.
- Components that are environmentally friendly.

Three types of cameras are commonly available for use in red-light running enforcement systems: 35-millimeter cameras, video cameras, and digital imaging cameras. Each of these camera types is presented.

35-mm Cameras The most commonly employed cameras in red-light running enforcement systems are 35-millimeter cameras. These cameras come in two primary varieties that produce black and white and color photographs. While black and white cameras are less expensive than color cameras, enforcement agencies must be aware that only color photographs eliminate any doubt as to the phase of the traffic signal when an alleged violation has occurred.

Red-light running camera systems are typically installed as shown in Figure 5-1. A photograph obtained from a red-light running camera in Victoria, Australia is illustrated in Figure 5-2.

The primary advantage of a 35-millimeter camera is its portability. This portability allows for "false installation" of cameras. Because 35-millimeter cameras can be easily transferred from one intersection to another, camera-housing units can be placed at a number of intersections, even though the unit may not actually contain a camera at any particular time. This placement of numerous housing units prohibits drivers from knowing if a unit actually contains a camera.

Video Cameras Full-motion video technology is not commonly used for red-light enforcement. The primary reason for this lack of use is that legislation and court rulings in a number of states did not support the use of video recordings as evidence. However, video cameras can be used as a mechanism to illustrate the prevalence of the red-light running problem, which can lead to the installation of alternate automated enforcement technologies.

Digital Cameras Digital cameras are among the newest innovations in the automated enforcement field. They have the ability to produce high-resolution sharply detailed images. These cameras are designed to prevent distortions due to image smears and headlight reflections.

The primary anticipated benefit of the use of digital cameras is improvement in the processing and distribution of citations. Digital cameras are versatile in their ability to be linked using dedicated lines or existing telephone lines to a central processing facility. After automated analysis of the images obtained by a digital camera, tickets can be processed and mailed to the violator.

While digital cameras and associated technology offer great potential, the equipment and its use in automated enforcement remains in its infancy.

Potential Countermeasures
As this research has progressed, the question of what countermeasures are available to the public to directly interfere with automated enforcement camera technology has been raised. Several Internet vendors provide products that are claimed to be effective against automated enforcement cameras under certain lighting conditions. Examples of these products are: license plate sprays, various varieties of license plate covers, and " slave-strobe" devices. Despite the potential consumer allure of these products, no research was discovered which could confirm the efficacy of these products.

Photo-Radar
Aside, from the use of motion photography, still photography is a very important tool used for the development of ITS technologies. One technology used in reducing the excessive speeds of vehicles is photo-radar. While photo-radar has been in development for over 30 years, it remains one of the most common methods of automated speed control. Photo-radar systems consist of a narrow beam, radar speed detector, a motor driven camera, a flash unit, and a computer. When a vehicle passes through the radar, a computer determines if it is exceeding a preset speed. If a vehicle is speeding, then the camera takes a picture of the vehicle, license plate, and the driver (if necessary). Photographs are then developed and the vehicle owner is mailed a notice of violation.

One study performed concerning the effectiveness of photo-radar took place in Riverside, California. The photo-radar test ran for two hours over a period of two days operating from 7-9 AM or 4-6 PM. The photo-radar was setup on a police van with a strobe light that flashed for every driver exceeding the speed limit. The speed data was collected at two points on each site. First, speed was obtained alongside the site and again about 0.2 miles downstream. The results of the Riverside study of photo-radar were an overall decrease in vehicle speed of 5.1 miles per hour alongside the site and reductions of 4.1 miles per hour 0.2 miles downstream from the site. While the study of photo-radar yielded positive results in reducing vehicle speed, the final analysis demonstrated that of the different types of automated speed control, photo-radar proves to be very expensive. The high costs associated with photo-radar implementation are due to the great expense of purchasing the radar equipment. However, despite the expense, photo-radar can be a very effective method of speed control because it does not require the use of law enforcement officials and drivers are not aware if they are being issued citations or not.

Photo Enforcement (Railroad-Grade Crossings)
As the use of video technologies for traffic management and safety grows across America the positive benefits of their use will not only be felt in the metropolitan areas across the nation, but in rural areas as well. One way in which video technology may be used in rural areas is by monitoring railroad-grade crossings. The following study was performed in Los Angeles County, California and, while the project was initiated in an urban center, the author believes that the same technology used may be implemented in rural regions across America.

The State of California Department of Transportation introduced in 1992 a proposal for the implementation of a Grade Crossing Safety Improvement Program. Part of this program consisted of photo enforcement at the Long Beach Blue Line Grade Crossings. After demonstration projects using photo enforcement equipment cameras at grade crossings were successful, the LACMTA (Los Angeles County Metropolitan Transportation Authority) approved the installation of photo enforcement equipment at 17 crossings on the Blue Line. For these projects, a large reduction in grade crossing violations was measured after implementation and issuing citations. Since the 17 grade crossings were equipped with photo-radar, beginning in September 1995, nearly 3,000 citations were issued. More importantly, the cameras have been effective in reducing train/vehicle collisions at the Long Beach Blue Line Crossings. From September 1995 through June 1997, no train/vehicle collisions occurred where photo enforcement was in place.

Section 6
Automated Enforcement Case Studies

Howard County, Maryland

Beginning in March 1996, officials in Howard County, Maryland began a field test of red-light running cameras. Enforcement utilizing the cameras began in February 1999. County transportation agencies have proceeded to install cameras at 12 county controlled traffic signals and two state highway signals. There are a total of 71 traffic signals in Howard County.

Howard County initiated a significant public awareness and education program in order to inform the driving public of the risks of red-light running. This campaign was concentrated in radio and television advertisements. In addition to the information campaign, signs were posted indicating the presence of red-light running enforcement cameras, however the locations of the cameras were not revealed. Public response during the program's test period was generally positive.

The use of automated enforcement technology was enabled by Maryland State House Bill 391, which was enacted in October 1997. This bill provided for "civil penalty if the motor vehicle is recorded by a traffic control signal monitoring system" (McFadden and McGee, 1999). For the purposes of the legislation, a traffic control signal monitoring system was defined as "a device with one or more motor vehicle sensors working in conjunction with a traffic signal to produce recorded images of motor vehicles entering an intersection against the red signal indication" (McFadden and McGee, 1999). The bill allows for citations to be mailed to violators and sets a two-week time limit for the distribution of the citation.

As a result of the implementation of the red-light running program, 23 percent reduction in the number of red-light violations was observed along with a reduction in crashes. That data, however, was not sufficient to allow statistically significant conclusions to be made.

Anchorage, Alaska

Anchorage, Alaska presents an example of the dangers of haphazardly administering an automated enforcement program. In 1996, the city government of Anchorage began a program to provide automated enforcement of speed limits in school zones. Three photo-radar units were provided. By October 1996, over 12,000 photo-radar citations had been issued. Given the large number of violations, Anchorage officials expanded the program beyond the normal school hours of 8 AM to 4 PM. Of the citations issued by October 1996, nearly one-half were contested.

Subsequently, a series of court rulings effectively disabled the photo-radar program. At question were the legality of the photograph's admissibility as evidence and the method of service of the citation. Alaska law required the service of a citation by a police officer or via certified mail.

The Anchorage photo-radar program was operating in violation of this law because the citations were delivered by regular mail. The City's contract with the photo-radar vendor then expired and the program was eliminated.

Los Angeles, California

The following data was obtained from the photo enforcement project implemented by Los Angeles County Metropolitan Transit Authority (LACMTA) to help reduce rail transit grade crossing violations and crashes. From July 1990 through the end of June 1997, there were 353 collisions resulting in 33 fatalities along the Metro Blue Line. To help lower the number of collisions and fatalities the LACMTA enacted the following provisions:

- Law enforcement at Metro Blue Line grade crossings by the Los Angeles Sheriff's Department for 90 days.
- Full-time traffic detail established by the Sheriff's Department.
- Pilot installations of photo enforcement to monitor the effectiveness of photo enforcement cameras at grade crossings.
- System-wide photo enforcement.

The data gathered from full-time traffic detail deputies gave researchers a good idea of the type of violations that were the most common at the Metro Blue Line grade crossings. As a result of the traffic detail enforcement, approximately 74 percent of the 11,792 citations issued at one particular segment of the Metro Blue Line fell into one of six categories.

The six target violations of the study are listed below in order of decreasing frequency:

1) Failing to stop for red traffic signal
2) Failing to stop for railroad flashing signals
3) Failing to stop for stop sign
4) Failing to obey turn prohibition sign
5) Pedestrian failing to obey sign or signal
6) Driving around closed crossing gate

The number of train/vehicle collisions at grade crossings on this segment of the Metro Blue Line declined significantly when the traffic detail deputies were patrolling the crossings.

The photo enforcement technology used to monitor grade crossings along the Metro Blue Line is composed of a vast network of street hardware. First, at each monitored site there is a 10-foot camera pole with a double-walled camera cabinet mounted at the top of each pole. The camera cabinet contains the camera unit. This camera unit, developed by Gatso, consists of a Robot Model 36 DAT-P camera, a flash unit, a four-channel loop detector board, and front panel with push buttons for camera operation and setup. Also, contained in the camera unit are lamps for vehicle detector and train approach circuit occupancy indications, switches for adjusting the loop detector and flash units, and a PCI memory card slot. These cameras are triggered by vehicle detection loops that are installed on the entrances of the track area. Four inductive loops are needed to relay the inputs for the camera unit logic. The LACMTA report also provides information concerning the use of existing traffic loops where space is limited. Finally, for each site where photo enforcement was present, advance-warning signs were set up for all directions approaching the crossing, letting travelers know that they were entering a photo-enforced area.

System-wide photo enforcement consisted of both video-based vehicle detection and digital-based vehicle detection. The results of photo enforcement speak for themselves. At 17 street crossings where approximately 2,800 citations have been issued using the cameras to date, there has not been a single train/vehicle collision. The costs to construct a photo enforcement system will depend on the infrastructure needs and the number of cameras to be purchased. The LACMTA projects yielded a cost range of $38,000 to $57,000 per crossing. It should also be noted that the use of revenues produced by the issuing of citations to pay for the cost of construction and operation of the system should be avoided. However the use of photo enforcement at grade crossings is considerably less expensive than using traffic detail officers. The Metro Blue Line photo enforcement system had construction and five-year maintenance costs of approximately $3.8 million. Comparing that to the use of 10 full-time police officers to patrol grade crossings each day, seven days per week, and working two eight-hour shifts with five officers per shift, the cost would be approximately $10.5 million. As you can see, the use of photo enforcement at grade crossings has proven to be cost effective both in terms of saving money and, more importantly, saving lives. The LACMTA's project represents the first use of photo enforcement at light rail transit grade crossings in North America. Today, it is one of the largest systems in North America.

Section 7
Legal/Institutional Issues

In a country like the United States, where there is a great value placed on personal freedom and privacy, the use of video technology for any reason will likely be scrutinized. The Intelligent Transportation Society of America (ITSA) has developed a set of privacy standards for ITS officials across America to use as a guideline for the implementation of intelligent transportation projects. These principles are designed to be flexible and durable to accommodate the entire scope of technological, social, and cultural change.

The nine ITSA provisions for guaranteeing privacy in contracts and agreements include:

1. ITSs must be individual centered, respecting and recognizing the individual's interests in privacy and information use.
2. ITSs should be constructed in a way that is visible to the public.
3. ITSs will comply with state and federal laws concerning privacy and information use.
4. ITSs will be secure.
5. Concerning law enforcement, in the absence of consent, government authority, or appropriate legal process, information of individuals will not be disclosed.
6. Personal information collected will be relevant to ITS purposes only.
7. Individuals should have the ability to access ITS on an anonymous basis.
8. ITS data not containing identifiers may be used for non-ITS purposes.
9. Information pertaining to ITS must be disclosed according to the Federal and State Freedom of Information Act (FOIA).

Legal Summary

The provisions are intended to educate and guide transportation officials and policy makers. The primary focus of ITS should be to use information to improve traveler safety and security, reduce travel times, enhance individuals' ability to handle highway interruptions, and improve air quality. The concept of visibility requires disclosure to the public of the type of data collected, how it is collected, what its uses are and how it will be distributed. ITS systems should also provide technological and administrative safeguards to assure that access to personally identifiable information is available to only those who should have it. In the absence of government authority, ITS should not be a means of traffic enforcement.

However, given the increased worldwide popularity of automated enforcement, this statement may have to be revised. Those who participate voluntarily in ITS programs should not feel like the information that they are providing will be used against them. Unless required, users of ITS systems should have the opportunity to choose anonymity. Transportation officials should always remember that information gathered by surveillance technologies is very sensitive.

Government agencies must walk a fine line between two opposing considerations when it comes to disclosing ITS information. The first of these is the individual's right to privacy. The second is the public's right to know, as protected by the Freedom of Information Act.

From a stricter legal standpoint, there is not presently a court case that has specifically defined an individual's First Amendment constitutional right to privacy while operating a vehicle. According to researchers familiar with the legal implications of privacy, the assertion that driving is a privilege and not a right and the fact that operating a vehicle occurs in view of the general public lends belief to the assumption that driving would not fall under the protections of the Constitution. Several Supreme Court decisions have dealt specifically with surveillance of vehicles and ruled in favor of surveillance on each occasion.

From the standpoint of automated enforcement, there is another entire set of legal issues. Of particular importance are rulings regarding the court admissibility of photographs taken by automated enforcement technology. Courts have demonstrated a need to establish a photograph's "competency and authenticity". In order to establish these elements, a photograph must identify the defendant as the same person in the photograph, must give clear identification of the vehicle's license plate, and the functionality of the camera at the time the photograph was taken must be verified.

With regard to photo-radar technologies, in 1958 the Supreme Court ruled that such a system was not a violation of an individual's constitutional rights. The Court stated: "We have passed the horse and buggy days and are living in a new era. The question is, did the defendant do it and was there sufficient proof to find the defendant guilty beyond a reasonable doubt."

In most states, to meet today's court tests, red-light running enforcement programs must establish three things: (1) that the photograph was taken, (2) the position of the vehicle in the intersection while the traffic signal was red, and (3) that the time shown were provided by an instrument that has been proven to accurately identify and photograph the red-light running sequence of events.

Section 8
Implementation Issues

A list of implementation considerations has been developed based upon the findings of this research. This list is as follows:

1) Identify and involve stakeholders in development and operation of system
2) Develop partnerships among stakeholders
3) Inform the public of system's benefits through a public awareness and education campaign
4) Ensure that legislation is in place that allows for operation of the system
5) Use vendors as a guide in evaluating hardware and software capabilities versus the agency's needs
6) Select hardware and equipment that will meet the needs of the system and be financially feasible (considering future compatibility issues)
7) Consider implementation on a small scale (pilot/demonstration project) in order to gauge potential effectiveness of the system and in order to address problems that may arise
8) Implement, evaluate, revise and expand as needed
9) Share information about the program's successes and failures (lessons learned) with others

These recommendations provide an agency, or other party interested in video technology implementation, a general overview of some of the important issues to be considered during planning and operation of a video system based upon lessons learned during the analysis of existing programs.

In addition to these considerations, it is important for each agency or locality to insure that the implementation of an ITS-based solution is right for their particular problem. Other alternatives should be considered in order to arrive a solution that is sound from both an engineering and financial standpoint.

Section 9
Evaluation of Alabama's Needs Related to Traffic Management and Safety

In order to determine Alabama's traffic management and safety needs, a study of crash data from the years 1996-98 was performed. This study identifies areas of concerns that may be able to be addressed through the implementation of one or more video technology applications discussed in this report.

Data Acquisition

The data for this report was obtained primarily from the *Alabama Traffic Accidents Facts* for the years 1996 through 1998 (readily available from the Alabama Department of Transportation) and the Crash Analysis Reporting Environment (CARE). CARE is "a software system designed to provide individual decision-makers within the traffic and aviation safety communities direct access to accident and incident information." The CARE system was developed at the University of Alabama in order to provide a simple tool to access a vast database of crash data. CARE is readily accessible via the Internet (http://care.cs.ua.edu).

General Crash Data and Trends

General crash data from 1996-98 for Alabama is summarized in Table 9-1. Included in this summary are vehicle miles traveled (VMT) for each year and the number of crashes, injuries, and deaths per 100,000 VMT.

This data indicates a reduction in injuries and deaths over the three-year period despite a steady increase in VMT. Furthermore, crashes, persons injured, and persons killed data has been obtained for Alabama on a county-by-county basis. This information is presented in Table 9-2. Information contained in Table 9-2 was used to create Figures 9-1, 9-2, and 9-3, which allows visualization of general county-by-county crash trends.

In order to gauge the potential impact of technology-based applications (traffic management and automated enforcement systems), it was necessary to obtain data related to specific crash types. The crash types examined in this report are: speed-related, red-light running, railroad-grade crossing, and fog-related crashes.

Alabama Speed-Related Crashes and Trends

For the purposes of this research a speed-related crash is defined as a crash attributed to "speeding," which is a variable available in the CARE database. Table 9-3 presents a general summary of speed-related crashes in the state of Alabama for the years 1996-1998. The data presented in Table 9-3 suggests a consistent, recurring incidence of speed-related crashes over the three-year period spanning 1996-98. For comparative purposes, the overall crash statistics are shown in Table 9-4. The variance in crashes, injuries, and deaths per one million vehicles is relatively insignificant. Thus, the problem of speed-related crashes remains persistent.

Alabama Red-Light Running Crashes and Trends

The CARE database identified red-light running crashes and analyzed trends related to these crashes. A certain level of uncertainty appeared to be present in relation to the specific definition of red-light running crashes in the CARE database. Prior research had utilized the CARE variable "Fail to Yield Right of Way" in order to identify red-light running crashes. When this variable is utilized with the "Traffic Control Unit" data filter, it becomes possible to identify crashes during which a driver failed to yield the right of way at a traffic signal.

Based upon the above definition of a red-light running crash, CARE data for Alabama for the years 1996-1998 was obtained and summarized in Table 9-5.

Alabama Railroad-Grade Crossing Crashes and Trends

In order to categorize crashes in which a vehicle and train crash, while the vehicle was in violation of warning signalization or signage, the specific variable available in the CARE database for such crashes was identified. For the purposes of this report the CARE database variable "Railroad Trains" was used for data collection and analysis.

Each county in the general listing had at least two or more railroad crashes for at least one of the three years, either rural or urban. For a county to be given "alert" status for the accident results for 1996-1998 it had to meet one of the following criteria:

- County shows an increase in railroad crashes over the three-year time period in either rural or urban categories.
- County maintains a level of five railroad crashes over the three-year time period in either rural or urban categories.
- County has a total of 10 or more crashes over the three-year time period in either rural or urban categories.

Table 9-6 provides the counties with most number of speed-related crashes during the years 1994-1998. Data is obtained using the filter "Speeding" from the CARE database. From this table it can be inferred that Jefferson County, followed by Mobile and Tuscaloosa counties, contributes a major number of speed-related crashes. This gives a basis to use video-based applications for automated enforcement in these counties to considerably reduce speed-related crashes.

Table 9-7 gives the list of counties that have the highest number of red-light running-related crashes. “Fail to yield right of way” filter was used to obtain this data. It is observed that Jefferson County stands first followed by Mobile and Montgomery counties. Proper implementation of automated enforcement programs in these counties would bring down the number of red-light running-related crashes.

Table 9-8 provides the list of the counties with the highest number of railroad-related crashes. “Railroad Trains” filter was used, which showed Jefferson County followed by Mobile and Tuscaloosa counties as the most important counties that require technology-based applications and other automated enforcement that would minimize the number of railroad-related crashes substantially.

Alabama Fog Crashes and Trends

The criteria for fog crashes by which counties were given "alert" status was determined by the CARE analysis results for 1996-1998. A county that was given alert status in the CARE analysis revealed an overall increase in fog-related crashes during the three-year time period. Baldwin and Lee counties were given alert status because they each had accident values that were more than 10 percent higher than the expected value.

Section 10
Recommendations for Video Technology Applications in Alabama

General Insights
It has been well documented throughout this report that for transportation officials to efficiently implement video technologies certain measures must be taken. First, after the problem or need has been identified, all potential stakeholders must be identified to develop ITS partnerships. Determination of which agencies may be able to utilize video technologies (i.e. Traffic, Police, Fire, EMS, etc.) must be made. As the architecture for video deployment is being developed it is important to ensure that deployment remains nonproprietary in nature. This will allow the maximum benefit from the implementation of video technology. Next, the issue of future compatibility with existing local systems must be addressed. As metropolitan areas across the state continue to grow, the possibility of merging adjacent traffic management systems arises. For compatibility with the video technology of the future, the systems should remain as open ended as possible to ensure that they are fully upgradeable. The application of video technology should be used primarily for safety purposes. If video technology is used for enforcement, however, the system should not be used to financially support the construction and maintenance costs of video deployment.

The State of Alabama has yet to approve legislation that will allow the operation of automated enforcement technologies. Until such legislation is passed, the implementation of automated enforcement tools remains stalled. However, should such legislation be enacted, transportation agencies should identify problem areas, perform pilot testing of enforcement technologies, and then deploy on a full-scale basis.

Red-Light Running Enforcement
Red-light running enforcement through the use of video technology has proven to be an effective deterrent. This technology, however, has not been implemented in Alabama. Further research should be conducted in order to determine possible locations for future pilot projects, and existing programs should updated by purchasing equipment that utilizes new technologies such as fiber-optic cables and cameras capable of digital imaging.

Speed Violations
Video technology to curb speeding violations is not currently used in Alabama. As in the case of red-light running technology, further research should be conducted to determine suitable locations for future pilot projects. The implementation of equipment capable of handling speed violations would allow more efficient use of manpower in the area of law enforcement. The biggest challenge would be the legal issues and earning public support.

Video Enforcement at Grade Crossings

While the use of video technology at railroad-grade crossings has not been implemented yet in the State of Alabama it has been discussed in this report for two reasons. First, since enforcement can be used for both heavy and light-rail systems it may be deployed in both rural and urban settings. Although Alabama is a growing state, it is still predominantly rural and utilizing video technology for both enforcement and safety purposes should be explored. If video technology were to be implemented in such a capacity, this would add Alabama to a growing list of other states investing in the Advanced Rural Transportation Systems (ARTS). The second reason for discussing the use of video enforcement for grade crossings is because the State of Alabama (as of 1998) ranks 11th nationally according to Operation Lifesaver in railroad-grade crossing crashes. As a result of the CARE analysis for counties throughout Alabama, seven counties were given "alert" status for high incidents of railroad crashes. Each of the counties cited for "alert" status could have only rural-specific or urban-specific grade crossing problems.

The Los Angeles County Metro Blue Line provides the relevant agencies and officials with a versatile solution to a rural and urban transportation problem. Also, it should be noted that the City of Birmingham has discussed the possibility of installing a light-rail system. Were such a system to be constructed in Birmingham, the city should investigate the benefits of using video technology as a means of enforcing traffic laws related to railroad-grade crossings.

Video Applications for Fog Alert Systems

Along with the ability to use video in a rural setting at grade crossings it may also be used in the deployment of fog alert systems. Fog alert systems use video images to provide transportation officials with an immediate visual confirmation of the current driving conditions and the level of traffic flow. As was discussed earlier in the report, a fog alert system was first implemented in the State in the City of Mobile after a tragic multiple car-crash in 1995. As a result of a CARE analysis, it was determined that Baldwin and Lee Counties should be placed on "alert" status and be considered potential candidates for the use of video technology to address fog-related crashes. Baldwin County's fog-related crashes may be due to the county having more shoreline than any other county in the State. Also, Baldwin County has a large number of miles of highways. One supposition is that Lee County's high number of fog-related crashes might be due to a large concentration of younger drivers on predominantly rural roadways, as compared to other Alabama counties. Installing a simple form of a video-based fog alert system in both Lee and Baldwin Counties may not only aid in reducing the number of fog-related crashes, but also aid in providing local and county officials with a direct knowledge of the current driving conditions.

Section 11
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Section 12
Appendix

Table 9-1. General Alabama Crash Data

Description	1996	1997	1998
Total Crashes	136,456	139,344	137,509
Persons Injured	48,200	49,202	47,310
Persons Killed	1142	1190	1071
VMT (billions)	51.29	53.4	55.2
Crashes/100000 VMT	0.266	0.261	0.249
Injuries/100000 VMT	0.094	0.092	0.086
Deaths/100000 VMT	0.002	0.002	0.002

Table 9-2. Alabama 1996-1998 County-by-County Crash Data

	Number of Crashes			Persons Killed			Persons Injured			Vehicle Miles Traveled (VMT)			Crashes Per Million VMT		
County	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
Jefferson	26,102	24,963	25,278	95	116	121	7342	6908	6824	7.43E+09	7.72E+09	8.03E+09	3.51E+00	3.23E+00	3.15E+00
Mobile	14,213	14,812	14,484	98	79	67	4380	4452	4520	3.55E+09	3.69E+09	3.84E+09	4.00E+00	4.01E+00	3.77E+00
Montgomery	11,157	10,869	10,545	40	35	45	3375	3413	3232	2.25E+09	2.34E+09	2.43E+09	4.96E+00	4.64E+00	4.33E+00
Autauga	1200	1280	1190	11	17	13	431	525	395	4.35E+08	4.52E+08	4.70E+08	2.76E+00	2.83E+00	2.53E+00
Baldwin	3144	3550	3560	36	32	45	1192	1283	1194	1.45E+09	1.51E+09	1.57E+09	2.17E+00	2.35E+00	2.27E+00
Barbour	706	688	643	5	9	8	281	257	249	4.19E+08	4.36E+08	4.53E+08	1.69E+00	1.58E+00	1.42E+00
Bibb	315	306	231	11	13	6	135	184	119	2.05E+08	2.13E+08	2.21E+08	1.54E+00	1.44E+00	1.04E+00
Blount	1027	1122	1042	11	15	10	425	479	477	5.05E+08	5.25E+08	5.46E+08	2.03E+00	2.14E+00	1.91E+00
Bullock	179	165	157	5	3	3	88	89	91	1.40E+08	1.46E+08	1.51E+08	1.28E+00	1.13E+00	1.04E+00
Butler	708	784	647	22	13	13	328	326	308	4.15E+08	4.31E+08	4.48E+08	1.71E+00	1.82E+00	1.44E+00
Calhoun	3969	3655	3492	29	25	28	1399	1317	1202	1.50E+09	1.56E+09	1.62E+09	2.65E+00	2.34E+00	2.15E+00
Chambers	1035	1066	1075	10	18	10	388	377	412	3.44E+08	3.58E+08	3.73E+08	3.00E+00	2.98E+00	2.89E+00
Cherokee	422	478	446	5	5	9	211	245	263	2.54E+08	2.65E+08	2.75E+08	1.66E+00	1.81E+00	1.62E+00
Chilton	1019	1020	1021	19	18	16	379	412	404	5.62E+08	5.85E+08	6.08E+08	1.81E+00	1.74E+00	1.68E+00
Choctaw	222	223	223	8	7	6	150	142	104	1.82E+08	1.89E+08	1.97E+08	1.22E+00	1.18E+00	1.13E+00
Clarke	513	594	579	11	12	5	278	272	304	2.78E+08	2.89E+08	3.00E+08	1.85E+00	2.06E+00	1.93E+00
Clay	189	188	182	5	4	4	118	152	99	1.60E+08	1.66E+08	1.73E+08	1.18E+00	1.13E+00	1.05E+00
Cleburne	419	465	450	8	20	12	180	181	162	2.77E+08	2.89E+08	3.00E+08	1.51E+00	1.61E+00	1.50E+00
Coffee	1081	1096	990	16	14	12	506	464	356	4.01E+08	4.17E+08	4.34E+08	2.69E+00	2.63E+00	2.28E+00
Colbert	1760	1644	1599	6	21	10	671	604	558	6.01E+08	6.25E+08	6.50E+08	2.93E+00	2.63E+00	2.46E+00
Conecuh	387	385	394	24	5	11	176	208	202	3.17E+08	3.30E+08	3.43E+08	1.22E+00	1.17E+00	1.15E+00
Coosa	250	256	280	7	6	6	167	167	142	1.82E+08	1.90E+08	1.97E+08	1.37E+00	1.35E+00	1.42E+00
Covington	766	887	728	4	14	11	351	371	308	4.32E+08	4.49E+08	4.67E+08	1.77E+00	1.98E+00	1.56E+00
Crenshaw	302	276	249	8	6	3	102	130	116	1.88E+08	1.96E+08	2.03E+08	1.61E+00	1.41E+00	1.22E+00
Cullman	2085	2160	2343	15	28	20	739	837	744	7.67E+08	7.98E+08	8.30E+08	2.72E+00	2.71E+00	2.82E+00
Dale	992	998	946	10	11	3	385	389	328	5.82E+08	6.06E+08	6.30E+08	1.70E+00	1.65E+00	1.50E+00
Dallas	1510	1587	1491	12	12	15	550	535	621	3.67E+08	3.81E+08	3.97E+08	4.12E+00	4.16E+00	3.76E+00
DeKalb	1625	1655	1679	21	14	17	749	633	663	6.79E+08	7.06E+08	7.34E+08	2.39E+00	2.34E+00	2.29E+00
Elmore	1424	1495	1487	24	20	14	588	630	616	5.17E+08	5.38E+08	5.60E+08	2.75E+00	2.78E+00	2.66E+00
Escambia	921	807	881	18	11	11	449	358	427	4.62E+08	4.81E+08	5.00E+08	1.99E+00	1.68E+00	1.76E+00
Etowah	3302	3356	3277	26	30	22	1323	1303	1272	1.13E+09	1.17E+09	1.22E+09	2.93E+00	2.86E+00	2.68E+00
Fayette	386	389	407	9	5	11	184	234	206	2.21E+08	2.30E+08	2.39E+08	1.75E+00	1.69E+00	1.70E+00
Franklin	687	675	721	5	3	9	300	322	299	4.29E+08	4.46E+08	4.64E+08	1.60E+00	1.51E+00	1.56E+00
Geneva	447	464	444	11	2	8	238	248	240	2.79E+08	2.90E+08	3.02E+08	1.60E+00	1.60E+00	1.47E+00
Greene	312	283	306	6	7	8	156	146	146	2.30E+08	2.40E+08	2.49E+08	1.35E+00	1.18E+00	1.23E+00
Hale	261	309	282	6	5	4	136	168	112	1.68E+08	1.75E+08	1.82E+08	1.55E+00	1.77E+00	1.55E+00
Henry	327	281	330	3	6	4	141	119	134	2.50E+08	2.60E+08	2.70E+08	1.31E+00	1.08E+00	1.22E+00
Houston	3471	3594	3532	20	22	20	1493	1639	1595	1.01E+09	1.05E+09	1.09E+09	3.43E+00	3.41E+00	3.23E+00
Jackson	1112	1049	1038	23	26	18	499	470	406	7.18E+08	7.46E+08	7.76E+08	1.55E+00	1.41E+00	1.34E+00

Table 9-2. Alabama 1996-1998 County-by-County Crash Data

	Number of Crashes			Persons Killed			Persons Injured			Vehicle Miles Traveled (VMT)			Crashes Per Million VMT		
County	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
Lamar	118	124	144	3	5	1	83	75	87	2.04E+08	2.12E+08	2.20E+08	5.79E-01	5.85E-01	6.53E-01
Lauderdale	2580	2510	2532	31	19	17	832	827	791	8.77E+08	9.12E+08	9.49E+08	2.94E+00	2.75E+00	2.67E+00
Lawrence	629	641	724	9	8	14	306	285	345	3.39E+08	3.52E+08	3.66E+08	1.86E+00	1.82E+00	1.98E+00
Lee	3606	3983	3687	24	26	18	1245	1255	1196	9.42E+08	9.80E+08	1.02E+09	3.83E+00	4.06E+00	3.62E+00
Limestone	1629	1750	1813	18	31	22	685	692	674	7.35E+08	7.64E+08	7.95E+08	2.22E+00	2.29E+00	2.28E+00
Lowndes	298	324	288	8	10	7	150	172	117	2.56E+08	2.66E+08	2.77E+08	1.16E+00	1.22E+00	1.04E+00
Macon	713	808	701	9	9	10	321	359	306	4.03E+08	4.19E+08	4.36E+08	1.77E+00	1.93E+00	1.61E+00
Madison	8167	8411	8810	29	44	45	2665	2703	2849	2.21E+09	2.30E+09	2.39E+09	3.70E+00	3.66E+00	3.69E+00
Marengo	492	463	366	13	9	8	222	219	199	2.55E+08	2.65E+08	2.76E+08	1.93E+00	1.75E+00	1.33E+00
Marion	800	788	705	16	11	10	335	402	300	5.15E+08	5.36E+08	5.57E+08	1.55E+00	1.47E+00	1.26E+00
Marshall	2492	2643	2581	24	27	27	883	981	937	6.87E+08	7.15E+08	7.44E+08	3.62E+00	3.70E+00	3.47E+00
Monroe	448	462	493	7	1	6	180	226	260	2.44E+08	2.54E+08	2.64E+08	1.84E+00	1.82E+00	1.87E+00
Morgan	3556	3652	3573	21	33	22	1216	1296	1158	1.17E+09	1.21E+09	1.26E+09	3.05E+00	3.01E+00	2.83E+00
Perry	221	200	201	5	8	2	122	104	110	1.31E+08	1.37E+08	1.42E+08	1.68E+00	1.46E+00	1.42E+00
Pickens	272	326	277	8	10	6	135	175	142	2.32E+08	2.41E+08	2.51E+08	1.17E+00	1.35E+00	1.11E+00
Pike	808	773	824	16	15	11	338	271	222	3.49E+08	3.63E+08	3.78E+08	2.31E+00	2.13E+00	2.18E+00
Randolph	358	374	365	8	6	9	130	179	150	1.94E+08	2.02E+08	2.10E+08	1.84E+00	1.85E+00	1.74E+00
Russell	1859	2019	2105	23	13	20	843	984	936	6.12E+08	6.36E+08	6.61E+08	3.04E+00	3.17E+00	3.18E+00
St. Clair	1351	1587	1520	9	22	15	533	627	599	7.84E+08	8.15E+08	8.48E+08	1.72E+00	1.95E+00	1.79E+00
Shelby	3439	3663	3715	20	34	18	1079	1057	1025	1.20E+09	1.25E+09	1.30E+09	2.87E+00	2.94E+00	2.86E+00
Sumter	402	363	338	7	8	7	181	182	162	2.66E+08	2.76E+08	2.87E+08	1.51E+00	1.31E+00	1.18E+00
Talladega	1911	2088	1978	29	28	27	769	830	833	6.61E+08	6.88E+08	7.15E+08	2.89E+00	3.04E+00	2.77E+00
Tallapoosa	875	1138	993	11	17	11	377	512	441	4.79E+08	4.98E+08	5.18E+08	1.83E+00	2.29E+00	1.92E+00
Tuscaloosa	6496	7246	7097	37	37	41	2204	2496	2366	2.03E+09	2.11E+09	2.19E+09	3.21E+00	3.44E+00	3.24E+00
Walker	2093	2202	2119	33	26	18	802	897	775	6.99E+08	7.27E+08	7.56E+08	2.99E+00	3.03E+00	2.80E+00
Washington	209	238	248	6	7	5	145	143	134	2.12E+08	2.20E+08	2.29E+08	9.87E-01	1.08E+00	1.08E+00
Wilcox	247	237	252	4	7	4	181	142	174	1.88E+08	1.96E+08	2.04E+08	1.31E+00	1.21E+00	1.24E+00
Winston	450	458	411	11	10	13	216	191	172	2.67E+08	2.77E+08	2.88E+08	1.69E+00	1.65E+00	1.43E+00

Table 9-3. Alabama Speed-Related Crash Data

Description	1996	1997	1998
Speed-Related Accidents	7173	7968	7908
Resulting Injuries	5522	6052	6079
Resulting Fatalities	338	335	335
Accidents/1000000 VMT	0.140	0.149	0.143
Injuries/1000000 VMT	0.108	0.113	0.110
Deaths/1000000 VMT	0.007	0.006	0.006

Table 9-4. Alabama Crash Data 1996-1998

Description	1996	1997	1998
Total Accidents	136,456	139,344	137,509
Persons Injured	48,200	49,202	47,310
Persons Killed	1142	1190	1071
VMT (billions)	51.29	53.4	55.2
Crashes/1million VMT	2.660	2.609	2.491
Injuries/1million VMT	0.940	0.921	0.857

Table 9-5. Alabama Red-Light Running Data

Description	1996	1997	1998
Red Light Running Accidents	4386	5706	4451
Resulting Injuries	1357	5857	1390
Resulting Fatalities	10	51	15
Accidents/1000000 VMT	0.086	0.107	0.081
Injuries/1000000 VMT	0.026	0.110	0.025
Deaths/1000000 VMT	0.000	0.001	0.000

Table 9-6. Crashes due to Speeding in Alabama

County	Number of crashes
JEFFERSON	4174
MOBILE	1923
CALHOUN	1248
MADISON	1463
TUSCALOOSA	1520

Table 9-7. Crashes due to Red-Light Running in Alabama

County	Number of crashes
JEFFERSON	18,688
MOBILE	14,700
MONTGOMERY	10,546
MADISON	7717
TUSCALOOSA	5310

Table 9.8. Crashes due to Trains in Alabama

County	Number of crashes
JEFFERSON	117
MOBILE	69
DALLAS	26
ESCAMBIA	36
TALLADEGA	27
TUSCALOOSA	46

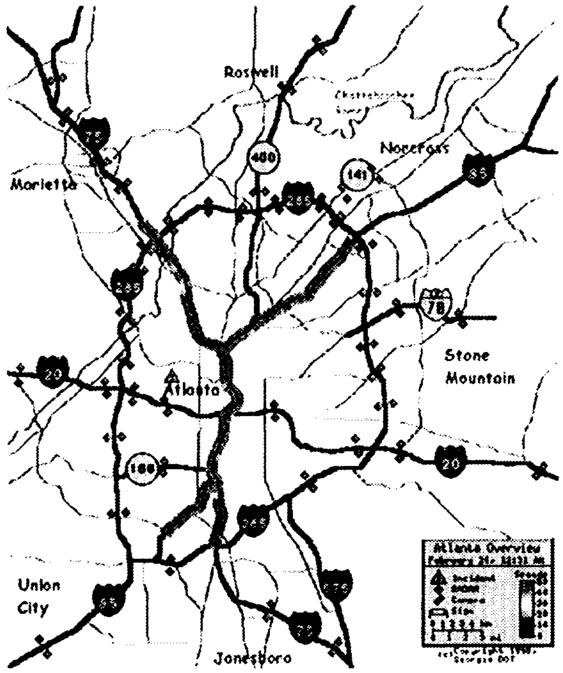

Figure 3-1. Atlanta Real-Time Traffic Data.

Figure 3-2. Photo-Radar in United Kingdom.

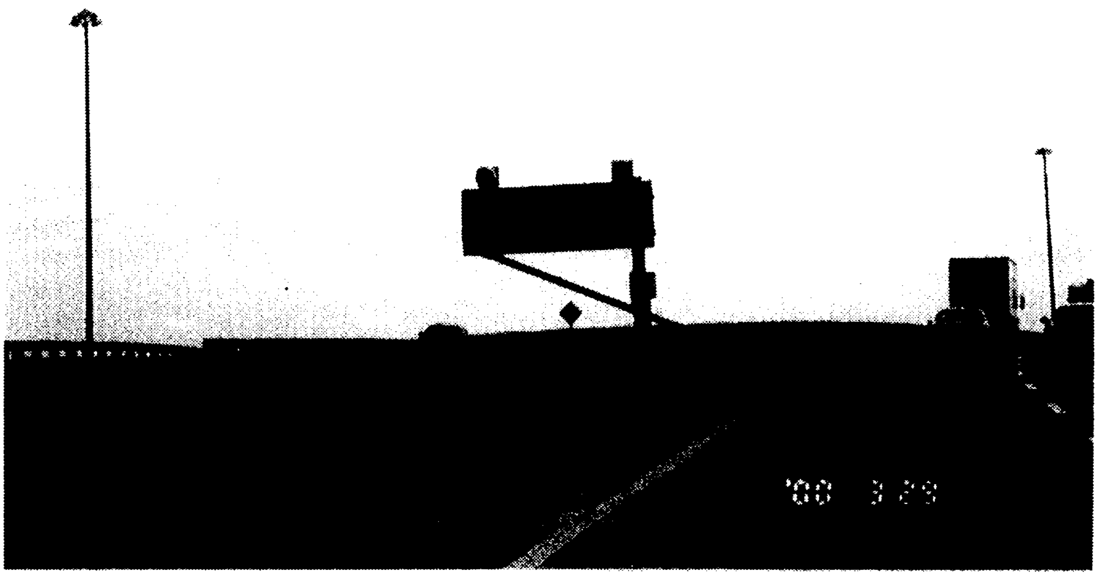

Figure 4-1. Mobile Fog Detection System Signage.

Figure 4-2. CCTV Camera Located in Tuscaloosa.

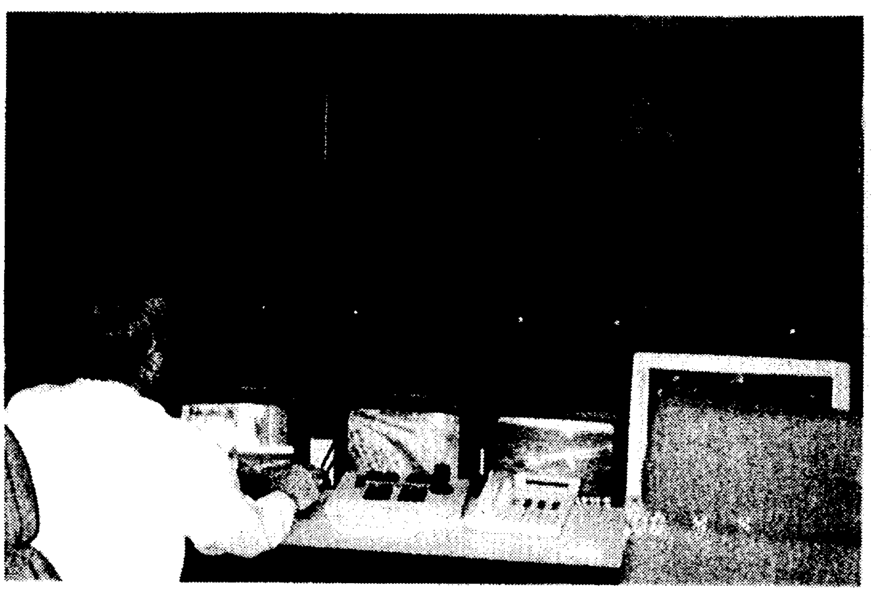

Figure 4-3. Birmingham's Traffic Management Center.

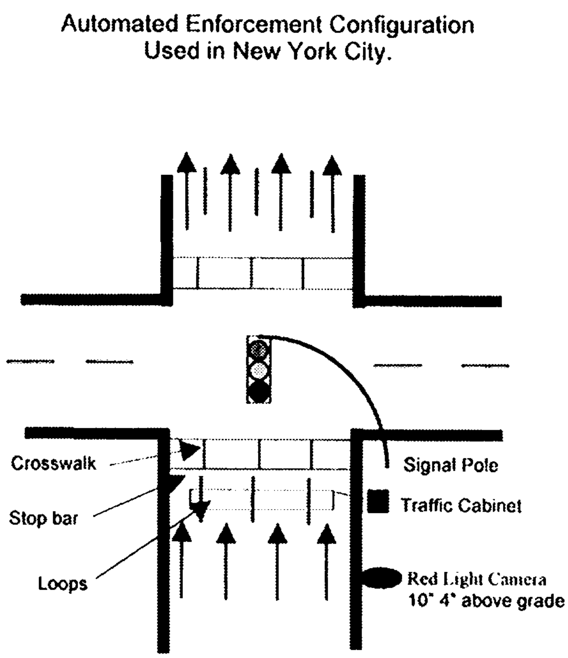

Figure 5-1. Typical Configuration of Red-Light Running Camera.

Figure 5-2. Red-Light Running Photograph (Victoria, Australia).

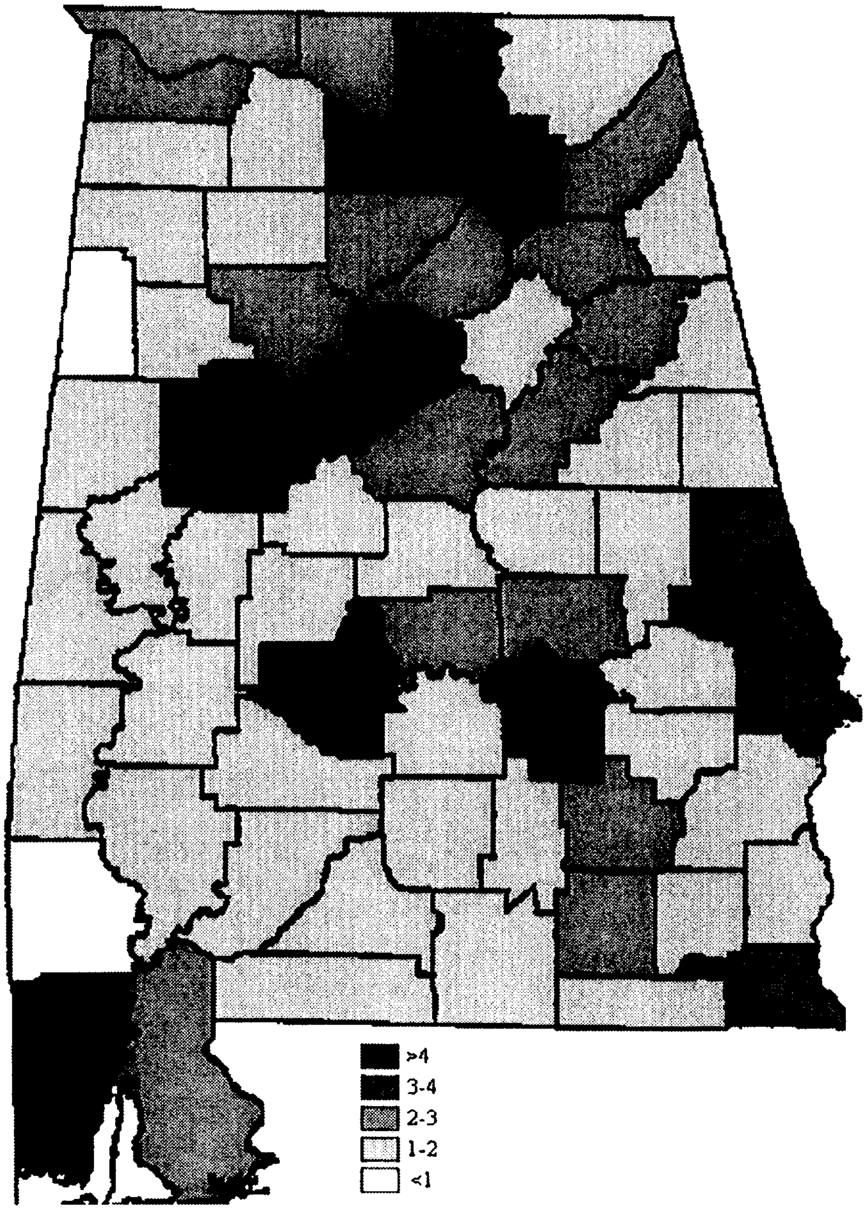

Figure 9-1. 1996 Alabama Crashes per 1,000,000 VMT.

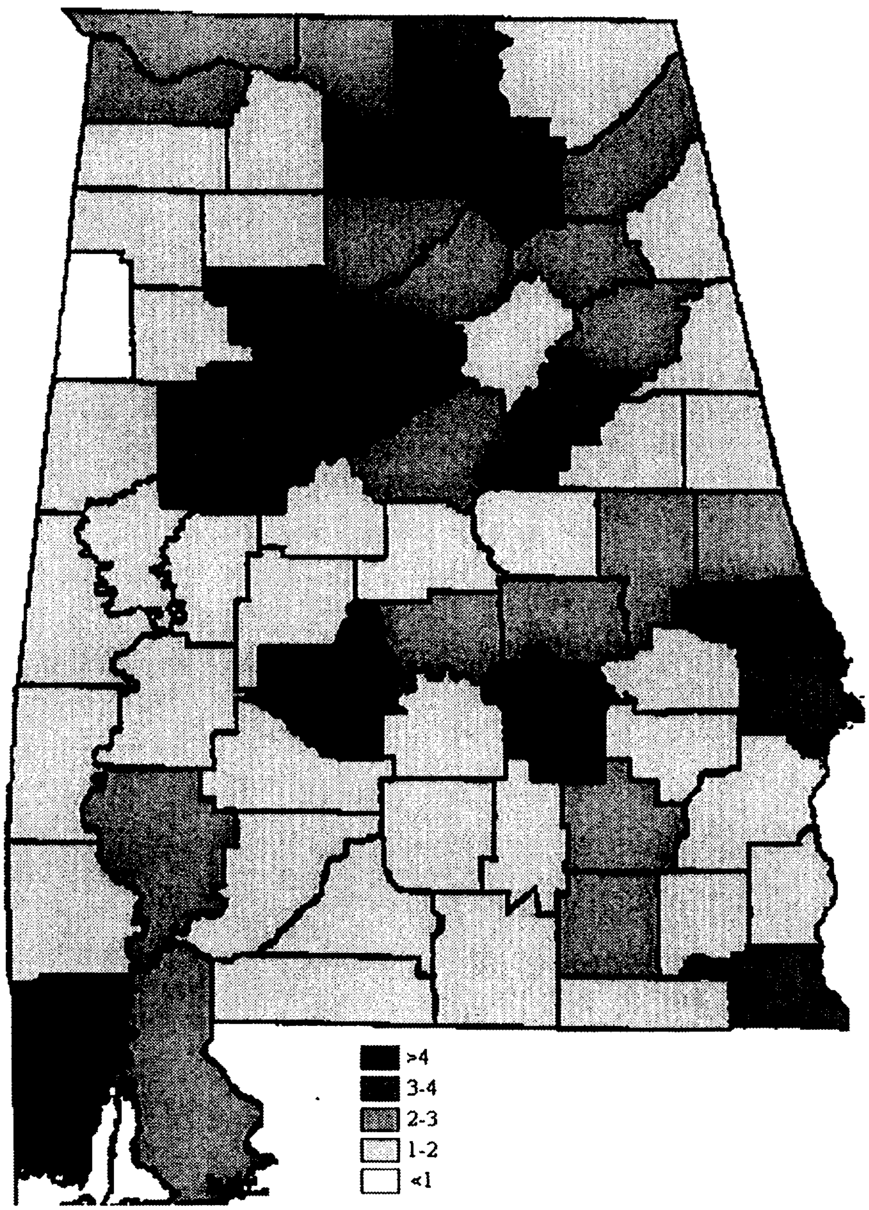

Figure 9-2. 1997 Alabama Crashes per 1,000,000 VMT.

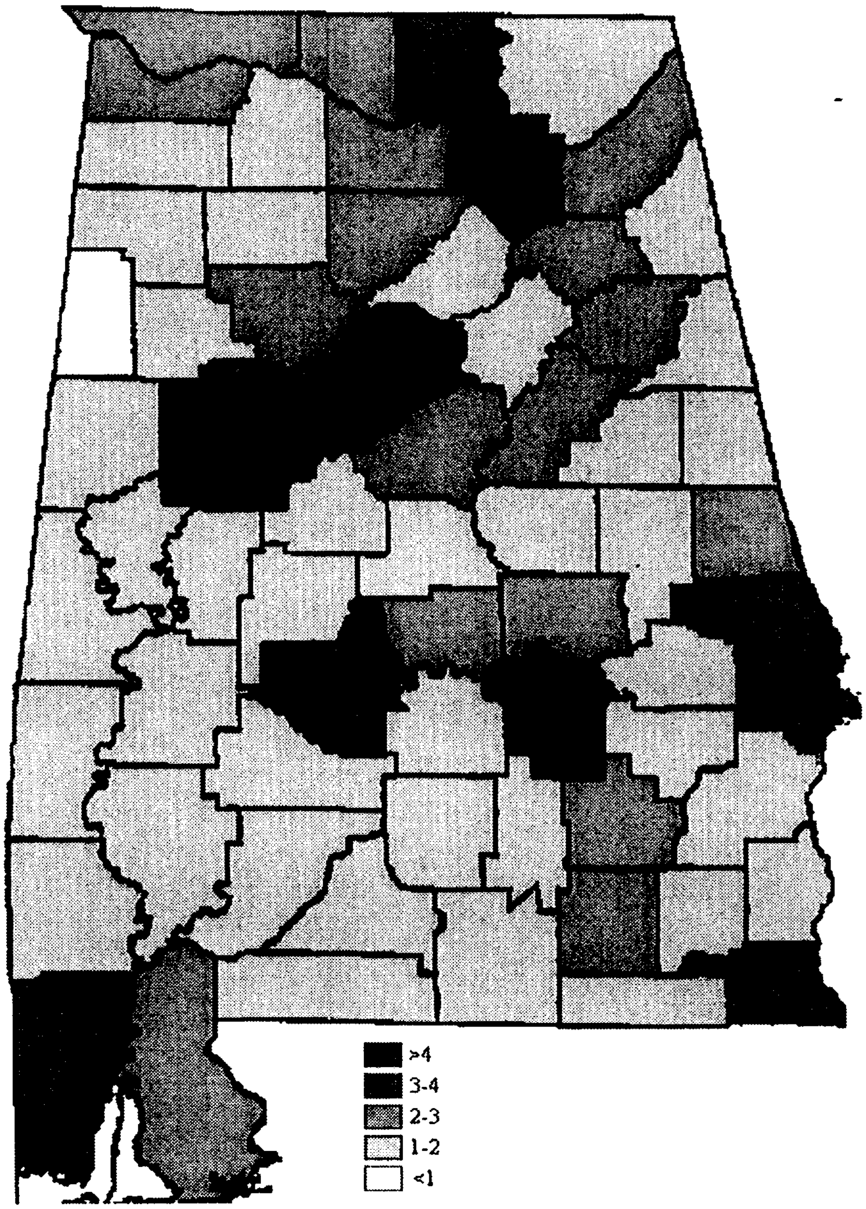

Figure 9-3. 1998 Alabama Crashes per 1,000,000 VMT.

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