Chapter 1.0 Introduction

1.1 Background

Interstate 81 runs from Danbridge, Tennessee to the US/Canada border, connecting the six states of Tennessee, Virginia, West Virginia, Maryland, Pennsylvania, and New York. Spanning a total of approximately 850 miles between Knoxville, Tennessee and Watertown, New York, it serves as a connection between the southern economic hubs and the northeastern United States (CTR, 1996). Figure 1 shows the I-81 corridor running from Tennessee to New York.

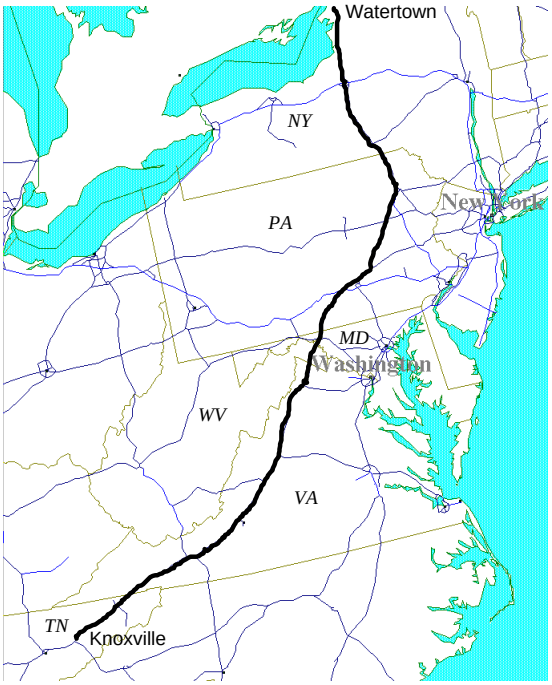

Figure 1. I-81 from Tennessee to New York (Source: CTR, 1996)

In Virginia, the I-81 corridor is primarily a four-lane, divided, restricted access highway characterized mainly by rolling terrain. It traverses the western part of the state, connecting Bristol in the south and Winchester in the North (Figure 2). The longest Interstate in Virginia, I-81 spans approximately 325 miles in Virginia and is located between the scenic Blue Ridge and Allegheny mountains. It runs through predominantly rural areas having a historic background and several scenic attractions. Interstate 81 in Virginia cuts through

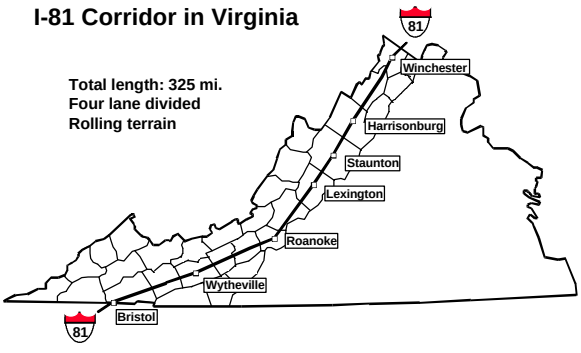

Figure 2. The I-81 Corridor in Virginia (Source: CTR, 1996)

seven planning districts (one through seven), constituting 21 cities and towns and 32 counties with a total population of 1.2 million (19% of Virginia's population in 1991; CTR, 1996). Voted as one of the most scenic Interstates in the US and the only one in the southeast by the American Automobile Association (AAA), the Corridor provides opportunities for a variety of recreational and sightseeing activities. In 1992, the total number of visitors to parks administered by the National Park Services within the Corridor accounted for 59% of the total visitors to Virginia (CTR, 1996).

The I-81 Corridor is connected to three other major Interstates (Figure 3), namely, I-64, I-66, and I-77, that connect to other areas within Virginia. It also connects to other major highways such as US 58, US 220, US 460, US 33, US 211, and US 17. US 11 runs along with I-81, intertwining around it and intersecting it at several locations along the entire length of the Corridor.

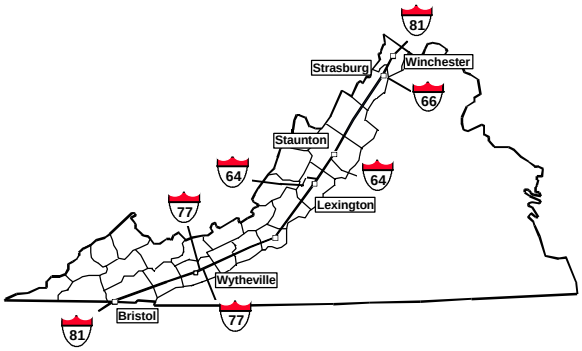

Figure 3. Major Interstate Connections (Source: CTR, 1996)

Constructed approximately three decades ago, I-81 now experiences Annual Average Daily Traffic (AADT) volumes ranging anywhere between 20,000 to 50,000 vehicles per day. Over the last twenty-five years, the AADT has nearly tripled, especially in urban areas (VDOT, 1996a). The Corridor registered a 5% increase in Vehicle Miles Traveled (VMT) from 1993 to 1994 (VDOT, 1994). The type of traffic using the facility includes daily commuters between urban areas along the Corridor, tourists, long distance travelers, and commercial traffic. A high percentage of this traffic constitutes trucks. I-81 typically carries truck traffic anywhere between 19 to 40 percent of the total traffic, depending on the time of the day and the section under consideration. Table 1 gives a summary of the characteristic features of I-81 in Virginia.

Table 1. Characteristic Features of I-81 in Virginia

Item	I-81 Characteristic Feature
Length, Highway Type, and Terrain	• Approximately 850 miles between Knoxville, TN and Watertown, NY • In VA, it spans approximately 325 miles • Four-lane, divided, restricted access highway characterized mainly by rolling terrain
Population Served	• I-81 cuts through seven planning districts (1-7), comprising 21 cities and towns and 32 counties, with a population of 1.2 million (19% of Virginia's total population in 1991)
Major connecting Interstates and Highways	• I-77, I-66, and I-64 • US 58, US 220, US 460, US 33, US 211, US 17, and US 11
Annual Average Daily Traffic Volumes	• Anywhere between 20,000 to 50,000 vehicles per day (1996)
Vehicle Miles Traveled	• 9.49 million in 1993, increased by 5% to 9.94 million in 1994
Type of Traffic	• Daily commuters, tourists, long distance travelers, and commercial traffic
Truck Percentage	• Ranges between 19 to 40 percent (1996)

The aging of Interstate 81 and increasing traffic volumes have necessitated reconstruction and maintenance activities along the entire length of the Corridor. The high percentage of truck traffic and rolling terrain characteristics of I-81 make it essential to construct dedicated climbing lanes for truck traffic at certain steep sections of the Corridor. The Virginia Department of Transportation (VDOT) estimates that the widening of I-81 will be a long and expensive project taking more than 20 years to complete and costing at least two billion dollars (VDOT, 1996a). In light of the level of construction and maintenance activities planned for the Corridor, its rolling terrain characteristics leading to limited sight distance on horizontal and vertical curves, and the nature and volume of traffic, due emphasis needs to be given to traffic safety issues on the Corridor.

The large number of construction and maintenance activities planned for I-81 in Virginia shows that work zones will be a common feature along the Corridor for the next twenty years or more. Past accident records show that I-81 in Virginia has been experiencing a rising trend in the number of total and fatal work zone-related accidents for the years 1991 to 1994. A high percentage of these accidents involved trucks. Rear-end collisions and fixed-object off road were the two major collision types recorded. Major accident causes included driver inattention, exceeding safe speed, and following too close. These facts emphasize the growing problem of work zone safety and traffic control in the Corridor. Several technological innovations have been developed to enhance work zone safety and facilitate traffic control. The static nature of these devices limits their capabilities in resolving work zone-related issues. The development of Intelligent Transportation Systems (ITS) has paved the path for the development of real-time advanced warning and traffic control systems for work zones. These real-time systems enhance work zone safety and control by providing dynamic/real-time reports and warnings on the status of traffic within the work zone to the motorists. This report describes the development of functional and system requirements for real-time advanced warning and traffic control systems and identifies evaluation criteria, measures of effectiveness (MOEs), and issues related to the evaluation of these systems.

1.2 Problem Statement

The I-81 corridor is one of the most traversed interstates in Virginia. Linking several economic hubs, the corridor carries an Average Annual Daily Traffic volume (AADT) as high as 50,000, a significant portion of which comprises truck traffic. Constructed thirty years ago and designed to carry 15% truck traffic, I-81 now carries traffic far beyond its planned capacity, with up to 40% truck traffic on some sections (VDOT, 1996a). Several widening and improvement projects have been proposed and planned to accommodate the growing and changing nature of traffic on the I-81 Corridor. The entire widening may take more than 20 years to complete and could cost approximately two billion dollars. The VDOT six-year improvement plan (1997-2002) shows 57 widening and improvement

projects planned for I-81 with an estimated cost of 568 million dollars. This shows the level of work zone activities planned and consequently the importance of having safe and efficient construction and maintenance zones.

Construction and maintenance zones pose a serious hazard to motorists who are accustomed to a clear and unobstructed highway. Statistics from the Fatal Accident Reporting System (FARS) show that national work zone fatalities are increasing with a maximum of 833 fatalities in 1994, a 29% increase over the number in 1992 (NHTSA, 1994). In several states, work zone accidents comprise about two to three percent of total accidents. For the state of Virginia, a total of 1,981 work zone accidents were recorded during the period 1991-1994 (provided by VDOT). These work zone accidents showed an increasing trend from 362 accidents in 1991 to 461 accidents for the year 1994. Another interesting fact is that the rate of fatal accidents has also increased every year. The I-81 Corridor in Virginia has been experiencing similar trends in work zone accidents. For the period 1991-1994, a total of 68 work zone accidents (1% of total work zone accidents in Virginia) were observed on the corridor; 7% of these accidents were fatal and 35% of them involved a truck (based on data provided by VDOT). Detailed analysis of work zone accidents showed that the most typical collision type was “rear-end collision” followed by “fixed object, off road.” The top two causes attributed to work zone accidents were “driver inattention” and “exceeding safe speed limit.” Studies also indicate that the taper zone, advance zone, and buffer area are the most accident prone locations within work zones. A review of these past work zone accident experiences outlines a cause of concern in terms of traffic and worker safety.

As per federal requirements, all highway agencies are to follow a set of guidelines for work zone safety and traffic control. The agencies may use the Manual on Uniform Traffic Control Devices (MUTCD) to meet the required standards, or they can adopt their own guidelines which should be consistent with those provided by the MUTCD. VDOT has developed a “Virginia Work Area Protection Manual” to meet the standards and requirements set forth by the MUTCD. The manual provides fundamental principles and

guidelines for the use of traffic control devices to enhance work zone safety and traffic control. Besides the traffic control devices and strategies provided by the MUTCD, several innovative technologies and systems have been developed to enhance work zone safety and facilitate traffic control. These include innovations such as the work zone intrusion alarm, portable rumble strips, lightweight changeable message signs, unmanned radars, solar-assisted arrowboards, flashing stop/slow paddles, and barrier lighting units. The above mentioned innovations provide means to enhance safety and traffic control at work zones. These innovations are static means of providing assistance to motorists regarding safety and traffic control and do not provide real-time information on the status of traffic, nor do they give advisory alternate route information as per need. Some of these devices, such as the portable rumble strips, have even been found to be ineffective in enhancing work zone safety. The static nature and inconsistency of the information disseminated make motorists lose trust in the information provided, thereby reducing the credibility of the messages.

Based on all the information presented above, the major problems experienced at work zones may be summarized as follows:

- Increasing fatality rate for work zone accidents
- High percentage of work zone-related accidents
- High percentage of rear-end collisions and fixed-object off road collisions
- Driver inattention and speeding within work zones
- Improper driving behavior leading to accidents at specific locations within the work zone
- Lack of dynamic advanced warning and credible, real-time information dissemination

With a huge number of construction and maintenance activities planned for the next twenty years, growing traffic volumes, changing nature of traffic, and past accident experience on the I-81 corridor, there are concerns regarding work zone safety and traffic control. Implementation of a real-time advanced warning and traffic control system may be

a viable solution to efficiently manage traffic and enhance safety at work zones. Before the implementation of such a real-time system, there is a need to develop the functional and system requirements for the real-time advanced warning and traffic control system, keeping in mind the special characteristics and its applicability to the I-81 Corridor. Evaluation criteria and Measures of Effectiveness (MOEs) for the real-time system needs to be identified. These may be used for the evaluation of the system to ensure its effectiveness in fulfilling its primary objectives. Given below is a brief description of the objectives and tasks involved in this research.

1.2.1 Research Objectives and Tasks

In view of the traffic volumes, special characteristics, and future reconstruction activities planned for I-81, there is an identified need to deploy real-time advanced warning and traffic control systems to help reduce the impacts of these activities on traffic flow and safety. Before deploying such a real-time system, there is a need to define the system and functional requirements. A set of evaluation criteria, as well as measures of effectiveness, need to be identified to ensure the effectiveness of the system in reducing work zone problems. The following sections describe the major objectives and specific tasks associated with this research.

The major objectives of this research are:

- *Development of Functional and System Requirements for the Real-Time Advanced Warning and Traffic Control System*

  The specific nature of implementation of the real-time systems for work zones requires that specific functional and system requirements be developed. The functional requirements for the system define the specific functions the system should incorporate in order to tackle and resolve the traffic safety and control problems experienced at work zones. Each function may include several sub-functions. In addition to the functional requirements, the system must possess basic features that are deemed

necessary for its application to work zones. These may be included under system requirements. There is a very fine line distinguishing the functional requirements from the system requirements. The system requirements basically define hardware requirements that are necessary for the system deployment. Since the real-time advanced warning and traffic control system is primarily being developed for work zones on the I-81 corridor, due consideration needs to be taken to cater to the special geographic and traffic characteristics of the corridor.

- *Identification of Evaluation Criteria and Measures of Effectiveness and Examination of Related Issues*

  Another objective of this research is the identification of evaluation criteria and measures of effectiveness (MOEs) for the real-time advanced warning and traffic control system. After the system is developed, there is a need to evaluate the system to ensure its effectiveness in fulfilling its primary objectives, namely, traffic control and safety at work zones. The system will be evaluated for its effectiveness using a set of evaluation criteria. The evaluation criteria would test the system for characteristics such as functionality, ease in operation, and accuracy. Measures of effectiveness for the identified evaluation criteria will also be developed. Additionally, the various issues involved in the evaluation of the system using the evaluation criteria and the MOEs will be identified and examined in detail.

The various tasks involved in completing this project are:

- *Literature Review*

  The first task for this project is a detailed literature review. A review of work zone-related accidents and technologies developed to enhance work zone safety and traffic control will be performed.

- *Development of Functional Requirements*

  Functional requirements for the real-time advanced warning and traffic control system will be developed. This is to ensure the functionality and reliability of the system for usage specific to work zones on the I-81 corridor.
- *Development of System Requirements*

  Overall system requirements will be developed. These requirements ensure that the system as a whole possesses specific characteristics such as portability, adaptability, and cost effectiveness, which are essential for work zone applications.
- *Identification of Evaluation Criteria*

  Evaluation criteria to ensure the effectiveness of the system in fulfilling its objectives and goals will be identified.
- *Identification of Measures of Effectiveness*

  Measures of effectiveness (MOEs) for the evaluation criteria will be identified. These MOEs may be used during the final evaluation of the system.
- *Examination of Issues Related to Evaluation*

  Several issues related to the evaluation of the system will be identified and examined.

1.3 Organization of this Report

This report is organized into eight chapters. The first chapter provides a background of the I-81 Corridor in Virginia, its characteristics, and work zone-related issues and concerns, identifying the motivation behind this research. Chapter 2 provides a detailed summary of the literature reviewed for this project. The main issues summarized include national work zone safety and control issues, and work zone-related issues specific to I-81 in Virginia. Literature on technological innovations to enhance work zone safety was also reviewed and summarized. Chapter 3 provides a case for the need for real-time advanced warning and traffic control systems to enhance work zone safety and facilitate traffic control. Currently available real-time work zone systems are also reviewed as part of this chapter. The fourth chapter gives a detailed description of the functional and system

requirements essential for the development of a real-time advanced warning and traffic control system. Considerations for a system architecture are also discussed as part of the fourth chapter. Chapter 5 identifies the evaluation criteria and potential measures of effectiveness (MOEs) for the system. It also examines and discusses the various issues involved in system evaluation. Chapter 6 provides a conclusion for this project and recommendations for future research. Chapter 7 provides a list of references used in this project.