CHAPTER 10. CONCLUSIONS AND FURTHER RESEARCH

10.1 Research Summary and Conclusions

This research effort aims at resolving one of the safety problems on two-lane rural roads, namely those roads witnessing head-on collisions resulting from aggressive drivers who violate the no-passing zone and attempt to overtake the vehicles ahead without having enough passing distance. Route 114 in southwest Virginia was taken as a case study where a segment of that road under study is subject to significant head-on accidents. All of these accidents resulted in fatalities and injuries.

A solution was proposed to deal with this problem. It consists of deploying a new Intelligent Transportation System ITS application whose two main functions are:

1- Detect those vehicles violating the solid yellow centerline using video image processing technology (Wrong Way module), and
2- Display a warning message through a warning sign to discourage violators from continuing their risky maneuvers and return to the right lane.

The conceiving power of the warning system is reinforced by a lower camera system that captures the license plate of the violating vehicles.

The research went into several steps of progression in order to develop the conceptual framework of the proposed system into a well defined one with all its subsystems components and functions designed, after which was explored the system capabilities and performance in achieving its main objective, which is reducing the number of head on crashes on Route 114.

The research started with a detailed and comprehensive literature review about Accidents, The Intelligent Transportation System safety applications and Collision avoidance systems Warning systems concepts, applications, and technologies.

The next step was to conduct intensive data collection efforts (Chapter 4) covering the roadway geometry, traffic flow, vehicle classification, and speed distribution by vehicle type, in addition to a violation field survey. Finally, accident history and attributes on Route 114 were investigated with official records provided by VDOT.
Data collected was analyzed and useful information and parameters were derived and then introduced in the further analysis in the following stages of the research.

The road link profile was carefully studied in Chapter 5 in order to identify the geometric characteristics of the project site. This step revealed some aspects related to site deficiencies that contributed to accident occurrences such as insufficient stopping and passing sight distances. It also helped in determining the project coverage area boundary that the system will cover.

System architecture was the focus of Chapter 6, where we identified the system requirements, described functional subsystems and developed a conceptual design of these subsystems, including the detection subsystem, the control processor, the warning subsystem, and the communication system. The data flows among the various subsystem components were also explored and depicted on a representative flowchart.

A detailed system design was developed in Chapter 7 for each functional entity. Equipment was selected based on detailed specifications for the video camera detection system with the central processor. Plans were made to locate the eight camera poles to ensure continuity of detection throughout the study area. The warning panel were specified in dimensions, color, face display and location. The topology of the communication network was specified, and finally the type and characteristics of the enforcement lower cameras needed to capture the image of the violator license plate were determined. All these components were integrated through a certain logic or algorithm developed to identify violating vehicles and activate both warning and enforcement systems.
Offline field tests of the system were conducted on the Smart Road facility. The results of the system functions tested were satisfactory and proved capable to serve the objectives

of the project. However, the tests revealed also some discrepancies but, fortunately, do not hinder the quality performance of the system.

In order to test the system functions and assess the new application performance, a system simulation was conducted in Chapter 8, where a special software program was written using the MATLAB language and a large number of parameters were introduced to reflect reality. The simulation was applied for both “with” and “without” the system cases. The simulation results were very close to the actual situation.

The simulation was used as a tool to conduct a system evaluation in chapter 9. More than twenty runs were made for the basic or original scenario reflecting the actual conditions. All runs showed that the system could virtually eliminate head on collisions totally, should violators obey the early warning messages displayed. Several sensitivity tests were made for different scenarios. In every test only one parameter was modified while the others remained constant. The output examined in all these tests showed a high degree of robustness of the system performance, and no single unavoidable crash resulted in all “with the systems” runs.

Finally, the viability of the system was evaluated from economic point of view. Costs components such as capital ($63,200) cost and annual O&M costs ($18,500) were offset with the benefits estimated from the reduction of fatalities, casualties and property losses per crash ($1,166,000). The financial calculation spreadsheets revealed high economic indicators in terms of BCR (38.9) and MIRR (65%) over the 10-year lifetime of the system.

In conclusion, a detection and warning system installed on Route 114, justifies itself by showing:

- Its effectiveness in eliminating all possible crashes resulting from actions 1 and 2, hence eliminating the possibility of having unavoidable crashes.
- Its high economic productivity concluded in a very conservative approach.

10.2 Recommendations for Future Research

This research actually opened the door to a new safety topic that might need further analysis and studies, and to a new ITS application as well that could be developed and upgraded to encounter more sophisticated functions and technologies.

The proposed application showed high integrity in drawing a conceptual framework of the system functions, followed by a detailed design of its components and a near-reality simulation proved to be satisfactory in explaining the major parameters as well as the sequence of the processes that leads to head-on crashes. However, like any other scientific area or field of knowledge, further researches and studies need to be accomplished in order to fill in the gaps of some missing pieces of the puzzle before a full picture is completed. Some of these were revealed in the context of the research development but need further efforts to be accomplished.

We may specify three areas that could be helpful in more understanding and developing the system:

1- Data Collection: we need to conduct more intensive field surveys over an extended area through continuing field surveillance. This task could be fulfilled after the system is installed then used to collect useful data, before and after the warning system is activated, over a long enough period of time. We may think of the following kind of missing data such as:

- Violation occurrences, frequency, direction, time of day and reasons if any, and this could be done throughout 24/24 hours of the day.
- More detailed data about crashes attributes such as violation direction, crash speed, type of actions and reactions taken by the three drivers.
- Traffic data related to violations attributes like, speed distribution of the population of violating vehicle A and the vehicle being passed B, directional traffic flow characteristics during the period of time when violations are taking place, etc.

The data collected may be very helpful in many ways such as:

a- It allows developing the simulation tool by refining (or adding) input parameters and then comparing its output with the field data.

b- It enables us to explore more deeply the relationship between traffic level of service or flow with the tendency to commit violation.

c- It helps in explaining when, where and how violators start their overtaking maneuvers.

d- It provides information from the field about the actions distribution, that is, the ratio of violators taking actions 1, 2 or 3 in both with and without the system cases.

e- It reveals the role of the enforcement system and how much it can affect the rate of violations as well as drivers decisions whether or not obey the warning message.

2- Human Factor Studies: Many questions need to be addressed and answered about human factors in such situation and the circumstances surrounding the process of violations, such as:

- Explore the perception reaction time (PRT), and reading lag time for driving under influence (DUI) cases with blood alcohol content BAC>0.1.
- Study human behavior under emergency and danger situation and how do drivers make their decisions.
- Study the environmental conditions and their effects on drivers' behavior (e.g. fog, rain, nighttime, etc.)
- Examine the conditions prevailing that might lead violators to accelerate or decelerate when they see the oncoming vehicle or get a warning (relative positions and speeds of A and B, vs. relative position and speeds of A and C), and the role of the psychological and aggressive history of the offender.
- Analyze the assumption that vehicle B is neutral all the way during the violation process, and the corresponding behavior of driver B once he/she perceives such situation.

3- **Detection Technology:** Equipment of the system has been selected from the technology available on the market. However, one may suggest some enhancements of the system hardware or software such as:

- Develop the current image-processing algorithm to overcome the discrepancies regarding the lateral motions (left turns), and assign different minimum number of pixels to different detection zones within the same cameras field of sight or detection area.
- Enhance the video camera capabilities and quality to perform its task (whether surveillance or detection) at higher accuracy and for larger distances.
- Explore the possibility to develop and use other less expensive technologies to detect wrong way direction on two-lane road (e.g. microwave radar).