

A Case Study on Potential Benefits of V2V Communication Technology on Freeway Safety

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Abstract. Vehicular crashes and road injuries continue to be a major safety concern in the United States. According to the Federal Highway Administration (FHWA) the main cause of freeway accidents is the misunderstanding of the situation from the driver side and motor vehicle crashes are the leading cause of death among Americans 1-34 years old. Based on the National Highway Traffic Safety Administration (NHTSA) estimates, there were 5.615 million crashes in 2012. Despite a decrease in the number of fatalities from vehicle crashes in recent years, the number is still an alarming 32,850 deaths in 2013 [1]. Vehicle safety engineers are constantly searching for new innovation and improvements to reduce the probability and severity of crashes.

This paper aims to study the potential benefits of the new Vehicle to Vehicle (V2V) communication technology on user's safety enhancement. V2V communication incorporates active safety technologies, which includes collision avoidance system, driver warning system, and vehicle stability system. A case study is presented to evaluate the potential benefits of V2V communication technology on preventing accidents using accident data on a segment of Interstate 5 freeway in the Orange County area. The study shows that the use of V2V communication technology in vehicles will reduce congestion delays by approximately 20 to 30 percent.

INTRODUCTION

Intelligent Transportation System (ITS) technology is rapidly gaining applications in reducing road side accidents, delay, and traffic congestion. The problem of traffic congestion is experienced in most major cities around the world. The 2012 Urban Mobility Report indicated that the national congestion translates to 5.5 billion extra hour of travel time, \$121 billion in total delay and fuel costs or (\$818 per U.S. commuter), and \$27 billion in truck freight moving costs [2]. The problem of congestion is increasing despite the fact that we are widening the existing system of roads and increasing its capacity.

Vehicular crashes, which contribute to traffic delay, continue to be a major safety concern in the United States. According to the Federal Highway Administration (FHWA) the main cause of freeway accidents is the misunderstanding of the situation from the driver side and motor vehicle crashes are the leading cause of death among Americans 1-34 years old. Based on the National Highway Traffic Safety Administration (NHTSA) estimates, there were 5.615 million crashes in 2012. In 2013, these crashes resulted in 32,719 fatalities [1]. A safer commute is an important feature of any transportation system and engineers are constantly searching for new innovation and improvements that will reduce the probability and severity of crashes. Vehicle to Vehicle (V2V) communication technology is one example that can improve travel safety.

This paper presents a case study to evaluate the potential safety benefits of V2V communication technology using accident data on a segment of Interstate 5 (I-5) freeway in the Orange County area. Many research activities are currently being done by various organizations related to real-time Vehicle to Vehicle (V2V) communication and Vehicle to Infrastructure communication (V2I). When fully implemented, V2V and V2I have the potential to help improve safety and reduce roadway traffic congestions.

METHODOLOGY

The segment of I-5 in the Orange County area is used for the case study. I-5 is about 45 miles long and acts as a major corridor for local and out of state traffic in California. The case study is based on the information obtained from the California Performance Management System (PeMS) and the Statewide Integrated Traffic Reporting System (SWITRS) reports.

LITERATURE REVIEW

Wireless technologies and communication systems have made route guidance system an essential equipment in vehicles. Conventional route guidance system is based upon the shortest path and does not take into account the

active road way condition. Ding, et. al [3] concluded that the advanced route guidance system using V2V not only provides real-time traffic information but also give drivers a choice on route preference. The route is calculated using minimum travel time rather than the shortest distance. Traffic routing based on the traffic information has been studied since 1990 but was more focused on a centralized system, but Yang [4] used distributed traffic information system built on vehicle to vehicle information exchange. The inter vehicle communication capable vehicle was able to optimize its path and was able to take rerouting path based on the current and historical recurrent traffic information. The result of the study suggests that distributed traffic information system based on the vehicles as a means of surveillance for traffic has not only benefited traveler but also improve the system.

V2V communication systems are capable of enabling a number of wireless-based features in the vehicles which will improve traffic safety, roadway efficiency, and driver convenience [5]. A number of research deals with driving safety by providing early warning messages through V2V communication. Huang and Lin [6] proposed a system that can alert drivers of an impending accident using an Early Collision Warning Algorithm (ECWA) and the Global Positioning System (GPS) to calculate the distance between vehicles and provide warning messages to the driver. This system can also track humans, motorcycles, and fixed objects and does not need special infrastructure. Chen, et. al [7] introduced the critical safe distance model in V2V communication to enhance the early braking safety feature, especially in case of sudden braking phenomena. They concluded that the critical safe distance model performs better especially when different vehicular speed is involved or when an obstacle appears in front of the leading vehicle, which is invisible to the vehicles behind.

V2V COMMUNICATION TECHNOLOGY

The technology which allows vehicles in a network to communicate with each other is called vehicle to vehicle (V2V) communication, also known as connected vehicles. This technology was developed by General Motors and successfully demonstrated in 2005. V2V incorporates active safety technologies, which includes collision avoidance system, driver warning system, automated emergency braking system, and vehicle stability system. For example, vehicles equipped with an automated emergency braking system will have the ability to activate an emergency braking system ahead of the perception reaction of the driver based on calculations by the host vehicle and its surrounding vehicles to avoid potential unexpected collisions. Communication between the vehicles in the network is established through a Dedicated Short Range Communication (DSRC). Due to the extended communication range, this system can provide roadway information and certain information about other vehicles equipped with the same technology. The vehicle equipped with this technology provides information on the vehicle's speed, braking status, and other information to vehicles within the range, and vice-versa. The events occurring beyond the driver's view are successfully being communicated using V2V technology. V2V communication has the potential to significantly reduce the number of fatal crashes through real time advisory warnings and preventive action. The most challenging part for the application of V2V communication technology is the simulation and filtering of the incoming information, and dealing with the volume of incoming data and false alarms. The benefits of this technology are numerous but the main challenge for future of the technology is the filtering of the incoming data with respect to a particular vehicle requirements. V2V communication technology can be used for early collision warning system, emergency braking, reporting an incident along the roadway, route guidance, and various other applications.

Collision Avoidance System. Safety is the first priority for the V2V communication technology. There are many aspects of the V2V communication technology which improves the driving condition for the driver and enhance safety. Collision avoidance system and driver warning system, along with vehicle stability system are provided to avoid collision and is considered an active safety technology. The minimum distance between vehicles to avoid collision based on the V2V communication is called Critical Safe Distance (CSD). When another vehicle enters the CSD, the vehicle's automated warning alarm will beep to alert the driver of an impending danger. The CSD depends on the speed of the two vehicles. This technology is particularly effective in avoiding accidents due slower reaction time of the driver.

Line of Sight. V2V communication technology plays an important role in improving road side safety condition, along with the collision avoidance system. The importance of V2V communication increases when there is no

adequate line of sight for maneuvering. Inadequate line of sight problems usually occur on merging and diverging lanes which connect to freeway at a certain angle. In this case, V2V communication plays an important role in collision avoidance by sending warning messages. When the line of sight is obstructed and the merging vehicle cannot see the oncoming vehicle the V2V communication technology assist in the situation and provides a warning signal to both vehicles. Vehicles equipped with the technology helps in avoiding a potential collision. Another benefit of line of sight is the motorcycle detection. A considerable number of accidents occur because of invisibility of motorcycles on the highway. This type of accident can easily be prevented by the use of line of sight technology.

Automated Emergency Braking System and Brake Light Warning System

Vehicles with an active safety system such as an automated emergency braking system are equipped with sensors that provide real-time information, on the position and speed of a vehicle, and in emergency situation, apply the brake when the driver fails to act on previously relayed visual and audio signals. The role of inter vehicle communication is essential for active safety of vehicles because they transmit the information which the driver cannot observe through visual connections. Brake lights express the intention of a driver to the vehicle behind. For example if a vehicle detects an incident in front, the automatic brake application sensor will transmit the signal to the vehicle behind which can avoid sudden rear end collision.

CASE STUDY

The objective of this case study is to estimate the effects of various V2V communication technology. The segment of Interstate 5 in the Orange County area is used in the analysis. I-5 is about 45 miles long and acts as a major corridor for local and out of state traffic. According to the Statewide Integrated Reporting System (SWITRS) report of the California Highway Patrol, the number of vehicle-involved accidents in the State of California is overwhelming, although it has gone down significantly in the last seven years, as shown in Table 1.

Table 1. Accidents comparison between 2005 and 2012 in California

	Year 2005	Year 2012
Persons Killed	4,304	2,995
Persons Injured	292,798	226,544
Fatal Collisions	3,822	2,758
Injury Collisions	198,708	159,696
Mileage Death Rate	1.31	0.92

Accident data shows a decreasing trend on I-5 in the northbound and southbound directions as presented in Figures 1a and 1b. Figure 2 shows that the number of accidents on the northbound direction is slightly higher than the southbound direction. In 2013, 6670 accidents were recorded on I-5 north, and 6085 on I-5 south. Most of the accidents occurred on the freeway mainlines, and the remaining 31percent occurred either on or off ramps as shown on Figure 3. The number of accidents decreased considerably despite an increase in the number of vehicles and vehicle-miles travelled. Among the reasons for decreased number of accidents could be the in-vehicle improvement in safety technologies, such as the blind side monitoring system and the automatic emergency braking system. These systems warn the driver about a potential collision.

Accidents are one of the main reasons of freeway congestion, as shown in Figure 4. Around 20 percent of the delay was caused by the incidents on the freeway which can be clearly reduced by the use of V2V communication technology. Potential reduction, which accounts for 18.9 percent of the accidents, is the congestion caused by not metering the ramp efficiently and effectively. Miscellaneous, which accounts for 38.02 percent of the accidents, are those which cannot be identified. Excess demand accounts for 23.48 percent of the congestion. With implementation of V2V communication technology, the number of accidents can be reduced significantly. Subsequently, non-recurring congestion and travel times can also be reduced.

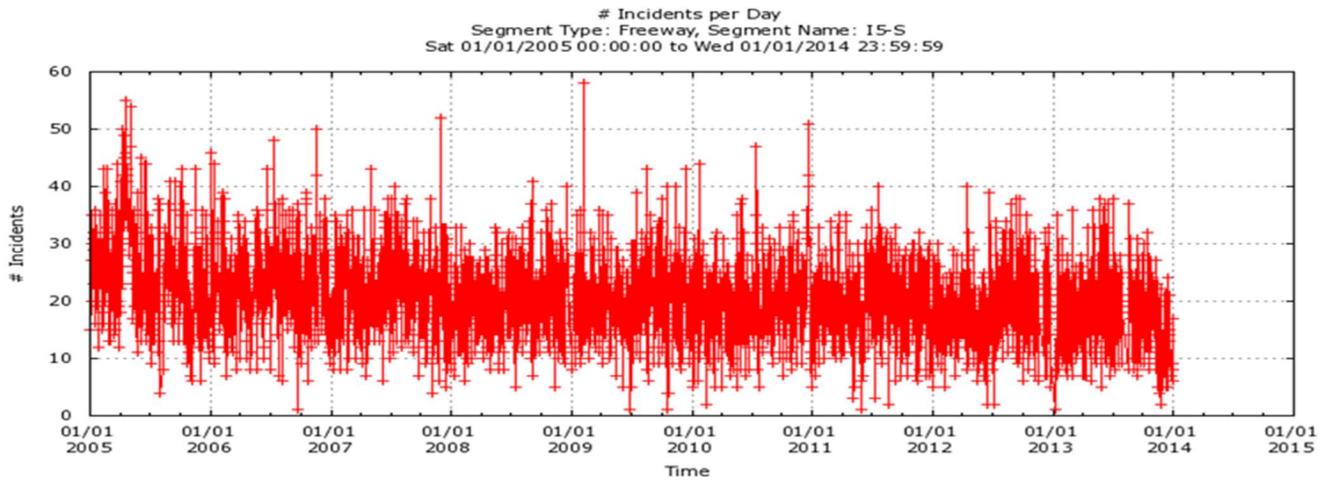


Figure 1a. Number of accidents per day on the northbound direction I-5 in Orange County. (Source: PEMS)

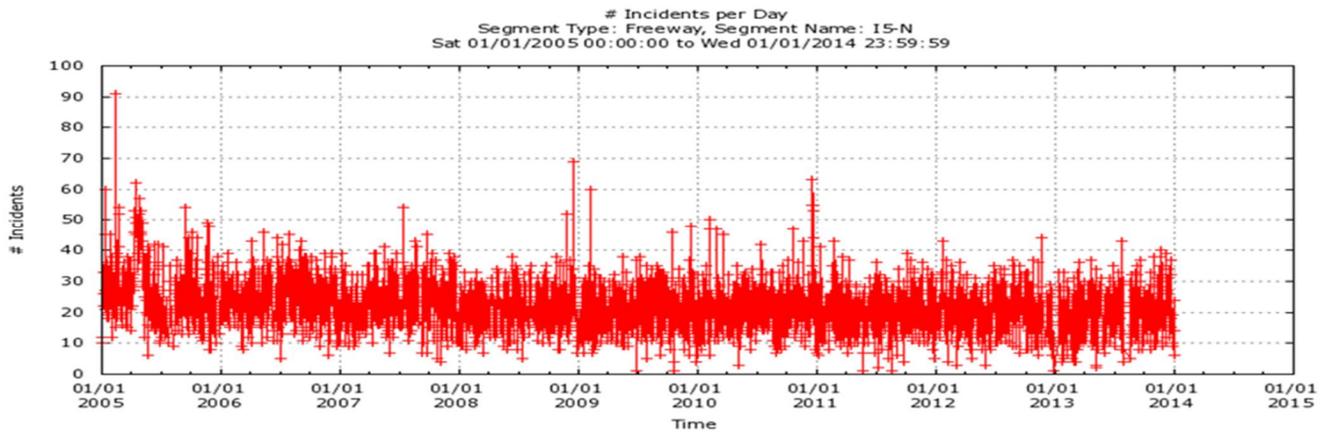


Figure 1b. Number of accidents per day on the southbound direction of I-5 in Orange County. (Source: PEMS)

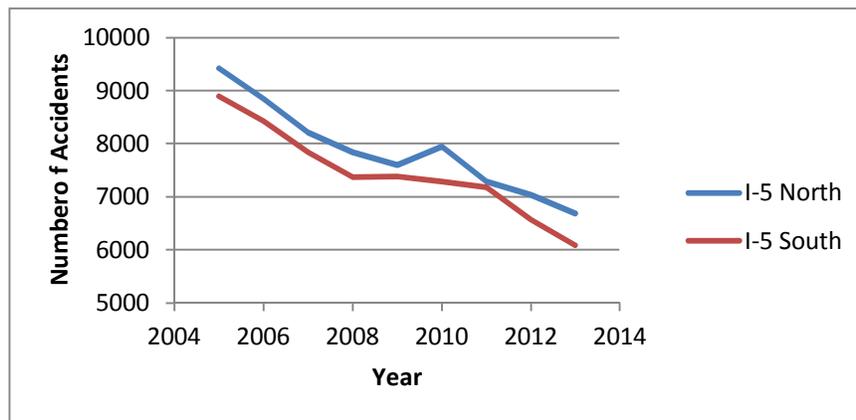


Figure 2. Annual accident data on I-5

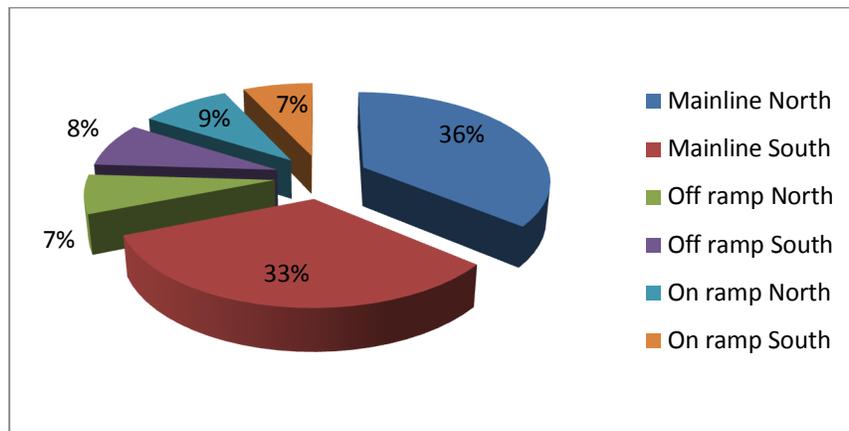


Figure 3. Location of accidents on I-5 (Source: PEMS 2011)

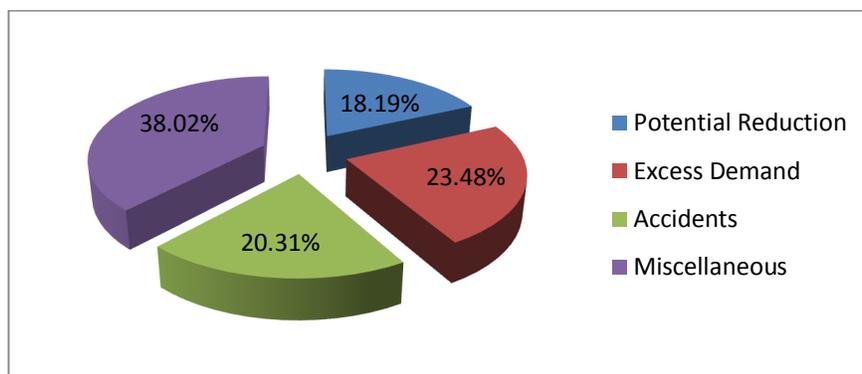


Figure 4. Causes of congestion on I-5 (Source: PEMS 2011)

Potential Reduction in Accidents due V2V Communication Technology

A total of 1119 vehicle incidents recorded in 2012 were categorized as follows: 372 rear end, 242 hit object, and 164 sideswipe and the rest are others. The percent distribution by type of accident and movement preceding collision are presented in Figure 5a and 5b. It should be noted that in most accidents, the movement preceding collision is "proceeding straight". A significant number of rear end collision occurred when the leading vehicle is "stopped".

Rear-end crashes represent 34 percent of the accidents. This type of crashes can be addressed by the automated emergency braking system, and brake lights warning system technologies. Vehicles equipped with these technologies can react ahead of time in order to prevent the incident. Sideswipe accidents represent 15 percent of the accidents. The main causes of these accidents are not enough visibility or limited line of sight. The side swipe accidents can be addressed by the line of sight technology. An improvement in the driver's line of sight will not only improve the safety conditions but also reduce the delay caused by these accidents. Around 12 percent of the accidents are hit object. This type of crashes can be addressed by the automated emergency braking system. A considerable number of accidents is caused by misjudgment of the drivers, or not enough reaction time. Other undefined factor accounts for 4%.

Vehicle to Vehicle (V2V) communication technology can warn the driver early about the potential situation coming ahead so the driver can react safely. If we assume that in the coming years, 50 percent of vehicles will be equipped with the V2V communication technology, the number of accidents can be reduced significantly.

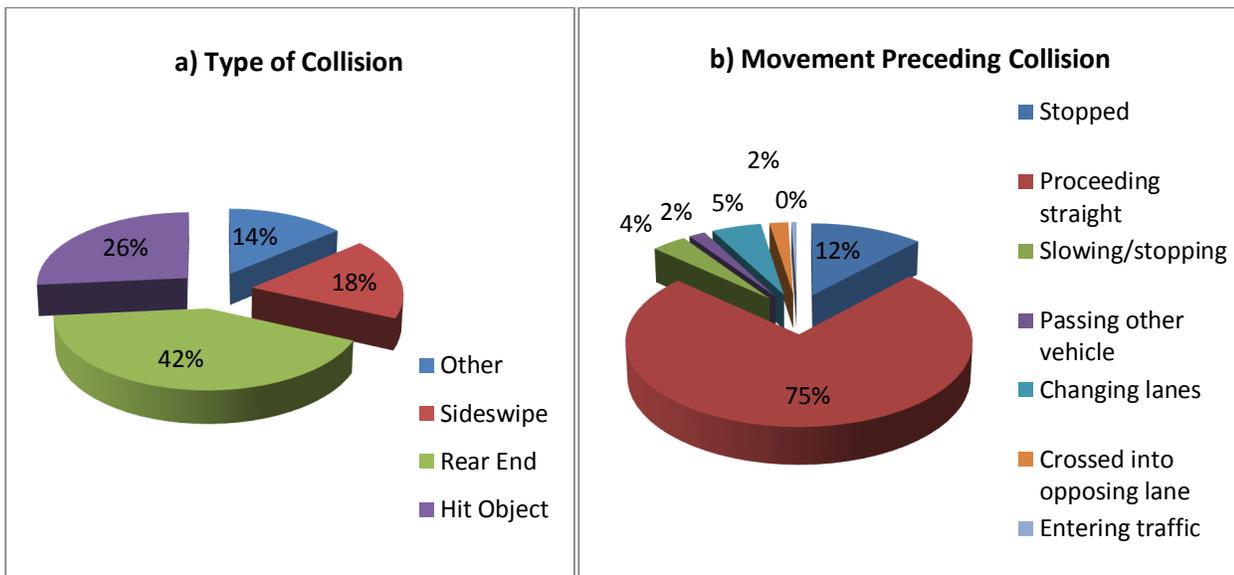


Figure 5. Movements before the collision and the types of accidents caused by that movement in 2012

CONCLUSION

The use of V2V communication technology is becoming more realistic and it seems like in the near future every vehicle will be equipped with this technology. V2V is envisioned to improve travel safety and reduce congestion and delay caused by traffic accidents. The application of the V2V interaction technology on I-5 in the Orange County will be beneficial because of the occurrence of the incidents and the amount of delay caused by the accidents on the freeway. The use of V2V communication technology on the I-5 segment will reduce congestion delays attributed to accidents by approximately 20 to 30 percent, assuming 50 percent of the vehicles use this technology.

The most challenging part for the application of V2V communication technology is the simulation and filtering of the incoming information, and dealing with the volume of incoming data and false alarms. The benefits of the technology are numerous but the main challenge for future of the technology is the filtering of the incoming data with respect to a particular vehicle requirements.

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