

Intelligent truck rollover advisory systems

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ABSTRACT

To address the serious problem of truck rollover accidents on freeway exit ramps a system was developed and implemented by the Federal Highway Administration (FHWA), a private consultant Bellomo-McGee, and a system integrator International Road Dynamics. The system utilizes several existing technologies to determine vehicle weight, vehicle type, vehicle speed, and vehicle deceleration. The system uses the information gathered to evaluate each vehicle on a freeway exit ramp to determine if they are in danger of a rollover accident and provides a warning to vehicles in potential danger.

The system was implemented at three sites in the Washington DC area that had a history of rollover accidents. A three year independent evaluation was conducted on behalf of the FHWA to determine the effectiveness of the system. The evaluation shows that the system has been effective in reducing speeds and reducing accidents at the three sites that were chosen, and shows that the systems are economically beneficial.

Keywords: rollover, truck safety, weigh in motion, advisory system, piezoelectric sensors, accident prevention

1. INTRODUCTION

Truck accidents on highways are a major concern of North American highway agencies and departments. A single accident has the potential to cause millions of dollars of physical damage and related costs. Besides the substantial direct damage costs usually associated with truck accidents, the intangible costs which include death and injury, insurance and economic consequences can be even more significant.

Truck rollover accidents are not uncommon on many freeway exit ramps. In 1992 there were more than 10,000 truck roll overs, resulting in 80 deaths and more than 3,000 injuries.¹ Three examples demonstrate the potential results of a major truck accident. On September 7, 1988 a tanker truck rolled over at an interchange on the Beltway in the Washington DC area and the fuel cargo began to burn. The initial clean up of the wreckage and spilled fuel backed up traffic for almost an entire day. The repairs to bridge girders damaged by the fire lasted for another month and required the closure of a section of a major freeway.² On July 9, 1992 a truck accident on Toronto's Highway 401 resulted in three express lanes being closed for almost 10 hours. The physical damage from this accident was minimal, but the delay to traffic was estimated at 325,000 vehicle hours with an estimated value of over \$4 million.³ On August 18 1997 a tanker truck at the interchange of I-695 and I-83 in Baltimore Maryland collided with a concrete railing, flipped over, and burst into flames. The driver of the truck was killed in the accident. It was estimated 3500 gallons of gasoline either burned or were spilled into a nearby storm sewer system and waterway. About 40 tons of contaminated soil had to be removed from the site.⁴ These three incidents illustrate the variety and magnitude of loss associated with major truck accidents.

Much of the geometric design of highways, including alignment and grade, were set during the facilities initial construction. In many cases, this design was performed 30 to 40 years ago. The volume of the traffic has generally increased, including commercial vehicle or truck traffic. Further, the size, weight, and power of these vehicles have increased. A situation has occurred where there are a number of highway locations that have become inherently dangerous to these larger more powerful vehicles. The cost of rebuilding the infrastructure to provide exit ramps with better alignment would be huge, and in many cases would not be possible due to limited space for construction.

The 1988 incident in Washington caught the attention of a local politician who provided the initiative for an improved warning system for heavy trucks using Intelligent Transportation Systems (ITS) technology. A feasibility study was conducted on the implementation of an automatic truck warning system.⁵ Based on the results of the study, the FHWA proceeded to procure a prototype Automated Truck Rollover Warning System (ATRWS) which was installed at three sites in the Washington area. The system was supplied and installed by International Road Dynamics, Inc. in 1993 and tested over a three year period to evaluate its performance and effectiveness.

2. Automated Truck Rollover Warning System Design

The warning system was designed to provide a specific warning directed specifically to trucks that are in danger of a rollover accident. Traditional highway warning signs can become commonplace and easily ignored by a driver. With the multitude of signs that a driver is exposed to during a trip on a major freeway the important warning signs are lost in the crowd. Even if the warning sign is noticed it is often ignored when a driver does not understand the nature of the danger and considers the warning irrelevant for his situation. Past experience with successfully ignoring warnings at less dangerous sites conditions a driver to consider warnings irrelevant and to not react fully to signs that they encounter. The more directed and specific the warning the less chance there will be that the message will be ignored by the driver. Also, the fewer times a driver is given a warning when there is no real danger, the less accustomed they become to ignoring the warning. In order to provide an accurate evaluation of the truck's potential for rollover, the system was designed to include information on the vehicle, the road, and the driver's operation of the truck. The warning system uses several common technologies in this new application to provide a new solution to the rollover problem.

The system consists of three parts as presented in Figure 1: an advance Weigh in Motion (WIM) and vehicle dimensioning system, a vehicle tracking system, and a vehicle advisory sign system.

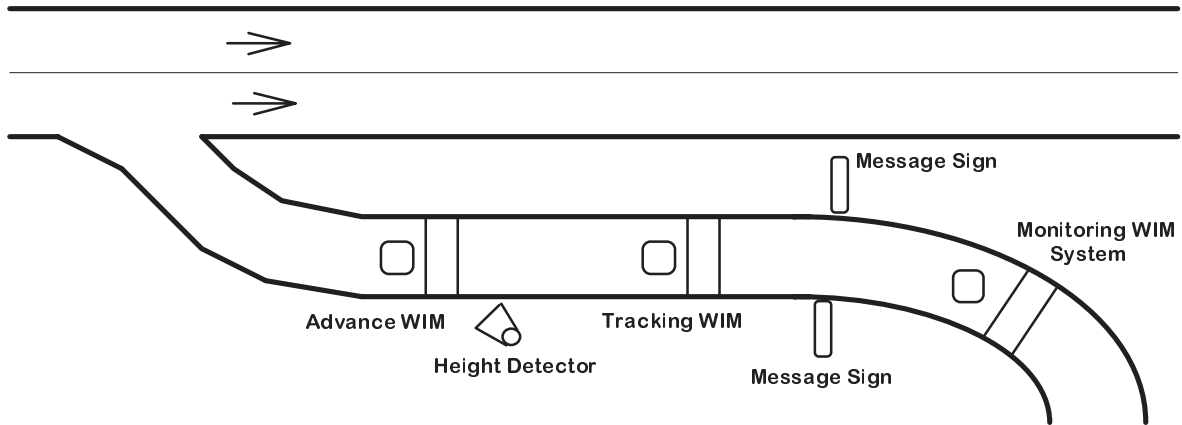


Figure 1: Layout of Rollover Warning System

The advance WIM system utilizes Piezoelectric sensors and inductive loops to provide the base vehicle configuration, size, and weight. Piezoelectric sensors have been installed at hundreds of locations throughout North America to provide vehicle information valuable for planning future roadway requirements and evaluating pavement performance under programs such as the Strategic Highway Research Program (SHRP). The piezoelectric sensor consists of a copper core, surrounded by a polarized ceramic Piezoelectric insulation contained in a copper sheath. Various encapsulation and installation methods are used to protect the sensor during installation and use. The sensor is sensitive to vibrations caused by the passing of tires and produces an output signal corresponding in size to the amount of load. The WIM electronics analyses the signals to determine axle weights, spacing between axles, axle group weights, gross vehicle weight, and vehicle classification.

To provide further distinction of the type of truck being analyzed a microwave height detector is used to determine vehicle height. This allows the system to distinguish between box trailers and tankers or flatbeds, since these types of vehicles at the same weight and speed have different rollover potentials due to differing centers of gravity. The current system uses a radar-type detector set at approximately 11.5 feet. Other height detection technologies such as an infrared beam with a transmitter and receiver unit could also be incorporated into the system.

These components give the system enough information to determine a safe speed, called the threshold speed, for the vehicle to negotiate the exit ramp based on the ramp geometry. The vehicle weight, vehicle type, curve radius, and curve superelevation are all considered in a calculation of the maximum safe speed for the specific conditions of the road and vehicle. The speed determined by the calculation is also checked against the predetermined maximum speed for the road for any vehicle. The lower of the two values is used in determining whether the sign should be activated. For example, if the calculated speed indicated that the vehicle could travel the curve at 50 miles per hour but the advisory or posted speed of the exit is 45 miles per hour, the predetermined value would over-ride the calculated value so that a vehicle is never allowed to exceed the speed limit without receiving a warning.

The previous analysis has considered the characteristics of both the vehicle and the roadway in determining a safe allowable speed. The final consideration is the action of the vehicle driver. A second set of in-road sensors was installed a short distance downstream of the first set to provide vehicle tracking. The tracking system monitors the vehicle's progress along the ramp, calculating the rate of deceleration and predicting the speed at which the truck will enter the curve. If a situation occurs where it is estimated that the vehicle will not slow down sufficiently to below the maximum allowable speed before the critical point in the curve, the automated vehicle advisory signing system is used to display a warning message to the vehicle.

The warning message is provided by a fiber optic sign with the message “TRUCKS REDUCE SPEED” installed directly below a static truck rollover warning sign that indicates ramp advisory speed. The warning message sign is different from a continuously flashing beacon or a permanently activated sign. It is a sign that is activated only when a truck is exceeding the rollover threshold speed at a particular curve. This prevents drivers from becoming so accustomed to the presence of a warning that it is easily ignored.

A third set of in-road sensors was installed on the curve of the exit ramp. These sensors are not needed for the operation of the system, but were used to collect data on the speed of vehicles at this point so that the effectiveness of the system could be evaluated.

3. System Implementation and Effectiveness

The Capital Beltway circles the greater Washington DC area, with numerous exit and entrance points in the form of ramps. Over the past decade, there have been several spectacular incidents involving commercial trucks rolling over while exiting the Beltway. In many cases the accidents have involved fatalities and in at least one case a fire created considerable damage to Beltway structures.

To evaluate the effectiveness of the ATRWS, three sites were selected as candidate sites for the installation of automated systems designed to advise drivers of the danger approaching. These three sites had previous incidents involving heavy trucks, and were considered the most vulnerable to these types of accidents. The location of the three sites is shown in figure 2.

WASHINGTON D.C. BELTWAY TRUCK ROLLOVER WARNING SYSTEMS



Figure 2: Automatic Truck Rollover Warning System Installations

The systems were installed in 1993 and evaluated independently over a three year period by Bellomo-McGee Inc. on behalf of the Federal Highway Administration. The draft final report released in March 1997 presented the findings of the evaluation.

One of the findings of the evaluation was that the activation of the sign was related to greater speed reduction. “The findings showed that the overall speed reduction of trucks ‘with’ activation is 21.7 % higher than those trucks that did not activate the sign. Therefore, it has been concluded that the ATRWS caused truck speed reductions at each of the sites.”⁶

A second and more significant finding of the evaluation was the overall effectiveness of system. The three sites chosen for testing the system were selected because of their previous history of experiencing rollover incidents. One of the sites chosen had experienced 6 accidents in five years while the two other sites had experienced 2 accidents in 4 years. Based on the previous history of the sites, it would be expected that more than 6 accidents would have occurred at these sites over the three year evaluation period. However, not a single rollover accident has occurred at the three sites since they were installed.⁷

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Site Number, Interchange, and Location	Truck Rollover Accidents 1985 to 1990	Truck Rollover Accidents Since Installation of System in 1993
#1 - I495/I95 Maryland	6	0
#2 - I495/VA123 Virginia	2	0
#3 - I495/I95 Virginia	2	0

Source: Bellomo-McGee, Inc. (Consultant to FHWA)

Figure 3: Rollover accidents before and after system installation

An effective system in reducing the number of rollover accidents can provide a wide range of benefits beyond the specific incident. The reduction of costs associated with an accident is of benefit to the trucking community and the general traveling public who may also be involved when a rollover occurs. The facility provider (Department of Transportation, Turnpike Authority, etc.) is also saved the expense of any physical damage that may occur such as the structural damage caused to the support structure by the fire on the Beltway in 1988. Likewise, the improved safety of the road and reduced time delays and road closures are of benefit to both the trucking community and the general traveling public. The closing of a section of a major freeway for even a day can result in several hundred thousand hours of vehicle delay. The delay impacts a huge number of people and the cost associated with this lost time can be much greater than the actual physical damage of the accident. When an environmental spill of fuels, chemicals, or hazardous waste can be avoided, the benefits range even wider including the general public as well as all highway users. Since this is a lower cost solution than an expensive reconstruction of an exit ramp, there are financial savings for both the authority in charge of the roadway and the general public whose funds are used to provide the facility. Whenever a serious accident occurs it affects the public perception of the safety of heavy trucks on the road and of the freeway system that is provided. The improved public perception of the safety of the roadway and trucks traveling the road benefits both the trucking community and the freeway provider.

Who Benefits ?

System Benefit	Trucking Community	Traveling Public	General Public	Facility Provider (DOT, Turnpike Authority, etc.)
Reduced accident costs	X	X		X
Improved traveling safety	X	X		
Reduced time delay	X	X		
Reduced environmental damage	X	X	X	
Reduced facility costs	X	X	X	X
Improved perception of safety	X			X

Figure 4: Summary of Benefits from an Automatic Truck Rollover Warning System

4. Economic Feasibility

The results of the evaluation have clearly shown that the system is effective in reducing speeds and accidents at the three locations where it was installed. A more difficult issue to address is the economic feasibility of the system. Compared to simple approaches such as static signing or permanent flashers, the system is quite expensive, but is also significantly more effective. Compared to the high cost involved in changing the geometry of an existing exit ramp the system is a low price alternative.

A reasonable estimate of the cost to fully install a one lane ATRWS and maintain it over a 10 year period is \$150,000 for the initial installation, and \$10,000 per year to fully maintain the system following that. Using an interest rate of 10%, the net present value for the cost of the system is \$211,500.

The benefit of having the system installed is the cost of the potential accidents that are prevented. The cost of a potential accident is very difficult to predict, since it is not known when it will happen and how severe it would be. Even for an accident that has occurred it is difficult to assign a value to items such as traffic delay costs, environmental damage, injuries, and loss of life. However, the following scenarios present an idea of the performance required for the system to be cost effective.

Given the results of the three year operation of the system, it is reasonable to estimate that if installed at critical locations the system could prevent at least one accident per year. If a single lane warning system with a net present value of \$211,500 is installed and is able to prevent one rollover accident with a cost of \$35,000 each year for the next ten years, the system will have paid for itself. From the examples given in the introduction it can be seen that a single accident can easily have a cost much greater than \$35,000. If the same system can prevent a \$50,000 accident each year, the cost of installing and operating the system for ten years will be recovered after six years. If the average cost of the accidents saved by the system is \$100,000 the investment will be recovered in only three years. The next seven years of operation and accident prevention will be paid for and all savings from prevented accidents will be added benefits of the system. The prevention of a single accident with a potential cost of one million dollars in the first year of operation would pay for the installation and operation of four systems for a period of ten years.

These scenarios deal only with the economic evaluation of the system. Attempts have been made to put a value to things such as pain, suffering and the loss of a life. For the people directly involved in these situations, the values assigned to these matters are irrelevant. For them, any amount required that could prevent the loss of a loved one would be worth paying. Transportation agencies must spend their limited funds carefully for the maximum return possible on their investment. If these funds can be spent in a way that is economically rewarding and can provide personal benefits to its clients, it seems to be a wise investment for everyone involved.

5. Conclusion

Truck rollover accidents result in costly damages in the form of injury, loss of life, property damage, environmental damage, clean up costs, and traffic delays. A single accident can result in damages in the millions of dollars.

The new system developed and installed on the Washington DC Beltway has integrated several existing technologies to provide a unique solution to this problem. The evaluation of truck weight, type, speed, and deceleration rate and curve characteristics allows an intelligent decision to be made regarding the likelihood of a problem and the triggering of a warning message under dangerous conditions.

The three year evaluation of the systems has shown that they are effective in reducing the speed of trucks on the exit ramps and in reducing accidents. The sites which were chosen because of their high incidents of rollovers have experienced no accidents of this type since the safety systems were installed. The systems have successfully contributed to a safer roadway for truck drivers, other motorists, and surrounding residents. In addition to improving safety, they have also provide a good return on the funds invested by the savings provided from reduced property damage, vehicle damage, time delays, and clean-up costs.

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