ECONOMIC EVALUATION OF TRUCK COLLISION WARNING SYSTEMS

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ABSTRACT

Collision warning devices are automatic systems to warn drivers when a potentially dangerous situation occurs, and thus allow the driver to take corrective actions. This paper addresses the potential economic value of warning truck drivers of dangerous maneuvers or danger due to failure to make a maneuver. The central issue addressed by the research is the value of warning the driver when he or she is making or about to make an unintentional lane change or roadway departure. Such unintentional lane changes are a symptom of drowsiness and inattentiveness. Also evaluated were the potential benefits of warning the driver in several other potentially dangerous situations.

The lack of exposure information in publicly available databases was one of the difficulties found in our attempts to analyze the per mile cost of accidents by maneuver. To accomplish this analysis, a database was created to support the estimation of accident cost by accident type using accident records over a three-year period from six truckload motor carriers. Together, the six motor carriers accounted for almost 350 million miles of truck travel during the three-year period with 264 accidents.

The analysis found that a collision warning system which alerted a driver to a potential accident due to an unintentional lane change or roadway departure only was not likely to be cost effective. However, a system which could warn of potentially hazardous situations when other maneuvers are being made (e.g., longitudinal warning in addition to warning during lateral maneuvers) could be very beneficial.

INTRODUCTION

Collision warning systems are a member of a family of systems categorized as Intelligent Transportation System (ITS) Collision Avoidance Systems (CAS). In general, CASs either passively or actively facilitate the avoidance of a collision. A collision warning system is a passive system which alerts the driver to take an action to avoid a collision, while an active system would intervene in the control of the vehicle to avoid a collision. Collision avoidance systems are categorized into five different types of systems.(1) They include:

- Longitudinal systems which look forward and/or rearward from the vehicle to maintain safe distances from other vehicle and objects.
- Lateral systems which look to the side of the vehicle to avoid accidents involving lane changes and roadway departures.
- Intersection systems which provide inputs from on-vehicle or infrastructure mounted devices to warning of a potential accident in and around an intersection.
- Vision enhancement systems which enhance the driver's ability to detect hazardous situations.
- Safety readiness systems which monitor the driver's and vehicle's safety worthiness.

Although technologies to support each of these types of systems are currently available, the introduction of the systems partially depends on the expected accident cost savings exceeding the cost of the device. This paper discusses research conducted to determine the potential cost savings attributable to a truck-mounted lateral warning system. The specific focus of the research is on systems which alerts the driver to an impending lane departure. In addition, data were collected which made it possible to infer the potential benefits of systems warning of collisions involving other maneuvers.

Unintentional lane departures are a result of inattentiveness or drowsiness, commonly caused by driver fatigue. Truck driver fatigue is estimated to be the contributing factor in 30 to 40 percent of all heavy truck accidents.(2) For example, a 1990 study of 182 fatal heavy truck accident found that 31 percent of those accidents were fatigue-related. In a 1994 National Highway Traffic Safety Administration (NHTSA) study it was estimated that driver inattentive, drowsy, or driver asleep cited as the major factor related to 31.5 percent of all fatal accidents involving combination-unit and single-unit trucks involved in single vehicle roadway departure accidents.(3) Clearly, accidents involving fatigue and unintentional lane changes or road departure are important and costly. The purpose of the research described here is to determine the potential value of being able to avoid such accidents.

ACCIDENT DATA

The objective of the research was to determine the cost associated with accidents involving specific vehicle maneuvers in advance of the accident (e.g., unintentional lane change or land departure, head-on, rear-end, turning, etc.). Depending on the maneuver prior to the accident, the researchers could interpret if a specific collision warning function would assist in avoiding the resulting accident.

There are publicly available accident databases but they generally do not provide adequate detail on the economic cost per accident and/or on exposure. For example, the Fatal Accident Report System (FARS) kept by the NHTSA contains information on fatal accidents for heavy trucks. It was deemed that the FARS and other publicly available sources of truck accident data do not offer the needed level of detail.

Because data with sufficient detail was not readily available, raw data were collected from trucking firms. Because truckload operations are more subject to long hours of operation over long distances (as opposed to less-than-truckload operations), the truckload segment of the truck industry was isolated as the subject population. Candidate Class I carriers (gross revenue greater than $10,000,000) in and around Iowa were selected randomly. Ultimately six carriers agreed to have their safety records summarized into an analysis database. The data collected for each carrier included accidents information and exposure data for a three-year period from July 1, 1991 to June 30, 1994. In total, the trucks in the six fleets traveled 345 million miles during the three-year period.

Data Elements Collected

In advance of determining which data elements to collect, a review was conducted of the literature to determine variables which are believed to have a significant impact on truck accident rates. Based on this review, a list of data elements related to the driver, the roadway (at the location of the accident), the vehicle, and the accident itself were identified. Data were only collected for preventable accidents. Accidents which were non-preventable were deemed accidents which were unavoidable and the driver would not be assisted by the presence of a collision-warning device.

Driver Data Elements

These elements identify relevant attributes of the driver at the time of the accident. The data elements collected include:

- The driver's age at the time of accident.
- The driver's experience as indicated by the number of years of professional driving experience.
- The driver's length of tenure with the motor carrier.
- Whether or not the driver had formal training.
- The driver's relative familiarity with roadway as indicated by distance from the motor carrier's base of operations. Distance was defined by less than 50 miles from the base of operations, more than 50 miles, and out-of-state.

Other desired data elements which are believed to be related to accident rates were not readily available, even from the motor carrier's records. This included information on the driver's hours of service at the time of the accident and the medical condition of the driver.

Roadway Data Elements

These data elements are related to the environmental conditions at the time of the accident and properties related to condition of the roadway. These elements included:

- The roadway type at the location of the accident categorized as urban or rural, the number of lanes (two or four lanes), and whether the facility was built to freeway standards.
- The weather condition and weather related pavement conditions at the time of the accident, including whether the pavements was dry, wet, or icy, whether it was sunny/clear or overcast, and the existence of precipitation (rain, snow, or sleet).
- The direction of travel when the accident occurred.

Vehicle Data Elements

These are data elements which deal with the characteristics of the truck and the load at the time of the accident. These elements include:

- The truck configuration at the time of the accident.
- Whether the truck was loaded at the time of the accident and the type of cargo.
- The trailer type (e.g., tanker, flatbed, dry van, etc.), the model of the trailer, and trailer length.

Accident Data Element

These are data elements which are specific to the accident. They identify the vehicle maneuver leading to the accident and severity of the ensuing accident. The data elements collected included:

- The time of day of the accident, the day of the week, and the time of the year.
- The vehicle maneuver immediately preceding the accident. The categories of maneuvers included:
  - Unintentional lane change;
  - Turn-right or turn-left at an intersection or driveway;
  - Swerving;
  - Longitudinal movement (for example, as a result of rear-ending a vehicle in front or as a result of broadsiding another vehicle in an intersection);
  - Slowing;
  - Passing; and
  - Intentional lane change.
- The type of impact with a fixed object or another vehicle. The impact maybe a sideswipe, rear-ended, broadside, etc.
- The direct cost associate with the accident. These data were tabulated from the motor carrier's records and insurance company records. The cost information collected included:
  - Costs to repair or replace the participant motor carrier's truck and/or trailer due to the accident;
  - Cost to repair or replace the other involved parties vehicle and/or property;
  - Cost of medical expenses for all injured parties;
  - Cost related to cargo loss or damage; and
  - Miscellaneous cost such as site cleanup, towing, vehicle downtime, and lost work or workers' compensation claims.

Data Collection

Between one to three days were spent at the site of each participating motor carrier. After interviewing key motor carrier staff members, data were collected at each of the six motor carrier's offices following five steps. The steps are:

- Review of the motor carrier's accident register. All six participating carriers keep records for accidents in their register, although they are legally only required to keep a register of accidents in which the damage sustained by any involved vehicles requires its removal from the accident scene, or injuries to involved parties requires medical attention away from the scene, or a death. From the register, accidents were identified, the date of the accident, and the driver involved in the accident.
- The individual accident files were reviewed for each accident identified in the first step. This included carrier copies of accident reports, transcripts taken from accident observers, and insurance reports.
- Examination of the driver qualifications files. The pertinent data related to the drivers involved in accidents were recorded.
- The carrier's equipment inventory list was reviewed to gain information related to tractor and trailer involved in the accident.
- The carrier's fuel and mileage reporting system was reviewed to determine miles traveled by the carrier's trucks during the three-year period.

Database Characteristics

The participant carriers operated 1,175 heavy trucks during the three-year period, in aggregate they traveled 344,825,531 miles, and were involved in 264 accidents. On average, each truck traveled 97,823 miles per year and their fleets incurred about 0.766 accidents per million-miles. This is far below the national overall average for truck accidents of 2.04 per million-miles.(3) However, in the case study database, non-preventable accidents were not included making it impossible to make comparisons to national averages. The total accident cost was $3,476,812, slightly more than one cent per mile.

Although all the carriers are truckload carriers located in and around Iowa, there is considerable variability in the data between carriers. The average mileage per truck per carrier varied from 83,403 to 124,419 per year. Accident rates varied from 0.08 per truck per carrier to 0.61 per truck per carrier over the three-year study period.

ACCIDENT COST PER MANEUVER PRIOR TO ACCIDENT

A tabulation of the accident cost categorized by the maneuver immediately prior to the accident is listed in Table I. Accidents involving longitudinal maneuvers were the most costly and accounted for more than half the costs of all accident types. Assuming a collision warning device would allow a driver to avoid all preventable accidents involving a longitudinal maneuver prior to the accident and an average distance traveled of 100,000 miles per year,

TABLE 1 ECONOMIC ANALYSIS OF ACCIDENT COSTS BY MANEUVER TYPE

Maneuver Type	Total Cost	Cost per Mile	% Total Costs
Straight	$1,979,298.38	$0.0057	56.93%
Unintentional Lane Change	$532,148.17	$0.0015	15.31%
Turn	$451,178.53	$0.0013	12.98%
Intentional Lane Change	$287,015.18	$0.0008	8.26%
Slowing	$120,801.23	$0.0004	3.47%
Passing	$43,164.15	$0.0001	1.24%
Stopped	$18,134.03	$0.0001	0.52%
Merge	$15,990.12	$0.0000	0.46%
Backing	$12,492.50	$0.0000	0.36%
Unattended Vehicle	$5,736.00	$0.0000	0.16%
Swerve	$5,395.79	$0.0000	0.16%
U turn	$2,962.00	$0.0000	0.09%
Straight/Backing	$2,496.00	$0.0000	0.07%
Total Accident Costs	**$3,476,812.08**	**$0.0101**	100.00%

the average cost savings of avoiding these accidents is $570 per year. Assuming the collision warning device has a three year life and an eight percent per year cost of capital, the device could be priced as high as $1,450 before the cost of the device exceeds the potential cost savings attributable to eliminating all longitudinal maneuver accidents. Admittedly, it is impossible to predict what proportion of these preventable accidents would actually be avoided through the use of a collision warning system without conducting a large scale field trial of the systems in actual use. It is clear, however, that the price of the system must be less than the expected cost of the accidents which could be potentially avoided. Therefore, $1,450 represents a per unit price ceiling for a longitudinal collision warning system.

Accidents involving unintentional lane changes only accounted for 15 percent of the total accident costs. Assume that a collision warning device would allow drivers to avoid all unintentional lane change accidents and based on the same criteria used to evaluate accidents involving longitudinal maneuvers, the price ceiling for the device is $380. Given the relatively low potential cost savings, it is unlikely a system which only provides collision warnings for unintentional lane changes or roadway departures would be cost effective. When trucking firm managers were interview and asked about the relative cost of warning systems to avoid unintentional lane change or lane departure accidents, some comment that they believed they would be better off investing in additional safety training for their drivers. On the other hand, if the system were able to warn of likely collisions under several maneuvers (longitudinal maneuvers, unintentional and intentional lane changes, and turning accidents) and allow the drive to avoid accidents involving these maneuvers, the expected savings over three year life is $2,400 and these savings are in the neighborhood of the cost of current onboard technology. If the collision warning system can conduct other onboard electronics functions (e.g., trip reporting, vehicle location, communications, etc.) then the bundled systems including collision-warning functions become highly cost effective.

CONCLUSIONS

The purpose of the research presented in this paper was to determine the potential cost savings attributable to being able to warn a driver of an impending situation involving a preventable accident. The specific issue being addressed is what are the potential benefits of being able to warn an inattentive or drowsy driver of an accident situation resulting from unintentional lane change or a roadway departure. Analysis of accident data collected from six truckload motor carriers covering 345 million miles during three years found that accident costs were slightly more than one cent per mile. Accidents involving an unintentional lane change or roadway departure accounted for only 15 percent of total preventable accident costs, while accidents involving longitudinal movement accounted for slightly more than half of all accident costs. Given the relative magnitude of unintentional lane change and roadway departure accident cost, a device to perform only this function would probably not be cost beneficial. However, an onboard collision warning system which could detect several potential accident situations and particularly those involving a longitudinal maneuver are likely to be beneficial. If these systems can be bundled with other onboard ITS functions, these systems are likely to very cost effective.

REFERENCES

1. Allen, R.W., "The Driver's Role in Collision Avoidance Systems," *Collision Avoidance Systems Issues an Opportunities Workshop Proceedings*, Sponsored by ITS America, March 1994.

2. Knipling, R.R., and J.Wang. "Crashes and Fatalities Related to Drive Fatigue," *Research Note/*, U.S. Department of Transportation, National Highway Traffic Safety Administration, 1994.

3. Wang, J., and R.R. Knipling, *Single-Vehicle Roadway Department Crashes: Problem Size Assessment and Statistical Description*, Report DOT-HS-808-113, National Highway Traffic Safety Administration, 1994.