

Modeling/Analysis of Pedestrian Back-Over Crashes from NHTSA's SCI Database

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ABSTRACT

An analysis of the first 35 back-over crashes reported by NHTSA's Special Crash Investigations unit was undertaken with two objectives: (1) to test a hypothesized classification of backing crashes into types, and (2) to characterize scenario-specific conditions that may drive countermeasure development requirements and/or objective test development requirements. Backing crash cases were sorted by type, and then analyzed in terms of key features. Subsequent modeling of these SCI cases was done using an adaptation of the Driving Reliability and Error Analysis Methodology (DREAM) and Cognitive Reliability and Error Analysis Methodology (CREAM) (similar to previous applications, for instance, by Ljung and Sandin to lane departure crashes [10]), which is felt to provide a useful tool for crash avoidance technology development. This modeling effort identified contributing causes of back-over crashes, thus providing a basis for countermeasure requirements development and identifying key elements of objective test conditions for evaluating countermeasure effectiveness. This analytic work

characterized the conditions under which back-over crashes occur, driver and pedestrian characteristics, and driver behaviors preceding the crash. Of particular importance, this CREAM/DREAM analysis assisted in identifying the five most common factors leading to a back-over crash (e.g., insufficient knowledge regarding line of sight and blind spots, hidden information in the environment).

INTRODUCTION

According to General Estimates System (GES), of the nearly six million light vehicle (i.e., passenger cars, sport utility vehicles, van, and pickup trucks) crashes reported in 2005, approximately 222,000, or 3.7 percent, were backing-related crashes (defined as a vehicle striking or being struck by an obstacle or other vehicle while moving backwards) [3]. The percentage of backing crashes remained relatively stable, around 3.8 percent, between 1992 and 2005 [1]. Eberhard [1] conducted a more detailed review of all backing-related crashes and classified each crash into seven major categories that included backing and striking (100,738), striking a

parked car (64,703), striking a parallel path vehicle (23,297), struck by a vehicle in transport (20,311), striking a fixed object (9,253), striking a pedestrian (2,798), and striking a pedacyclist (794). A subset of these backing crashes can be characterized as *back-over* crashes, which occur when the driver of a vehicle unintentionally backs over a person (often a small child). Back-over crashes are a major concern and are an under-appreciated source of auto-pedestrian injuries and fatalities [2,7]. In the United States, children experience a disproportion of the severe and fatal pedestrian injuries (38% of back-over fatalities in 1998 were for children under the age of five-and, for them, fatal back-over crash risk was 3 to 7 times as high as for any other age group except those over 70) [8]. The National Highway Traffic Safety Administration's (NHTSA's) Report to Congress [8] estimates that vehicles backing into pedestrians result in 183 fatalities and between 6,700 and 7,419 injuries every year. An epidemiological investigation was conducted on the incidence of driveway back-over crashes during the years 1998-2003 in the state of Utah [9]. This investigation attempted to quantify the risk of back-over injuries to children and found that 7.09 per 100,000 children under 10 would be involved in a driveway-back-over-related injury crash.

It has been difficult to obtain accurate data regarding the magnitude of this problem, mostly because, as currently implemented, national databases such as the Fatality Analysis Reporting System (FARS) and GES only collect *traffic-related* crashes. Those crashes that occur in driveways, parking lots or other non-traffic situations are excluded from these databases. Beyond FARS and GES, relevant data are available from hospital emergency departments, death certificates, and through various media sources (e.g., the advocacy groups *Kids in Cars* and *Kids and Cars*TM). These data sources have limitations of their own. For example, hospital records include only a small subset of a representative population and typically lack the detail needed to fully understand the circumstances of the crash. Death certificates also lack the detail needed to recreate the crash incident. Newspaper sources do not present a statistically valid sample. Also, not all newspaper crash reports are retrievable through archives such as LexisNexis. As a result, various sources report different numbers of fatalities and injuries due to back-over crashes [8].

“Since 1972, NCSA's Special Crash Investigation (SCI) Program has provided NHTSA with the most in depth and detailed level of crash investigation data collected by the agency. The data collected ranges from basic data contained in routine police and insurance crash reports to comprehensive data from special reports by professional crash investigation teams. Hundreds of data elements relevant to the vehicle, occupants, injury mechanisms, roadway, and safety systems involved are collected for each of the over 200 crashes designated for study annually. SCI cases are intended to be a case-based data set useful for examining special crash circumstances or outcomes from an engineering perspective. The benefit of this program lies in its ability to locate unique real-world crashes anywhere in the country, and perform in-depth clinical investigations in a timely manner that can be utilized by the automotive safety community to improve the performance of its state-of-the-art safety systems” (<http://www.nhtsa.gov/PEOPLE/ncsa/sci.html>). In order to assist NHTSA's efforts to mitigate harm due to back-over crashes, the SCI Program conducted a national investigation into a number of reported cases. These cases can be accessed by the general public through the following link: www-nass.nhtsa.dot.gov/BIN/logon.exe/.

METHODS

In order to identify the potential contributing and causal factors of back-over crashes, a detailed analysis of 35 SCI back-over-related cases was undertaken using the methods described below. Sample cases were included that originated from the following states: Arizona, California, Florida, Hawaii, Illinois, Iowa, Michigan, Missouri, Nebraska, New Mexico, New York, North Carolina, Oregon, Texas, Tennessee, Utah, Virginia, Washington, and Wisconsin. From each of the 35 SCI technical reports, the following dependent variables were extracted for analysis:

1. Driver's age, gender, height
2. Struck pedestrian's age, gender, height, position, location, clothing
3. Whether driver was distracted
4. Vehicle model
5. Vehicle measurements (beltline height, bottom of bumper, undercarriage elements height)

6. Sight distance/line of sight
7. If other vehicles were present in area
8. Speed of vehicle
9. If backup device was installed
10. Point of impact
11. Direction of travel
12. Direction of path relative to impact point
13. Location characteristics
14. Nature of locale
15. Presence of low-lying objects
16. Driver expectation notes
17. Weather/lighting conditions
18. Fatal/Non-Fatal

Moreover, notes on drivers' expectations and the resulting sequence of events were included in the reports and entered into the analysis matrix (in short form).

An adaptation of two related methodologies, one derived from the other, was used to understand and organize contributing factors and possible causes for the 35 pedestrian back-over cases from SCI that are the subject of this report. Those methodologies are Driving Reliability and Error Analysis Methodology (DREAM) and Cognitive Reliability and Error Analysis Methodology (CREAM). The DREAM methodology was developed in Sweden by Ljung [6], and has recently been updated as Version 3.0 by Warner, Aust, Sandin, Johansson, and Bjorklund [11]. It was developed to enable systematic classification and storage of accident causation information from in-depth investigations of driving conflicts and crashes. It provides a structured way of sorting the causes and contributing factors behind crashes into a set of formally defined categories [11]. One important difference between the DREAM analysis and other techniques used to identify causal factors such as Sequentially Timed and Events Plotting (STEP) and Why-Because Analysis (WBA) is that DREAM uses predefined causal categories, whereas STEP and WBA describe events in terms of causal factors that are defined *ad hoc* [10]. This method was derived from the earlier CREAM method developed by Hollnagel [4]. Sandin and Ljung [10] demonstrated the power of this analysis technique in understanding and identifying crash types when they applied it to lane-departure crashes. In coding a set of individual lane-departure crashes with the DREAM methodology, and then classifying those cases with similar phenotypes together, they discovered that the category of lane-departure crashes is actually composed of four different crash types (i.e., phenotypes or scenarios), each associated with a unique and different linked network of contributing causes.

The data analysis described here relied heavily on the original CREAM method, with the authors of this research making adaptations suitable to driving based on their understanding from verbal reports of what had been done in DREAM (as well as from the published work of Sandin and Ljung, [10]. An English translation of DREAM (Version 2.1) was not available to the researchers, therefore the work reported here was done without the advantage of DREAM 3.0 (it was subsequently made available after the data analysis was completed). While the exact definitions of DREAM 2.1 and their updates in 3.0 may not have been precisely followed, at a general level (at the level of highest coding categories), the CREAM/DREAM method was followed as closely as possible, given what was available to the research team in the way of written material. It is for this reason that the method used here is identified as an adaptation of the CREAM/DREAM methodology.

In the CREAM/DREAM method, crashes are conceptualized as resulting from an unsuccessful interplay between the *driver*, the *vehicle-and-traffic environment*, and the *organization* responsible for shaping the conditions under which the driving occurs. Its classification scheme is built upon this conceptualization, and composed of observable effects immediately prior to the crash in the form of human actions and system events that it calls "Phenotypes." Contributing factors that may have brought about these observable effects are separately identified and are called "Genotypes." The Genotypes are organized into the three categories set forth in the basic conceptualization: Human (driver), Environment (vehicle and traffic), and Organization (i.e., the design of roads, the design of the vehicle [versus its actual operation during the incident], and vehicle/road maintenance). The methodology provides a method for linking genotypes (contributing causes) to phenotypes (observable effects immediately prior to crash) as well as for linking phenotype to phenotype. The notion is that a crash type is uniquely identifiable through its phenotype, using a metaphor from natural biological systems. In addition, application of this technique by Sandin and Ljung (2007) has demonstrated that different crash types often necessitate different countermeasure approaches (since they arise through a different network of contributing causes and effects). Thus, the CREAM/DREAM analysis was applied to pedestrian back-over crashes from SCI, to discover if it would yield new insights about contributing causes and confirm or refine proposed objective tests used to evaluate various countermeasures (particularly relative to where in the crash sequence countermeasures of different types can provide support or assistance to the driver). These categories, which are used for coding information from the in-depth crash investigations, are shown in [Table 1](#) below (adapted from Warner et al. [11]).

To further illustrate the concept behind this analysis method, a figure from Sandin and Ljung [10] has been adapted and