Motor Vehicle Crash Involvements:
A Multi-Dimensional Problem Size Assessment

Paper to be presented at:
ITS America Sixth Annual Meeting;
Intelligent Transportation: Realizing the Benefits
Houston, Texas; April 15-18, 1996

Jing-Shiam Wang
Information Management Consultants, Inc.
c/o USDOT NHTSA NRD-53, 400 Seventh Street SW, Washington, DC 20590
Phone 202-366-5666, FAX 202-366-7237

Ronald R. Knipling, Ph.D.
Office of Motor Carrier Research and Standards, Federal Highway Administration
USDOT FHWA HCS-30, 400 Seventh Street, SW, Washington, DC 20590
Phone (202) 366-4003, FAX (202) 366-8842
[formerly: Office of Crash Avoidance Research, NHTSA]

Lawrence J. Blincoe
Office of Regulatory Analysis, National Highway Traffic Safety Administration
USDOT NHTSA NPP-2 1, 400 Seventh Street SW, Washington, DC 20590
Phone 202-366-2558, FAX 202-366-2559

ABSTRACT

The size of the U.S. police-reported motor vehicle crash problem is analyzed in four dimensions: crash involvement type/role (e.g., single vehicle roadway departure, left turn across path); subject vehicle body type (i.e., passenger cars, light trucks/vans, heavy combination-unit trucks, medium/heavy single-unit trucks, and motorcycles); type of metric (i.e., crashes, involved vehicles, persons killed/injured, and monetary cost); and problem size referent (i.e., U.S. annual, per-crash, per-vehicle, per-driver, and per mile traveled). A valid assessment of market opportunities for ITS or conventional crash avoidance countermeasure requires a precise understanding of the target crash involvement types addressed, the types of vehicles likely to be equipped, and the pattern of countermeasure application (e.g., factory-installed versus "pay-as-you-go"). Monetary assessments of crash problem size may be based on narrow economic loss criteria or comprehensive societal value criteria. From a cost-benefit perspective, the most meaningful target crash problem size statistics for many ITS devices are monetary measures of the expected lifetime target crash experience of individual vehicles of different body types.

INTRODUCTION

Devices intended to prevent motor vehicle crashes are generally characterized by specificity (1); that is, they are designed to prevent a specific type of crash involvement. For example, headway/forward obstacle detection systems are designed to prevent vehicles from being in rear-end crashes as the striking vehicle. With some exceptions, such devices have little potential effects on other types of crash involvements and thus need to be assessed in terms of their potential effects on a specific target crash scenario.

NHTSA (2,3) and others (4,5) have recently conducted research to identify and define promising opportunities for the application of advanced technologies to crash prevention. The principal NHTSA effort was a large multi-disciplinary project (23) to define principal ITS target crash scenarios and identify required countermeasure actions for effective interventions. Associated accident data analyses (6,7,8,9,l0 have quantified individual target crash problems in terms of such metrics as annual number of crashes, number of injuries, and rates of occurrence. In addition, the studies have documented some of the significant differences in crash involvement patterns among various vehicle body types -- in particular passenger vehicles (i.e., cars and light trucks), combination-unit trucks, and medium/heavy single-unit trucks; also known as "straight trucks"),

NHTSA has also assessed the overall economic costs of motor vehicle crashes (1l). This study focused on direct economic losses but also provided estimates of the monetary values society places on the human consequences of crashes including functional impairment due to injury, "pain and suffering," and even loss of life. In 1990, the average economic cost of a police-reported crash was approximately $11,000, and the total economic cost of U.S.

motor vehicle crashes (police reported plus non-police-reported) was $137.5 billion (B) On a comprehensive scale incorporating derived valuations for life and "pain and suffering" in addition to direct economic loss, the estimates were $33,600 per police-reported crash and $379.4 B for the national total.

These monetary studies have provided analytical breakdowns of various categories of economic loss including property damage, economic losses due to lost production, and medical expenses. They also demonstrated the huge proportion of crash costs associated with alcohol approximately one-third of all crash costs. Recently, Miller et al (12) developed estimates of the economic costs and harm associated with specific crash types, but did not disaggregate these estimates by vehicle body type.

To date, only limited analyses have been performed of the economic costs of specific crash scenarios involving specific vehicle body types, and characterizing these costs from the standpoint of the expected "per transportation unit" lifetime crash experience of an individual vehicle (or the individual driver). Such "per unit" statistics are likely to be more meaningful than national statistics to system developers, vendors, and buyers because they provide a basis for assessing the potential cost-benefits of new systems introduced into the vehicle fleet. Disaggregation by vehicle type is important because marketing strategies for many devices usually involve initial deployment within a specific vehicle type fleet (most frequently combination-unit trucks) followed by deployment among other vehicle types.

Accordingly, this paper provides an assessment of the U.S. motor vehicle crash problem from the standpoint of a number of major crash involvement types/roles and vehicle body types. Both non-monetary (e.g., crashes, persons killed/injured) and monetary metrics are employed. In addition, the motor vehicle crash problem is viewed from the perspective of different problem size "referents"; i.e., the U.S. annual national total as well as various "per-unit" referents including per-crash, per-vehicle, per-mile,. and even per-driver. All four of these analytical dimensions -- crash type, vehicle type, problem size metric, and problem size referent -- are fundamental to a valid assessment of the potential crash amelioration benefits, and thus market opportunities, of motor vehicle safety interventions.

METHOD

Unless otherwise noted, all accident data were retrieved or derived from the 1989-93 GES and thus are intended to be representative of the population of U.S. police-reported (PR) crashes. There were four analytical dimensions: crash involvement type/role, subject vehicle body type, type of metric, and problem size referent.

Crash Involvement Type/Role

The crash involvement types/roles are primarily those which have been analyzed and defined in recent NHTSA-sponsored studies of crash causation and countermeasure applicability (3). Note that, with the exception of "all crashes," each category includes an explicit or implicit definition of the crash subject vehicle (SV). The SV is the vehicle regarded as having the critical precipitating role in the crash; for example, the left-turning vehicle in left-turn-across-path crashes. The SV is also the vehicle likely to be equipped with the crash countermeasure; e.g., the striking vehicle in rear-end crashes. In general, the SV is the vehicle whose driver is "at fault" in the crash, although there are many exceptions to this general rule. For example, some single vehicle roadway departures are precipitated by an evasive maneuver to avoid an encroaching vehicle, and some left turn across path crashes are associated with a traffic signal violation by the vehicle going straight. Crash involvement type/role categories were:

- All crashes (the universe).
- Single vehicle roadway departure (SVRD) crashes, including struck parked vehicle crashes.
- Pedestrian (first harmful event only; not pedestrian impacts occurring as a result of a prior impact).
- Rear-end, lead vehicle stopped (RR-LVS) crashes (SV = striking vehicle).
- Rear-end, lead vehicle moving (RE-LVM) crashes (SV = striking vehicle). This category includes crashes where the lead vehicle was coded as traveling more slowly than the following vehicle or coded as decelerating at the time of impact. The differentiation of RR-LVS versus RR-LVM crashes is based on police accident report (PAR) information only. RE crashes not identified as either LVS or LVM were distributed proportionately across the two subtypes.
- Lane change/merge (LC/M) crashes, not including any rear-end crashes (SV = vehicle making lane change/merge maneuver).
- Backing crashes, including both "encroachment" and "crossing path" subtypes (7) but not including pedestrian impacts (SV = vehicle making backing maneuver).
- Opposite direction (OD) crashes, including head-on and opposite-direction sideswipes (SV = encroaching vehicle). For the small number of OD crashes in which the SV was not identifiable, the SV designation was distributed among vehicle types in proportion to their known roles in other OD crashes.
- Left turn across path (LTAP) at intersection crashes (SV = left-turning vehicle).

With the exception of the "all crashes" category, the above crash types were defined in a manner which ensured mutual exclusivity. For example, the lane change/merge category excluded rear-end crashes resulting from such maneuvers. Similarly, the backing crash category excluded backing-into-pedestrian crashes.

Obviously, not all crash involvement types of current safety interest are addressed here. For example, rear-end crashes could be analyzed from the perspective of the struck vehicle to provide insights into the potential benefits of safety enhancements to rear brake light or other rear signaling systems (6). Two key intersection crash types, signalized and unsignalized perpendicular crossing path crashes (l0), have not been subjected to detailed analysis because of the difficulty of identifying the SV (i.e., the vehicle violating the right-of-way) based on GES coded variables alone for the five years under study. Limited, non-vehicle-type-specific statistics for these two crash subtypes are provided, however.

Subject Vehicle Body Type

Five vehicle types were addressed: passenger cars, light trucks/vans (LT/Vs), combination-unit trucks (CUTs), single-unit trucks (SUTs), and motorcycles (MCs) These vehicle types were defined as in previous reports (7,8,l0) and as suggested by the taxonomy of the GES Body Type variable. "Passenger cars" here include standard automobiles and derivatives. "Light truck/vans" include van-based light trucks, pickups, utility vehicles, and other light trucks of less than 4,500 kg Gross Vehicle Weight Rating (GVWR). The CUT' category includes bobtails. For all specific crash types/roles, the specified vehicle type was the SV in the crash; e.g., the left-turning vehicle in an LTAP crash.

Type of Metric

"Type of metric" refers to what is actually counted in the statistic. The current analysis counted crashes, SVs, involved vehicles, involved persons (classified by injury severity), monetary cost, and fatal equivalents. "Crashes" is self-explanatory, although it is worth noting that the number of crashes&o equals the number of SVs involved in crashes (except for "all crashes," in which no SV is defined). Two levels of "Involved vehicles" are quantified: (1) all of the vehicles of a particle body type involved in a crash (e.g., all the light trucks/vans involved in LTAP crashes, regardless of crash role) and (2) all of the vehicles involved in a crash regardless of body type

Involved persons were classified by injury severity level, and include all persons involved regardless of vehicle role or type (i.e., not just those in the SV) PAR-based KABCO severity levels were converted to Maximum Abbreviated Injury Scale (MAIS) values using conversion matrices generated for injuries occurring in crashes involving the different vehicle types based on 1982-86 -National Accident Sampling System data. In addition to a count of all persons involved in target crashes, the following three categories are presented: Not Injured (MAIS) 0), Minor-to-Moderate (MAIS) l-2), and Serious-to-Fatal (MAIS 3-Fatal). Fatality counts are not presented separately because unacceptably large sampling errors would be associated with the small fatality estimates for specific crash/vehicle types (l3) and because GES generally undercounts fatalities. These sources of error are reduced by aggregating injury data across multiple severity levels (e.g., MAIS 3, 4, 5, and Fatal).

The GES data on which this study was based provide estimates of the relative frequencies of different crash types. Sampling errors associated with GES crash, vehicle, and person estimates are not provided. For some small estimates these may be significant (l3), although the use of five year averages rather than single-year estimates reduces sampling errors.

This report also contains a number of monetary metrics of the US. crash problem size. Unlike the non-monetary accident statistics based principally on GES, most monetary metrics used in this report were adjusted to account for undercounting of police reports and for non-police-reported (NPR) crashes. These adjustments were derived from Blincoe and Faigin (ll).

Monetary assessments of crash problem size may be based on narrow economic loss criteria or comprehensive societal value criteria (ll). This report provides both economic (E) and comprehensive (C) monetary crash problem size metrics. Estimates from Blincoe and Faigin (ll) were adjusted to 1994 price levels using a variety of cost adjusters including Consumer Price Index (CPI) statistics and increases in average hourly earnings (14). Economic costs (E) represent the value of goods and services which must be purchased as a result of motor vehicle crashes; they include medical care, legal services, emergency services, vehicle repair services, and insurance administration costs. In addition, economic costs include the value of both workplace and household productivity lost due to death or injury, the value of travel delay to non-involved motorists, and costs incurred due to workplace disruption when an employee is killed, injured, or delayed.

In contrast, comprehensive (C) costs incorporate not only economic losses, but a valuation for less tangible consequences such as “pain and suffering” and loss of life. These values have been derived from “willingness-to-pay” studies which examine marketplace behavior to determine the value that people place on reducing risk. There is far more uncertainty involved with these estimates than those based on direct economic costs. However, these less tangible impacts are often the most devastating aspects of serious motor vehicle injuries, and they should be incorporated whenever a direct comparison is made of costs and benefits, or of the potential benefits of competing countermeasures. Failure to include consideration of these aspects could result in a serious underestimation of the true harm caused by motor vehicle crashes or the societal benefits associated with proposed safety countermeasures.

In this report, both E and C costs are expressed in present value terms (i.e., 1994 dollars) using a 4% annual discount rate to value future economic losses such as future lost wages. Discounting is necessary to reflect the decreased (or “discounted”) value of future economic losses in present value terms. A 4% annual discount rate was also applied to calculations of expected monetary cost “per-vehicle over operational life” and “per driver over driver career.” These metrics are defined and discussed later in this Method section.

One way to simplify the metrics of motor vehicle crash consequences is to express these consequences in terms of "fatal equivalents." This is achieved by dividing the annual monetary cost of any given target crash type by the cost of a fatality. For example, annual C cost of all crashes is $407.2 B and the C cost of a fatality is $2,927,820 The total annual "fatal equivalents" associated with all crashes equals $407.2 B/$2,927,820 = 139,080. NHTSA uses C monetary cost and this method to derive a cost-per-equivalent-fatality for their analyses of proposed safety regulations. For this study, fatal equivalents provide a convenient single-number basis for comparing crash consequences across crash types and vehicle types.

Problem Size Referent

Crash problem sizes must be expressed in relation to a referent; for example, most traffic crash statistics refer to a particular time (e.g., a year) and place (the United States). Six different referents are used in this report:

- U.S. annual (average of 1989-93)
- Per police-reported target crash
- Per mile traveled (for convenience, per 100 Million Vehicle Miles Traveled; M VMT). Passenger car and LT/V VMT were obtained from Walsh (15). All other VMT statistics were obtained from Highway Static 16,17,18,19,20).
- Per registered vehicle annually (for convenience, per 1,000 registered vehicles annually). Passenger car and LT/V registrations were based on Shelton (21) All other vehicle registration statistics were obtained from Highway Static .
- Per manufactured vehicle over expected operational life
- Per driver over expected driving career.

The first four of the above referents are self-explanatory and commonly used in traffic safety research. The fifth (per manufactured vehicle over its expected operational life) is relevant to quantifying a crash problem in relation to the average or expected experience of individual vehicles which may, for example, be equipped at the factory or dealership with a particular safety device lasting the life of the vehicle. The expected number of target crash involvements over a vehicle's life is derived by the formula:

$$\text{Expected number} = \frac{\text{Average annual number of involvements X Average vehicle}}{\text{Average number of registered vehicles}}$$

The following values were used for average vehicle life by vehicle type: all vehicles, 13.1 years; passenger cars, 11.8 years; LT/Vs, 16.0 years; CUTS and SUTs, 14.7 years; and MCs, 7.5 years (22,1).

The referent "per driver over expected driving career" attempts to capture the expected lifetime driving experience of the average driver. It is derived by the formula:

$$\text{Expected number} = \frac{\text{Average annual number of involvements X Average driving carrer (years)}}{\text{Average number of registered drivers}}$$

The average life expectancy of a beginning driver (e.g., 17 year old) person today is approximately 76 years (23). Such a person might drive for a total of 55-60 years. For example, a person beginning to drive at age 17 and ceasing driving at age 75 would have driven for 58 years. This "years of driving" value -- 58 years -- is used here although it is recognized to be an approximation. The extrapolation of five years of crash data across 58 years of driving is also acknowledged to be inexact, since many crash-relevant factors (e.g., driver behavior, road safety, vehicle safety, emergency medicine, etc.) may change over such a long time period.

"Per driver over expected driving career" statistics are derived for "all vehicle types" only. Disaggregation by vehicle type would be highly problematic because many drivers drive several different vehicle types during their careers and may drive certain vehicle types (e.g., large trucks, MCs) for only a few years.

Statistics: Metric/Referent Combinations

Each metric above could be applied to each referent to constitute a specific crash statistic; for example, crashes (a metric) per year in the U.S. (a referent). The current analysis includes the statistics listed below. All vehicle, injury, and monetary measures of crash problem size include all individuals and vehicles involved in the crash; not just those in the SV. All statistics on crashes, involved vehicles, involved persons, and all "per crash" statistics (monetary value, fatal equivalents) are based on PR crashes as retrieved from GES Monetary and fatal equivalent statistics for the U.S., per mile traveled, per registered vehicle, per vehicle over operational life, and per driver over driving career all include both PR and NPR crashes. These are indicated below.

- Annual U.S. number of PR crashes (also equals the number of SVs involved in these crashes)
- Annual number of vehicles involved (of the particular body type) in PR target crashes
- Annual number of vehicles involved (regardless of body type) in PR target crashes

Annual U.S. number of persons involved in PR crashes
- Total
- Not injured (MAIS 0)
- Minor-to-Moderate (MAIS l-2)
- Serious-to-Fatal (MAIS 3-Fatal)

- Vehicle involvement rate in PR crashes
  - Per 100 million vehicle miles traveled (M VMT)
  - Per 1,000 registered vehicles
- Expected involvements in PR crashes
  - Per vehicle over operational life
  - Per driver over driving career (“all vehicles” only)
- Annual U.S. monetary cost (includes PR + NPR crashes)
  - Economic cost (E)
  - Comprehensive cost (C)
- Average monetary cost (E and C)
  - Per PR crash
  - Per 100 M VMT (PR + NPR crash involvements)
  - Per registered vehicle annually (PR + NPR crash involvements)
- Expected monetary cost (E and C)
  - Average per vehicle over operational life (PR + NPR crash involvements)
  - Average per driver over driving career (“all vehicles” only; PR + NPR crash involvements)
- Fatal equivalents
  - Annual national total (PR + NPR crash involvements)
  - Average per PR crash
  - Per vehicle over operational life (PR + NPR crash involvements).

Expected monetary costs over vehicle life were calculated using the same vehicle usage-by-vehicle-age projections used by NHTSA to analyze its safety regulations and, as noted, using a 4% annual discount rate. MC usage-by-age projections were based on the passenger car pattern, but they were accelerated to reflect the shorter operational life of MCs. The “all vehicles” projection was a weighted average of the individual vehicle types. Driver discounting was based on the 1989-93 distribution of crash involvements by driver age, The cumulative discounting for the different vehicle types and for drivers (reflecting their different operational lives) was as follows: all vehicles, 17.45%; passenger cars, 16.73%; LT/Vs, 19.82%; CUTS and SUTs, 18.48%; MCs, 11.69%; drivers, 44.56%. For example, the discounted ‘all vehicles” expected monetary costs over vehicle life was derived by first obtaining a gross cost estimate (calculated using the formula shown earlier) and then reducing this gross value by 17.45 %.

No discounting was applied when deriving fatal equivalents per vehicle over operational life from the annual national total. Thus, injuries of equivalent severity are assigned identical fatal equivalent values regardless of when they were expected to occur during the vehicle’s operational life.

RESULTS AND DISCUSSION

Results are shown in Table 1 for all crashes and Tables 2-9 for specific crash types. The statistics provided are too numerous to describe completely. This discussion will focus on major findings, caveats, and clarifications of appropriate interpretations.

The following rounding rules have been applied to all the statistics presented in this report. For crash and injury statistics, values have been rounded to the nearest 1,000 if they are 2,000 or greater, or to the nearest 100 if they are less than 2,000. Other statistics, including rates and monetary costs, have been rounded in a manner to ensure that the smallest value in each row contains at least two, and usually three, significant digits. As a result of rounding, some table entries may not sum to the posted totals. In addition, percentage estimates and the derived statistics in the tables were calculated before numbers were rounded.

"All Crashes" Statistics

At the highest level of analysis are the statistics for all crashes and all vehicles types. During the years 1989-93 there were an average of 6,261,OOO PR crashes annually involving 10,964,OOO vehicles and 15,905,OOO persons. There were 500.41 vehicle involvements in PR crashes per 100 M VMT and 59.33 involvements per 1,000 registered vehicles. Each vehicle can be expected to be involved in 0.7789 PR crashes during its operational life and each driver can be expected to be involved in 3.7383 PR crashes during his or her driving career.

The average annual total economic cost of motor vehicle crashes (PR+NPR) was $163.4 B. Average annual national comprehensive costs were $407.2 B. The average PR-crash caused direct economic losses of $17,129 and had a comprehensive cost of $48,672. Not shown in Table 1 are the economic costs of NPR crashes; Blincoe and Faigin (ll) estimated that 22 % of all injuries, mostly minor, are not accounted for in PARS In addition, 48 % of all property-damage-only (PDO) crashes are unreported.

A hypothetical vehicle traveling 100 M miles would be involved in crashes (PR + NPR) with a total value of $13,056,954 (E) or $32,547,839 (C). On average, each registered vehicle annually was involved in crashes with a value of $1,548 (E) or $3,859 (C). Over the total operational life of the vehicle, these values are extrapolated to discounted values of $16,778 (E) or $41,824 (C). Extrapolation of the 1989-93 statistics across a 58-year driving career (discounted to current value) indicates that each driver would be expected to be involved in crashes with a value of $54,078 (E) or $134,803 (C).

It is important to understand that the above monetary statistics are all inclusive of all vehicles and individuals involved in crashes, not just those of the SV. To determine non= inclusive statistics (i.e., statistics that do not include damage and injuries occurring in other involved vehicles), one would multiply the above monetary statistics by the ratio of total crashes to total vehicle involvements or (6,261,000/10,964,000 = 0.571). Thus, for example, over its operational life, the average motor vehicle would be associated with crash costs of $16,778*0.57 = $9,580 (E) or $41,824*0.57 = $23,881 (C) exclusive of any costs associated with damage to other vehicles (and their occupants) involved in its crashes. These non-inclusive monetary statistics are not shown in Tables l-9.

For the individual crash types, it is generally true that the SV driver is "at fault" in the crash, and thus may be considered responsible for all the consequences of the crash. However, it is not true that drivers are "at fault" in all their crash involvements (i.e., those shown in Table 1 for "all crashes'). If one makes the simplistic assumption that every crash has one "at fault" driver/vehicle, then the same non-inclusive monetary costs presented in the above paragraph can be used as the estimates of expected monetary costs of all crashes for which a driver/vehicle will be "at fault" during a vehicle's operational life. To the extent that the "at fault" driver is held financially liable for crash consequences, these statistics represent the expected liability of the owners of individual vehicles.

Fatal equivalents statistics indicate an annual national average of 139,080 fatal equivalents associated with motor vehicle crashes. Each PR-crash results in an average of 0.01662 fatal equivalents (the total of all involved persons) and each vehicle over its operational life can be expected to be involved in crashes resulting in 0.00132 fatal equivalents (inclusive of all persons involved).

The above statistics can be used to assess potential benefits from the application of specific safety interventions, whether real or hypothetical. For example, a vehicle-based device lasting the life of the vehicle and capable of reducing all crash involvements by 5 % would have a societal economic value of $16,778*0.05 = $839 (E) or $41,824*0.05 = $2,091 (C) for each equipped vehicle. These represent current monetary values because the monetary costs projections were discounted. This monetary benefit would be shared by the owners of equipped vehicles and those in non-equipped vehicles who would have crashed with the equipped vehicle had the device not been installed.

Similarly, a new driver education program or similar intervention capable of reducing a driver's lifetime crash involvements by 10% would have a current societal economic value of $54,078*0.10 = $5,408 (E) or $134,803*0.1 = $13,480 (C) for each young driver exposed. This benefit would be shared by the driver, his or her passengers, and other motorists and non-motorists (e.g., pedestrians) whose crashes with the subject driver were prevented.

As noted previously, the "per vehicle over operational life" and "per driver over driving career" monetary cost estimates are discounted to reflect the current economic value of future costs. For drivers, this discounting is substantial (44.56%). The **non-discounted** value of all expected crash involvements for the typical 58-year driving career is $97,543 (E) or $243,151 (C). Applying the cumulative discount of 44.56% yields the discounted value presented in Table 1.

Another way of expressing the non-discounted driver values presented in the paragraph above is to consider per-driver-per-year crash costs. On an annual basis, the average driver can be expected to be involved in crashes with a total value (inclusive of all involved vehicles and people) of $1,682 (E) or $4,192 (C). The potential cost-benefits of ongoing, continuously-applied safety programs such as public service announcements might be assessed using these values.

Crash Type Comparisons

Table 10 provides some comparative all-vehicle-type statistics on the eight specific crash types addressed in Tables 2-9, plus two additional crash types, signalized and unsignalized intersection perpendicular crossing path (SI/PCP and UI/PCP) crashes (l0) These 10 crash types represent essentially the same ITS target crash scenarios addressed in the recent NHTSA-sponsored crash problem analysis (2,3). For each crash scenario, three summarizing statistics are provided: annual U.S. number of PR crashes, average monetary cost (E) per PR crash, and annual U.S. monetary cost. The three statistics represent comparative measures of PR crash frequency, average PR crash severity, and total societal problem size (PR+NPR) Other statistics could have been chosen from the tables to provide essentially the same comparisons.

Table 10 shows that the most numerous crash categories are rear-end crashes (1.45 M annual crashes for RE-LVS + RE-LVM), SVRD (1.3 1 M annual crashes), and intersection crossing path crashes (1.30 M annual crashes for LTAP + SI/PCP + UI/PCP). The most severe crash types are OD ($46,155 per crash) and pedestrian crashes ($38,606 per crash). The highest annual U.S. total monetary costs are associated with intersection crossing path crashes ($39.0 B for the three subtypes combined), RE crashes ($35.2 B for the two subtypes combined), and SVRD crashes ($3 1.3 B).

A specific caveat relating to the backing crash problem size is that the majority of the crash problem shown in Tables 7 and 10 is represented by crossing path backing crashes whereby a backing vehicle backs into traffic is struck by a another vehicle (7) Crossing path backing crashes are probably less amenable to technological solution (i.e., rear object detection) than are encroachment backing crashes, in which a backing vehicle backs into a ‘stationary object.

Vehicle Type Comparisons

For all crashes and for each of the individual crash types, passenger cars and light trucks/vans dominate the statistics on total number of crashes and associated injuries and monetary costs. For example, a comparison of the annual national total economic cost (E) row in Table 1 indicates that total costs for all vehicle types combined were $163.4 B. The costs of crashes involving the individual vehicle types were: passenger cars, $149.5 B; LT/Vs, $57.8 B; CUTs, $8.5 B; SUTs, $5.1 B; and MCs, $5.9 B. The individual vehicle types add up to greater than $163.4 B because each vehicle type statistic is inclusive of all vehicles (and people) involved in their crashes.

Passenger cars and LT/Vs dominate the national crash picture in terms of numbers of crashes and associated total monetary costs. Thus, from a national perspective, safety interventions are not likely to have dramatic effects unless they address the huge passenger car and LT/V crash populations.

Passenger cars represent more than three times as many vehicle crash involvements than LT/Vs, but otherwise these two large vehicle populations are highly similar in their crash profiles. Compared to passenger cars, LT/Vs have somewhat lower involvement rates, monetary costs per 100 M VMT, and average annual monetary costs per registered vehicle. On the other hand, since LT/Vs have longer operational lives, their expected monetary costs per vehicle over their operational lives are slightly higher.

CUTS are associated with a very different crash size profile, however. Although they have low crash rates per 100 M VMT and, surprisingly, low monetary crash costs per 100 M VMT, their high mileage exposures, long operational lives, and high crash severities (24,22) combine to give them very high per-vehicle crash costs. Indeed, for "all crashes" and each of the eight specific crash types/roles, CUTS stand out as having the highest per-vehicle crash cost and thus as the most promising platform for achieving positive cost-benefits on a per-vehicle basis. For example, in Table 1 it is shown that the per-vehicle life monetary costs of all CUT crashes is $64,332 (E) or $166,349 (C). These costs are about four times as great as those for any other vehicle type. From a percentage cost-benefit standpoint, this means that crash avoidance systems can generally afford to be considerably more expensive and/or less effective for CUTS and still be more attractive than the same device installed on other vehicle types. Still, the national impact of such deployments will be limited; only 3.4% of all crashes and 5.2 % of associated monetary costs are associated with CUT crashes.

SUTs have a less dramatic crash picture than do CUTs. SUTs represent 1.4 % of all vehicle crash involvements and they have low involvement rates, both on a per mile traveled and per registered vehicle basis annually. Their crashes are almost twice as severe, measured by average monetary cost per PR crash, as those of "all vehicles," but they are less severe than those of CUTS or MCs The per vehicle produced monetary costs of SUT crashes are only 22.7 % of those of CUTS and are even lower than per-vehicle costs for "all vehicles."

The attractiveness of CUTS as a target for safety interventions applies to interventions applied on an annual basis as well as those lasting the life of a vehicle. Annually, on average, each CUT was involved in crashes with a monetary value of $5,368 (E) or $13,882 (C). This is about four times as great as the comparable values for all vehicle types combined. Thus, an annual safety intervention (e.g., vehicle safety inspections) would have more than three times the payoffs for CUTS as for other vehicle types, assuming equivalent intervention costs and effectiveness.

An important caveat which bears repeating is that the current CUT and SUT monetary cost statistics are based on an assumption of zero unreported crash costs. Since in reality there undoubtedly are some such crashes, the current monetary cost statistics understate CUT and SUT crash costs somewhat. However, this underestimation is not likely to be more than a few percentage points.

The crash picture of MCs presents another sharp contrast to that of other vehicle types. MCs represent a relatively small percentage of the overall national crash picture, but their per-crash costs are high; e.g., $51,957 per PR crash (E) versus $17,129 for all vehicle types combined, Of course, this reflects the relatively high vulnerability of MC riders to crash injuries. The average police-reported MC crash is associated with 0.06412 fatal equivalents -- nearly four times greater than the value for all vehicle types combined. In addition, MCs have a rate of involvement in crashes per vehicle mile traveled that is nearly twice that of all vehicle types combined. These two factors have a multiplicative effect in making MC travel nearly five times as costly in terms of monetary costs per mile traveled than that of all vehicle types combined.

The irony of the MC crash picture -- exactly opposite to that of CUTS -- is that MCs have low mileage exposure and relatively short operational lives. These factors give MCs the nmailest per-vehicle produced crash costs of all the vehicle types. From a strict monetary cost-benefit perspective, this makes MCs a relatively unattractive platform for safety devices lasting the life of the vehicle, assuming equivalent costs and effectiveness levels. On the other hand, MCs are an extremely attractive platform for safety devices having a limited mileage life. For example, assuming comparable effectiveness, a general safety device (i.e., targeting all crashes) installed for 1,000 miles on an MC would produce about five times the expected benefit as the same device installed for 1,000 miles on other vehicle types.

For the individual vehicle types the current statistics do not provide information to disaggregate "inside" versus "outside" damage, injuries, and associated costs. However, it is well known that there are major differences across vehicle types in this disaggregation, with CUTS and MCs representing the extremes. A supplemental analysis (not shown in the tables) indicates that approximately 67.2 % of the monetary costs of combination-unit truck crashes are associated with damage and injuries outside the truck; e.g., occupants of other involved vehicles. In contrast, only 12.5% of the monetary costs of MC crashes are "outside" the MC. (The small number of crashes involving multiple CUTS or multiple MCs were excluded from this analysis.)

Crash Type/Vehicle Type Interactions

The crash type/vehicle type statistics provided in Tables 2-9 are too numerous to discuss in detail. For each vehicle type, SVRD crashes and RE crashes (when the RE-LVS and RF-LVM categories are combined) are the most numerous of those shown here. Intersection crossing path crashes are also numerous (10), although statistics for only one subcategory of these crashes (i.e., LTAP crashes) are presented here for individual vehicle types.

Comparison of crash statistics across various crash types and vehicle types reveals several notable examples of overrepresentation or underrepresentation of particular vehicle types in particular crash types/roles. For example, LT/Vs represent 22.7 % of all vehicles involved in crashes-but 36.2% of SVs in backing crashes.

The largest relative over involvement of CUTS is in LC/M crashes. CUTS represent only 2 .0 % of vehicles involved in crashes but represent 8.5 % of vehicles involved in LC/M crashes as the SV. On a per vehicle over operational life basis, CUT involvements in LC/M crashes are 11 times as costly as those of SUTs and 13 times as costly as those of all vehicle types combined. CUT are also relatively underrepresented in certain crash types; for example, they represent only 1.1% of the SVs in RE-LVS crashes and 0.5 % of those in LTAP crashes, Nevertheless, for every crash type, CUTS have the highest crash costs per vehicle over the operational life of the vehicle.

The only major overrepresentation of SUTs is in backing crashes; they represent 1.4 % of vehicles involved in all crashes but account for 5.3 % of SVs in backing crashes. CUTS and SUTs show a different pattern of SV involvements in RE-LVS versus RE-LVM crashes; CUTS have more RE-LVM crashes whereas SUTs have more RE-LVS involvements. This likely reflects the different exposure patterns of these two large truck types; CUTS accumulate most of their mileage on highways whereas SUTs accumulate relatively more mileage on secondary/local roads.

MCs are relatively overrepresented in SVRD crashes. They represent 0.8 % of all vehicles involved in crashes but 1.2% of SVRD crash involvements. Further, MC SVRD crashes are approximately four times as severe as those of any other vehicle type. On a per mile traveled basis, MC SVRD crashes are more than nine times more costly than those of all vehicle types combined. The per vehicle produced monetary costs of MC SVRD crashes are actually slightly higher than the “all vehicles” average, an exception to the general rule that MC per vehicle produced crash costs are generally low compared to other vehicle types.

Conclusion

This paper has attempted to develop target crash problem size metrics that have relevance to specific traffic safety initiatives. Safety initiatives may vary dramatically in their patterns of application. For example, driver education programs, highway design improvements, and vehicle countermeasure installations all require very different evaluation perspectives. Objective assessment of a safety initiative to be applied nationally would obviously benefit from consideration of national target crash problem size statistics. However, few vehicle-based ITS safety initiatives are likely to be deployed in this manner during their early stages of implementation. Instead, individual buyers decide whether they want their new vehicle(s) equipped with a particular safety option or, perhaps, manufacturers decide to equip a particular vehicle type/make/model with the device as standard equipment.

For crash countermeasures deployed on a "pay as you go" basis (for example, enhanced brake pads with a limited mileage life), statistics on the average monetary costs of target crashes per mile traveled (or other exposure measure) provide an accurate assessment of potential device cost-benefits (after crash mitigation effectiveness estimates have been factored in). However, most vehicle-based crash countermeasures, whether conventional or ITS, are installed at the factory and are likely to function for the entire life of those vehicles. For such devices, measures of crash involvement rate per mile traveled or per any other measure of exposure (e.g., number lane changes, number of left turns across traffic) are likely to have little practical relevance to cost-benefit assessment.

Instead, the most meaningful target crash problem size statistics relating to devices lasting the life of the vehicle are measures of the expected lifetime target crash experience of individual vehicles of different types. Per-vehicle-produced monetary crash cost statistics incorporate data on both the probability of crashes and their human and material consequences, but reduce that data to the level of the purchased vehicle. For many ITS safety initiatives, per-vehicle-produced monetary crash cost statistics are Likely to be the most useful problem size statistics to enlightened decision makers.

REFERENCES

1. Knipling, RX. Could advanced technology have prevented this crash? IVHS Review, IVHS America. pp. 23-44, Fall, 1993.
2. Najm, W.G., Mironer, M.S., and Fraser, L.C. Analysis target crashes and ITS/countermeasure actions. Paper presented at the ITS America 5th Annual Meeting, Washington, DC, March, 1995.
3. Najm, W.G., Mironer, M., Koziol, J.S. Jr., Wang, J.S., and Knipling, R.R. Examination Target Vehicular Crashes and Potential ITS Countermeasures Report for Volpe National Transportation Systems Center, DOT HS 808 263, DOT-VNTSC-NHTSA-95-4, May, 1995.
4. Fancher, P., Kostyniuk, L., Massie, D., Ervin, R., Gilbert, K., Reiley, M., Mink, C., Bogard, S., and Zoratti, P. Potentialty Applications of Advanced Technology Technical Report Number FHWA-RD-93-080, January, 1994.
5. Deering, R.K. General Motors Safety Center, Crash avoidance technologies to assist the driver, Presentation at the American Society of Civil Engineers Conference Innovations in Highway Safety AR- May, 1994.
6. Knipling, R.R., Wang, J.S., & Yin, H.M. Rear-EndCrashes Problem Size Assessment and Statitical Description, NHTSA technical report, Publication Number DOT HS 807 994, May, 1993.
7. Wang, J.S. and Knipling, R.R. Hacking Crashes: Problem Size Assessment and Statistical JkacQ&n, NHTSA technical report, Publication Number DOT HS 808 074, January, 1994.

8. Wang, J.S. and Knipling, R.R. Lane Change/ Merge Crashes; Problem Size Assessment and Statistical NHTSA technical report, Publication Number DOT HS 808 075, January, 1994.

9. Wang, J.S. and Knipling, R.R. Single Vehicle Roadway Departure Crashes Problem Size Assessment and Statistical Description, NHTSA technical report, Publication Number DOT HS 808 113, March, 1994.

10. Wang, J.S. and Knipling, R.R. Intersection Crossing Path Crashes: Problem Size Assessment and Statistical description, NHTSA technical report, Publication Number DOT HS 808 190, September, 1994.

11. Blincoe, L.J. and Faigin, B.M. The Economic Cost [redacted]or Vehicle Crashes, 1990. NHTSA Technical Report DOT HS 807 876, September, 1992.

12. Miller, T., Lestina, D., Galbraith, M., Schlax, T., Mabery, P., Deering, R., Massie, D., and Campbell, K. Understanding the harm from U.S. motor vehicle crashes. Paper presented at the 39th Annual Conference for Association for the Advancement of Automotive Medicine, Chicago, October, 1995.

13. NHTSA. Technical Note for 1988, 1989, 1990 National Accident Sampling System Genral Estimates System, Report No. DOT HS 807 796, February, 1992.

14. Blincoe, L.J. The Economic Cost of Motor Vehicles Crashes, 1994. NHTSA Technical Report No. TBD, 1st Quarter, 1996. (report citation to be updated).

15. Walsh, W.H. Review of adjustments to vehicle miles traveled data (memo from the NHTSA National Center for Statistics and Analysis), June, 1995.

16. Federal Highway Administration (FHWA). Highway 1989, FHWA-PL-90-003, 1990.

17. FHWA. Highway Statistics 1990, FHWA-PL-91-003, 1991.

18. FHWA. Highway Statistics 1991, FHWA-PL-92-025, 1992.

19. FHWA. Highway Statistics 1992, FHWA-PL-93-023, 1993.

20. FHWA. Highway Statistics 1993, FHWA-PL-94-023, 1994.

21. Shelton, T.S.T. Registered Penenger Cars and Light Trucks. DOT HS 808 235, February, 1995.

22. Miaou, S.P. Study of Vehicle Scrappage Rates Oak Ridge National Laboratory, Oak Ridge, TN, August, 1990.

23. National Center for Health Statistics, Public Health Service, U.S. Department of Health and Human Services, Vital Statistic of the United States for 1988 Year published: 1991.

24. Clarke, R.M., Radlinski, R. W., and Knipling, R.R. Improved Brake System for Commercial Motor Vehicles, NHTSA technical report, Publication Number DOT HS 807 706, April, 1991.

TABLES

(Next 10 Pages)

Table 1. Statistics for All Crashes

statistics		All Vehicles	Passenger Cars	Crash Involving Light Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
Annual # of PR Crashes		6,261,000	5,307,000	2,209,ooo	214,000	154,000	89,ooo
Annual # of Veh Involved of This Veh Type in PR Crashes*		10,964,000	7,929,ooo	2,485,000	221,000	157,000	90,000
Annual # of all Vehicles Involved in PR Crashes*		**10,964,ooo**	**9,688,000**	4,141,000	392,000	287,000	145,000
Annual U.S. # of Person Involved in PR Crashes*		15,905,oOO	14,101,000	5,932,ooo	494,000	376,000	183,000
Not Injured (0)*		12,278,000	10,936,000	4,684,000	399,000	307,000	WJQO
Minor to Moderate (MAIS l-2)*		3,433,OOo	3,020,OoO	1,183,000	85,000	65,ooO	78,000
Serious to Fatal (MAIS 3-Fatal)*		194,000	146,000	65,000	9,ooo	5,000	15,000
Vehicle **Involvement Rate in PR Crashes**							
Per 100 Million VMT		500.41	556.15	415.59	225.52	289.33	927.60
Per 1,000 Registered Vehicles Annually		**59.33**	64.91	47.87	135.14	36.60	21.54
Expected Involvements in PR Crashes							
Over Vehicle Operational life		**0.7789**	0.7640	0.7684	1.9866	0.5380	0.1615
Per Driver Over Driver Career							
Annual U.S. Monetary Cost *	**(E)**	$163.4 B	$149.5 B	$57.8 B	$8.5 B	$5.1 B	$5.9 B
	(C)	$407.2 B	$337.8 B	$140.0 B	$22.0 B	$11.7 B	$20.7 B
Average Monetary Cost							
Per PR Crash*	**(E)**	$17,129	$18,281	$16,862	$36,381	$3 1,079	$51,957
	03	$48,672	$46.930	$47,060	$89,504	$67,491	$187,735
Per 100 Million VMT*	**09**	$13,056,954	$15,660,737	$10,874,553	$8,958,650	$9,655,995	$61,954,607
	03	$32,547,839	$35,396,694	&6,340,401	$23,165,253	$22,026,914	$215,560,041
Per Registered Vehicle Annually*	**(E)**	$1,548	$1,828	$1,253	$5,368	$1,221	$1,438
	(C)	$3,859	$4,131	$3,034	$13,882	52,786	$5,004
Expected Monetary Cost							
Per Vehicle Over Operational Life*	**(B) d**	$16,778	$17,915	$16,120	$64,332	$14,635	$9,526
	(C) d	$41,824	$40,492	$39,046	$166,349	$33,386	$33,144
Per Driver Over Driving Career	**(B) d**	$54,078					
Total Annual National Fatal Eguivalents*		139,080	115,375	47,819	7,391	3,940	7,066
Average Fatal Equivalents Per PR Crash*		0.01662	0.01603	0.01607	0.03010	0.02270	0.06412
Expected Fatal Equivalents Over Vehicle Life*		0.00132	0.00141	0.00104	0.00467	0.00094	0.00171

Legend: PR-Police Reported; B-Billion; E-Economic Cost; C-Comprehensive Cost; d-Discounted

* **Inclusive; i.e. includes all crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.**

Table 2. Statistics for Single Vehicle Roadway Departure (SVRD) Crashes

Statistics		All Vehicles	Passenger Cars	Crash Involving Light Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
4nuual I of PR Crashes		1,310,000	907,000	323,000	31,000	23,000	16,000
Annual # of Veh Involved of This Veh Type in PR Crashes		1,310,000	907,000	323,000	31,000	23,000	16,000
Annual U.S. # of Person Involved in PR Crashes			1,277,000	435,000	34,000	27,000	19,000
Not Inqiured (0)		1,190,000	849,000	290,000	27,000	22,000	3,000
Miuor to Moderate MAIS l-2)		553,000	397,000	133,000	7,000	4,000	12,000
Serious to Fatal (MAIS 3-Fatal)		48,000	32,000	12,000	800	300	3,000
Vehicle Involvement Rate in PR Crashes							
Per 100 Million VMT		59.79	63.62	53.97	31.64	41.91	167.65
Per 1,000 Registered Vehicles Annually		7.09	7.43	6.22	18.96	5.30	3 89
Expected involvements in PR Crashes							
Over Vehicle Operational life		0.0931	0.0874	0.0998	0.2787	0.0779	0.0292
Per Driver Over Driver Career							
Annual U.S. Monetary Cost	(E)	$31.3 B	$21.5 B	$7.7 B	$559 M	$360 M	$1.3 B
	(C)	$95.1 B	$64.7 B	$23.5 B	$1.4 B	$832 M	$4.8 B
Average Monetary Cost							
Per PR Crash*	WI	$17,527	$17,337	$17,503	$16,652	$14,620	964,281
	(C)	$57,292	$56,113	$57,619	$40,168	$32,411	$240,395
Per 100 Million VMT	(E)	$1,427,657	$1,509,766	$1,281,053	$570,032	$665,120	$13,337,980
	(C)	$4,342,358	$4,539,110	$3,928,388	$1,437,271	$1,537,059	$49,260,761
Per Registered Vehicle Anuually	(E)	$169	$176	$148	$342	$84	$3 10
	(C)	$515	$530	$453	$861	$194	$1,144
Expected Monetary Cost							
Per Vehicle Over Operational Life	(E) d	$1,835	$1,727	$1,899	$4,093	$1,008	$2,051
	(C) d	$5,580	$5,192	$5,823	$10 321	$2,330	$7 574
Per Driver Over Driving Career	(E) d	$5,913					
	(C) d	$17,958					
Total Annual National Fatal Equivalents		32,497	22,104	8 ,022	474	280	1,634
Average Fatal Equivalents Per PR Crash		0.01957	0.01917	0.01968	0.01351	0.01090	0.08211
Expected Fatal Equivalents Over Vehicle Life		0.00191	0.00177	0.00199	0.00347	0.00078	0.00259

Legend: PR-Police Reported; B-Billion; M-million; E-Economic Cost; C-Comprehensive Cost; d-Discounted

Table 3. Statistics for Pedestrian/Cyclist (Ped/Cyc) Crashes

Statistics		AU Vehicles	Passenger Cars	Crash Involving Light Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
Annual # of PR Crashes		176,000	133,000	37,000	1,200	1,500	2,000
Annual # of Veh Involved of This Veh Type in PR Crashes*		178,000	134,000	37,000	1,200	1,500	2,000
Annual # of all Vehicles Involved in PR Crashes*		178,000	134,000	37,000	1,300	1,500	2,000
Annual U.S. # of Person Involved in PR Crashes*		415,000	315,000	85,000	3,000,	3,000	5,000
Not Injured (0)*		245,000	188,000	50,000	1,400	1,800	1,400
Minor to Moderate (MAIS l-2)*		155,000	117,000	32,000	900	**1,300**	3,000
Serious to Fatal (MAIS 3-Fatal)*		15,000	10,000	3,000	400	200	500
Vehicle **Involvement Rate in PR Crashes**							
Per 100 Million VMT.		8.12	9.39	6.15	1.21	2.79	24.07
Per 1,000 Registered Vehicles Annually		0.96	1.10	0.71	0.73	0.35	0.56
Expected Involvements in PR Crashes							
Over Vehicle Operational life		0.0126	0.0129	0.0114	0.0107	0.0052	0.0042
Per Driver Over Driver Career		0.0607					
Annual U.S. Monetary Cost *	**(E)**	$9.1 B	$6.1 B	$2.2 B	$300 M	$128 M	$199 M
	(C)	$28.8 B	$18.7 B	$7.2 B	**$1.1** B	$411 M	$711 M
Average Monetary Cost							
Per PR Crash*	**(E)**	$38,606	$33,780	$46,170	$211,119	$73,802	$67,537
	(C)	$130,093	$111,437	$158,520	$752,357	$232,174	$246,918
Per 100 Million VMT*	**(E)**	$413,258	$425,362	$370,987	$305,582	$237,103	$2,050,054
	(C)	$1,314,705	$1,314,695	$1,211,911	$1,095,259	$759,696	$7,319,462
Per Registered Vehicle Annually*	**(E)**	$49	$50	$43	$183	$30	$48
	(C)	$156	$153	$140	$656	$96	$170
Expected Monetary Cost							
Per **Vehicle Over Operational Life+**	**(E) d**	$531	$487	$550	$2,194	$359	$315
	(C) d	$1,689	**$1,504**	**$1,796**	**$7,865**	**$1,151**	**$1,125**
Per Driver Over Driving Career	**(E) d**	$1,728					
	(C) d	$5,499					
Total Annual National Fatal Equivalents*		9,839	002	2,475	361	138	243
Average Fatal Equivalents Per PR Crash*		0.04443	0.03806	0.05414	0.25303	0.07808	0.08434
Expected Fatal Equivalents Over Vehicle Life*		0.00058	0.00051	0.0061	0.00265	0.00039	0.00038

Legend: PR-police Reported; B-Billion; E-Economic Cost; C-Comprehensive Cost; **d-Discounted**

* **Inclusive; i.e. includes sll crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the** columns **are not additive.**

Table 4. Rear-End, Lead Vehicle Stopped (RE-LVS) Crashes

Statistics		All Vehicles	Crash Involving Striking Vehicle as: Passenger Cars	Light Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
Annual # of PR Crashes		974,000	696,000	229,000	11,000	12,000	3,000
Annual # of Veh Involved of This Veh Type iu PR Crashes*		2,144,000	1,331,000	319,000	13,000	14,000	4,000
Annual # of all Vehicles Involved in PR Crashes*		2,144,000	1,532,000	504,000	24,000	27,000	7,000
Annual U.S. # of Person Involved in PR Crashes*		3,107,000	2,020,000	652,000	27,000	34,000	9,000
Not Injured (0)*		2,469,000	1,608,000	523,000	21,000	26,000	6,000
Minor to Moderate (MAIS 1-2)*		618,000	401,000	125,000	6,000	7,000	3,000
Serious to Fatal (MAIS 3-Fatal)*		20,000	11,000	4,000	300	300	300
Vehicle Involvement Rate as SV in PR Crashes							
Per 100 Million VMT		44.46	48.85	38.30	10.98	22.98	33.51
Per 1,000 Registered Vehicles Annually		5.27	5.70	4.41	6.58	2.91	0.78
expected Involvement as SV in PR Crashes							
Over Vehicle Operational life		0.0692	0.0671	0.0708	0.0967	0.0427	0.0058
Per Driver Over Driver Career		0.7308					
Annual U.S. Monetary Cost *	(E)	$23.3 B	$15.4 B	$5.0 B	$338 M	S4Q7M	$135 M
	(C)	346.1 B	$29.0 B	$9.6 B	$640 M	$789 M	$405 M
Average Monetary Cost							
Per PR Crash*	(E)	$14,127	$12,749	$12,668	$30,249	$31,122	$29,497
	(C)	$32,721	$28,290	$28,644	$54,764	$57.794	$96,910
Per 100 Million VMT*	(E)	$1,062,422	$1,078,985	$842,776	$344,433	$752,346	S1,391,205
	(C)	$2,102,510	$2,037,239	$1,609,532	$652,615	$1,458,281	$4,172,068
Per Registered Vehicle Annually*	(E)	$126	$126	$97	$206	$95	$32
	(C)	$249	$238	$185	$391	$184	$97
Expected Monetary Cost							
Per Vehicle Over Operational Life*	(E) d	$1,365	$1,234	$1,249	$2,473	$1,140	$214
	(C) d	$2,702	$2,330	$2,386	$4,686	$2,210	$641
Per Driver Over Driving Career	(E) d	$9,681					
	(C) d	$19,159					
Total Annual National Fatal Equivalents*		15,735	9,921	3,278	215	265	138
Average Fatal Equivalents Per PR Crash*		0.01118	0.00966	0.00978	0.01842	0.01944	0.03310
Expected Fatal Equivalents Over Vehicle Life*		0.00092	0.00080	0.00081	0.00158	0.00074	0.00022

Legend: PR-Police Reported; SV-Subject Vehicle (Striking Vehicle); B-Billion; M-Million; E-Economic Cost; C-Comprehensive Cost; d-Discounted

* Inclusive; i.e. includes all crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Table 5. Rear-End, Lead Vehicle Moving (RELVM) Crashes

Statistics		Crash Involving Striking Vehicle as: All Vehicles	Passenger Cars	Light Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
Annual # of PR Crashes		480,000	329,000	118.000	10,000	7,000	3,000
Annual # of Veh Involved Of This Veh Type in PR Crashes*		1,057,000	624,000	165,000	13,000	8,000	4,000
Annual # of all Vehicles Involved in PR Crashes*		1,057,000	724,000	260,000	22,000	15,000	7,000
Annual U.S. I of Person Involved in PR Crashes*		1,522,OOO	966,OOO	341,000	28,000	17,000	8,000
Not Injured (0)*		1,212,000	772,000	273,000	21,000	14,000	5,000
Minor to Moderate (MAIS l-2)*		299,000	188,000	66,000	6,000	3,000	3,000
Serious to Fatal (MAIS 3-Fatal)*		ll,ooo	6,000	2,000	500	200	500
Velicle Involvement Rate as sv in PR Crashes							
Per 100 Million VMT		21.92	23.07	19.76	10.41	12.53	34.14
Per 1,000 Registered Vehicles Annually		2.60	2.69	2.28	6.24	1.59	0.79
Expected Involvements as SV in PR Crashes							
Over Vehicle Operational life		0.0341	0.0317	0.0365	0.0917	0.0233	0.0060
Per Driver Over Driver Career		0.3603					
Annual U.S. Monetary Cost *	(E)	$11.9 B	$7.5 B	$2.8 B	$493 M	$203 M	$177 M
	(C)	$24.7 B	$14.7 B	$5.6 B	$1.1 B	$378 M	$578 M
Average Monetary Cost							
Per PR Crash*	(E)	$14,962	$13,383	$13.789	$39,899	$28,812	$39,846
	(C)	$36,200	$30,774	$32,863	$92,511	$51,449	$138,811
Per 100 Million VMT*	(E)	$544,789	$526,92 l	$460,892	$447,828	$374.483	$1,822,309
	(C)	$1,127,OO3	$1,030,725	$930,693	$1,089,790	$697.722	$5,954,418
Per Registered Vehicle Annually*	(E)	$65	$62	$53	$268	$47	$42
	(C)	$134	$120	$	$653	$88	$138
EXpected Monetary Cost							
Per Vehicle Over Operational Life*	(E) d	$700	$603	$683	$3,216	$568	$280
	(C) d	$1,448	$1,179	$1,380	$7,826	$1,058	$916
Per Driver Over Driving Career	(E) d	$4,964					
	(C) d	$10,270					
Total Annual National Fatal Equivalents*		8,434	5,019	1,901	360	127	197
Average Fatal Equivalents Per PR Crash*		0.01236	0.01051	0.01122	0.03111	0.01730	0.0474 l
Expected Fatal Equivalents Over Vehicle Life*		0.00049	0.00040	0.00047	0.00263	0.00036	0.00031

Legend: PR-Police Reported; SV-Subject Vehicle (Striking Vehicle); B-Billion; M-Million; E-Economic Cost; C-Comprehensive Cost; d-Discounted

* Inclusive; i.e. includes all crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Table 6. Lane Change/Merge (LC/M) Crashes

Statistics		Crash Involving Striking Vehicle as: All Vehicles	Passenger Cars	Light Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
Annual # of PR Crashes		234,000	155,000	55,000	20,000	5,000	1,000
Annual # of Veh involved of This Veh Type in PR Crashes*		476,000	267,000	65,000	20,000	5,000	1,000
Annual # of all Vehicles Involved in PR Crashes*		476,000	315,000	111,000	4,000	11,000	2,000
Annual U.S. # of Person Involved in PR Crashes+		689,00	$484,000	160,000	53,000	13,000	3,000
Not Injured (0)*		595,000	400,000	140,000	46,000	12,000	2,000
Minor to Moderate (MAIS 1-2)*		91,000	62,000	19,000	7,000	1,500	800
Serious to Fatal (MAIS 3-Fatal)*		3,000	2,000	600	400	100	100
Vehicle Involvement Rate as SV in PR Crashes							
Per 100 Million VMT		10.68	10.85	9.13	20.04	9.93	10.29
Per 1,000 Registered Vehicles Annually		1.27	1.27	1.05	12.01	1.26	0.24
Expected Involvements as SV in PR Crashes							
Over Vehicle Operational life		0.0166	0.0149	0.0169	0.1766	0.0185	0.0018
Per Driver Over Driver Career							
Annual U.S. Monetary Cost *	(E)	$4.4 B	$2.9 B	$1.0 B	$487 M	$116 M	$37 M
	(C)	$7.8 B	$4.8 B	$1.8 B	$815 M	$166 M	$108 M
Average Monetary Cost							
Per PR Crash*	(E)	$10.316	$18,565	$18,673	$24,78 1	$21,641	$37,197
	(C)	$21,748	$3 1,272	$32,991	$41,430	$30,916	$108,573
Per 100 Million VMT*	(E)	$201,921	$201,374	$170,452	$496,702	$214,835	$382,609
	(C)	$355,063	$339,201	$301,156	$830,404	$306,909	$1,116,771
Per Registered Vehicle Annually*	(E)	$24	$24	$20	$298	$27	$9
	(C)	$42	$40	$35	$498	$39	$26
Expected Monetary Cost							
Per Vehicle Over Operational Life*	(E) d	$259	$230	$253	$3,567	$326	$59
	(C) d	$465	$338	$446	$5,963	$465	$172
Per Driver Over Driving Career	(E) d	$1,701					
	(C) d	$2,991					
total Annual National Fatal Equivalents*		2,657	1,652	615		56	37
Average Fatal Equivalents Per PR Crash*		0.00743	0.01068	0.01127	0.01393	0.01040	0.03708
Expected Fatal Equivalents Over Vehicle Life*		0.00016	0.00013	0.00015	0.00201	0.00016	0.00006

Legend: PR-Police Reported; SV-Subject Vehicle (Lane Changing/Merging Vehicle); B-Billion; M-Million; E-Economic Cost; C-Comprehensive Cost; d-Discounted

+ Inclusive; i.e. includes all crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g.. a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Table 7. Backing Crashes (Encroachment & Crossing Path)

Statistics		All vehicles	Passenger Cars	Light Trucks/ Vans	Combination- Unit Trucks	SingleUnit Trucks	Motorcycles
			Crash Involving Striking Vehicle as				
Annual # of PR Crashes		171,000	88,000	62,000	10,000	9,000	300
Annual # of Veh Involved of This Veh Type in PR Crashes*		332,000	150,000	73,000	9,000	9,000	300
Ammal # of all Vehicles Involved in PR Crashes*		332,000	170,000	122,000	17,000	17,000	500
Ammal U.S. # of Person Involved in PR Crashes+		456,000	235,000	167,000	21,000	22,000	600
Not Injured (0)*		406,000	207,000	151,000	19,000	20,000	400
Minor to Moderate (MAIS l-2)*		49,000	27,000	16,000	2,000	2,000	200
Serious to Fatal (MAIS 3-Fatal)*		1,000	500	200	100	0	0
Vehicle Involvement Rate as SV in PR Crashes							
Per 100 Million VMT		7.81	6.17	10.33	9.39	16.35	2.74
Per 1,000 Registered Vehicles Annually		0.93	0.72	1.19	5.63	2.07	0.06
Expected Involvements as SV in PR Crashes							
Over Vehicle Operational life		0.0122	0.0085	0.0191	0.0828	0.0304	0.0005
Per Driver Over Driver Career		0.1133					
Ammal U.S. Monetary Cost*	(E)	$2.7 B	$1.4 B	$912 M	$221 M	$172 M	$12 M
	(C)	$4.0 B	$2.1 B	$1.2 B	$390 M	$211M	$37 M
Average Monetary Cost							
Per PR Crash*	(E)	$7,848	$8,081	$6,863	$23,523	$19,876	$32,072
	(C)	$13,881	$14,597	$10,302	$38,901	$23,776	$112,151
Per 100 Million VMT*	(E)	$123,436	$98,766	$152,556	$225,078	$318,603	$119,712
	(C)	$183,315	$149,794	$198,708	$397,362	$390,652	$385,864
Per Registered Vehicle Annually*	(E)	$15	$12	$18	$135	$40	$3
	(C)	$22	$17	$23	$238	$49	$9
Expected Monetary Cost							
Per Vehicle Over Operational Life*	(E) d	$159	$113	$18	$1,616	$483	
	(C) d	$236	$171				
Per Driver Over Driving Career	(E) d	$993					
	(C) d	$1,475					
Total Annual National Fatal Equivalents*		1,372	729	406	131	71	
Average **Fatal Equivalents Per PR Crash***		0.00474	0.00499	0.00352	0.01380	0.00800	0.03831
Expected Fatal Equivalents Over Vehicle Life*		0.00008	0.00006	0.00010	0.00096	0.00020	0.00002

Legend: PR-Police Reported; SV-Subject Vehicle (Backing Vehicle); B-Billion; M-Million; E-Economic Cost; C-Comprehensive Cost; d-Discounted

- Inclusive; i.e. includes all crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Table 8. Opposite Direction (OD) Crashes

Statistics		All Vehicles	Passenger Cars	Liiht Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
		Crash Involving Striking Vehicle as					
Annual # of PR Crashes		190,000	137,000	44,000	4,000	2,000	1,800
Annual # of Veh Involved of This Veh Type in PR Crashes*		378,000	230,000	58,000	4,000	3,000	1,800
Annual # of all vehicles Involved in PR Crashes*		378,000	274,000	87,000	7,000	5,000	4,000
Annual U.S. # of Person Involved in PR Crashes*		557,000	408,000	127,000	10,000	6,000	5,000
Not Injured (0)*		386,000	274,000	91,000	7,000	5,000	3,000
Minor to Moderate (MAIS l-2)*		154,000	121,000	33,000	2,000	1,300	1,600
Serious to Fatal (MAIS 3-Fatal)*		17,000	13,000	3,000	300	200	700
Vehicle **Involvement Rate as SV in PR Crashes**							
Per 100 Million VMT		8.68	9.63	7.30	3.77	4.47	18.21
Per 1,000 Registered Vehicles Annually		1.03	1.12	0.84	2.26	0.56	0.42
Expected Involvements as SV in PR Crashes							
Over Vehicle Operational life		0.0135	0.0132	0.0135	0.0332	0.0083	0.0032
Per Driver Over Driver Career		0.1289					
Annual U.S. Monetary Cost*	(E)	$11.8 B	$9.0 B	$2.3 B	$262 M	$142 M	$347 M
	(C)	$37.3 B	$28.6 B	$7.1 B	$773 M	$401 M	$1.3 B
average Monetary Cost							
Per PR Crash+	(E)	$46,155	$49,213	$38,986	$62,425	$52,449	$157,718
	(C)	$156,008	$165,490	$128,769	$178,018	$143,391	$585,179
Per 100 Million VMT*	(E)	$536,528	$632,634	$388,108	$267,123	$261,832	$3,568,903
	(C)	$1,702,577	$2,004,033	$1,188,473	$788,412	$741,539	$13,037,082
Per Registered Vehicle Annually*	(E)	**$64**	$74	$45	$160	$33	**$83**
	(C)	**$202**	$234	$137	$472	$94	$303
Expected Monetary Cost							
Per Vehicle Over Operational Life*	(E) d	$689	$724	$575	$1,918	$397	$549
	(C) d	$2,188	**$2,292**	$1,762	$5,662	$1,124	$2,005
Per Driver Over Driving Career	(E) d	$4,417					
	(C) d	$14,017					
Total Amutal National Fatal Equivalents*		12,742	9,759	2,427	260	135	432
Average Fatal Equivalents Per PR Crash*		0.05328	0.05652	0.04398	0.05987	0.04822	0.19987
Expected Fatal Equivalents Over Vehicle Life*		0.00075	0.00078	0.00060	0.00190	0.00038	0.00068

Legend: PR-Police Reported; SV-Subject Vehicle (Encroaching Vehicle); B-Billion; M-Million; E-Economic Cost; C-Comprehensive Cost; **d-Discounted**

* Inclusive; i.e. includes all crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Table 9. Left Turn Across Path (LTAP) Crashes

Statistics		Crash Involving Striking Vehicle as: All Vehicles	Passenger Cars	Light Trucks/ Vans	Combination-Unit Trucks	Single-Unit Trucks	Motorcycles
Annual # of PR Crashes		396,000	318,000	71,000	2,000	2,000	900
Annual # of Veh Involved of This Veh Type in PR Crashes*		792,000	571,000	87,000	3,000	2,000	1,000
Annual # of all vehicles Involved in PR Crashes*		792,000	637,000	141,000	5,000	4,000	1,900
Annual U.S. # of Person Involved in PR Crashes*		1,178,000	948,000	209,000	6,000	6,000	3,000
Not Injured (0)*		865,000	696,000	155,000	5,000	4,000	1,600
Minor to Moderate (MAIS l-2)*		297,000	241,000	51,000	1,400	1,600	800
Serious to Fatal (MAIS 3-Fatal)*		16,000	11,000	3,000	200	100	100
Vehicle Involvement Rate as SV in PR Crashes							
Per 100 Million VMT		18.07	22.34	11.82	2.44	4.09	9.65
Per 1,000 Registered Vehicles Annually		2.14	2.61	1.36	1.46	0.52	0.22
Expected Involvements as SV in PR Crashes							
Over Vehicle Operational life		0.0281	0.0307	0.0219	0.0215	0.0076	0.0017
Per Driver Over Driver Career		0.2700					
Annual U.S. Monetary Cost *	(E)	$11.8 B	$9.1 B	$2.2 B	$140 M	$74 M	$61 M
	(C)	$29.1 B	$21.7 B	$5.6 B	$405 M	$152 M	$201 M
Average Monetary Cost							
Per PR Crash*	(E)	$19,675	$18,598	$20,728	$52,558	$31,391	$49,125
	(C)	$54,912	$50,432	$59,413	$146,154	$62,468	$170,988
Per 100 Million VMT*	(E)	$540,522	$639,112	$368,647	$142,819	$136,261	$627,334
	(C)	$1,329,060	$1,522,608	$931,771	$412,824	$281,402	$2,067,781
Per Registered Vehicle Annually*	(E)	$64	$75	$42	$86	$17	$15
	(C)	$158	$178	$107	$247	$36	$48
Expected Monetary Cost							
Per Vehicle Over Operational Life*	(E) d	$695	$731	$546	$1,026	$207	$96
	(C) d	$1,708	$1,742	$1,381	$2,964		$318
Per Driver Over Driving Career	(E) d	$4,477					
	(C) d	$11,009					
Total Annual National Fatal Equivalents*		9,946	7,415	1,903	136	51	69
Average Fatal Equivalents Per PR Crash*		0.01876	0.01723	0.02029	0.04915	0.02101	0.05840
Expected Fatal Equivalents Over Vehicle Life*		0.00058	0.00059	0.00047	0.00100	0.00014	0.00011

Legend: PR-Police Reported; SV-Subject Vehicle (Left Turning Vehicle); B-Billion; M-Million; E-Economic Cost; C-Comprehensive Cost; d-Discounted

* Inclusive; i.e. includes all crash involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Table 10. Crash Type Comparisons (all vehicle types combined, 1989-93 average)

Statistic: Crash Type	Annual U.S. Crashes	Average Cost (E) Per PR Crash	Annual U.S. Monetary Cost (E)
All Crashes	6,261,000	$17,129	$163.4 B
SVRD Crashes	1,310,000	$17,527	$31.3 B
Pedestrian Crashes	176,000	$38,606	$9.1 B
RE-LVS Crashes	974,000	$14,127	$23.3 B
RE-LVM Crashes	480,000	$14,962	$11.9 B
LC/M Crashes	234,000	$10,316	$4.4 B
Backing Crashes	171,000	$7,848	$2.7 B
OD Crashes	190,000	$46,155	$11.8 B
LTAP Crashes	396,000	$19,675	$11.8 B
SI/PCP Crashes	266,000	$20,748	$8.3 B
UI/PCP Crashes	633.000	$19,603	$18.9 B

ABBREVIATIONS AND ACRONYMS

B	Billion
C	Comprehensive Cost
CPI	Consumer Price Index
CUT	Combination-Unit Truck
E	Economic Cost
GES	General Estimates Systems
GVWR	Gross Vehicle Weight Rating
ITS	Intelligent Transportation Systems
LC/M	Lane Change/Merge
LTAP	Let? Turn Across Path
LTN	Light Trucks/Vans
M	Million
MAIS	Maximum Abbreviated Injury Scale
MC	Motorcycle
NPR	Non-Police-Reported
OD	Opposite Direction
PR	Police-Reported
PAR	Police Accident Report
PDO	Property Damage Only
RE	Rear-End
RE-LVM	Rear-End, Lead Vehicle Moving
RE-LVS	Rear-End, Lead Vehicle Stopped
SI/PCP	Signalized Intersection/Perpendicular Crossing Path
s v	Subject Vehicle
SVRD	Single Vehicle Roadway Departure
SUT	Single-Unit Truck
UI/PCP	Unsignalized Intersection/Perpendicular Crossing Path
VMT	Vehicle Miles Traveled