

Opportunities for Reducing Casualties in Far-side Crashes

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ABSTRACT

This paper uses the National Automotive Sampling System/Crashworthiness Data System (NASS/CDS) to estimate the population of front seat occupants exposed to far-side crashes and those with MAIS 3+ and fatal injuries. Countermeasures applicable to far-side planar crashes may also have benefits in some far-side rollovers. The near-side and far-side rollover populations with MAIS 3+ injuries and fatalities are also calculated and reported. Both restrained and unrestrained occupants are considered. Populations are subdivided according to ejection status – not ejected, full ejection, partial ejection and unknown ejection. Estimates are provided for the annual number of MAIS 3+ injuries and fatalities that occur each year in each category for the following belt use scenarios: (1) belt use as reported in NASS and (2) 100% belt use. In scenario 1, the exposure and casualties for the unbelted population are also shown.

About 34% of the MAIS 3+F injuries in side crashes are in far-side crashes. More than half of the MAIS 3+F injuries in rollover are in far-side rolls. The annual population of MAIS 3+F injuries in near-side planar crashes was found to be 14,074. The corresponding number of far-side MAIS 3+F injuries in far-side planar crashes is 7,260. The combined planar and roll MAIS 3+F injuries that occur in far-side crashes is 17,125. For a 100% restrained population, the estimated numbers of MAIS 3+F and fatal injuries in far-side planar and rollover crashes were estimated to be 8,194 and 2,090, respectively.

METHODOLOGY AND DATABASES

In this study, National Automotive Sampling System/Crashworthiness Data System (NASS/CDS) for the years 1995 to 2004 was used to examine the opportunities for reducing casualties in far-side planar and rollover crashes.

The National Highway Traffic Safety Administration (NHTSA) maintains the NASS/CDS database of vehicle crashes in the United States. The NASS/CDS is a stratified sample of light vehicles involved in highway crashes that were reported by the police and involved sufficient damage that one vehicle was towed from the crash scene.

In the NASS/CDS data query, far-side occupants in planar crashes were defined as drivers in vehicles with right side damage or right front passengers in vehicles with left side damage. Drivers in rollover crashes with clockwise vehicle rotation were classified as being in far-side rollovers. The converse was true for the right front passenger.

Each NASS/CDS case contains a weighting factor that is used by the NHTSA to extrapolate the individual cases to the national numbers. The distributions to follow are based on the NASS/CDS weighted events. In the analysis to follow, the populations will be limited to front seat occupants, age 12 and older. It is anticipated that any countermeasures developed would initially apply to this population.

In the tables and analysis to follow, serious and fatal injuries are designated as MAIS 3+F. This designation applies to all injuries MAIS 3 and greater and all fatalities, including those coded with MAIS 0, 1, 2 and 7 injuries. It was found that 13% of the fatalities were not coded as having MAIS 3, 4, 5, and 6 level injuries. Consequently, these fatalities can be missed in queries that only examine MAIS 3+ injuries.

Table 1 shows the annual distribution of MAIS 3+F injuries in side impacts and rollovers by belt use, crash direction and crash mode. The injury data in Table 1 was weighted. The raw number of MAIS 3+F injuries in far-side planar and rollover crashes for the years 1995-2004 was 2,007.

Table 1. Annual MAIS 3+F Injuries from NASS/CDS in Near-side and Far-side Crashes by Crash Type, Direction and Belt Use – Weighted Data

Crash Type/ Belt Use	Planar	Roll	Total
Far Belted	2,166	3,540	5,706
Far Unbelted	5,095	6,325	11,419
Far Total	7,260	9,865	17,125
Near Belted	7,360	3,532	10,892
Near Unbelted	6,714	5,551	12,264
Near Total	14,074	9,083	23,157
Near and Far Total	21,334	18,948	40,282
% Due to Far Side	34%	52%	43%

CLASSES OF EJECTION IN FAR-SIDE CRASHES

Table 2 shows the annual number of relevant front seat occupants exposed to far-side crashes and the number of MAIS 3+F injuries by ejection status. Both planar and rollover far-side crashes are included in the data. The “Eject-Unk” designation is assigned to cases where ejection occurred but the extent was unknown. In subsequent analysis, beginning with Table 3, the data in the “Ejection”, “Part Eject”, and “Eject-Unk” categories has been aggregated into the single category “All Ejection”. The Unknown category has been distributed between “No Ejection” and “All Ejection” in proportion to the relative size of these categories.

Table 2. Annual Exposed Occupants and MAIS 3+F Injuries in All Far-side Crashes by Ejection Extent

Ejection Extent	Belted		Unbelted	
	Occup.	3+F	Occup.	3+F
No Eject	351,085	5,069	103,458	6,663
Ejection	63	51	7,200	3,688
Part Eject	1,799	521	2,674	994
Eject-Unk	29	5	32	22
Unknown	381	60	402	51
Total	353,357	5,705	113,766	11,419

For belted occupants in far-side planar and rollover crashes, there are 572 occupants with MAIS 3+F injuries among the 1,862 ejected and partially ejected occupants. The vast majority of these injured occupants (1,799) were partial ejections. For unbelted occupants there are 4,682 annual MAIS 3+F injuries among 9,874 ejected occupants. The majority of the unbelted ejections (7,200) were complete ejections.

FATALITY FRACTION IN FAR-SIDE CRASHES

For the overall population of MAIS 3+ F injuries, more than 50% are at the lowest level – MAIS 3. Consequently, the lowest severity injuries have a large influence on any observations made from the combined MAIS 3+F data. One approach to overcoming this deficiency is to weight each injury according to its average cost. This approach leads to the Harm quantity that has been widely used to assess the magnitude of

opportunities for casualty reduction. This method has been used in past analysis of far-side injuries [Gabler, 2005]. Another method, applied here, is to examine the fatality content of the MAIS 3+F injuries.

Table 3 shows the percentage of fatalities for the MAIS 3+F injuries summarized in Table 2. There were only nine unweighted belted fatalities in the No/Roll All Ejection category as compared to 127 for the unbelted cases. Consequently, the accuracy of the 73% fatality fraction for belted No/Roll/All Ejection cell is questionable due to insufficient data.

Table 3. Fraction of Fatalities in MAIS 3+F Cells for Belted and Unbelted Occupants in Far-side Crashes by Presence of Rollover and/or Ejection

Rollover & Ejection Status	Fatality Fraction	
	Belted	Unbelted
Roll No Ejection	20%	24%
Roll All Ejection	34%	46%
No/Roll No Ejection	20%	19%
No/Roll All Ejection	73%	53%
All Far-side	22%	32%

BELT USE IN FAR-SIDE CRASHES

Table 4 displays the belt use rate as reported in NASS/CDS for far-side crashes. The belt use is shown for all occupants, those with MAIS 3+F injuries and those fatally injured. The belt use rate is further broken down according to the presence or absence of rollover and ejection. Among occupants in all far-side crashes including, both planar and rollover crashes, the belt use rate was 76%. However, it was only 33% for MAIS 3+F and 26% for fatal injuries.

Table 4. Belt Use Rate for All Occupants, MAIS 3+F and Fatalities in Far-side Crashes by Presence of Rollover and/or Ejection

Rollover & Ejection Status	Belt Use Rate		
	Occup.	3+F	Fatals
Roll No Ejection	77%	51%	47%
Roll All Ejection	18%	13%	10%
No/Roll No Ejection	77%	35%	36%
No/Roll All Ejection	6%	3%	4%
All Far-side	76%	33%	26%

ROLLOVER AND EJECTION IN FAR-SIDE CRASHES

Table 5 shows the distribution of occupants in far-side crashes by the presence or absence of rollover and ejection. The distribution of MAIS 3+F and fatal injuries is also shown. The percentages in the columns add to 100%. The annualized number for each category is shown in the bottom row of the table. The percentages in the (MAIS)3+F and fatal injuries columns provide an indication of the relative magnitude of the opportunities

for injury reduction, based on the NASS/CDS recorded belt use.

Table 5. Distribution of Occupants, MAIS 3+F and Fatalities in Far-side Crashes by Presence of Rollover and/or Ejection; Belt Usage as in NASS

Rollover & Ejection Status	Belts as Used		
	Occup.	3+F	Fatals
Roll No Ejection	26.5%	34%	26%
Roll All Ejection	2.0%	24%	37%
No/Roll No Ejection	71.0%	35%	23%
No/Roll All Ejection	0.5%	7%	13%
Annual Numbers	467,123	17,125	4,931

Table 6 shows data similar to Table 5, except it is restricted to the unbelted population in NASS/CDS.

Table 6. Distribution of Occupants, MAIS 3+F and Fatalities in Far-side Crashes by Presence of Rollover and/or Ejection; All Unbelted Occupants

Rollover & Ejection Status	All Unbelted		
	Occup.	3+F	Fatals
Roll No Ejection	25%	25%	19%
Roll All Ejection	7%	31%	44%
No/Roll No Ejection	66%	34%	20%
No/Roll All Ejection	2%	10%	17%
Annual Numbers	113,766	11,419	3,660

Table 7 shows the distribution of occupants, MAIS 3+F injuries and fatal injuries for a population that is 100% belted. To estimate the magnitude of these populations, the unbelted population was added to the belted population, applying the same proportions of ejection that existed in the NASS/CDS belted population. The injury risks for the belted population were used to estimate the serious injuries and fatalities for 100% belt use.

Table 7. Distribution of Occupants, MAIS 3+F and Fatalities in Far-side Crashes by Presence of Rollover and/or Ejection; 100% Belt Use Rate

Rollover & Ejection Status	100% Belt Use		
	Occup.	3+F	Fatals
Roll No Ejection	27%	52%	49%
Roll All Ejection	0.5%	10%	15%
No/Roll No Ejection	73%	37%	34%
No/Roll All Ejection	0.04%	0.7%	2%
Annual Numbers	467,123	8,194	2,090

INJURY RATES BY ROLLOVER AND EJECTION

Table 8 displays the injury rates for the belted and unbelted populations in NASS/CDS. The rates are the number of MAIS 3+F injuries per 100 occupants

exposed to the same crash environment. In this case the crash environments are the presence or absence of rollover and ejections in far-side crashes.

Table 8. Severe and Fatal Injuries in Far-side Crashes by Presence of Rollover and/or Ejection; Belted and Unbelted

Rollover & Ejection Status	MAIS 3+F/100 Exposed	
	Belted	Unbelted
Roll No Ejection	3.1	9.8
Roll All Ejection	30.9	45.3
No/Roll No Ejection	0.8	5.2
No/Roll All Ejection	25.3	55.3
All Far-side	1.6	10.0

DISCUSSION

Table 1 shows the annual distribution of MAIS 3+F injuries in side-impact planar and rollover crashes. It may be noted that the population of MAIS 3+F injuries in near-side planar crashes is 14,074. Mitigation of these crashes is the subject of the FMVSS 214 side impact regulation that requires crash testing. The corresponding number of far-side MAIS 3+F injuries in planar crashes is 7,260. In our earlier research where we examined modeling and testing of far side crashes, we found that the initial occupant motion in far-side rollovers is generally similar to that in far-side planar crashes [Digges, 2005]. Consequently, injury mitigation systems might be able to address some of the casualties in both planar and rollover crashes. The total annual population of MAIS 3+F injuries in far-side planar and rollover crashes was found to be 17,125. This figure exceeds the serious injuries in near-side crashes and suggests the need for further examination of the casualty reduction opportunities in far-side crashes.

Head injury from impact with the opposite vehicle side structure has been found to be a significant source of severe injuries in far-side planar crashes [Digges 2001, Fildes 1991 and 1995, Gabler 2005]. Countermeasures, such as the inflatable head protection devices used in near-side crashes may also have benefit in far-side crashes. These or other countermeasures may also reduce the risk of ejection. Such a countermeasure would be particularly valuable to reduce casualties to unbelted occupants.

Table 2 shows the distribution of the 17,125 MAIS 3+F in far-side planar and rollover crashes distributed by restraint usage and ejection status. The table shows that there are 5,705 belted MAIS 3+F's that might benefit from advanced restraint technology. Another 4,682 unbelted ejected or partially ejected might benefit from ejection prevention technologies. This combination yields over 10,000 MAIS 3+F's as prime candidates for mitigation through advanced far-side protection.

The MAIS 3+F data in Table 2 does not adequately indicate the value of reducing ejection and partial

ejection. The fatality fractions shown in Table 3 further illuminate this point. For far-side belted occupants, 22% of the MAIS 3+F's are fatalities. The fatality fraction for the unbelted MAIS 3+F's is 32%. However, for unbelted ejections, the fatality fraction is about 50%. Ejections carry a much higher percentage of fatalities than exist in the non-ejected MAIS 3+F's.

Lack of belt usage strongly influences the ejection risk as shown in Table 4. This table shows that the overall belt use rate is 76%. However, for ejections and partial ejections the belt use rate is between 6% and 18%. As shown in Table 2, most of the belted ejections are partial ejections. The overall belt use rates for the MAIS 3+F's and fatalities are shown to be 33% and 26%, respectively.

Tables 5, 6 and 7 show the relative opportunities for casualty reduction in far-side crashes according to the extent of belt usage. The tables partition the occupants and casualties according to the presence or absence of rollover and ejection. Table 5 addresses population as currently recorded in NASS with a far-side belt use rate of 76%. The largest opportunity for addressing MAIS 3+F's is the no ejection far-side planar crash with 35% followed by the no ejection rollover with 34%. The largest fatality reduction opportunity is the far-side rollover with ejection with 37% of the fatalities.

As shown in Table 6, the unbelted population exposed to far-side rollover with ejection has a high percentage for both MAIS 3+F (31%) and fatalities (44%). These fractions exceed the values for rollover without ejection. The latter fractions are 25% for MAIS 3+F and 19% for fatalities.

The extrapolation of the NASS to estimate the opportunities for a 100% belted population is shown in Table 7. For this population, 8,194 MAIS 3+F's and 2,090 fatalities remain. The far-side planar crash continues to account for about 38% of the MAIS 3+F's and 36% of the fatalities in far-side planar and rollover crashes.

Table 8, provides a further analysis to illustrate the relationships between ejection and increased risk of severe injury. This relationship shows that for the unbelted, a large fraction of those ejected suffer severe injuries. The rates of MAIS 3+F injuries per 100 ejected unbelted occupants are 45.4 and 55.3 for non-rollover and rollover, respectively. The injury fractions are lower for belted occupants because their ejections are primarily partial ejections which carry a much lower injury risk.

CONCLUSIONS

About 43% of the MAIS 3+F injuries in side crashes and rollovers occur in far-side crashes. More than half of the MAIS 3+F injuries in rollover are in far-side rolls. The population of MAIS 3+F injuries in near-side planar crashes was found to be 14,074. The corresponding

number of far-side MAIS 3+F injuries in planar crashes is 7,260. The combined planar and roll MAIS 3+F injuries that occur in far-side crashes is 17,195.

Countermeasures to reduce far-side casualties may also provide benefits to reduce far-side ejections in both rollover and planar crashes. For the NASS/CDS belt usage of 76%, approximately 31% of MAIS 3+F and 50% of the far-side fatalities are associated with ejections. There are 4,684 MAIS 3+F injured unbelted ejected or partially ejected occupants that might benefit from ejection prevention technologies. Another 5,705 MAIS 3+F belted occupants might benefit from advanced restraint technologies. This combination yields 10,000 MAIS 3+F's as prime candidates for mitigation through advanced far-side protection.

For a 100% restrained population, the estimated numbers of MAIS 3+F and fatal injuries in far-side planar and rollover crashes were estimated to be 8,194 and 2,090, respectively. Of these populations 38% of the MAIS 3+F and 36% of the fatal injuries were in far-side planar crashes.

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