Title: Frequency and Cost of Crashes, Fatalities, and Injuries Involving Disabled Vehicles

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Abstract

Objective: To quantify the total number and cost of crashes, fatalities, and injuries that could be addressed by improved conspicuity of disabled vehicles to approaching traffic.

Methods: Using the Fatality Analysis Reporting System (FARS) and the Crash Report Sampling System this study defines three crash scenarios where insufficient conspicuity of a disabled vehicle ("low conspicuity emergency") resulted in injury or death: Scenario 1) Moving vehicle strikes non-moving vehicle following an initial event; Scenario 2) Pedestrian (primarily a motorist who has exited their vehicle) is struck while tending to a disabled or stopped vehicle; and Scenario 3) A vehicle departs the roadway and crashes unnoticed and rescue initiation is delayed significantly.

Results: Annually, between the years 2016 and 2018, an estimated 71,693 people were involved in low conspicuity emergency events, including 566 fatalities and 14,371 injured. Most (95%) of these cases occurred under scenario 1. Notable, however, is the severity of scenario 2 crashes where the majority were severely injured (22%) or killed (19%). Based on the FARS data, nearly 300 people were killed under scenario 2 each year and cases have increased 27% since 2014. Overall, crashes under these three scenarios resulted in an annual estimated $8.8 billion in societal costs, including the economic costs of medical payments and wage loses in addition to the value of quality of life lost due to death or disability. Scenario 1 crashes resulted in an average of $4.3 billion in losses, scenario 2 crashes in $3.4 billion in losses, and scenario 3 crashes in $1.2 billion in losses annually.

Conclusions: A significant number of people die or are injured in low conspicuity events every year; an estimated 1.55 deaths and nearly 40 injuries per day. This analysis highlights the risks to a special subset of pedestrians: motorists who exited their vehicles to attend to a disabled or stopped vehicle. These deaths and injuries that result from crashes related to low-conspicuity events are preventable. Countermeasures to reduce the incidence and severity of the crash scenarios studied should be explored.

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Introduction

In 2018, a total of 36,560 deaths occurred as a result of motor vehicle crashes occurring on US public roadways (NCSA, 2019 October). Of these, 6,283 (17.2%) were pedestrians and 22,697 (62%) were occupants of passenger vehicles. Overall, fatalities declined for the second consecutive year. However, pedestrian deaths increased 3.4% since 2017 (NCSA, 2019 October) and have increased 42% since 2008 (NCSA, 2019 March). These pedestrian fatalities occur overwhelmingly after dark (76%) and away from intersections (74%). In order to understand the size of the problem potentially addressed by improved conspicuity of emergency events to approaching traffic, this study quantifies the total number of fatalities and injuries resulting from low-conspicuity emergency events.

Drivers rely heavily on visual inputs to safely navigate U.S. roadways. Early recognition and interpretation of threats by drivers can prevent or mitigate the severity of a crash. The conspicuity of stopped or disabled vehicles on and off the road is critical in recognizing and responding to a hazard. Vehicle occupants and, in particular motorists who have exited a disabled vehicle, in low conspicuity emergency situations are at high risk of being struck by another vehicle. Lighting features on vehicles are an important contributor to increased conspicuity and communicating hazards (Gail et al., 2001; Flannagan et al., 2007). Other countermeasures to reduce crashes, injuries, and deaths related to low-conspicuity emergency events include traffic incident management and control policies, move-over laws and public education (Bui et al, 2018; Carson 2010; Wisconsin Department of Transportation, 2014).

Traffic incident management and control seeks to detect and remove incidents and restore traffic capacity as safely and as quickly as possible (Carson, 2010). Most states (for example, Wisconsin Department of Transportation (2014)) develop guidelines for emergency scene management and traffic control with the objective of providing a safe work environment for incident responders. These guidelines (or protocols) were developed in response to an increasing trend in emergency responder deaths and serious injuries resulting from traffic incidents that occur secondary to an event they are responding to. The guidelines cover issues like emergency vehicle lighting, incident management area establishment, and public communications.

In recent years, attention has been given to emergency medical services and police officers killed when responding to crashes on the side of the road. “Move-over” laws exist in all 50 states to mitigate this problem. The laws vary by state (AAA, 2020), but, in general, require motorists to move over and/or change lanes to give safe clearance to emergency responders and law enforcement officers, and other responders to disabled vehicles, such as tow trucks. States use public media campaigns to increase awareness of these laws.

The interventions described above were developed to address responder safety in emergency situations. However, there are solutions to also improve non-emergency vehicle occupant and pedestrian safety both before and after emergency responders have arrived. One notable technique is to increase conspicuity through enhanced hazard lighting. Messaging is an important function of hazard lighting (Post, 1978; Gail et al., 2001; Flannagan et al., 2007). Post (1978) proposed five key messages that should be conveyed by the warning lamps of emergency vehicles: 1) Clear the right-of-way; 2) hazard, vehicle on right-of-way; 3) caution, slow moving vehicle; 4) vehicle present in hazardous location; 5) stop immediately. Current hazard lighting regulations are specified by FMVSS 108 and the SAE J1690 Recommended Practice. This standard was initially proposed in 1966 and was last revised in 1993.

Methods

This study defines three crash scenarios that involved a “low conspicuity emergency event”:

1) Moving vehicle strikes non-moving vehicle following an initial event,
2) Pedestrian is struck while tending to a distressed vehicle situation, and
3) A vehicle departs the roadway unnoticed and rescue initiation is delayed significantly.

Data Sources

Data from NHTSA's 2010-2018 Fatal Analysis Reporting System (FARS) and the 2016-2018 Crash Report Sampling System (CRSS) were analyzed to quantify the number of deaths and injuries attributed to the three scenario types defined in this study.

The FARS is a census of fatal traffic crashes occurring in the U.S. where one or more motor vehicles traveling on public roadways is involved and one or more persons (vehicle occupants or pedestrians) died within 30 days due to crash injuries. For both overall fatalities and light vehicle occupant fatalities, trends indicate a significant decrease in fatalities between 2008 and 2014, followed by an increase starting in 2015. For this reason, 2010–2017 FARS data spanning this entire period were used in this analysis. To validate the analysis assumptions and review important crash attributes not reflected within FARS, the full Police Accident Report for a subset of Florida crashes was obtained.

The CRSS is a weighted U.S. population sample of police reported motor vehicle crashes. The system captures crashes of all severities, from minor to fatal. These data were analyzed to identify the number of injuries resulting from the study crash scenarios. Fatalities from CRSS were excluded so as not to double-count fatalities.

Separately, the FARS 2010-2018 and CRSS 2016-2018 calendar year data were analyzed by merging crash, vehicle, person and event level data. Both data sources include U.S. crashes severe enough to result in a police report. Generally, police reporting criteria includes any crash where there was injury or fatality and/or resulting in damage to a vehicle of at least $500 to $1,000. This analysis considered passenger vehicles only as the target vehicle (struck in a secondary crash) due to their similar rear lighting geometries. Passenger vehicles include passenger cars, SUVs, pickups weighing less than 10,000 pounds gross vehicle weight rating and passenger vans. Motorcycles and large trucks were excluded as the target vehicle but retained as the bullet vehicle (the striking vehicle in a secondary crash).

Scenario 1 - Moving Vehicle Hits Non-Moving Vehicle (including secondary collisions, multicar pile ups and disabled vehicles)

Scenario 1 includes several sub-categories where a moving vehicle strikes a non-moving vehicle from the rear. Cases where the struck/non-moving vehicle was involved in a prior collision were retained and those where the target vehicle was disabled and parked on or off the roadway were also retained. These parked vehicles without a prior crash were involved in crashes occurring on state and interstate highways only. Finally, the eligible injury or fatality could occur in either the striking or struck vehicle. Conditions where the struck vehicle was pushed into the rear of a vehicle ahead were not included as increased visual conspicuity would not affect driver behavior if no prior collision occurred and it would not impact the likelihood of a second impact. Scenario 1 takes into consideration the number of vehicles involved in the crash, the impact location, and crash type. Scenario 1 includes the following sub-scenarios:

- Scenario 1.1: Same Traffic Way Chain Reaction – Injury/Death in Middle Vehicle: These cases are identified where related factors must include 'recent previous crash scene nearby'.

- Scenario 1.2: Same Traffic Way Chain Reaction – Injury/Death in Last Vehicle. These cases are identified identical to scenario 1.1 but with the injury/death in the last vehicle.
- Scenario 1.3: Same Traffic Way Disabled Vehicle on Road.
- Scenario 1.4: Same Traffic Way Disabled Vehicle on Shoulder.
- Scenario 1.5: Same Traffic Way Disabled Vehicle on Median/Roadside
- Scenario 1.6: Same Traffic Way Stopped Vehicle on Shoulder of state highway or interstate.
- Scenario 1.7: Same Traffic Way Stopped Vehicle on Median/Roadside of state highway or interstate.

<u>Scenario 2 – Pedestrian (Primarily a Motorist Who Has Exited Their Disabled Vehicle) is Hit While Tending to Distressed Vehicle</u>

Scenario 2 includes events where vehicles are disabled for any reason (crash or non-crash) and the motorist has exited their vehicle (or another pedestrian – "Good Samaritan" – is providing aid) to attend to the vehicle. The disabled vehicle can be located on, near or off the roadway with a subsequent pedestrian impact occurring while they are attending to the vehicle. In identifying these cases, we considered impact location, the pedestrian crash type, and restricted cases to those where a contributing factor was 'stalled/disabled vehicle.' Scenario 2 includes the following sub-scenarios:

- Scenario 2.1: Pedestrian Attending to Disabled Vehicle on Road.
- Scenario 2.2 Pedestrian Attending to Disabled Vehicle on Shoulder.
- Scenario 2.3 Pedestrian Attending to Disabled Vehicle on Median/Roadside.
- Scenario 2.4: Pedestrian Entering/Exiting Stopped Vehicle on Road
- Scenario 2.5: Pedestrian Entering/Exiting Stopped Vehicle on Shoulder
- Scenario 2.6: Pedestrian Entering/Exiting Stopped Vehicle on Median/Roadside

<u>Scenario 3- Unnoticed Run-off Roadway (ROR)</u>

For Scenario 3, we identified roadway departure collisions where a vehicle departed the roadway before or after a crash and went unnoticed by neighboring traffic and a victim dies from their injuries due to crash forces. Increased conspicuity, in some circumstances, could improve the chances that passing traffic takes notice and provides support or calls 911. Cases included those where the crash time to notification of EMS/PSAP included an extended delay of 60 minutes or more between crash time and notification time and where time of death was reported to be more than 30 minutes after the crash (i.e. victims did not die from crash injuries immediately).

<u>Validating relevancy of cases to each scenario using police accident reports</u>

To validate the applicability of the FARS coding and assumptions made during analysis to categorize cases by scenario, detailed police reports for the Florida cases were acquired to confirm that low conspicuity contributed to the severity of the event or that, under ideal conditions, the crash may not have occurred if visual conspicuity were significantly increased. To identify the case police reports, the sample of Florida cases were probabilistically linked based on crash date, time of day, victim type and GPS coordinates. Since fatalities are infrequent events, identifying specific crash report numbers in the Florida state files corresponding to each FARS record was straightforward. After identifying the specific police accident report number for Florida, the electronic police accident reports were obtained to review each coded field, scene diagrams and narrative text information. Each case was coded as applicable, possibly applicable or not applicable by a panel of 3 researchers familiar with crash causation and police reporting methods. For each sub-scenario, the percent of cases determined applicable to the scenario definition was noted. These percentages were then used to adjust the number of cases identified in the FARS and CRSS datasets.

Cost of crashes, fatalities and injuries

Unit costs, from Blincoe et al (2015) and inflated to 2018 dollars, were applied to the case populations by injury severity (KABCO). Costs included both economic and quality of life costs. Economic costs include the medical care, emergency services, insurance administration, workplace costs, legal costs, congestion, property damage, and lost productivity. Congestion costs include travel delay, added fuel usage, and adverse environmental impacts. The quality of life costs measure the non-monetary value of quality of life lost due to death and disability. Comprehensive costs are the economic plus the quality of life costs. For additional information on using the value of a statistical life in cost analyses see a 2015 Office of the Secretary memorandum on the "Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses." www.dot.gov/regulations/economic-values-used-in-analysis.

These costs were computed and assigned per scenario in order to determine the relative benefit of a countermeasure that increase the cost of a vehicle relative to the societal costs associated with injuries and deaths potentially impacted by that countermeasure. Countermeasures could be technology related, policy interventions or public awareness changes.

Results

The review of FARS cases, crash years 2010-2018, identified 4,540 cases that met the criteria defined for each scenario and sub-scenario (Table 1). Over half (51%) of deaths occurred under Scenario 2, pedestrians (usually a motorist who has exited the vehicle) attending to a disabled or stopped vehicle on the road, median or shoulder. The majority of these cases occurred under sub-scenario 2.1, "Pedestrian Attending to Disabled Vehicle on Road." An additional 39.5% of cases occurred under Scenario 1, occupants of vehicles where a moving vehicle hits a non-moving vehicle in the road. The majority of these cases occurred under sub-scenario 1.1, "Same Traffic Way Disabled Vehicle on Road". The number of cases in these scenarios increased over time (Figure 1). Scenario 1 cases increased 24% since 2014 and 59% since 2010. Scenario 2 cases increased 27% since 2014 (the earliest data available). Scenario 3 cases made up a small portion of low-conspicuity-related fatalities. Scenario 3 counts declined 43% since 2010.

Table 2 describes the average annual count of fatalities presented in Table 1 by scenario and the number of Florida cases reviewed and validated. On average, 654 fatalities occurred annually that met one of the three low conspicuity emergency crash scenario definitions (Table 2). These included 238 fatalities where a moving vehicle hits a non-moving vehicle, 339 pedestrians (primarily motorists who exited their vehicle) attending to a disabled vehicle, and 77 fatalities in unnoticed run-off roadway crashes.

A total of 75 police records were acquired from Florida in order to validate the applicability of the FARS scenario definitions. Of these 75 records, 35 were scenario 1, 36 were scenario 2, and 4 were scenario 3 cases (Table 2). An insufficient number of sub-scenario 2.5 and 2.6 cases were identified in Florida for the years reviewed and therefore we assumed 100% applicability for these cases. Overall, 56 of the 75 Florida cases were confirmed as applicable to the sub-scenario upon review. The percent applicable varied by sub-scenario from 50% to 100%. Additional cases were flagged as potentially applicable but, in order to quantify a conservative population, these counts were not considered applicable for this study.

Table 3a presents the overall FARS fatal case counts, not adjusted by the percent applicable, with their distribution within each scenario, by person age, time of day, weather conditions and roadway type. Table 3b presents the distributions of non-fatal case counts, not adjusted by the percent applicable, based on the CRSS analysis. Scenario 1 cases are more likely to be age 60 years and over compared to scenarios 2 and 3, where cases are more likely to be teens and young adults age 16-29 years. The majority of cases occurred in the evening and nighttime hours for all scenarios. However, scenario 1 and 2 cases were more likely in the early evening and night hours between 6PM and midnight, while scenario 3 cases were more likely to occur in the early morning hours between midnight and 6AM. The distribution of cases within scenarios did not vary by weather condition. Scenario 1 and 2 cases ("Moving Vehicle Hits Non-Moving Vehicle" and "Pedestrian Attending Vehicle", respectively) occur disproportionately on interstates. Alternatively, scenario 3 cases, "Unnoticed Run-Off Roadway" crashes, occur disproportionately on country roads and local streets.

Table 4 summarizes the average annual fatal and nonfatal cases identified in FARS and CRSS adjusted by the percent applicable by sub-scenario. Average annual cases are based on crash and data years 2016-2018, the most recent available from CRSS. The table further categorizes the counts by police reported injury severity. After adjusting for applicability, we estimate that annually, from 2016 to 2018, an estimated 71,693 people were involved in low conspicuity emergency events, including 566 fatalities and 14,371 injured. While Scenario 2 events represent only 2.1% of these events, they represent 52% of deaths and 18% of serious injuries. Scenario 1 represents fully 95% of events, with majority in scenarios 1.1 (Same Traffic way Chain Reaction – Death/Injury in Middle Vehicle) and 1.3 (Same Traffic way Disabled Vehicle on Road). Scenario 1 is less likely than Scenario 2 to result in death (37% of deaths) or serious injuries (60% of serious injuries).

These crashes resulted in an annual estimated $8.8 billion in societal costs, including the economic costs of medical payments and wage loses in addition to the value of quality of life lost due to death or disability (Table 5). Scenario 1 crashes result in $4.3 billion in losses, scenario 2 crashes in $3.4 billion in losses, and scenario 3 crashes in $1.2 billion in losses.

Table 1: Low-Conspicuity Event-Related Fatalities, by Crash Scenario, Sub-Scenario and Crash Year; based on Fatal Analysis Reporting System Crash Years 2010-2018 (not adjusted by percent applicable, Table 2)

Scenario Number and Description	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Sum 2014-2018 (% of Total)**
Scenario 1: Moving vehicle hits non-moving vehicle										
1.1 Same Traffic way Chain Reaction – Death/Injury in Middle Vehicle	120	108	128	146	152	157	148	152	166	775
1.2 Same Traffic way Chain Reaction – Death/Injury in Last Vehicle	9	8	17	20	11	8	12	12	12	55
1.3 Same Traffic way Disabled Vehicle on Road	33	25	47	52	51	61	69	71	83	335
1.4-1.5 Same Traffic way Disabled Vehicle on Shoulder, Median / Roadside	7	14	11	13	11	16	11	22	16	76
1.6-1.7 Same Traffic way Stopped Vehicle on Shoulder, Median / Roadside	15	12	14	11	10	18	17	32	15	92
Scenario 1 Subtotal	**184**	**167**	**217**	**242**	**235**	**260**	**257**	**289**	**292**	**1333 (39.5%)**
Scenario 2: Pedestrian Attending to Vehicle										
2.1 Pedestrian Attending to Disabled Vehicle on Road					191	218	200	202	255	1066
2.2 Pedestrian Attending to Disabled Vehicle on Shoulder					43	42	73	53	61	272
2.3 Pedestrian Attending to Disabled Vehicle on Median / Roadside (not Shoulder)					30	31	51	41	37	190
2.4 Pedestrian Entering/Exiting Stopped Vehicle on Road					26	22	18	25	20	111
2.5 Pedestrian Entering/Exiting Stopped Vehicle on Shoulder					5	7	18	9	3	42
2.6 Pedestrian Entering/Exiting Stopped Vehicle on Median / Roadside (not Shoulder)					4	1	8	4	4	21
Scenario 2 Subtotal					**299**	**321**	**368**	**334**	**380**	**1702 (51.0%)**
Scenario 3. Unnoticed Run-Off-Road Crash – 60 Minute Cut-off	**123**	**113**	**65**	**75**	**70**	**65**	**59**	**55**	**70**	**319 (9.5%)**
Total (2014-2018)					**604**	**646**	**684**	**678**	**742**	**3354 (100%)**

Figure 1: Trends in Low-Conspicuity Event-Related Fatalities, by Crash Scenario and Crash Year; based on Fatal Analysis Reporting System Crash Years 2010-2018 (not adjusted by percent applicable, Table 2)

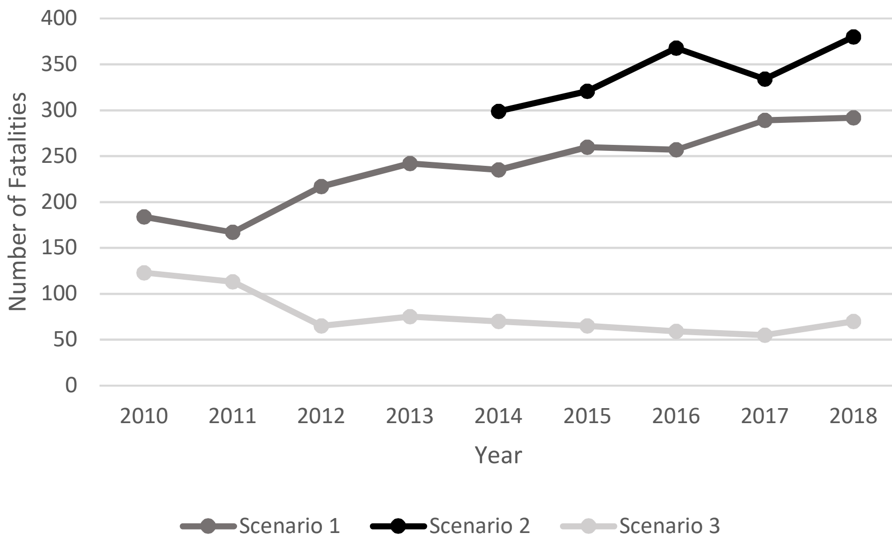

Table 2: Fatal Cases from FARS Reviewed Using the Corresponding Florida Police Accident Report, and Percent Applicable; by Crash Scenario

Category	*Scenario Number and Description*	*Cases Reviewed*	*Applicable Cases*	*Percent Applicable*
Moving vehicle hits non-moving vehicle	1.1 Same Traffic way Chain Reaction – Death/Injury in Middle Vehicle	13	9	69%
	1.2 Same Traffic way Chain Reaction – Death/Injury in Last Vehicle	2	2	100%
	1.3 Same Traffic way Disabled Vehicle on Road	13	10	77%
	1.4-5 Same Traffic way Disabled Vehicle on Shoulder, Median / Roadside	4	4	100%
	1.6-7 Same Traffic way Stopped Vehicle on Shoulder, Median / Roadside	3	3	100%
Pedestrian Attending to Vehicle	2.1 Pedestrian Attending to Disabled Vehicle on Road	16	14	88%
	2.2 Pedestrian Attending to Disabled Vehicle on Shoulder	4	2	50%
	2.3 Pedestrian Attending to Disabled Vehicle on Median / Roadside (not Shoulder)	9	7	78%
	2.4 Pedestrian Entering/Exiting Stopped Vehicle on Road	4	4	100%
	2.5 Pedestrian Entering/Exiting Stopped Vehicle on Shoulder	2		
	2.6 Pedestrian Entering/Exiting Stopped Vehicle on Median / Roadside (not Shoulder)	1		
Unnoticed run-off roadway crash	3. Run-Off-Road Crash – 60 Minute Time Cut-off	4	4	100%

Table 3a: Fatal Cases, Crash Years 2010-2018, by Crash Characteristics and Person Demographics (based on FARS data, not adjusted for percent applicable)

Attribute		*Scenario*					
		1	**%**	**2**	**%**	**3**	**%**
Victim age	0-15 YRS	83	4%	46	3%	17	2%
	16-29 YR	578	27%	529	31%	246	35%
	30-59 YR	1,007	47%	879	52%	273	39%
	60-75 YR	342	16%	177	10%	69	10%
	75+ YRS	128	6%	58	3%	33	5%
	Unknown	12	1%	13	1%	57	8%
Time of Day	9:00am to 11:59 am	192	9%	88	5%	33	5%
	12:00pm to 2:59 pm	209	10%	128	8%	56	9%
	3:00pm to 5:59 pm	217	10%	119	7%	67	11%
	6:00pm to 8:59 pm	238	11%	259	15%	55	9%
	9:00pm to 11:59 pm	312	15%	379	22%	35	6%
	12:00am to 2:59 am	293	14%	223	13%	161	26%
	3:00am to 5:59 am	368	17%	273	16%	139	23%
	6:00am to 8:59 am	217	10%	144	8%	64	10%
	unknown	104	5%	89	5%		0%
Weather Condition	Normal	1,421	66%	1,115	66%	434	62%
	Rain	195	9%	161	9%	51	7%
	Snow/Sleet	100	5%	52	3%	21	3%
	Fog	65	3%	30	2%	9	1%
	Cloudy	304	14%	292	17%	123	18%
	Other	27	1%	5	0.3%	8	1%
	Unknown	38	2%	47	3%	49	7%
Roadway Functional Class	Interstate	1,203	56%	830	49%	68	10%
	U.S. Highway	335	16%	209	12%	72	10%
	State Highway	439	20%	352	21%	180	26%
	County Road	54	3%	93	5%	172	25%
	Local Street - Township	13	1%	15	1%	77	11%
	Local Street - Municipality	61	3%	137	8%	84	12%
	Local Street - Frontage Road	9	0%	12	1%	4	1%
	Other	28	1%	41	2%	30	4%
	Unknown	8	0%	13	1%	8	1%

Table 3b: Non-Fatal Cases, Crash Years 2016-2018, by Crash Characteristics and Person Demographics (based on CRSS data, not adjusted for percent applicable)

Attribute		*Scenario*					
		1	**%**	**2**	**%**	**3**	**%**
Victim age	0-15 YRS	15,687	6%	118	2%	2,139	6%
	16-29 YR	91,550	34%	2,230	34%	15,917	41%
	30-59 YR	115,034	43%	3,096	47%	12,501	32%
	60-75 YR	23,878	9%	835	13%	2,492	6%
	75+ YRS	20,384	8%	275	4%	4,632	12%
	Unknown	2,924	1%	64	1%	1,173	3%
Time of Day	9:00am to 11:59 am	23,491	9%	461	7%	4,283	11%
	12:00pm to 2:59 pm	38,618	14%	514	8%	5,170	13%
	3:00pm to 5:59 pm	66,314	24%	792	12%	6,210	16%
	6:00pm to 8:59 pm	50,896	18%	1,950	29%	5,577	14%
	9:00pm to 11:59 pm	20,681	8%	1,265	19%	5,061	13%
	12:00am to 2:59 am	7,120	3%	449	7%	2,928	8%
	3:00am to 5:59 am	17,055	6%	493	7%	3,223	8%
	6:00am to 8:59 am	47,848	17%	548	8%	4,767	12%
	unknown	3,432	1%	144	2%	1,715	4%
Weather Condition	Normal	175,434	64%	4,477	68%	23,140	59%
	Rain	40,558	15%	794	12%	5,500	14%
	Snow/Sleet	10,520	4%	242	4%	2,508	6%
	Fog	5,393	2%	91	1%	324	1%
	Cloudy	33,156	12%	825	12%	5,364	14%
	Other	1,190	0%		0%	259	1%
	Unknown	9,204	3%	190	3%	1,837	5%
Roadway Functional Class	Non-Trafficway or Driveway	1,484	1%	93	1%	1,190	3%
	Two-Way, Not Divided	50,389	18%	2,516	38%	20,184	52%
	Two-Way, Divided, Unprotected Median	45,825	17%	451	7%	3,487	9%
	Two-Way, Divided, Positive Median Barrier	114,761	42%	1,397	21%	5,676	15%
	One-Way Trafficway	3,807	1%	164	2%	804	2%
	Two-Way, Not Divided With a Continuous Left-Turn Lane	9,622	3%	185	3%	650	2%
	Entrance/Exit Ramp	10,855	4%	465	7%	1,032	3%
	Not Reported	38,208	14%	1,346	20%	5,863	15%
	Unknown	502	0%	-	0%	48	0%

Table 4: Average Annual Fatalities and Injuries by Reported Severity and Crash Scenario, Adjusted by Percent Applicable (see Table 2); Crash Years 2016-2018

Scenario	*No Apparent Injury (O)*	*Possible Injury (C)*	*Suspect. Minor Injury (B)*	*Suspect. Serious Injury (A)*	*Fatal Injury (K-FARS)*	*Injured, Severity Unk.*	*Unk/Not Reported*	*Annual Average Total*
1.1	36,350	4,383	1,504	504	118	69	1,282	44,210
1.2	4,448	494	128	57	9		142	5,278
1.3	10,917	1,933	1,012	239	56	27	639	14,823
1.4-1.5	1,248	95	202	25	12		66	1,648
1.6-1.7	1,293	303	345	239	16		143	2,339
Scenario 1 Subtotal	54,256	7,208	3,191	1,064	211	96	2,272	68,298
2.1	51	120	71	132	179	8	0	561
2.2		22	38	53	51	8	0	172
2.3		14	40	35	35		0	124
2.4	65	204	188	72	17		0	546
2.5		49	8	28	8		0	93
2.6			13	8	4		0	25
Scenario 2 Subtotal	116	409	358	328	294	16	0	1,521
Scenario 3 Subtotal	0	0	1,419	394	61	0	0	1,874
Total	54,372	7,617	4,968	1,786	566	112	2,272	71,693

Table 5: Annual Cost of Fatalities and Injuries by Reported Severity and Crash Scenario, Adjusted by Percent Applicable (Table 2); Cost in Millions of U.S. Dollars, Crash Years 2016-2018

Scenario	*No Apparent Injury (O)*	*Possible Injury (C)*	*Suspect. Minor Injury (B)*	*Suspect. Serious Injury (A)*	*Fatal Injury (K-FARS)*	*Average Annual Total*
1.1	$280	$354	$224	$262	$1,271	$2,391
1.2	$34	$40	$19	$30	$98	$221
1.3	$84	$156	$151	$124	$608	$1,123
1.4-1.5	$10	$8	$30	$13	$134	$195
1.6-1.7	$10	$24	$51	$125	$175	$385
Total Scenario 1	$418	$582	$475	$554	$2,286	$4,315
2.1	$0	$10	$11	$69	$1,924	$2,014
2.2	$0	$2	$6	$28	$548	$584
2.3	$0	$1	$6	$18	$378	$403
2.4	$1	$16	$28	$37	$185	$267
2.5	$0	$4	$1	$14	$88	$107
2.6	$0	$0	$2	$4	$47	$53
Total Scenario 2	$1	$33	$54	$170	$3,170	$3,428
Total Scenario 3	$0	$0	$211	$205	$660	$1,076
Total	419	615	$740	$929	$6,116	$8,819

Conclusions

Annually, an estimated average of 71,529 people were involved in low conspicuity emergency events, including 566 fatally injured and 14,483 non-fatally injured. This translates to approximately 1.55 deaths and nearly 40 injuries per day. Most (95%) of these cases occur in scenario 1 crashes (a moving vehicle hits a non-moving vehicle). Notable, however, is the severity of scenario 2 crashes (pedestrians attending to a stopped vehicle) where the majority of pedestrians involved are severely injured (22%) or killed (19%).

This analysis highlights the risks to pedestrians who are attending to disabled or otherwise stopped vehicles. Based on the FARS data, nearly 300 people are killed under this scenario each year and the problem is on the rise with a 27% increase in fatal cases since 2014. The magnitude of this problem had not previously been quantified and, prior to 2014, U.S.-level datasets lacked the level of detail needed to identify these cases. While the person type is technically noted as “pedestrian”, these cases are mostly motorists who have exited their vehicles with risk factors for traffic-related injury distinctly different from other pedestrians walking or standing on the road. To better understand how to address their risks, further research should analyze this person type separately as a special subset of pedestrians. In addition, because these are motorists of primarily private vehicles, this scenario would not be covered by current “Move-Over” laws or traffic control policies and guidelines designed to protect responders in emergency vehicles. Technologies to improve conspicuity in emergency scenarios before responders arrive could prevent or mitigate the severity of these crashes.

Estimating the economic burden of these crashes is important for setting priorities, allocating scarce resources, and planning cost-effective prevention activities. As a metric of burden, costs account for multiple injury consequences—death, severity, disability—in a single unit of measurement (dollars). Annually, these crashes result in an estimated $8.8 billion in economic and quality of life losses annually. The distribution of cost by scenario differs from that of raw cases because injury severity distributions differ. While 95% of cases were accounted for by scenario 1, just 49% of costs are due to scenario 1 cases. Scenario 2 generally results in severe injury and death and accounts for 39% of the costs. Another 12% of the costs are due to scenario 3 injuries and fatalities.

Discussion

The analysis performed represents a conservative estimate of the number of deaths that may be positively impacted by increased conspicuity following an emergency event like a first impact, disabled vehicle or vehicle parked in a hazardous location.

A number of data challenges were identified and addressed. Recent changes to the FARS have introduced data attributes vital to this analysis. Beginning in 2014, the NHTSA began summarizing and reporting pedestrian crash conditions in more detail including pedestrian crash types and specific pre-crash factors. These data points were vital for this analysis and therefore all Scenario 2 results were computed using this 4-year period.

Differences in coding type and detail between FARS and CRSS presented several challenges. Scenarios 1.6 and 1.7 when applied to FARS, include only crashes that occur on interstates and state highways. Roadway types are defined differently in CRSS and while identifying interstates is straightforward, identifying state highways is not. Therefore, CRSS the scenarios 1.6 and 1.7 roadway criterion for state highways is defined as a divided road with a posted speed limit greater than 55. In addition, CRSS does not have a variable that flags if a previous crash was a noted as a factor

In the CRSS, crash time is not known and therefore it is not possible to identify time to rescue and time to injury (rather than death), both critical scenario 3 criteria, are not known. Therefore, to identify applicable scenario 3 cases in CRSS, the study computed the percent of overall run-off roadway crashes in FARS that qualified for scenario 3 and applied that percentage to the CRSS run-off roadway counts. This assumes that a similar percentage of run-off-the-road crash victims not fatally injured would experience a delay in the recognition of the crash if they could not initiate a call for help themselves. In addition, all occupants had to have severity of B (suspect minor injury) to meet the assumption that no one in the vehicle could leave to flag down help and the vehicle remained unnoticed for a time.

One objective of this study was to identify crashes where there was a high likelihood that increased conspicuity would improve outcomes. During the review, an additional larger population of crashes were identified that, assuming an extended time to secondary collision (Scenario 1), may have been preventable by increased conspicuity of the target vehicle. In addition, run-off-the-road crashes were identified where extended duration times above 30 minutes to first notification occurred (expanded scenario 3), however, reporting errors may impact the reliability of these estimates.

Based on data collected and reported by police, it is not possible to characterize the severity per event and therefore it is not possible to attribute the fatality to the first or second impact. In some cases, increased conspicuity may have prevented a crash, however, the primary crash or the most harmful impact event occurred prior to or after the event identified as potentially avoidable. To validate the assumptions in the study, we utilized a sample of full police accident reports estimate percent of identified crashes that were applicable per scenario.

This study presents a conservative estimate of the number of deaths and injuries that might be prevented by increased conspicuity following an emergency event. To estimate an upper limit of relevant fatal cases we applied expanded definitions for Scenario 1 and 3 fatalities where insufficient information existed within the FARS case to draw a conclusion, but where increased conspicuity following the first crash might prevent the fatality.

The expanded Scenario 1 definition removed the requirement that the vehicles were travelling along the same roadway and a previous crash was a noted as a factor. In most cases, the reports do not note the timing between first and second crash events making their classification as preventable with increased conspicuity challenging. In addition, while crashes where the first impact forces one or more vehicles into adjacent lanes with traffic travelling in the opposite direction suggests that a second crash occurs rapidly, a portion of these crashes may also be preventable with increased conspicuity. Some of these cases may also be impacted by increased conspicuity of the first crash-involved vehicles.

The expanded Scenario 3 definition criteria (unnoticed run-off roadway crashes) included crashes where first notification occurred just 30 minutes following the reported estimated crash time (as opposed to 60 minutes). Like the 60 minute time to first notification, a 30 minute time difference also suggests that first notification was somehow delayed because the vehicle was unnoticed.

Using the expanded Scenario 1 definition, an additional 4,068 cases were identified in FARS from 2010 to 2018, resulting in 2.9 times more cases in the expanded compared to the base definition. For Scenario 3, approximately 64% of cases in the FARS 2010-2018 CY period have unknown notification time, while 7% of report unknown crash and death times. It is possible that cases where notification time was not reported are overrepresented in the scenarios where a delayed discovery of crash victims occurred.

Using the expanded definition, an additional 620 fatalities were identified, resulting in 1.9 times more cases in the expanded compared to the base definition.

A number of promising countermeasures can reduce the incidence and severity of the crash scenarios studied. These include traffic incident management, Move Over laws and enhanced hazard lighting.

Tools and strategies have been developed and implemented in an effort to improve overall traffic incident management and control practices. Policies to reduce secondary crashes when emergency services are responding to a traffic incident include dispatching two vehicles to every highway incident and utilizing one vehicle primarily for blocking, assigning a spotter to watch for oncoming traffic and ensure people are yielding and slowing down, and increasing on scene visibility with flares, safety cones and flashing lights. These vary by state and may reflect different priorities, congestion conditions, and investment. A 2010 FHWA report on best practices for traffic incident management found that the reported effectiveness of individual or combined strategies is inconsistent (Carson, 2010). The authors could not explicitly identify best practices and suggested that local conditions related to the nature and extent of operation, maintenance, marketing, etc. have a significant impact on the perceived or measured success of specific traffic incident management efforts. An update of this report is warranted given the date of the report and the introduction of new technologies and practices in the intervening decade.

'Move Over' laws intended to protect emergency responders and others involved in the incident are currently in place in various forms in every U.S. state. However, first responders continue to be killed and injured in secondary crashes to the incident they are responding to. The U.S. Government Accountability Office (GAO) announced in June 2019 that they will conduct a new study to review the effectiveness of 'Move Over' laws and to better understand the challenges states face in implementing these laws and how the federal government can help states educate the public to avoid these preventable injuries and fatalities.

'Move Over' laws and traffic incident management practices are designed to protect emergency responders, workers and others who are stopped on the side of the road. They are in effect once emergency responders arrive. However, technologies designed to increase conspicuity that are triggered at the time of the crash or incident would protect much earlier and could therefore have an enhanced effect.

Vehicle hazard lighting, triggered manually or automatically can immediately convey a message to oncoming vehicles that a hazard exists. This message can differ depending on the combination of color, intensity, flash rate and flash pattern. Flannagan et al. (2005) explored three crash data sources to better understand crashes involving emergency vehicles responding to events and make recommendations to improve safety. The authors came to the conclusion that stronger warning lamps (in frequency and brightness) might reduce the risk of crashes in which another driver fails to detect an emergency vehicle. The authors noted that hazard lights did not prevent all crashes; in 30% of the crashes studied the non-emergency vehicle did not detect the emergency vehicle even though the hazard lights were on The Flannagan (2005) study was performed before the current proliferation of LED lights on newer model year vehicles. Future research is needed to better understand the characteristics of hazard lights that might prevent crashes in low-conspicuity emergency events, in particular during the period before emergency vehicles arrive.

This study quantifies the consequences related to secondary crashes resulting from low conspicuity emergency events. The burden of these crashes, injuries and fatalities is significant but may be prevented or mitigated through a combination of policies like Move-Over laws, improved traffic management in hazardous situations, and new and innovative hazard lighting technologies.

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