Journal of Safety Research xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Safety Research

journal homepage: www.elsevier.com/locate/jsr

# Fatal crashes involving large numbers of vehicles and weather

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ARTICLE INFO

*Article history:*
Received 22 April 2017
Received in revised form 18 June 2017
Accepted 16 August 2017
Available online xxxx

*Keywords:*
Traffic crashes
Traffic fatalities
Traffic safety
Adverse weather
Data analysis

ABSTRACT

*Introduction:* Relationships between fatal crashes involving large numbers of vehicles and weather were derived using all 1,513,792 fatal crashes in the Fatality Analysis Reporting System (FARS) data, 1975–2014. *Results:* We found: (a) fatal crashes involving more than 35 vehicles are most likely to occur in snow or fog; (b) fatal crashes in rain are three times as likely to involve 10 or more vehicles as fatal crashes in good weather; (c) fatal crashes in snow [or fog] are 24 times [35 times] as likely to involve 10 or more vehicles as fatal crashes in good weather. If the example had used 20 vehicles, the risk ratios would be 6 for rain, 158 for snow, and 171 for fog. *Conclusions:* To reduce the risk of involvement in fatal crashes with large numbers of vehicles, drivers should slow down more than they currently do under adverse weather conditions. Driver deaths per fatal crash increase slowly with increasing numbers of involved vehicles when it is snowing or raining, but more steeply when clear or foggy. *Practical applications:* We conclude that in order to reduce risk of involvement in crashes involving large numbers of vehicles, drivers must reduce speed in fog, and in snow or rain, reduce speed by even more than they already do.





## 1. Introduction

All 1,513,792 fatal crashes documented in the Fatality Analysis Reporting System [FARS] (NHTSA, 2016) are used to examine how weather affects fatal crashes involving large numbers of vehicles. Such crashes provide robust empirical evidence that is interpreted to provide information on how weather more generally affects risk of fatal crashes.

Nearly all (94%) fatal crashes in the United States involve, at most, two vehicles, so fatal crashes involving large numbers of vehicles are rare. There are eight crashes per year involving 10 or more vehicles, fewer than one involving 27 or more vehicles.

In order to obtain enough cases for analysis, we accumulated data over the entire period for which FARS data are available, namely, the 40 years 1975 thru 2014. The accumulated more than 1.5 million fatal crashes allow us to explore how weather affects the occurrence of fatal crashes as a function of the number of involved vehicles and to explore what happens when that number becomes large.

The rare crashes studied here are not a major component of the overall harm caused by 30,000 annual U.S. fatal crashes. However, they cause numbers of deaths that would be considered an important national public health problem in any context other than traffic. Over the study period, more than a thousand people were killed in crashes involving eight or more vehicles. This provides sufficient reason to encourage their study. Additionally, the analyses presented here show that fatal crashes involving many vehicles can solidify understanding of the role of weather in fatal crashes in general, and encourage countermeasures.

There is an extensive literature on weather effects on traffic safety. The investigation most similar in data source to the present is that of Eisenberg and Warner (2005), who used 1975–2000 FARS and other data to investigate effects of snowfalls on crashes, injuries, and fatalities. Many methods and approaches have been deployed to investigate relationships between weather and traffic safety. These include using crash data (Moore & Cooper, 1972; Orne & Yang, 1972; Codling, 1971; Satterthwaite, 1976; Evans, 1991), driving simulators (e.g. Saffarian, Happee, & Winter, 2012), questionnaires (Hassan & Abdel-Aty, 2011), behavioral investigations (Kilpeläinen & Summala, 2007), literature reviews (Theofilatos & Yannis, 2014), and case studies (e.g., Chakrabarty & Gupta, 2013). Many reported effects compliment the present investigation, as discussed later. We believe the present study is the first to empirically investigate relationships between crashes involving large numbers of vehicles and weather.

## 2. Data and methods

The atmospheric, or weather, conditions used in FARS are shown in Fig. 1, reproduced from the *FARS Analytical User's Manual (1975–2011)* (NHTSA, 2013) The reasons for such a complex structure is that over the years increasing experience and enormously increased computer storage facilitated ongoing refinements. We focus on four weather conditions, CLEAR, RAIN, SNOW, and FOG, extracted from the items in Fig. 1

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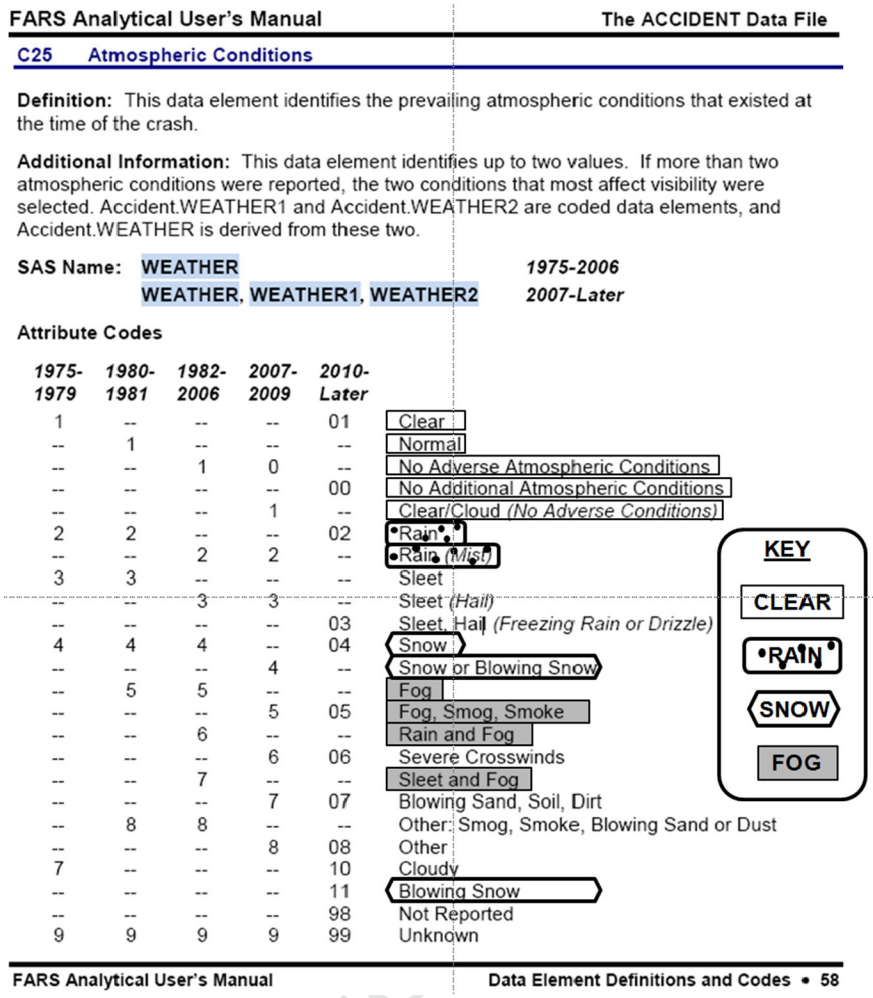
http://dx.doi.org/10.1016/j.jsr.2017.08.001
0022-4375/



FARS Analytical User's Manual — The ACCIDENT Data File

C25 Atmospheric Conditions

**Definition:** This data element identifies the prevailing atmospheric conditions that existed at the time of the crash.

**Additional Information:** This data element identifies up to two values. If more than two atmospheric conditions were reported, the two conditions that most affect visibility were selected. Accident.WEATHER1 and Accident.WEATHER2 are coded data elements, and Accident.WEATHER is derived from these two.

**SAS Name:** WEATHER *1975-2006*
WEATHER, WEATHER1, WEATHER2 *2007-Later*

**Attribute Codes**

| *1975-1979* | *1980-1981* | *1982-2006* | *2007-2009* | *2010-Later* | |
|---|---|---|---|---|---|
| 1 | -- | -- | -- | 01 | Clear |
| -- | 1 | -- | -- | -- | Normal |
| -- | -- | 1 | 0 | -- | No Adverse Atmospheric Conditions |
| -- | -- | -- | -- | 00 | No Additional Atmospheric Conditions |
| -- | -- | -- | 1 | -- | Clear/Cloud *(No Adverse Conditions)* |
| 2 | 2 | -- | -- | 02 | Rain |
| -- | -- | 2 | 2 | -- | Rain *(Mist)* |
| 3 | 3 | -- | -- | -- | Sleet |
| -- | -- | 3 | 3 | -- | Sleet *(Hail)* |
| -- | -- | -- | -- | 03 | Sleet, Hail *(Freezing Rain or Drizzle)* |
| 4 | 4 | 4 | -- | 04 | Snow |
| -- | -- | -- | 4 | -- | Snow or Blowing Snow |
| -- | 5 | 5 | -- | -- | Fog |
| -- | -- | -- | 5 | 05 | Fog, Smog, Smoke |
| -- | -- | 6 | -- | -- | Rain and Fog |
| -- | -- | -- | 6 | 06 | Severe Crosswinds |
| -- | -- | 7 | -- | -- | Sleet and Fog |
| -- | -- | -- | 7 | 07 | Blowing Sand, Soil, Dirt |
| -- | 8 | 8 | -- | -- | Other: Smog, Smoke, Blowing Sand or Dust |
| -- | -- | -- | 8 | 08 | Other |
| 7 | -- | -- | -- | 10 | Cloudy |
| -- | -- | -- | -- | 11 | Blowing Snow |
| -- | -- | -- | -- | 98 | Not Reported |
| 9 | 9 | 9 | 9 | 99 | Unknown |

KEY: CLEAR, RAIN, SNOW, FOG

FARS Analytical User's Manual — Data Element Definitions and Codes • 58

**Fig. 1.** Annotated copy of page 58 of *FARS Analytical User's Manual (1975–2011)* (NHTSA, 2013). Note: The weather categories CLEAR, RAIN, SNOW, FOG, and XTRA included all data, with XTRA including all 10 rows of data not assigned to the specific 4 weather categories.

and accumulate data from the 40 years, 1975 through 2014. An additional condition, XTRA, includes the 10 items that do not fit into any of the 4 weather conditions. This additional category (which will not be mentioned again) facilitated the many checks that were performed at every stage of the analysis to ensure that all tabulations were correct. The study investigates the weather conditions at the time of the crash. That is, conditions that affect visibility. For example, SNOW means that snow is falling at the time of the crash; crashes with snow on the roadway surface are not included in the SNOW category unless it is snowing.

The distribution of the fatal crashes into the weather conditions is shown in Table 1. Also shown is the distribution for the 1,002,359 drivers killed in these crashes. We focus on driver deaths rather than total fatalities because every involved vehicle has one driver at risk, whereas a vehicle with many occupants has the potential to produce many deaths from a single vehicle. Inferences based on driver deaths are more directly related to crash risk (Evans, 2004).

These same data according to the number of vehicles, $n$, involved in the fatal crash are shown in Table 2. We use $t_{RAIN}(n)$ to denote the number of fatal crashes involving $n$ vehicles that occurred in rain, and $d_{RAIN}(n)$ to denote the number of drivers killed in these crashes, with corresponding definitions for the other atmospheric conditions. Note that for $n = 41$ and $n = 90$ there are no driver deaths. These crashes are included because for each there is one fatal crash, but the driver was not killed. Table 1 implies that there were $1{,}513{,}792 - 1{,}002{,}359 = 511{,}433$ fatal crashes in which no drivers were killed. We chose to include all crashes to increase sample sizes and to avoid the complexity of having to specify an essentially arbitrary list of exclusion criteria. All quantities in this paper can be derived from the data in Table 2.

**Table 1**
Distribution of the 1,513,792 fatal crashes leading to 1,002,359 driver deaths.
Source: FARS, 1975–2014.

| Weather | Fatal crashes | Percent | Driver deaths | Percent |
|---|---|---|---|---|
| CLEAR | 1,298,855 | 85.80 | 858,526 | 85.65 |
| RAIN | 127,328 | 8.41 | 83,335 | 8.31 |
| SNOW | 24,695 | 1.63 | 16,860 | 1.68 |
| FOG | 22,745 | 1.50 | 16,530 | 1.65 |
| XTRA | 40,169 | 2.65 | 27,108 | 2.70 |
| Total | 1,513,792 | 100.00 | 1,002,359 | 100.00 |

## 3. Results

### 3.1. Weather effects on number of vehicles involved in fatal crashes

An immediate observation from Table 2 is that the atmospheric conditions producing fatal crashes with the largest numbers of vehicles are FOG and SNOW, this even despite the overwhelming prevalence of CLEAR crashes documented in Table 1. The largest number of vehicles involved in any fatal crash was a 92-vehicle crash that occurred in FOG. The second largest was a 90-vehicle crash that occurred in

Please cite this article as: Wang, Y., et al., Fatal crashes involving large numbers of vehicles and weather, *Journal of Safety Research* (2017), http://dx.doi.org/10.1016/j.jsr.2017.08.001