# An Analysis of the Speed-Severity Relationship in a Typical Auto Accident

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**Abstract**

This document examines the paper written by Wang in an attempt to derive a relationship between a vehicle's speed immediately prior to a collision and the insurable costs associated with that collision. Sources of uncertainty are listed and accounted for.

## 1 Background

In his 2022 paper, Jing-Shiarn Wang uses simulated crash data and actual injury data to infer a relationship between the change in speed during the tenth-of-a-second after the onset of a collision ("delta-v") and the severity of injuries arising from that collision. We aim to use this relationship, along with outside data, to estimate the marginal costs associated with a marginal increase in speed in the event of a collision.

## 2 Data

Data from Wang's paper was taken from the 2010–2015 National Automotive Sampling System Crashworthiness Data System (CDS).

From Wang:

"CDS is a nationally representative sample of passenger vehicle (PV) crashes. Passenger vehicles (PVs) are vehicles with a gross vehicle weight rating less than or equal to 10,000 lbs. PVs include passenger cars, sport utility vehicles, and light trucks and vans. The database includes crashes where at least one PV was towed due to damage. Since 2009, CDS recorded AIS (MAIS also) injury only for occupants in PVs 10 years and newer when crashes occurred."

Of the approximately 15.9 million PV occupants included in the CDS data, 5,492,758 with known delta-v and MAIS severity were included in the study.

# 3 Analysis

## 3.1 Model

The posited relationship between speed prior to collision and insurable costs is as follows:

$$C_v = n * \sum_s p_{s,v} C_s$$

where:

$C_v$: The total expected insurable costs associated with a collision at speed $v$.

$n$: The number of parties involved in the collision (drivers and passengers)

$s$: The severity of an injury, as measured by the MAIS score

$p_{s,v}$ : The probability of an injury of severity $s$ given that a collision occurs at speed $v$

$C_s$ : The insurable cost associated with an injury of severity $s$

## 3.2 Assumptions

We have made the following assumptions in our analysis:

1. The probability of an injury of a particular severity is based on the logistic regression model provided by Wang.

2. Because Wang's paper relates the severity of an accident with the *change* in speed during the accident, rather than the speed immediately prior to the accident, we need to assume a relationship between those two variables:

$$v = \beta \Delta v.$$

The relationship between v and delta-v is highly dependent on the speed of the collision, the type of collision, as well as the characteristics of the colliding objects. Due to the absence of data on two-vehicle collisions, we estimated $\beta$ for a two-vehicle collision by looking at the range of delta-v values provided by Gabler, Hampton, and Roston, and set it conservatively at 0.3. For one-vehicle barrier collisions, Nolan's data suggested a $\beta$ closer to 0.8.

3. For the expected costs associated with an injury of a specific severity, we used the values provided by Harmon, Bahar, and Gross. Since their results were published in 2010, expected costs were inflated to 2024 using the CPI

provided by the Bureau of Labor Statistics.

4. The number of parties involved in a two-vehicle collision was assumed to be three. This is an estimate which follows from data obtained from the 2022 National Household Travel Survey, indicating the average number of people per trip for household vehicles in the United States was 1.5.

## 3.3 Sources of Uncertainty

One major source of uncertainty comes from the derivation of delta-v in Wang's paper. Rather than measuring the change in speed directly using an installed Event Data Recorder (EDR), the National Highway Traffic Safety Administration (NHTSA) uses a software program called "WinSMASH" to estimate the delta-v of the vehicles involved in crashes using detailed measurements from the crash scene.

The accuracy of the WinSMASH software was considered by Gabler. As shown in the table below, although there is significant variability around the estimate, there is still a strong linear relationship between the delta-v recorded by a vehicle's EDR and the delta-V simulated by the WinSMASH software.

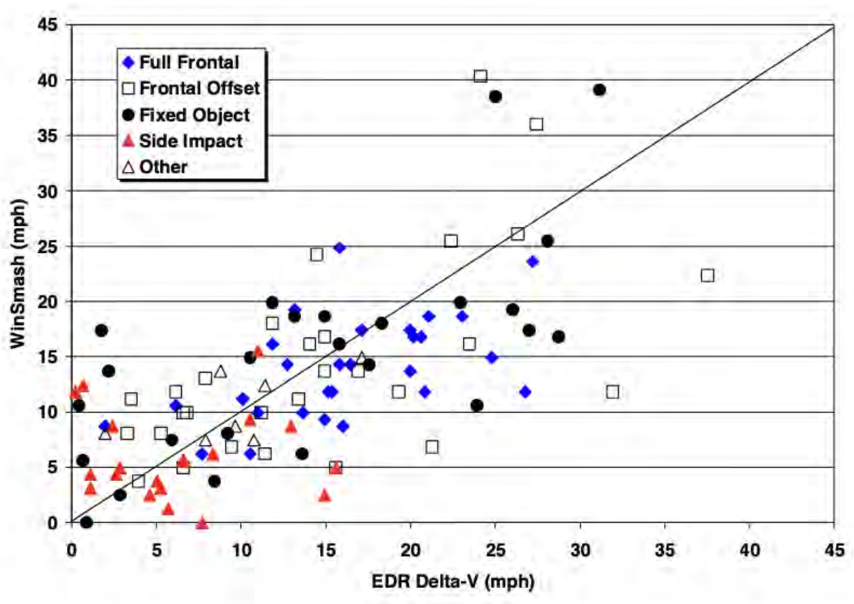


Figure 1: Delta-v Gathered from EDR vs. Simulated using WinSMASH (from Gabler et. al.)

A second major source of uncertainty is in parameter risk, especially surrounding the parameters $\beta$, $n$, and $C_s$ . In all these cases, we aim to mitigate parameter risk by making conservative estimates of these parameters. For example, we have deliberately excluded social inflation into our cost estimates, meaning that our selected values for $C_s$ are likely underestimated. Lastly, we should consider any common characteristics of the vehicles that were included in the study before generalizing to all auto collisions. The studied vehicles were private passenger autos weighing less than 10,000 pounds. Although they were not included in the study, it stands to reason that larger vehicles (i.e. busses, heavy trucks, etc.) would cause more damage and greater injury vs. autos for a collision at a specific speed.

## 4 Conclusions

After analyzing the paper by Wang, and making some assumptions about the behavior of a typical auto collision, we reached the following conclusion: Collisions at higher speeds create costlier accidents.

The collision-contingent costs associated with a marginal increase in speed are shown in the exhibits below:

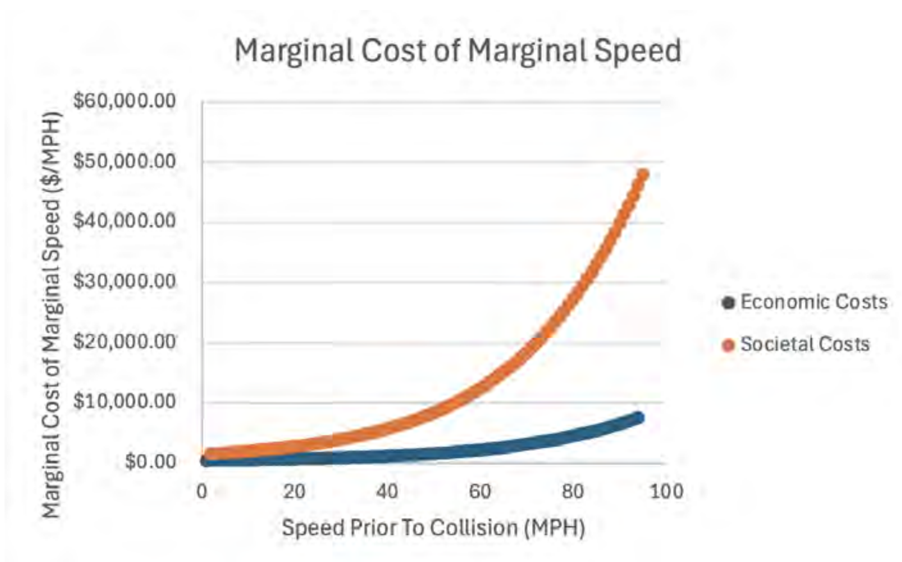


Figure 2: Marginal Costs Associated with Marginal Velocity

From Harmon et. al.,

"Economic costs (a.k.a., human capital costs) are the monetary impacts of crashes including goods and services related to the crash response, property damage, and medical costs."

"Societal crash costs are the combination of tangible impacts (i.e., economic costs) and the monetized pain and suffering (i.e., QALY). Societal costs are meant to capture all the impacts that result from crashes."

Societal crash costs are more likely to reflect insurable costs in an Auto Liability claim, while economic costs are more likely to reflect insurable costs in a PIP claim or a Workers' Compensation claim.

The table below shows the savings associated with a five mile-per-hour reduction prior to a collision, evaluated at different starting speeds.

| Base Speed (MPH) | Revised Speed (MPH) | Economic Savings ($) | Societal Savings ($) |
|---|---|---|---|
| 25 | 20 | 3,155 | 15,033 |
| 35 | 30 | 4,191 | 21,652 |
| 45 | 40 | 5,698 | 31,659 |
| 55 | 50 | 7,939 | 46,819 |
| 65 | 60 | 11,308 | 69,654 |
| 75 | 70 | 16,362 | 103,570 |
| 85 | 80 | 23,848 | 152,871 |
| 95 | 90 | 34,698 | 222,671 |

Figure 3: Sample Savings Associated with a Reduction in Speed prior to a Collision Event

## 5 Acknowledgment of Qualifications

I, Don Grimm, am a Principal and Consulting Actuary with Archer Actuarial Consulting LLC. I am a Fellow of the Casualty Actuarial Society and a Member of the American Academy of Actuaries and meet the Qualification Standards of the American Academy of Actuaries to render the actuarial opinion contained herein.

Please contact me with any questions you may have concerning this report.

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## 6 Citations

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