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Comparing motor-vehicle crash risk of EU and US vehicles

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ABSTRACT

Objective: This study examined the hypotheses that passenger vehicles meeting European Union (EU) safety standards have similar crashworthiness to United States (US) -regulated vehicles in the US driving environment, and vice versa.
Methods: The first step involved identifying appropriate databases of US and EU crashes that include in-depth crash information, such as estimation of crash severity using Delta-V and injury outcome based on medical records. The next step was to harmonize variable definitions and sampling criteria so that the EU data could be combined and compared to the US data using the same or equivalent parameters. Logistic regression models of the risk of a Maximum injury according to the Abbreviated Injury Scale of 3 or greater, or fatality (MAIS3 + F) in EU-regulated and US-regulated vehicles were constructed. The injury risk predictions of the EU model and the US model were each applied to both the US and EU standard crash populations. Frontal, near-side, and far-side crashes were analyzed together (termed "front/side crashes") and a separate model was developed for rollover crashes.
Results: For the front/side model applied to the US standard population, the mean estimated risk for the US-vehicle model is 0.035 (sd = 0.012), and the mean estimated risk for the EU-vehicle model is 0.023 (sd = 0.016). When applied to the EU front/side population, the US model predicted a 0.065 risk (sd = 0.027), and the EU model predicted a 0.052 risk (sd = 0.025). For the rollover model applied to the US standard population, the US model predicted a risk of 0.071 (sd = 0.024), and the EU model predicted 0.128 risk (sd = 0.057). When applied to the EU rollover standard population, the US model predicted a 0.067 risk (sd = 0.024), and the EU model predicted 0.103 risk (sd = 0.040).
Conclusions: The results based on these methods indicate that EU vehicles most likely have a lower risk of MAIS3 + F injury in front/side impacts, while US vehicles most likely have a lower risk of MAIS3 + F injury in llroovers. These results should be interpreted with an understanding of the uncertainty of the estimates, the study limitations, and our recommendations for further study detailed in the report.

1. Introduction

One barrier to trade between the European Union and the United States is the differing safety standards testing and requirements for vehicles sold in the EU and the US. Testing the same make/model under both regimens and adapting design to each can be expensive, and negotiation of common standards may be difficult and time-consuming. An alternative to item-by-item harmonization is mutual recognition, an approach that has been implemented to some degree in the airline domain (BASA, 2011). Under this solution for the automotive industry, vehicles that meet EU regulations would be recognized for sale in the US, and vehicles that meet US regulations would be recognized for sale in the EU. To justify mutual recognition, it would be necessary to demonstrate that safety performance in EU- and US-regulated vehicles is

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essentially equivalent. A review of the literature did not find documentation of previous work in this area.

This paper describes development and implementation of a statistical methodology to investigate the hypothesis that passenger vehicles meeting EU safety standards would perform equivalently to US-regulated passenger vehicles in the US driving environment, and that vehicles meeting US safety standards would perform equivalently to EU-regulated vehicles in the EU driving environment. Crash datasets from each region represent the combination of risk and exposure for a given environment and vehicle population. Risk is the probability of injury or crash involvement given a particular set of circumstances, while exposure is the particular collection of those circumstances. If a vehicle is moved to a different driving environment, its risk characteristics are carried with it, but the exposure to different crash characteristics changes with the alternate environment. This paper focuses on crashworthiness, the risk of injury given that a crash has occurred.

2. Methods

The methods for this analysis consist of four steps: 1) Identify appropriate databases that include in-depth crash information, such as estimation of crash severity using the change of velocity in a crash (delta-V) and injury outcome based on medical records; 2) Harmonize variable definitions and sampling criteria so that the EU data could be combined and compared to the US data; 3) Build logistic regression models of injury risk in EU-regulated and US-regulated vehicles using the same parameters; and 4) Apply injury risk predictions of the EU injury risk model and the US injury risk model to both US and EU standard crash populations.

2.1. Datasets

Datasets used were the National Automotive Sampling System-Crashworthiness Data System (NASS/CDS or CDS) for the US, the Co-operative Crash Injury Study (CCIS) from Great Britain, the Véhicule Occupant Infrastructure Etudes de la Sécurité des Usagers de la Route - Vehicle Occupant Infrastructure and Road Users Safety Studies (VOIESUR) from France, and the German In-Depth Accident Study (GIDAS) from Germany. In addition, a sample from the European Pan-European Co-ordinated Accident and Injury Database (PENDANT) project was included. PENDANT covered eight EU countries; cases were removed that could be duplicated in other datasets. For weighting the European datasets towards the whole EU, we also used the Community Road Accident Database (CARE). CARE contains aggregated national crash data (police-reported crashes) from all 28 EU countries plus Iceland, Liechtenstein, Norway and Switzerland.

Sampling restrictions used in any of the datasets were applied to all datasets to avoid sampling bias. Key restrictions were: 1) at least one occupant in the crash had an injury with Abbreviated Injury Scale value of 1 or greater (AIS1 +); 2) at least one vehicle was towed away from the accident site (though all databases did not include this variable), and 3) at least one vehicle had a damage extent of 2 or greater according to its Collision Damage Classification (CDC) for the crash. The analysis was conducted at the occupant level, and additional restrictions were applied to focus on risk that could be associated with vehicle design related to regulatory requirements. These restrictions included: 1) Vehicle model years 2003 +; 2) front outboard occupants aged 13 + with known belt use status; 3) vehicles with reconstructed Delta-V (does not apply to rollover); 4) cases with non-missing values of predictors; and 5) vehicles with front or side damage (based on the CDC for the most harmful event) or vehicles that experienced a rollover.

2.2. Harmonization

Among the datasets, crash severity for planar impacts is described by delta-V. However, the reconstruction method varied with dataset using either a crush-based and trajectory-based method. To assess the comparability of these methods, we identified cases in the Swedish Investigation Network and Traffic Accident Collection Techniques (INTACT) and the Road Accident Sampling System India (RASSI) in-depth databases with data that allowed both reconstruction methods to be applied (Fagerlind et al., 2017, Rameshkrishnan et al., 2013). The two reconstructions were compared separately for frontal and side impacts, and found to be generally similar. From these comparisons, we developed a linear transformation which, when applied to crush-based reconstruction cases, harmonizes them with the trajectory-based reconstructions. Thus, the Delta-V values used throughout this study can be considered to be equivalent to trajectory-based reconstructed Delta-V.

Table 1
Definitions of intrusion level from each dataset (cm).

	None	Minor	Major
CDS	0–2	3–15	16 +
PENDANT	0–5	6–15	16 +
GIDAS	0–5	6–15	16 +
CCIS	0–5	6–15	16 +
VOIESUR	0%	1–25%	25% +

Each dataset included information on intrusion, which was grouped categorically as defined in Table 1. A harmonized method of classifying roadways as urban or rural is shown in Table 2.

Frontal, near-side, and far-side crashes were analyzed together (termed "front/side crashes") to maximize sample size. A separate model was developed for rollover because delta-V is generally not reconstructed for rollover.

The starting list of harmonized predictors for front/side crashes, to be considered in the model development process described below, included: delta-V (log and square transformations considered), crash type (front, near side, far side), age, age^2 (to allow a quadratic relationship), belt use (3-point or none), road type, vehicle type (≤ 6 seating positions or 7 + seating positions), model year group (2003–2006 or 2007 +), principal direction of force (PDOF) (0, 30, > 30 relative to side of damage), intrusion (relative to side of impact), airbag deployment, crash partner (car, narrow, wide, other), presence of multiple impacts, and interactions of Delta-V and crash direction. For rollover, the starting list included: age, age^2, gender, roof intrusion, ejection, belt use, road type, model year, light condition, and seat position. Further details of the weighting process for the EU standard population, harmonization of Delta-V and other variables are described in the project report (Flannagan et al., 2014).

2.3. Model development

The injury outcome used in analysis was based on the Maximum Abbreviated Injury Scale (AIS) score. Occupants whose worst injury had

Table 2
Definitions of crash location/road type from each dataset.

	Rural	Urban
CDS	Undivided road with speed limit > 40 mi/h	All other roads
PENDANT	("Local area" rural) or ("Local area" mixed, "carriageway type" motorway and speed limit > 90 km/h) or ("Local area" mixed, "carriageway type" not motorway and speed limit > 50 km/h)	("Local area" urban) or ("Local area" mixed, "carriageway type" motorway and speed limit < = 90 km/h) or ("Local area" mixed, "carriageway type" not motorway and speed limit < = 50 km/h)
GIDAS	Out of city	In city
CCIS	Speed limit > 40 mi/h	Speed limit ≤ 40 mi/h
VOIESUR	Outside urban area	Inside urban area