Accident Analysis and Prevention 117 (2018) 392–397

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Comparing motor-vehicle crash risk of EU and US vehicles

Carol A.C. Flannagan[a], András Bálint[b,e], Kathleen D. Klinich[a,*], Ulrich Sander[c,e], Miriam A. Manary[a], Sophie Cuny[f], Michael McCarthy[g], Vuthy Phan[f], Caroline Wallbank[g], Paul E. Green[a], Bo Sui[c,e], Åsa Forsman[d,e], Helen Fagerlind[b,e]

[a] University of Michigan Transportation Research Institute, United States
[b] Chalmers University of Technology, Vehicle Safety Division, Gothenburg, Sweden
[c] Autoliv Research, Vårgårda, Sweden
[d] The Swedish National Road and Transport Research Institute, Linköping, Sweden
[e] SAFER Vehicle and Traffic Safety Centre at Chalmers, Gothenburg, Sweden
[f] Centre Européen d'Etudes de Sécurité et d'Analyse des Risques, Nanterre, France
[g] TRL (Transport Research Laboratory), Crowthorne, United Kingdom

ARTICLE INFO

Keywords:
Crash risk
United States
European Union
Statistical methods
Regulations

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

* Corresponding author.
E-mail address: kklinich@umich.edu (K.D. Klinich).

https://doi.org/10.1016/j.aap.2018.01.003
Received 2 May 2017; Received in revised form 2 January 2018; Accepted 6 January 2018
Available online 23 February 2018

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 Cooperative 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

an AIS score of 3 or higher or those who were fatally injured were classified as "MAIS3 + F injured."; those who were uninjured or whose worst injury had a score of 2 or less were classified as "not MAIS3 + F injured." This injury level was selected because it is typically used for regulatory analysis to define targets and assess vehicle performance (e.g. NHTSA, 2007).

The first step in the model development process was to generate injury risk models for front/side crashes and rollovers separately for each of the EU and US datasets. The US risk models for front/side and rollover were developed using logistic regression. Case weights from the NASS-CDS dataset (based on sampling strategies) were used in analysis, and survey methods (Taylor series) were used to account for the sample survey design and estimate the variance-covariance matrix for the coefficients. The EU model was also developed using logistic regression. Cases in the four EU development datasets were weighted based on CARE, and weights were normalized to the raw sample size to appropriately estimate the variance-covariance matrix for the coefficients. Based on the results from the initial four EU and US models, all predictors significant in any models were included in the final analysis and non-significant model parameters were dropped. In marginal cases, changes to Akaike Information Criteria (AIC) were considered in deciding whether to include a parameter or not. The final models used the same set of 18 predictors (including an intercept) for front/side and 9 predictors (including an intercept) for rollover.

2.4. Application to standard population

To estimate overall injury risk in the crash population for each model, we required a standard crash population for each region. The EU standard population consisted of the combined EU datasets used for model development (the in-depth data from each country) weighted to the EU crash population based on the CARE dataset using the most recent years per country (2009 to 2013). The US standard population was the CDS crash years 2007–2012 with previously identified restrictions applied. Assessment of overall injury risk was carried out in parallel: once on the US standard population and once on the EU standard population.

Finally, the EU and US logistic regression models were applied side-by-side on each standard population, generating a risk estimate and standard error for each observation. Because these estimates can be considered asymptotically normal, we used the weighted average risk to estimate the mean of the estimated risk for each vehicle group across the *whole* of each population and weighted mean of the squared standard errors as the estimate of the variance. The square root of this value provided the standard error of the risk estimate for each vehicle group. Treating these as normal distributions, we then computed the mean and standard deviation of the difference between the two vehicle groups within each standard population. Thus, we obtained a distribution of the risk difference between the two models for the US standard population and the EU standard population. Risk differences were computed as EU minus US, such that positive values indicate lower risk for US vehicles and negative values indicate lower risk for EU vehicles.

To provide a balanced approach to the question of whether safety for the two vehicle groups is equivalent, we did not use hypothesis testing. Failure to reject the null hypothesis is not evidence *for* the null (Wasserstein and Lazar, 2016). Instead, we present the distributions of risk differences for the two standard populations and discuss their implications.

3. Results

Table 3 lists the predictors and coefficients of the best-fit EU and US models for the front-side and rollover populations that predict risk of MAIS3 + F injury. The front-side models use 18 coefficients, while the rollover models use 9 coefficients.

Fig. 1 shows the distributions of estimated overall population injury risk for EU and US front-side injury risk models applied to the US front-side standard population, while Fig. 2 shows the EU and US front-side injury models applied to the EU standard population. The resulting distributions of risk differences are shown in Fig. 3 for the US

Table 3
Coefficients of best-fit models of MAIS3 + F Injury.

Variable	EU: frontal/side	US: frontal/side	EU: Rollover	US: Rollover
Intercept	−6.099	−9.353	−3.386	−4.454
Delta-V	0.072	0.075		
Age	−0.075	0.073	0.014	0.027
Age*Age	0.081	−0.031		
Far	0.715	−1.522		
Near	0.759	−0.353		
Unbelted	0.361	1.498	2.145	0.866
Delta-V*Far	0.037	0.069		
Delta-V*Near	−0.024	0.050		
Intrusion: minor	0.662	1.249	−0.835	0.268
Intrusion: major	1.790	1.607	0.447	0.693
PDOF 30	−0.344	0.141		
PDOF > 30	−1.692	−0.509		
Partner: narrow	1.171	1.227		
Partner: wide	2.363	0.789		
Partner: other	1.115	1.036		
Model year 2007 +	−0.413	−0.175	0.069	−0.557
Rural	1.383	0.598	0.385	0.637
Ejection			1.587	1.740
Female			−0.1576	−0.0786

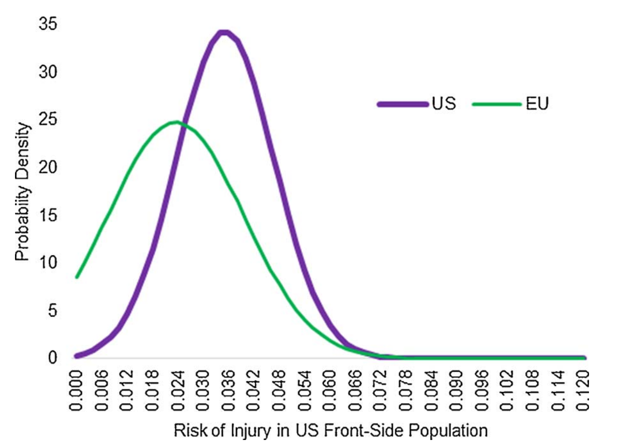

Fig. 1. EU (thin green) and US (thick purple) front-side injury models applied to the US front-side population.

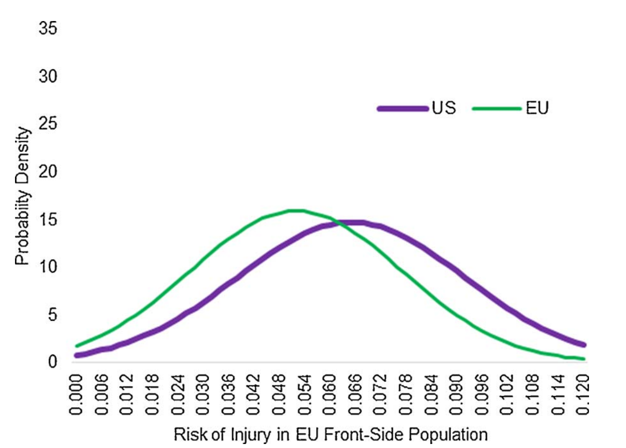

Fig. 2. EU (thin green) and US (thick purple) front-side injury models applied to the EU front-side population

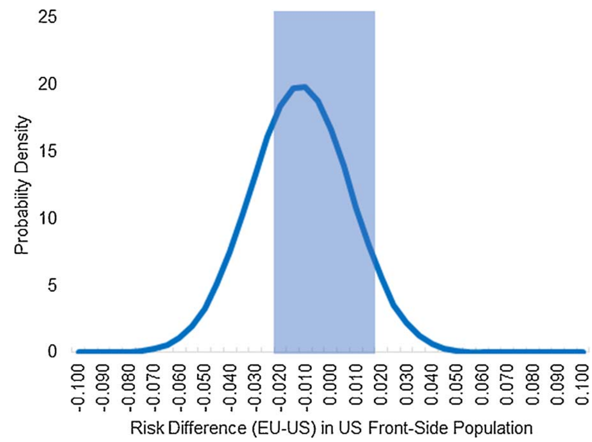

Fig. 3. Difference in risk between EU and US models applied to the US front-side population.

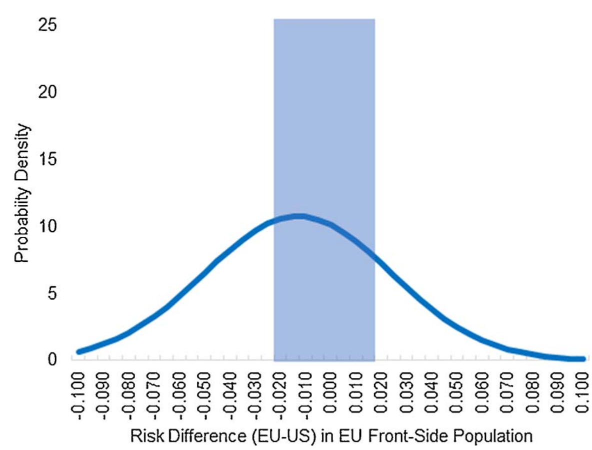

Fig. 4. Difference in risk between EU and US models applied to the EU front-side population.

population and Fig. 4 for the EU population. Note that in Fig. 1, the EU population includes a non-trivial proportion of cases at 0. This occurs because asymptotic normality may be violated for this dataset and the variance is large enough that the distribution should extend into negative values and must be cut off at 0.

When applied to the US front-side standard population, the mean estimated risk for the US-vehicle model is 0.035 with a standard deviation of 0.012, and the mean estimated risk for the EU-vehicle model is 0.023 with a standard deviation of 0.016. The mean risk difference is −0.012, indicating that risk would be lower on the US front-side population when the EU model is applied. The standard deviation of the risk difference is 0.020 and the 95% CI is (0.051, 0.027).

To illustrate a possible way of interpreting the figures taken from the bioequivalence literature (e.g., Committee for Medicinal Products for Human Use, 2010), the blue-shaded box represents a defined region of “essential equivalence.*” The boundaries shown here from −0.02 to + 0.02 risk difference were arbitrarily selected;* in real-world applications, these boundaries should be determined by negotiations regarding the maximum tolerated risk difference. In this example, since 59% of the area under the curve lies within the blue box, there is a 59% probability that the risk difference lies between −0.02 and + 0.02.

When applied to the EU front-side standard population, the mean estimated risk for the US-vehicle model is 0.065 with a standard deviation of 0.027, and the mean estimated risk for the EU-vehicle model is 0.052 with a standard deviation of 0.025. As shown in Fig. 4, the mean risk difference is 0.013. The standard deviation of the predicted risk difference is 0.037 and the 95% CI is (0.084, 0.059). There is a 39% probability that the risk difference falls between 0.02 and + 0.02.

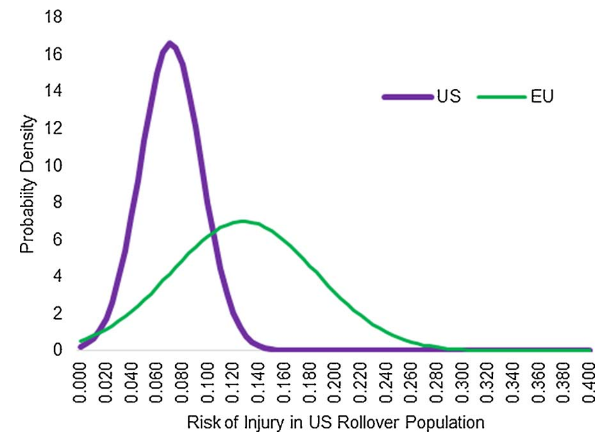

Fig. 5. EU (thin green) and US (thick purple) rollover models applied to the US rollover population.

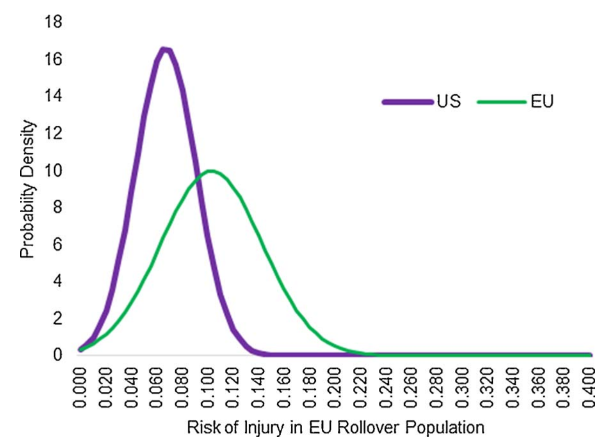

Fig. 6. EU (thin green) and US (thick purple) rollover models applied to the EU rollover population.

Comparable results for the rollover models are shown in Fig. 5 through Fig. 8. The rollover models applied to the US population are in Fig. 5 and the rollover models applied to the EU population are in Fig. 6. For the US standard population, the predicted mean risk is 0.071 (sd = 0.024) for the US-vehicle model and 0.128 (sd = 0.057) for the EU-vehicle model. The mean risk difference applied to the US population is 0.057, with a standard deviation of 0.062. The 95% CI is (0.064, 0.179). As shown in Fig. 7, only 17% of the area below the curve falls within the range of -0.02 to + 0.02.

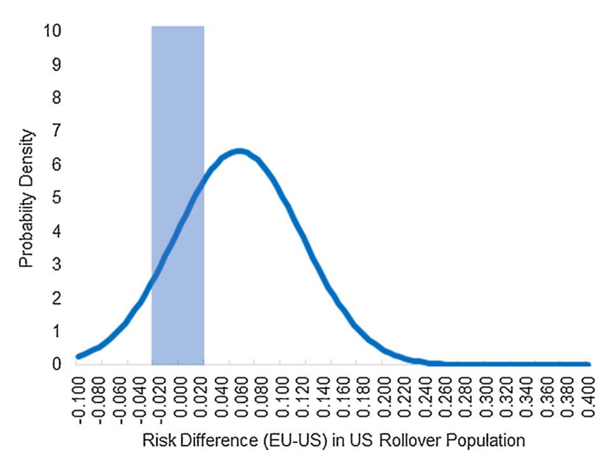

Fig. 7. Difference in risk between EU and US models applied to the US rollover population.

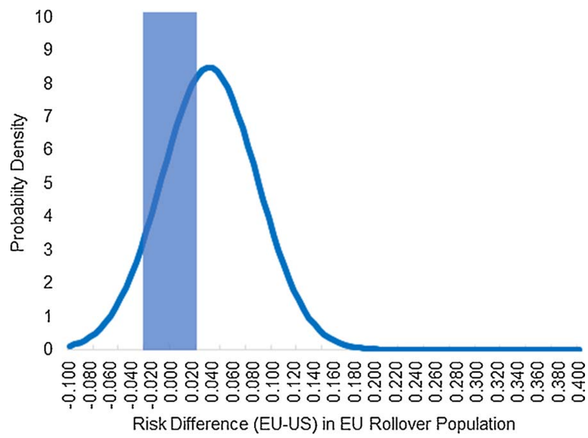

Fig. 8. Difference in risk between EU and US models applied to the EU rollover population.

For the EU rollover standard population shown in Fig. 6, the mean predicted risk for the US-vehicle model is 0.067 (sd = 0.024) and for the EU-vehicle model the mean is 0.103 (sd = 0.040). The mean risk difference shown in Fig. 8 is 0.037, with a standard deviation of 0.047. The 95% CI is (0.055, 0.128), and 25% of the area below the curve falls within the range of −0.02 to + 0.02.

4. Discussion

4.1. Approach

The approach we chose to compare crashworthiness was to develop statistical injury risk models for EU-regulated vehicles and US-regulated vehicles and then to compare the predictions of these models on the EU crash population and the US crash population. This allows us to separate risk (which is influenced by crashworthiness-related regulations) from exposure (the collection of crashes experienced by occupants in each region). It is not useful or appropriate for the present purposes to compare risk of injury of US vehicles within the US population to the risk of injury in EU vehicles within the EU population, because the total injury risk in each region is a combination of the risk and exposure.

Although the risk model approach is a good way to separate risk from exposure, it does not perfectly eliminate all possible alternative explanations. We presume that regulatory differences are the primary mechanism to explain differences between the risks from the two populations. However, because regulation provides a *minimum* standard, one alternative explanation for differences is that one population of vehicle owners tends to purchase safer vehicles (i.e. vehicles higher above the minimum standards) than the other. This cannot be controlled or measured with our datasets and could produce overall differences in risk. A related alternative explanation is that consumer ratings systems, such as New Car Assessment Programs in the US and EU, (US NCAP or Euro NCAP), which are also different in the two regions, drive vehicle design, and differences are related to the elements emphasized by the ratings rather than the base regulations. Finally, the possibility exists that data artifacts not accounted for by the models are influencing the results. Significant effort was put into removing foreseeable artifacts, but unforeseen issues are always possible in analysis of observational data.

Two steps in the data analysis served to remove as many alternative explanations as possible. First, we constrained the inclusion criteria for all of the samples to be the same. This way, we sampled from the same population of crashes, even though they may arise very differently in the two regions. Second, we used the same set of predictors to build risk models that estimate injury risk under a specified set of circumstances of the crash, vehicle, or occupant. The circumstances (e.g., occupant age, crash severity, crash direction) were designed to isolate risk from exposure as much as possible. That is, injury risk should not be affected by whether a crash was caused by speeding, texting, or falling asleep at the wheel as long as the nature of the crash (its direction and severity, indicating the forces acting on the vehicle occupants) is the same.

4.2. Findings

Results from the side-by-side application of the two maximum likelihood models were consistent for the two standard populations. For front and side impacts, overall estimated risk for EU vehicles was lower than for US risk, but the variability is relatively large resulting in a distribution of risk differences that extends above and below zero. For rollovers, US vehicles have lower risk for both populations, and the distribution of risk differences, though crossing zero, indicates that the risk difference is likely larger than zero.

The distributions of probable risk differences give a more complete picture of the uncertainty in the analysis and the relative support for different risk differences. For the same reason, confidence intervals are presented besides the best estimate (the mean) in order to convey the level of uncertainty.

The overall injury risk in the combined EU dataset is higher than that of the US dataset. However, when models were compared side-by-side, the risk differences for both front-side and rollover were in the same direction. This pattern suggests that the population of crashes in the EU, at least within the population studied, may be more dangerous than those in the US. However, the risk model predictions for both regions track this pattern, suggesting that the intercepts of the risk models are not driving the relative risk predictions.

4.3. Limitations

The primary limitations of this study arise from data limitations. First, the EU includes 28 countries, but the analysis used in-depth data from only 8 of them. We adjusted using the CARE dataset to better represent EU crashes as a whole, but such weighting notably could not account for lower belt-use rates in some countries outside of the data-collection set. For example, IRTAD (2013) reports that seat belt use rates in the front seat are lower in Greece (74%–77%), Italy (63%-75%), and Hungary (82%) in comparison to France (98%), Germany (98%), and the UK (95%). If belt-use rates are lower in the EU than in our dataset, overall risk differences would be expected to increase in both populations (i.e., greater negative risk difference for front/side and greater positive risk difference for rollover). Further, the distribution of injury severity for several EU countries observed in CARE led to the observation that there is a tendency towards underreporting of slight or not injured occupants, which in turn may result in increased risk estimates.

Some additional artifacts might account for some of the risk differences seen. For example, the sample analyzed was the population of vehicles purchased by US and EU drivers. If drivers in one country purchase higher-end, safer vehicles on average, the overall risk for that region would be lower. Another possibility is that the inclusion criteria requiring crashes with an injured occupant, combined with different occupancy rates in the EU compared to the US, might result one region's population of crashes being somewhat more severe (because multiple occupants provides more opportunities for someone to be injured).

Harmonization of datasets was generally successful, but this activity introduces unquantifiable uncertainty—that is, the success of harmonization cannot be tested, so the process itself may introduce variance that cannot be measured. As a result, uncertainty is relatively large and it is difficult to distinguish definitively among competing hypotheses. We also cannot be certain that the sampled populations are identical, though we believe that the inclusion criteria harmonization was generally successful in preventing bias.

It is also important to mention that, due to the need to harmonize the inclusion criteria, the crashworthiness analysis addresses the risk of severe or fatal (MAIS3 + F) injury *in the event of an injury crash also resulting in a towaway*. This selection criterion was applied to all datasets because NASS-CDS only includes towaway crashes. This is a slightly different focus than the risk of MAIS3 + F injury in case of *any* (unconstrained) crash which is addressed by the regulations. That said, the majority of MAIS3 + F injuries in the US occur in crashes that would meet these inclusion criteria.

Another limitation is the focus on injury to vehicle occupants. Injuries to pedestrians and cyclists can also be affected by vehicle regulations in each country, but there were insufficient data to assess these populations.

4.4. Conclusions

Overall risk across front-side crashes in the US and EU (given the selection criteria for this study) is likely lower for EU vehicles. Though the range of estimates is wide, the best estimate of the risk difference for the US standard front/side population is 0.012. The best estimate of the risk difference for the EU standard front/side population is 0.013.

Overall risk across both EU and US rollover crash populations is lower for US vehicles. The best estimate of the risk difference for the US population is 0.057. The best estimate of the risk difference for the EU population is 0.036.

The goal of this study was to address the equivalence of the real-world safety performance of passenger vehicles developed in two separate regulatory environments. In principle, the approach is designed to evaluate evidence related to the elements of relative field performance of EU and US vehicles that can be attributed to regulatory differences (rather than environmental differences). In practice, the causal tie between regulatory differences and observed field performance differences cannot be made without randomized controlled trials. Thus, the modeling approach used here can identify observed differences and can eliminate as many alternative explanations as possible, but analysis of observational field data cannot establish cause with certainty.

In conjunction with this analysis, a productive next step would be to conduct a detailed meta-analysis of work done on the component datasets. This study combined different European datasets as well as one from the US, and involved considerable effort to harmonize variables and adjust for delta-V. However, published work using the component datasets should show similar results if the effects are robust. Meta-analysis would benefit from the harmonization work in this paper (e.g., in interpreting variables in separate analyses from EU and US datasets.) It would also provide estimates of the variability in particular effect sizes across data sources, which would lend further help in understanding the results we reported here.

4.5. Recommendations

To our knowledge, this is the first published side-by-side comparison of predicted risk for EU-regulated and US-regulated vehicles. As such, further work should be done to replicate the results, identify artifacts that may have influenced the patterns seen, and/or seek evidence for mechanisms linking the results to vehicle design differences that result from regulatory differences. We recommend several options for next steps in research.

First, we recommend additional detailed analyses of the field data. In particular, this analysis represents a high-level comparison in which several crash modes are combined for overall estimates of relative risk. Since regulation applies to specific crash modes, a follow-on study should look at detailed comparisons of particular crash modes.

Similarly, crash context should be investigated in more detail to assess the extent to which the different driving and crashing context in the EU and US influences results. For example, the potential effect of the substantially greater share of SUVs and pickup trucks in the US population than in the EU should be examined. In addition, roadway type and terrain may influence rollover propensity and likely differ between the US and EU populations. Datasets with a rollover severity measure could be used to look at whether different ESC penetration in the two populations could have influenced the rollover results. While the US dataset includes number of quarter turns as a measure of rollover severity, this measure is not included in all of the EU datasets.

Second, we recommend using computational models of typical US-regulated and EU-regulated vehicle designs to investigate potential physical mechanisms of the similarities and differences. Crash testing is only done in extreme conditions, but most crashes in the field data are lower severity. Computational models allow investigation of injury mechanisms over a wide range of field conditions. When combined with crash data analysis, this approach can help find mechanisms for the results seen in the field.

Finally, in this paper, the use of crash data in various contexts has been demonstrated and at the same time, certain gaps in data availability have been identified. Future reproductions and extensions of this study would greatly benefit from the availability of globally harmonized accident data, hence further data collection and data harmonization efforts are encouraged.

Acknowledgment

This work was carried out by the University of Michigan Transportation Research Institute (UMTRI) in association with SAFER – Vehicle and Traffic Safety Centre at Chalmers, Sweden; Centre Européen d'Etudes de Sécurité et d'Analyse des Risques (CEESAR), France, and Transport Research Laboratory (TRL), United Kingdom. UMTRI, CEESAR, TRL and three SAFER partner organizations were involved in this project: Chalmers University of Technology, Autoliv Research, and VTI, the Swedish National Road and Transport Research Institute. We would like to thank the following agencies for use of their data: TRL Limited (on behalf of the UK Department for Transport), The German Federal Highway Research Institute (BASt) and the German Research Association for Automotive Technology (FAT), the French National Research Agency and Foundation MAIF, the European Commission. This research was sponsored by the Alliance of Automotive Manufacturers. The opinions expressed within this report represent those of the authors and not necessarily those of the funding agency.

References

Bilateral Air Safety Agreement, 2011. Agreement Between The United States of America and The European Community on Cooperation in The Regulation of Civil Aviation Safety, 2011-0088. Available at http://www.state.gov/documents/organization/169475.pdf.

Committee for Medicinal Products for Human Use, 2010. Guideline on the Investigation of Bioequivalence. European Medicines Agency (EMA), London, pp. 27.

Fagerlind, H., Brown, J., Bálint, A., 2017. A novel approach to study the health consequences of road crashes. J. Transport Health 7, 280–287. http://dx.doi.org/10.1016/J.JTH.2017.09.009.

Flannagan, C.A.C., Green, P.E., Klinich, K.D., Manary, M.A., Bálant, A., Sanders, U., Sui, B., Sandqvist, P., Selpi, Howard, C., 2014. Mutual Recognition Methodology Development, UMTRI Report No. UMTRI-2014-32. . http://hdl.handle.net/2027.42/111736.

International Road Traffic Accident Database IRTAD, 2013. Road Safety Annual Report. OECD/ITF.

National Highway Traffic Safety Administration, 2007. The New Car Assessment Program; Suggested Approaches for Future Program Enhancements, DOT HS 810 698. US Department of Transportation, Washington, DC.

Rameshkrishnan, N., Sathyakumar, A., Balakumar, A., Hassan, R., Rajaraman, R., Padmanaban, J., 2013. The new in-depth, at-the-scene, accident investigation database in India. In: Proceedings International Research Council on the Biomechanics of Impact (IRCOBI). Gothenburg.

Wasserstein, R.L., Lazar, N.A., 2016. The ASA's Statement on P-Values: Context, Process, and Purpose. The American Statistician.