ACCEPTED – to appear in conference proceedings of International Research Council on Biomechanics of Injury

Ride-hailing in the Safe System: Increased Seat Belt Compliance and Late Model Year Vehicles

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Abstract Though aggregate rear seat belt use is at an all-time high in the U.S. (82%), research has shown that fewer than 40% of ride-hailing passengers buckle up. Similarly, the age of ride-hailing vehicles, and thus the availability of the latest passive safety features, can vary considerably. Given the opportunity for passive safety benefits, this study evaluated the aggregate effect of these factors on injury at the serious (MAIS3+) and critical (MAIS5+) levels given the current U.S. planar crash severity distribution. Data from 2017-2023 of NHTSA's Crash Investigation Sampling System (CISS) were input to a previously-published vehicle occupant injury risk model to estimate the MAIS3+ and MAIS5+ risk. The effect of increased seatbelt compliance and driving newer vehicles were estimated by varying these parameters. Relative to the current worst-case state of ride-hailing in the United States, a Vision Zero fleet, with increased seat belt compliance and new vehicles, has the potential to reduce serious (MAIS3+) and critical (MAIS5+) injuries, including fatalities, by 75% or greater. Accordingly, a ride-hailing service which consistently provides the safest available vehicles at the time for all occupants represents a key approach toward reducing serious and greater crash-related injuries and working toward the goal of Vision Zero.

Keywords injury risk, safety benefits, seat belt, Vision Zero.

I. INTRODUCTION

Vision Zero is an approach toward the elimination of serious and fatal injuries within the road transport system [1-4]. As adopted by the United States, as the Safe System Approach, there are five key objectives aimed toward the elimination of crashes that result in fatalities and serious injuries: Safer People, Safer Vehicles, Safer Speeds, Safer Roads, and Post-Crash Care [5]. An underlying, implicit aspect of Vision Zero is that the biomechanical tolerance of the human body to injury represents the limiting factor in a Safe System [1]. Within ride-hailing specifically, Safer People and Safer Vehicles may be addressed. Encouraging/mandating seat belt use (Safer People) as well as making vehicle active and passive safety features more accessible (Safer Vehicles) represent a couple of ways that serious and fatal injuries may be mitigated in the road traffic network.

Safer People

As part of the annual National Occupant Protection Use Survey (NOPUS), the National Highway Traffic Safety Administration (NHTSA) observes the frequency with which vehicle occupants wear their seat belts. The most recent data from 2022 indicates that both front and rear seat belt usage have increased over the last decade, though rear belt usage (81.7%) still lags behind the front (91.6%) [6]. It should be noted that not all states have primary seat belt laws. Notably, NHTSA reported that 50% of vehicle occupants killed with known restraint status in traffic collisions in 2022 were unrestrained [7]. This percentage has largely remained unchanged over the last decade, ranging from 47% to 51% since 2013 [7].

A national telephone survey conducted in 2016 indicated that respondents who rode primarily in the rear seat of hired vehicles (57%) wore their seat belts at a lower percentage than those who primarily rode in the rear seat of personal vehicles (75%) [8]. Further, 50% of riders who either only wear a seat belt part-time or do not use seat belts ever reported that they were less likely to do so in a hired vehicle. The most commonly-cited reasons for failing to don a seat belt by responders were forgetting, perceiving it as unnecessary, or not being in the habit of doing so. Nearly 70% of riders who did not report regularly wearing their seatbelt noted that short trip distances were their reason for not buckling up [8]. Another study using the same dataset reported that 63% of respondents reported always wearing a seat belt when seated in the rear of a vehicle [9]. In another survey (ConsumerStyles),

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71% of respondents reported that seat belt use was very important in the rear seat, compared to 84% for the front seat [10]. Given that rear seat safety has lagged behind front seat safety [11], this rider perception and lower observed belt rates are concerning.

Naturalistic driving studies investigating the rate at which rear seated passengers use seat belts in the ride-hailing environment have been carried out in recent years. An investigation of four rideshare vehicles (600 total trips) reported that 64.5% of riders did not use their seat belt in the rear seat of a rideshare vehicle [12]. A similar study compared rear seat belt use in ride-hailing vehicles compared to non-ride-hailing and observed that 68% of occupants were unbelted in ride hailing vehicles, compared to only 35% of non-ride-hailing vehicles [13]. Another observational study (n = 489 total seat belt observations) investigated rear seat belt use in Las Vegas and San Francisco, observing that taxi passengers wore seatbelts 28% of the time in Las Vegas and 26% of the time in San Francisco and ridesharing passengers did so 18% of the time in Las Vegas and 52% in San Francisco [14]. A larger investigation of taxicab riders in New York City in 2014 found that only 38% wore their seat belts when riding in taxicabs [15]. While these studies are observational in nature and modest in scale, they clearly point to a lack of seat belt compliance among passengers in traditional ride-hailing environments.

Safer Vehicles

Researchers have investigated the in-field results of higher performing vehicles in consumer-facing vehicle ratings protocols, such as New Car Assessment Programmes (NCAP). Previous investigations of field crash data in Sweden have found that higher performing cars in Euro NCAP were associated with reductions in in-field injury outcomes [16-17]. Another study from the U.S. showed that NCAP ratings provided some ability to differentiate real-world injury risk for rear seat occupants in frontal collisions, though no such signal was present for side impact protection [18]. Recent analysis of insurance claims has also observed that the rate of both property damage and bodily injury claims are significantly lower for newer vehicles than the overall driving population [19].

Current estimates by the Bureau of Labor and Statistics in the U.S. indicate that the average passenger vehicle is 14 years old [20]. As such, this necessarily means that key active and passive safety technologies, such as electronic stability control (ESC), automated emergency braking (AEB), forward collision warning systems, side curtain airbags, and seat belt pretensioners and load limiters, may not be present in a large portion of the current U.S. driving fleet. Research has previously shown the estimated aggregate safety benefits associated with these technologies [11][21-25].

Specific to ride-hailing, the current policy for the two most popular human-driven, ride-sharing companies (Uber and Lyft) in the United States allow for vehicles to be up to 10 or 15 years old though local regulations and restrictions may apply. It should be noted that Uber reported in 2022 that vehicles used via their platform were 5 years old on average [26]. As part of a prospective analysis related to the Paris Olympics, officials reported in 2021 that the average age of a taxi in Paris was 3.5 years, compared to 4.5 years for other ride-hailing services [27]. In New York City in 2020, the average age of a taxi was 4.5 years, compared to 4.2 years for ride-hailing services [28]. As it relates to ride-hailing, consumers often do not have the option to select newer model year vehicles when booking a ride.

The Scale of Ride-hailing

While discerning injury data from human-driven, ride-hailing companies as part of the national crash sampling systems is not feasible, the major ride-hailing companies do provide information related to fatalities. As part of their Safety Report published in 2022, Lyft reported 111 fatalities that occurred via their service during the 3-years from 2020-2022 [29]. From 2021-2022, Uber reported 153 fatalities related to their system [26]. Both companies only consider their own vehicle fleet's mileage when capturing rates, and their aggregate fatality rate is 0.87 fatalities per 100 million miles of vehicle travel. Given these fatality counts, these transportation network companies are represented in 0.3% of all traffic fatalities (42,514) in the U.S. in 2022 [30]. While information is not readily available for taxis across the country, it is anticipated that their contribution would not bring the total proportion of fatalities involving ride-hailing vehicles to represent more than 1% of all traffic fatalities. While a direct comparison is not possible given that Uber and Lyft only report mileage for vehicles using their platform, a national estimate, which considers all vehicle miles traveled, for the fatality rate for passenger vehicles at the crashed vehicle level is 1.8 fatal incidents per 100 million miles [31].

Similarly, getting an accurate assessment of vehicle miles traveled for ride-hailing can be complicated given that ride-hailing is highly concentrated in urban areas but divided amongst transportation network companies and taxi companies. Available research indicates that a typical ride-sharing trip in a city is, on average, 3-7 miles, depending on transportation network and geographic location [26][28-29][32]. A 2018 study of Uber and Lyft found that 70% of their total trips were concentrated in only nine major U.S. metropolitan areas, with trips via transportation network companies dominating the total ride-hailing market for those cities [32]. For 2022, Uber reported 10.3 billion total miles driven via their service, and Lyft reported 4.9 billion total miles driven across the United States [26][29]. Comparatively, passenger vehicles were estimated to travel 2.8 trillion total vehicle miles in 2022 [33]. Transportation network companies thus make up less than 1% of the overall traffic volume in the U.S., with taxi companies not expected to increase this beyond 1%. A traffic volume commissioned by Uber and Lyft in 2018 revealed that the companies represented approximately 1%-3% of all traffic volume across the greater metropolitan areas of six major U.S. cities, noting that this proportion increased to 2%-13% if only mileage driven in the primary county encompassing the cities were counted [34]. These services thus represent a non-negligible portion of total roadway traffic within cities in the U.S., and the sheer number of daily trips provided by these companies highlights the potential exposure to crash risk for millions of occupants.

Research Objective

That riders in the rear seat of ride-hailing vehicles tend to not buckle up but are often in newer model year vehicles than the average population represents opposite safety trends that obfuscate the relative safety of ride-hailing. To that end, this study evaluated the aggregate effect of increased rear seat belt compliance and newer model year vehicles as part of the Safe System on injury at the serious (MAIS3+) and critical (MAIS5+) levels given the current U.S. planar crash severity distribution. Given the lack of readily-available collision data specific to ride-hailing, this study used a counterfactual approach to model injury risk given the aggregate U.S. planar crash severity distribution. Additional comparisons to average vehicle fleets based on previously-published information were also carried out to estimate the safety benefits associated with a ride-hailing fleet in the Safe System.

II. METHODS

Data Source

Data from 2017-2023 of NHTSA's Crash Investigation Sampling System (CISS) were used for this analysis. CISS is a nationally-representative probability sample of police-reported, tow-away crashes in the U.S. For this study, data were aggregated at the crashed vehicle level. Cases involving fire or rollover were excluded from the analysis. Only cases with a known resultant vehicle delta-v and defined principal direction of force (PDOF) were included as these were the principal factors defining the severity distribution for this analysis. Delta-v is only captured for in-transport, CISS-applicable vehicles, which consist of all passenger cars, light trucks, vans, and sport utility vehicles with gross vehicle weight ratings below 10,000 pounds (4536 kg) [35]. Vehicle delta-v is not reported for cases involving rollover, side swipes, non-horizontal forces, over/under ride, multiple, or overlapping impacts, among others [36]. After applying the above exclusion criteria, delta-v missingness was observed for 38% of vehicles in the dataset. The resulting dataset, which excluded these cases of unknown delta-v, represented a known estimate for the current human planar crash severity distribution with the caveat that it does not capture collisions with all object types. Case weights supplied as part of CISS were used to scale individual events appropriately for analysis, with all cases with a weight exceeding 5,000 capped at 5,000, in accordance with previous work [37].

A ride-hailing specific crash severity distribution was not possible using CISS data for a variety of reasons. Ride-hailing is primarily confined to urban areas, and the CISS sampling design does not feature many of the top ride-hailing environments [35]. Further, the vehicle special use field that is meant to capture taxi services and other ride-hailing vehicles is inconsistently used by crash investigators. Lastly, the sampling system is not a census and is designed to capture a representative sample of police-reported tow-away collisions. There has not been research to-date to indicate that the ride-hailing crash severity distribution is more severe, or markedly different, than that of the general population, so use of the aggregate human-driven crash severity distribution for this counterfactual analysis was deemed appropriate.

Injury Risk Model

This planar crash severity distribution served as input to a previously-published, state-of-the-art vehicle occupant injury risk model [38]. Unlike traditional injury risk models which discretise collision forces into specific regions (e.g., frontal, side, rear), the model used in the present study is an omni-directional, planar collision model which features a Fourier series term that captures the varied interaction of resultant vehicle delta-v and impact direction, as measured by PDOF. The model also features predictor variables related to seatbelt usage, occupant age, sex, and seating position, vehicle model year, and a categorical variable capturing the struck object (e.g., passenger vehicle, heavy vehicle, fixed object).

For this study, seatbelt usage and vehicle model year were varied, both in isolation and in specific combination for comparisons. All other variables were held constant. Default predictors for occupant age (MAIS3+: 42 years old; MAIS5+: 46 years old) and sex (MAIS3+: 54% female; MAIS5+: 50% female) were selected as reported in [38] to approximately reproduce population-average risk. Given the target evaluation of passive safety in the ride-hailing environment, all crashed vehicles were evaluated as having a single rear-seated occupant in an outboard seating position. For a conservative assessment of safety benefits, the vehicle occupant was assumed to be in a SUV/Truck/Van striking a passenger car.

The resulting logistic regression models for predicting injury risk at the MAIS3+ and MAIS5+ severity levels are presented below (Equations 1-5), with the model coefficients presented in the Appendix as available in [38]. Given that CISS provides the resultant collision delta-v and PDOF distribution and the selected parameters outlined above, the only unknowns to vary for risk evaluation were seat belt compliance and vehicle model year age.

$$p(MAISx+) = \frac{1}{1+e^{(\beta_0+\beta_1*\Delta v+\eta_{\Delta v-PDOF}+\eta_{PDOF}+\eta_{veh}+\eta_{occ})}} \quad (1)$$

$$\eta_{\Delta v-PDOF} = \beta_2 * \Delta v * \cos(PDOF) + \beta_3 * \Delta v * \sin(PDOF) + \beta_4 * \Delta v * \cos(2 * PDOF) + \beta_5 * \Delta v * \sin(2 * PDOF) \quad (2)$$

$$\eta_{PDOF} = \beta_6 * \cos(PDOF) + \beta_7 * \sin(PDOF) + \beta_8 * \cos(2 * PDOF) + \beta_9 * \sin(2 * PDOF) \quad (3)$$

$$\eta_{veh} = \beta_{10} + \beta_{11} + \beta_{12} + \beta_{13} * (model\ year - 2010) \quad (4)$$

$$\eta_{occ} = \beta_{14} * Sex + \beta_{15} * Age + \beta_{16} * Belted \quad (5)$$

As noted in the introduction, the goal of Vision Zero is to eliminate serious injuries and fatalities within the traffic network. The injury risk model used in this study did not assess fatal injuries, though. It should be noted that field crash data has shown that the occurrence of injury at the MAIS5+ severity level correlates best with a fatal outcome, with approximately 50% of injuries at the MAIS5 severity level resulting in fatality and nearly all injuries at the MAIS6 level resulting in fatality [39]. Absent a fatal injury risk curve, an MAIS5+ injury risk curve represents the best available measure to estimate fatal injury risk and would tend to be a conservative estimate (i.e., expected safety benefits would be reduced for the MAIS5+ level relative to fatal injuries). It should be noted that other scoring systems based on the AIS, such as the Injury Severity Score (ISS) or New Injury Severity Score (NISS), may offer additional insights and granularity into injury severity assessment than a score like the MAIS, which does only assess the single highest severity injury.

In order to assess the effect of uncertainty within the injury risk model, the model coefficients were sampled (R: rmvnorm) with 1,000 replicates using the model coefficients and the variance-covariance matrix from [38]. The above analysis was then carried out using these replicate models in order to obtain 95% confidence intervals, the lower and upper bounds of which were defined by sorting the samples and taking the 25th and 975th values, respectively. The mean and variance for each coefficient across the replicates was evaluated and compared to the published model, with close agreement.

Accumulated Injury Risk

Accumulated injury risk (MAIS3+ and MAIS5+) was defined by summing the individual risk estimates for each collision event into an aggregate measure that reflects the expected number of injuries at the given severity level. The effect of varying levels of seat belt compliance was modeled by varying the belted parameter from 0% to 100% in increments of 1%, with vehicle model year held constant as a 2024 vehicle. Similarly, vehicle model year effects on injury risk were modeled from 2010 to 2024 in increments of one model year, with seat belt compliance held constant at 100%. In addition to varying seat belt use and vehicle model year independently, various comparisons were then made for vehicle fleets to estimate the potential safety benefits (Table I).

Values for these fleets were taken from available literature and may not reflect the true status for any of these configurations. A hypothetical Safe System fleet was defined as having maximum seat belt compliance and relying on the most current vehicle fleet. All comparisons were made relative to the worst-case human-driven ride hailing fleet outlined below. The seat belt rate for this worst-case scenario was set at 40%, rather than some of the lower estimates observed in the literature for rear seat ride-hailing occupants, in order for the safety benefits analysis to be conservative. Vehicle fleet age was defined as being relative to a 2024 model year vehicle. This counterfactual approach for evaluating expected safety performance has been applied elsewhere in the automotive and sports safety industries, most notably with NCAP's performance ratings and the Summation of Tests for the Analysis of Risk (STAR) ratings for sports headgear [40-42].

TABLE I
MODELED VEHICLE FLEET COMPARISONS

Vehicle Fleet	Seat Belt Compliance	Vehicle Fleet Age	Reference
Human-driven ride-hailing (worst case; comparison)	40%	15 years	[14]
NYC taxi	38%	4.5 years	[15][28]
Improved human-driven ride-hailing	82%	5 years	[6][26]
Average passenger vehicle rear seat occupant	82%	14 years	[6][20]
Safe System fleet	100%	0 years	

III. RESULTS

The final dataset consisted of 14,944 collided vehicles, weighted to represent approximately 10.2 million total collided vehicles. The median case weight was 243, the 90th percentile case weight was 1,784, and the 95th percentile case weight was 3,455. The median, 95th percentile, and 99th percentile delta-v were 17 kph, 40 kph, and 60 kph respectively. For plotting purposes, PDOF was discretised into impact locations with the following designations (*Front*: 11, 12, or 1 o'clock PDOF; *Driver Side*: 8, 9, or 10 o'clock PDOF; *Passenger Side*: 2, 3, or 4 o'clock PDOF; *Rear*: 5, 6, or 7 o'clock PDOF). Consistent with previous research utilising NHTSA's nationally-representative crash sampling systems, frontal PDOFs (64% of weighted vehicles) were most commonly observed in this dataset (Figure 1) [39].

The collision severity (delta-v and PDOF) for each of the 14,944 collisions were then input into the occupant injury risk model to estimate the probability of injury at the MAIS3+ and MAIS5+ severity levels for each event. When modeling a Safe System fleet (100% rear seat belt compliance and a 2024 model year vehicle), individual event risk varied at the MAIS3+ severity level from 0.02% to 100% and from 0% to 96% at the MAIS5+ severity level. Median, 95th percentile, and 99th percentile risk at the MAIS3+ severity level were 0.2%, 1.7%, and 9.8%, respectively, and 0%, 0.1%, and 0.6% at the MAIS5+ severity level. When modeling an average rear seat occupant (82% belted, 2010 model year vehicle), median, 95th percentile, and 99th percentile risk at the MAIS3+ severity level were 0.4%, 4.5%, and 23.1%, respectively, and 0.1%, 0.7%, and 3.8% at the MAIS5+ severity level. These individual injury risk estimates were then summed together to determine the expected aggregate number of MAIS3+ and MAIS5+ severity level injuries.

When evaluating the effect of increased seat belt compliance independently, there was expectedly a marked reduction in expected MAIS3+ and MAIS5+ injuries (Figure 2). Specifically, increasing rear seat belt usage from 40% (representative of current ride-hailing estimates) to 82% (national average for all rear seated occupants) was estimated to reduce injuries by 41% at the MAIS3+ level and 50% at the MAIS5+ level. Further improvements in seat belt compliance to 90% or 95% would be expected to have injury reductions of 46% and 50%, respectively, at the MAIS3+ level and 56% and 59% at the MAIS5+ level. Achieving maximum seat belt compliance (0% unbelted) would be expected to result in injury reductions of 53% and 62% at the MAIS3+ and MAIS5+ severity levels, respectively.

Similarly, based on the underlying risk curve, newer model year vehicles were associated with decreases in expected injuries. Compared to the current average passenger vehicle (14-years-old, modeled as 2010 model year), a hypothetical rear seat occupant of a 2020 model year vehicle exposed to the human crash distribution shown in Figure 2 would be expected to have a 34% reduction in injuries at the MAIS3+ severity level and 57% at the MAIS5+ severity level (Figure 3). Additional, increasing safety benefits were estimated for 2022 (injury reductions of 39% at the MAIS3+ level and 64% at the MAIS5+ level) and 2024 vehicles (injury reductions of 44%

at the MAIS3+ level and 69% at the MAIS5+ level) as well. The confidence intervals are expectedly wider when varying vehicle model year in comparison to varying seatbelt compliance given the magnitude of the variance of these coefficients relative to the coefficients, as reported in [38].

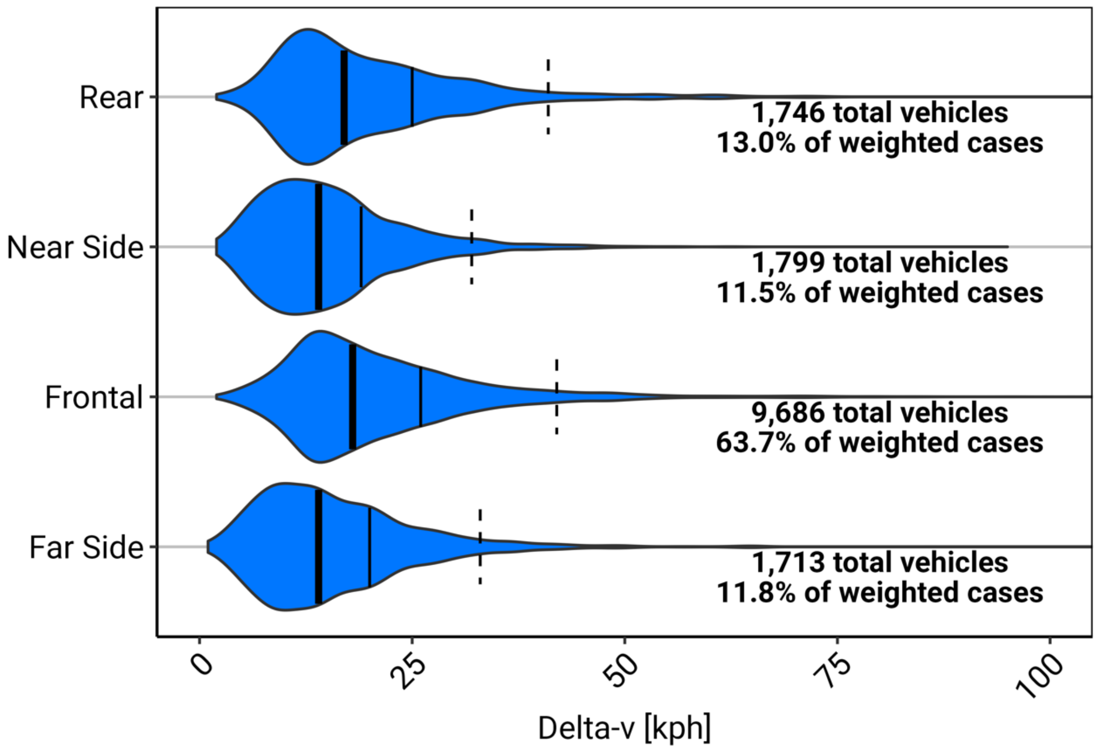

Fig. 1. Summary of human collision severity distribution. PDOFs were grouped into collision configurations for plotting purposes. The thick line represents the median, the solid line represents the 75th percentile, and the dashed line represents the 95th percentile delta-v.

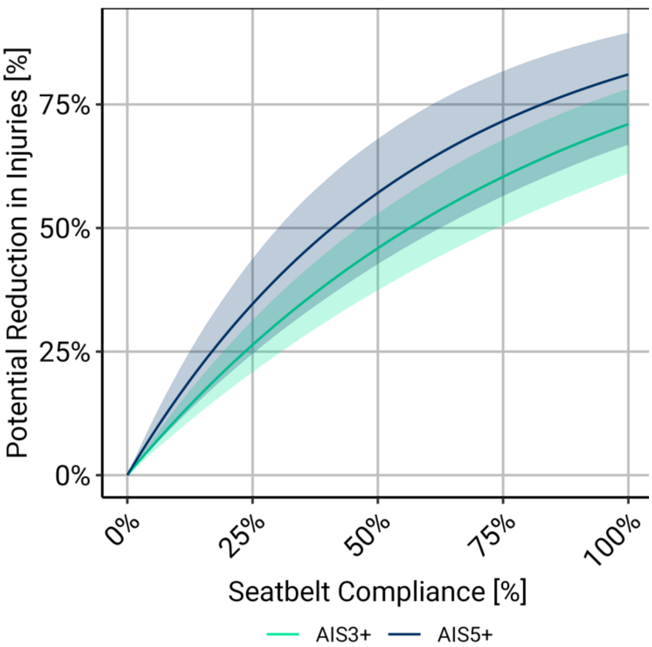

Fig. 2. Expected injury reductions at the MAIS3+ and MAIS5+ severity levels associated with increased seat belt compliance.

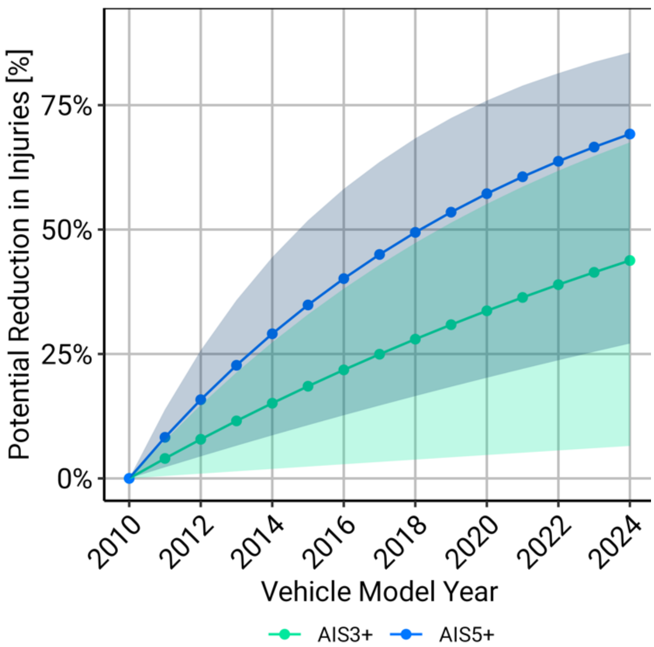

Fig. 3. Expected injury reductions at the MAIS3+ and MAIS5+ severity levels associated with newer model year vehicles.

Lastly, specific comparisons of the effect of increased seat belt compliance and newer model year vehicles for vehicle fleets were evaluated. Individual risk estimates were generated for each configuration of seat belt compliance and vehicle model year as outlined in Table I. Using the worst-case human-driven ride-hailing vehicle fleet as the reference point, each of the other evaluated fleets was associated with greater than 30% reductions in accumulated MAIS3+ injury risk and greater than 50% reductions in accumulated MAIS5+ injury risk (Figure 4). The NYC taxi fleet (newer model year vehicles) and average passenger vehicle fleet (increased seat belt compliance) largely illustrate an isolated effect for injury reduction. Improving rear seat belt use in the average ride-hailing vehicle fleet from 40% up to the national average for rear seats of 82% would be estimated to reduce the number of injuries at the MAIS3+ and MAIS5+ severity levels by more than half. A Vision Zero fleet, comprised of total seat belt compliance and the newest vehicles, was associated with the highest injury reduction potential of 75% [95% confidence interval: 55-85%] (MAIS3+) and 90% [95% confidence interval: 70-96%] (MAIS5+).

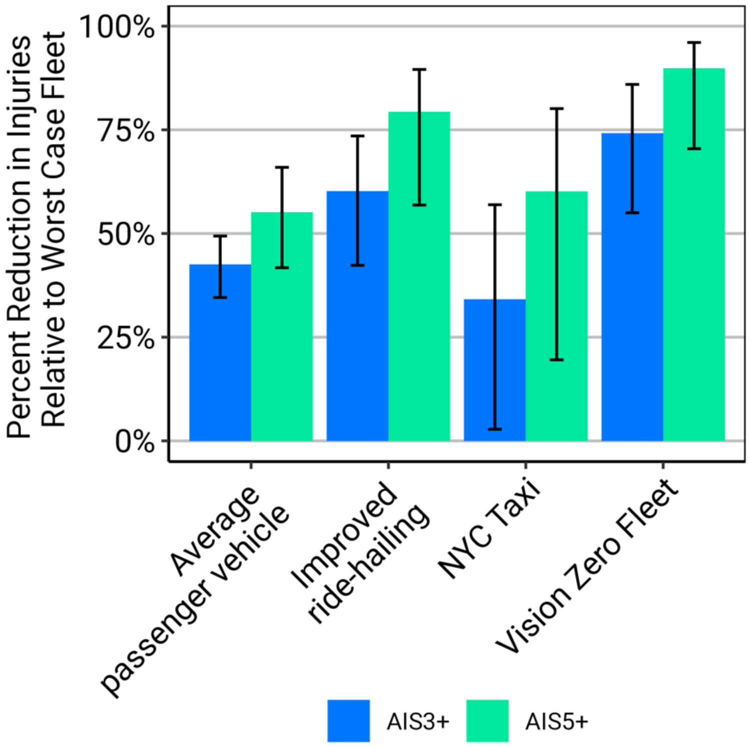

Fig. 4. Summary of expected injury reductions for various vehicle fleets (Table I) relative to a worst-case vehicle fleet as defined using available information from the literature.

IV. Discussion

This study quantified the current U.S. driving planar crash severity distribution to estimate potential safety benefits associated with moving toward Vision Zero, Safe System Approach principles in the ride-hailing environment: increased rear seat belt compliance and newer model year vehicles. Leveraging a state-of-the-art, occupant injury risk model in conjunction with data from nearly 15,000 collided vehicles, individual collision risk was estimated at the MAIS3+ and MAIS5+ severity levels and aggregated across different combinations of rear seat belt use rate and vehicle model years. Relative to the current worst-case state of ride-hailing in the United States, a Vision Zero fleet has the potential to reduce serious (MAIS3+) and critical (MAIS5+) injuries by 75% or greater.

While this study used an injury risk model approach to estimate the effect of seat belt use on injury reduction, NHTSA has historically leveraged observed field collision outcomes directly using double-pair comparison analysis [43]. This approach only considers cases with at least two occupants and allows for direct comparison of the effect of safety equipment usage on injury outcome given the same collision. The most recent estimates for seat belt effectiveness for outboard rear seat vehicle occupants report that seat belts reduce fatalities by 54% in passenger cars and 75% in light trucks and vans when controlling for sex and age differences [44]. The most analogous result from the present study of an estimated 62% reduction in injury at the MAIS5+ severity level associated with total seat belt compliance is consistent with this previous research and supports continued safety messaging surrounding seat belt usage in the U.S.

Increasing Rear Seat Belt Compliance

Given that this study adds to the growing body of literature highlighting the protective effect of seat belt usage, it is important to consider ways in which increased seat belt compliance may be achieved, with particular attention given to the ride-sharing environment. Within the Safe System, increased seat belt usage, which primarily is an aspect of *Safer People*, acknowledges that humans make mistakes and responsibility for preventing serious injuries and fatalities is shared among stakeholders. As such, encouragement to don a seat belt through safety campaigns and increased enforcement represents one method.

Each year, NHTSA carries out a national campaign *Click It or Ticket* which aims to increase seat belt usage and awareness of the negative consequences of failure to wear a seat belt. This initiative focuses on increased enforcement by state and local law enforcement personnel. Early analysis of the national program showed that seat belt usage increased nationwide [45]. A recent analysis of the campaign in New York (2014-2017) revealed that there was a statistically significant reduction in occupant mortality during the enforcement period and shortly thereafter compared to the rest of the year [46]. The authors concluded that the effect suggested that enforcement also affects risky driving behavior.

Another method leverages the *Safer Vehicles* aspect of the Safe System, whereby the development and implementation of new technologies, such as seat belt reminder systems, can work to limit the frequency at which vehicle occupants ride without wearing their seat belts. To that end, researchers have also investigated the effect of seat belt reminders on occupant belt use. Early studies in the early 2000s in Europe showed increases in seat belt use from 85.8% to 97.5% for vehicles with seat belt reminders relative to those without [47-48]. Similar analysis in the United States in 2007 showed an increase of 3% to 4% for drivers in vehicles with enhanced seat belt reminder systems compared to drivers in vehicles without such a system [49]. More recently, researchers at the Insurance Institute for Highway Safety (IIHS) investigated the effectiveness of driver seat belt reminder systems and found that an audible reminder lasting at least 90 seconds was both more effective and more accepted by drivers than a speed-limiting interlock or an intermittent audible reminder [50-51].

These seat belt reminders are now part of vehicle consumer rating programs around the world. In December 2024, NHTSA finalised a rule which will require seat belt use warnings for the rear seats beginning in September 2027. The requirement will consist of a visual warning upon ignition of at least 60 seconds if a rear seat is occupied, and there is no seat belt in use; an additional visual and auditory warning of at least 30 seconds is required in instances where the rear seat belt becomes unfastened with the vehicle in drive [52]. Rear seat belt warnings and reminders are already part of Euro NCAP and IIHS. IIHS's rear seat belt reminder requirement mirrors that which NHTSA set forth in its requirement, with some additional speed-related criteria for when a rear seat belt is unfastened while the vehicle is in motion [53]. Under the current testing protocol at IIHS, a vehicle cannot attain a *Good* rating, the highest IIHS offers, without satisfying the rear seat belt reminder requirements. The Euro NCAP rating procedure is similar, where failure to satisfy rear seat belt reminder in all available rear seats precludes a maximum safety rating [54].

Specific to ride-hailing, a small-scale experiment (n=86 rear seat ride-hailing passengers) evaluating the effect of warning signage on rear seat belt use indicated that 60% of passengers wore their seat belt when the warning signage was in place compared to only 20% of passengers when no warning was present [55]. Based on this and other research, there are several procedures in place to encourage seat belt compliance in ride-hailing vehicles. As of July 2024, Uber utilises seat-belt alerts, which provides an in-vehicle voiceover and in-app reminder to buckle up [26]; Lyft uses a similar system. Waymo, an autonomous ride-hailing service, uses a combination of in-vehicle screen notifications, audio alerts, and seat-back cards, in addition to leveraging vehicle seat belt sensors to remind riders to buckle up. As the analysis in the present study showed, higher levels of seat belt compliance have the potential to offer tremendous aggregate safety benefits.

The Effect of New Model Year Vehicles

As defined in the underlying risk model used in this study, there is a static effect for new model year vehicles that indicates a reduction in expected injury of 5% at the MAIS3+ level and 10% at the MAIS5+ level for each new model year increase [38]. An analysis of the historical effect of vehicle design changes on driver fatality rate observed an 8% reduction in risk of driver death for 2009 model year vehicles relative to 2008 model year vehicles for drivers aged 65 and older [56]. A similar analysis reported a 46% lower risk of death for drivers (65 years old and older) of model year 2010 and newer vehicles in comparison to model year 2000 to 2009 over the years of 2010 to 2015 [57]. This effect has also been observed across all age groups, with newer model year vehicles being associated with lower crash-related mortality than older vehicles [58-59].

It is also important to consider the effect of newer model year vehicles, which may be outfitted with additional passive and active safety features relative to older model year vehicles, on the risk of injury for older vehicle occupants, who represent a particularly vulnerable cohort given their decreased biomechanical tolerance with increasing age. Research from IIHS has shown that older drivers (70 years old +) have a tendency to drive older, less safe vehicles than middle-aged drivers (35-54 years old). They concluded that if the older population drove vehicles more similar to the younger cohort, an estimated reduction in crash fatalities of 3.3% could be attained [60]. It has also been reported previously that older adults are less aware of in-vehicle safety features and less likely to drive/purchase new vehicles [61-63]. Accordingly, there is clear opportunity for newer model year vehicles in ride-hailing services to limit high severity collision outcomes for older occupants. A ride-hailing service which consistently provides the safest available vehicles at the time for all occupants represents a key approach toward reducing serious and greater crash-related injuries and working toward the goal of Vision Zero.

Limitations

There are several limitations of this study that should be noted. As noted in the methods, CISS is associated with systematic data missingness for specific collision configurations. There is also greater uncertainty in estimates for rear seat occupant injury risk than front seat occupants given that rear seated occupants appear less frequently in the underlying dataset used to develop the injury risk model [38]. Still, this study leveraged a subset of CISS for which all relevant case information was known. Absent a crash severity distribution specific to ride-hailing, the current U.S. distribution based on CISS data was used in order to generate an estimate for the current human crash severity distribution for use in a counterfactual analysis. There has not been research to-date to indicate that the ride-hailing crash severity distribution is more severe, or markedly different, than that of the general population. Additionally, the use of the model, and default predictors in general, to represent average risk may necessarily under/over-estimate risk for certain populations (e.g., elderly) or collision types, such as small overlap crashes or collisions with narrow, fixed objects. That being said, all comparisons in this study were made using the same underlying dataset and injury risk model, so reported results are of relative differences. Further, the seat belt compliance and vehicle fleet age information for various fleets are based on publicly available information and may not be reflective of actual vehicle fleet data. It is also important to note that the vehicle model year factor may also be capturing effects that could affects the crash severity distribution (e.g., increased vehicle mass, changes in vehicle crash compatibility, presence of active safety features to mitigate crashes), though the use of vehicle delta-v as the model parameter related to collision severity should mitigate these effects. As noted in the methods, the present analysis did not capture all possible collision configurations, only planar collisions with known vehicle delta-v. While the effect of seatbelt usage and newer vehicles was not assessed for these excluded events, a high-level review of the maximum crash AIS distribution indicated that moderate and higher severity injuries were observed similarly among the included and excluded crashes. Lastly, since the publication of the injury risk models in [38], four new years of data have become available in CISS. It is anticipated that the model coefficients would change due to incorporating these new years of data or removing the NASS-CDS data from analysis were the model to be re-generated, leading to some differences in the expected injury reductions reported here, though the general conclusions would be expected to remain unchanged. In particular, the model years in the original dataset used to develop the injury risk model used in this study from [38] ranged from 2002 to 2020. As this study looked at relative risk between model years, the results would be unchanged if using the same vehicle age comparison in the present study (e.g., 2024 vs. 2009) as in the original dataset (2020 vs. 2006).

V. CONCLUSIONS

With data from nearly 15,000 collided vehicles, this study quantified the current U.S. driving planar crash severity distribution to estimate potential safety benefits associated with moving toward Safe System Approach principles in the ride-hailing environment: increased rear seat belt compliance and newer model year vehicles. Encouraging higher levels of seat belt compliance toward the national average (or even higher) has the potential to offer tremendous aggregate safety benefits of serious (MAIS3+) injury reductions exceeding 40%. A ride-hailing service which consistently provides the safest available vehicles at the time for all occupants represents a key approach toward reducing serious and greater crash-related injuries and working toward the goal of Vision Zero. Relative to the current worst-case state of ride-hailing in the U.S., a Vision Zero fleet has the potential to reduce serious (MAIS3+) and critical (MAIS5+) injuries, including fatalities, by 75% or greater for rear-seated, ride-hailing occupants.

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VII. APPENDIX

Table AI lists the specific coefficients for the MAIS3+ and MAIS5+ injury risk models as outlined in Equations 1-5 in the methods section.

TABLE AI
Occupant Injury Risk Model Coefficients

Parameter	MAIS3+ Model Coefficient	MAIS5+ Model Coefficient
β_0	9.995	11.893
β_1	-0.117	-0.102
β_2	-0.008	-0.006
β_3	0.010	0.007
β_4	0.033	0.012
β_5	0.009	0.012
β_6	-0.264	0.123
β_7	0.249	-0.376
β_8	-0.053	0.942
β_9	-0.298	-0.181
β_{10} (vehicle type)	0.234	0.174
β_{11} (rear seat)	-0.091	-0.592
β_{12} (non-driver)	-0.331	-0.028
β_{13}	0.052	0.104
β_{14}	-0.257	-0.288
β_{15}	-0.047	-0.006
β_{16}	-1.579	-2.041