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Oral
1 - Effect of Various Cross-sectional Designs on Vehicle Operating Speeds

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Background: Over the past several decades, numerous studies have been conducted to develop speed profile models on rural highways. These models serve various purposes, including evaluating design consistency, conducting safety analyses, and setting curve advisory speeds. These models account for geometric design variables, vehicle type, and traffic control variables such as posted speed limit. However, most of the models focus on one type of highway and a comparison across different cross-sectional designs is seldom conducted.

The first objective of this study is to conduct a comparative analysis of speed profiles collected on different rural cross-sectional configurations. The configurations considered in the study are four-lane undivided (4U), four lane with 4-ft median buffer (4M), four lane with two-way left-turn lane (TWLTL) (4T), Super 2 (2S), and Super 2 with TWLTL (2ST) highways. The second objective is to develop a speed prediction model that provides the effect of different cross-sectional widths on operating speeds.

Methods: The research team used stratified random sampling and identified 4U segments across Texas for data collection. For the 4M, 4T, 2S, and 2ST configurations, the team conducted a survey of Texas Department of Transportation (TxDOT) districts and used their responses in preparing a database, and then developed a data collection plan to obtain the needed vehicle speed observations. The speed data were collected at one or two points at each site using side-fire radar units. The radar units were deployed for approximately 24 hours at each site. Data collection occurred only during clear-weather conditions.

In this study, the Analysis of Variance (ANOVA) test was used to analyze the differences in operating speeds among different cross sections within the same pavement width categories. The research team also developed a regression model to predict 85th percentile speeds at the study sites.

Results: The ANOVA results show that the speeds on 4M configurations were higher than on 4U and 4T configurations, and the result was statistically significant. The speeds on 2S were not significantly different from speeds on 2ST configurations but higher than on 4U configurations. The speeds on 4T configurations were the lowest of all configurations.

The regression results show that drivers chose higher speeds on highways with wider lanes and shoulders. The speed on a 12-ft lane highway was about 8 percent higher than on a highway with 11-ft lanes. Similarly, for every 2-ft increase in shoulders, there was an approximate 1 percent increase in speeds. Figure 1 shows the free-flow speeds for different lane and shoulder widths on a highway with a posted speed limit of 70 mph [1]. The results show that truck drivers generally chose lower speeds than passenger car drivers.
Conclusions: It is necessary to account for both safety and operational effects when selecting a cross section. The 2S configurations has the best operational performance in all circumstances at volumes up to 15,000 vehicles per day (vpd). The study results showed that reducing the lane width has a much bigger effect on operating speeds than reducing a shoulder.

Selected references


2 - The impact of indirect benefits in cost benefit analysis of road safety infrastructure countermeasures

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Background: In cost benefit analysis (CBA) of road safety infrastructure countermeasures, it is important that all relevant effects on safety, travel time, environment and operational conditions are taken into consideration as these have a substantial influence on the results of a CBA (Martensen and Lassarre, 2017). However, in some of the most widely used road safety investment appraisal tools such as SafetyAnalyst (AASHTO, 2020) and iRAP (iRAP, 2015); safety benefits relating to reduced number of crashes or casualties are only considered ignoring the indirect benefits that relate to mobility (travel time and vehicle expenses) and environment (noise and pollution). Similarly, some CBA studies conducted for safety measures consider benefits as reduced number of crashes or injuries (Daniels et al., 2019) and appear to ignore the side effects due to lack of models to evaluate them (Yannis et al., 2008). Some of the road safety analysts who prefer the CBA tool against cost effectiveness argue in its ability to provide a complete assessment of all possible objectives (safety,
mobility and environment). In some cases, there are additional impacts of road safety measures on mobility and the environment that should be included in a CBA (EC, 2018; OECD/ITF, 2015; SWOV, 2011). In a competing world of resources coupled with the need to promote and increase road safety programs, public money expenditure may probably be justified if these indirect benefits are included in economic appraisal of safety countermeasures. The quantitative and qualitative impacts of safety investments are important in an economic appraisal to improve the consistency and reliability of decisions when evaluating and ranking countermeasures (Lawrence et al., 2018). Nonetheless, the quantitative impact of these indirect benefits particularly from the angle of reduced crashes in CBA of safety countermeasures appears to be undocumented. Therefore, this paper attempts to document the likely impact of reduced travel time, vehicle operating costs (VOCs) particularly fuel use and emissions on the overall economic benefits and countermeasure selection during economic appraisal of safety measures.

**Methods:** The impact of indirect benefits on the overall safety benefits is demonstrated using the 20-year infrastructure improvement program taken from iRAP (2021) for Netherlands (Utrecht 2014 Provincial Roads), developed using EuroRAP and ViDA software which was modified accordingly to compute the benefits and benefit cost ratio (BCR) values. However, the iRAP casualty numbers were converted to crash numbers using the relationships developed from the crash and casualty data for 9 countries taken from Wijnen et al. (2017). The National Highway Traffic and Safety Administration (NHTSA) methodology and the established factors of delay, fuel and emissions taken from Lawrence et al. (2018) were used to compute the indirect benefits. The calculation for benefits are computed using reductions in the number of crashes and a BCR was computed for direct safety benefits only (BCR 1) and for combined direct and indirect benefits (BCR 2).

**Results:** The results show that indirect benefits of travel time, VOC and emissions increase the benefits due to countermeasure implementation by 7% considering 4 crash severity levels. For example, the direct benefits due to installation of a signalised crossing increase from $17.6m to $18.9m with the addition of indirect benefits. The analysis further shows that reduced travel time benefits contribute the highest percentage of all indirect benefits (92%) followed by VOC (6%) and lastly reduced emission benefits (2%). This perhaps supports the previous recommendation by Wesemann (2000) to prioritize research effort into the mobility side effects of measures since they constitute the majority of indirect benefits. Therefore, travel time benefits for countermeasures appear to be substantial in the same way being the greatest expected benefit and important for road transportation infrastructure improvements (USDOT, 2021; USDOT, 2006; VTPI, 2017). In addition, the results show that indirect benefits have an impact on countermeasure selection by comparing the computed BCR values. Assuming budget constraints and setting the BCR threshold value to be greater than 4, 39 and 41 countermeasures can be selected for direct and both direct and indirect benefits respectively, which represents a 5% increase. Street lighting (mid-block) for 10.3 km and 2 sites of street lighting (pedestrian crossing) are the two measures added to the program with the addition of indirect benefits in the analysis. These two measures combined have the potential to reduce 163 PDO crashes over the analysis period. In addition, the BCR of 80% of the analysed countermeasures increases due to addition of indirect benefits in the analysis. It is possible that some of the measures during economical appraisal of countermeasures, considering direct benefits only, might not be justified (with a BCR less than 1) but with the addition of indirect benefits, a good number of them might then be chosen. Finally, the results demonstrate that safety benefits constitute 93% of the total benefits, followed by travel time benefits (6%). This agrees and
supports the fact that the most common form of a countermeasure implementation effect is the reduction in the number of crashes (PIARC, 2020; Yannis et al., 2008).

**Conclusions:** This study has documented the likely impact of including indirect benefits in a CBA on the monetary value of benefits and countermeasure selection resulting from a change in safety performance (reduced crashes) during economic appraisal of road safety countermeasures. Indirect benefits may increase the value of benefits up to 7% considering 4 crash severity levels, which ultimately increases the number of countermeasures for implementation. Travel time benefits constitute the highest portion of all indirect benefits as compared to VOC and emission benefits. There are well-developed techniques for mobility effects of road transport projects (Hakkert and Wesemann, 2005) that could suffice for travel time benefits. Therefore, it is important that travel time benefits are included in the appraisal of safety measures as previously recommended by Elvik (2014). The study recommends more research effort in travel time indirect benefits since they constitute a higher share compared to the other benefits. Finally, indirect benefits should be included in the economic evaluation of countermeasures as these have a substantial impact on the overall economic benefits and on countermeasure selection.

**Selected references**


3 - Use of Ice Detection Sensors for Improving Winter Road Safety

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**Background:** Adverse conditions on roads and bridges present significant safety issues during the winter season that negatively impacts society, the economy, and the environment. With more than 70% of the roadways in the United States affected by winter weather, it is crucial to employ sensor technology to mitigate these impacts. In the United States, accidents on the road that occur during wintry weather conditions account for 7000 fatalities and 1.5 million crashes with an estimated cost of over 40 billion dollars per year (Snow & Ice- FHWA Road Weather Managment, 2020). Studies have shown that accident rates increase significantly due to wintry precipitation events (Eisenberg & Warner, 2005). The use of sensors for ice detection provides real-time data to DOT agencies allowing for better maintenance decision-making. This saves time, money, and, most importantly, lives. Sensor technology can be applied to active warning signs for drivers. Studies in California have shown that active warning signs led to a 15% decrease in accident frequency (Veneziano, 2016). A survey in Oregon revealed that 90% of drivers would slow down based on the message from an active warning sign and a wet pavement active warning system in North Carolina reduced crashes by 39%. Sensor technology can enhance anti-icing programs by giving more accurate information to assist with the timing and amount of chemical application. In northern Idaho, when sensor technology was combined with an anti-icing program winter maintenance labor hours were reduced by 62% and accident frequency was reduced by 83% (Snow & Ice- FHWA Road Weather Managment, 2020). Another emerging benefit to sensor technology is the use of automatic anti-icing systems on bridges. Fixed automated spray technology (FAST) is installed on a bridge deck and the system is programmed to spray deicing chemicals when predetermined conditions are met. The sensors allow for the correct amount and timing of chemical application to the bridge deck. This is particularly beneficial as bridges tend to ice before roadways and are particularly prone to black ice. In Utah, there was a 64% reduction in accident rates because of the combination of sensor technology and the use of the FAST system on bridges (Snow & Ice- FHWA Road Weather Managment, 2020). This study aims to review the existing sensor technology to determine state-of-the-art and explore future applications of sensors to improve the characterization of winter road conditions and thus, increase the safety of winter travel.

**Methods:** A review of sensor technology literature was performed. The categories that were specifically explored were how sensors are employed in transportation, the benefits they provide, and how the application of sensor technology increases the safety of travel. Once the literature was collected and reviewed, the sensors were grouped into types, mainly embedded and non-embedded.

**Results:** Non-embedded sensor technology is a non-intrusive method used to detect pavement surface conditions. These technologies include camera imaging and infrared spectroscopy. Due to the properties of light, surface conditions can be classified using the polarization or reflection of light waves. It was found that the non-embedded sensors perform well, but because they require a constant source of illumination for accuracy, they are not as robust as the embedded sensors. Embedded sensors are installed in the pavement, level with the road surface. These systems detect the presence of ice or water based on a change in the capacitance detected by the sensor at a given frequency. This is based on the values of the capacitance changing during a phase change such as
wet to icy, or dry to wet. The embedded sensors were found to be reliable at detecting ice on the surface of the pavement and do not require a light source, making them applicable to the detection of dangerous conditions during the night and pre-dawn hours. A drawback to the embedded sensors is that there is a possibility of contamination from pollutants on the road that could undermine their accuracy. It was found that sensors connected to dynamic signage warning drivers of dangerous conditions in real-time affected the behavior of drivers through reduced speed and increased awareness, thereby decreasing the rate of accident occurrence. The study also found emerging future sensor technology is using Vehicle-to-Infrastructure technology (V2I) as a method to employ wireless communication for the exchange of data between traveling vehicles and installed sensors. This would enhance the winter maintenance decision-making for local DOTs and allow drivers to be aware of current conditions while driving.

**Conclusions:** Winter weather creates treacherous conditions on the roadways. The safety of winter travel is greatly enhanced due to the application of sensor technology to alert maintenance personnel and drivers to the current conditions. Sensor technology is an integral part of creating a safe and sustainable transportation system for all users.

**Selected references**

4 - AI-Empowered Vehicle Analytics for Smart Transportation (AVAST)

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**Background:** With pandemic hits, many public agencies have suspended their traffic count programs. ITS solution such as traffic cameras are widely deployed, they can serve as a vital data source for generating traffic count and even capture traffic safety events. The AVAST system developed by ACTION Lab at UTA is based on one of the most advance AI engines, with deep customized algorithms, it is capable of tracking different road object and even capturing safety events with live stream and pre-record videos.

**Methods:**

**Results:**

**Conclusions:**
Session: Safety modelling and crash analysis, part 1

5 - Arithmetical Correlation of Traffic Crashes to Traffic Circles Tennessee

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Background: The study used Binary logistic regression and Negative Binomial regression to assess the injury severity and crash frequency on the traffic circles at three regions in the state of Tennessee. The data were obtained from E-Trims then MS excel and Stata were used for the analysis. Angle/head-on collisions have shown to have high likelihood (more than 4 times) of resulting in injury/fatal severity than PDO. For rear end crashes the odds are 60% more on injury/fatal severity while for side-swipe collision the odds are 83% in favor of PDO. Also, for each additional car involved in a crash there is 73% more chance that it will result in PDO severity compared to injury/fatal. Crashes which occurs in unclear weather are likely to result in injury/fatal severity than PDO, the odds are 7% more in injury/fatal than PDO. While For crashes which occurs on weekend, during entering the traffic circle and in no light condition there is high probability of resulting in injury/fatal severity category than PDO and odds are 115%, 112% and 111% respectively. From Negative Binomial model it shows having multiple lanes, high traffic volume and high percentage of passenger cars in the traffic circle increases the crash frequency. Furthermore, the model results show the directional hourly distribution has a negative coefficient which shows as the directional distribution increases the likelihood of crash frequency decreases. Transportation engineers and planners can use the results in their recommendations and design plans for safer traffic circles.

Methods: In this paper the study data were used to analyze crash frequency and injury severity crashes that occur within traffic circle locations. The common regression methods used for crash frequency and severity analyses are of Multinomial Logit/Probit, ordered probit/logit, Negative Binomial, and Zero Inflated Models. In this study the Binary logit was used for injury severity modeling and negative binomial was used for crash frequency analysis.

Results: Crash severity analysis

It was found that there is high likelihood (more than 4 times) of crash resulting in injury or fatal severity category than PDO if the crash occurs in a head-on or angle collision. For rear end crashes the odds are 60% more on injury and fatal severity while for side-swipe collision the odds are 83% in favor of PDO severity. The results also show at 95% confidence level that as the number of vehicles in a crash increases the likelihood of resulting in base severity (PDO) increases. For each additional car involved in a crash there is 73% more chance that it will result in PDO severity compared to injury/fatal. Unclear weather condition has a positive variable which shows crashes which occurs at traffic circle in unclear weather is likely to result in injury/fatal severity than PDO, the odds are 7% more in injury/fatal than base category. There is 12% more chance that crash which occur due to conflict of entering in the traffic circle will result in injury/fatal severity than Property damage only. Also, the variable no light has a positive coefficient which shows there is high likelihood that crash which occur in dusk/no light conditions will result in severe injury severities like injury/fatal compared to PDO.

For the total number of crashes occurring on a traffic circle the Negative Binomial (NB)
regression model was used to analyze the influence of different variables. The variables AADT, DHV, passenger cars, and the number of lanes available leading into traffic circles are explained by checking the magnitude and sign of the coefficients. The positive coefficient in the number of lanes entering and being utilized by the traffic circle shows having multiple lanes within the traffic circle increases the chances for crash. Another interesting fact from the model was that AADT has a positive coefficient which shows as traffic volume increases in the traffic circle the chance of crash also increases. The traffic circles have the maximum capacity which if it is exceeded the operational performance will not be in a safety manner. The results show that as the passenger cars increase in the traffic composition of the traffic circle the probability of crash frequency increasing is high. The passenger car driver has higher maneuverability compared to trucks and other kinds of vehicles in the mix, this cause drivers of passenger cars to be overly confident and un-attentive and this may cause the observed increase in crash frequency explained by the model. Also, the results show the directional hourly distribution has a negative coefficient which shows as the directional distribution increases the likelihood of crash frequency decreases. This may be since traffic circle operates best at certain traffic pattern

Conclusions: From the binary logistic regression results which assessed how traffic circle injury severity is influenced by different variables. It can be seen in the table 4 total vehicles, weather, lighting conditions, entering the traffic circle and collisions were all influencing the severity of the crash in a traffic circle. Angle/head-on crashes have positive coefficient from the model and it shows there is high likelihood (more than 4 times) of crash resulting in injury or fatal severity category than PDO. For rear end crashes the odds are 60% more on injury and fatal severity while for side-swipe collision the odds are 83% in favor of PDO severity. Also, for each additional car involved in a crash there is 73% more chance that it will result in PDO severity compared to injury/fatal. Crashes which occurs in unclear weather is likely to result in injury/fatal severity than PDO, the odds are 7% more in injury/fatal than base category. While For crashes which occurs on weekend, during entering the traffic circle and in no light condition there is high probability of resulting in injury/fatal severity category than PDO and odds are 1.15, 1.12 and 1.11 respectively. Furthermore, the Negative Binomial results show the directional hourly distribution has a negative coefficient which shows as the directional distribution increases the likelihood of crash frequency decreases. Traffic circles and roundabouts are relatively safer than most common intersections.

Selected references
6 - Testing the spatial dynamics between logistics restructuring and truck crashes over time in South Korea

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Background: Over the last decade, rising consumer-based economies have restructured how supply chains are managed and how logistics practices are conducted (Hesse & Rodrigue, 2004). Production and distribution networks have been globalized, and retail/logistics companies fiercely compete to fulfill ever-increasing consumers’ demand for instant delivery. Such changes have reorganized the geography of goods supply chains at the national scale (Bowen, 2008). Hence, we may expect that the geography of freight flows has also been reorganized. We may further expect that changes in freight flows would lead to changes in truck movement patterns (e.g., travel distance, travel duration, frequency, speed, origin-destination) and the geography of negative externalities (e.g., congestion, emissions, infrastructure damage, and vehicle crashes). However, due to the proprietary nature of logistics activity, there is a dearth of empirical understanding of freight movement and its road safety outcomes (McDonald et al., 2019).

This research examines the factors that explain the spatial dynamics of truck crashes over time in South Korea. Prior studies have examined various risk factors, such as driver factors, vehicle factors, working conditions, network/road design, safety devices, traffic patterns, and built environment characteristics. Here, we focus on testing the association between built environment – e.g., logistics system accessibility – and truck crashes, controlling for various exposure variables. As crash risk factors, the built environment has been rigorously and empirically tested (Merlin et al., 2020). However, few studies have analyzed relation between freight land use and truck crashes. With this paper, we aim to fill the research gap.
Methods: To explain the spatial distribution of truck crashes (fatal and severe crashes only), we use a vector of logistics system accessibility as the primary explanatory variable \((\text{transport supply, } S)\), which include access to logistics parks, access to industrial parks, shortest distance to transportation nodes (seaports, airports, intermodal terminals) and highway exits, and warehouses. A distance-weighted gravity measure is used to estimate the accessibility variables. As a control variable for urban structure, population density is used \((\text{transport demand, } D)\). As a measure for exposure, a composite variable consisting of population, registered vehicles, and road length is used \((\text{exposure, } E)\). We adopt a spatially disaggregate analysis, using a spatial unit of a city and county-equivalent (Noland & Quddus, 2004). A conceptual model is presented as below:

\[ Y = f(S, D, E) \]

Where \(Y\) is the number of fatal and severe truck crashes in a zone \((i)\); \(S\) is a vector for transport supply; \(D\) is a vector for transport demand; \(E\) is a vector for exposure. \(f\) is a functional form. To account for the skewed and over-dispersed nature of truck crash data across spatial units, a count data model (negative binomial) is used.

Approximately 500,000 truck crash records (2003-2005, 2007-2009, and 2017-2019) were provided by the Korea Trucking Association (KTA), which operates an insurance and mutual aid fund for commercial freight vehicle accident compensation. 80% of the commercial freight vehicles are enrolled in KTA’s insurance plans. In total, 1,560 fatal crashes and 4,240 severe crash records are examined in 6 separate models: two crash types by three time periods.

Results: Spatial analysis results indicate significant heterogeneity in the distribution of fatal and severe truck crashes over time, road type, and spatial units. The spatial dynamics of truck crashes are also substantially distinguished from those of all-vehicle fatal crashes. Over time, the number of truck crashes decreased due to various nationwide road and vehicle safety measures and campaigns. Yet, more crashes are concentrated on highways (27% in 2003 vs. 34% in 2019) and certain jurisdictions. Econometric analysis results indicate (1) all the variables except highway access are statistically significant, (2) some changes in the factors that explain truck crashes over time, and (3) significant differences in the risk factors between truck and all vehicle crashes.

Conclusions: The heterogeneity (1) in the geography of truck crashes over time and (2) in the risk factors between truck and all vehicle crashes suggests the need for a clear understanding of truck crash risk factors aside from logistics system accessibility, as well as tailor-made revisions of road safety measures at the individual jurisdiction level. Indeed, logistics systems have faced abrupt restructuring in how goods are distributed, and trucks are now making more deliveries in residential areas. Provided that truck crashes are more prone to severe or fatal outcomes than those involving other modes of transportation, further research is imperative.

Selected references
7 - Exploring the sequential effects of critical driving situations and driving errors on non-freeway rear-end crashes

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Background: In order to develop effective countermeasures for improving traffic safety, a better understanding of crash generating processes is of the utmost importance. The crash generating process often involves interactions that include, but are not limited to, human factors, roadway characteristics, and event attributes; furthermore, these interactions progress over time. Although past research has identified two elements influential to the crash generating process – namely, (1) critical driving situations, often referred to as triggering or precipitating events, and (2) driving errors – to date there has been limited research incorporating these two elements when modeling a crash generating process. For this reason, this study seeks to examine the tangled effects of critical driving situations and driving errors on crashes during the crash generating process.

The challenges to studying the crash generating process include (1) the lack of pre-crash data in real-world driving, (2) the lack of information with regard to critical driving situations and driving errors, and (3) a quantitative model to account for the sequence of crashes. Fortunately, the emerging naturalistic driving study (NDS) data provides an unprecedented opportunity to support the data requirements for critical driving situations and driving errors in real-world driving. However, since modeling a crash generating process involves simultaneously modeling the progression of interactions over time, a structure equation model (SEM) which also accounts for the endogeneity of the progression is proposed. In summary, this study aims to shed light on how critical driving situations and driving errors affect crash probability in real-world driving, in the hope that by so doing it will better inform the development of countermeasures.

Methods: To model a crash generating process while accounting for the endogeneity, a structural equation modeling (SEM) was constructed. The SEM model consisted of two stages: (1) the effects of roadway characteristics, traffic flow conditions, and driver characteristics on critical driving situations and driving errors, and (2) the subsequent effects of critical driving situations and driving errors on crash outcomes.

The SHRP2 NDS data was utilized since it provides comprehensive pre-crash information. Although
the SHRP2 data is valuable for studying this topic, the data still has a few inherent limitations. Most importantly, the data collection was from a “local view,” meaning only the data of the participants’ vehicles was collected. In a situation where there were multiple vehicles involved, as, for example, a head-on crash, what happened in the other vehicle was not known. Therefore, this study only focused on rear-end crashes. A total of 86 non-freeway rear-end crashes and 847 near-crashes were included in this study.

To retrieve information on critical driving situations and driver errors from the NDS data, this study utilized video data collected from forward cameras and the detailed narratives recorded. 14 types of critical driving situations and 15 types of driving errors were defined. Critical driving situations represent precipitating events in a specific state of environment or action, which in turn made a crash or near crash possible. The events were classified into 14 types according to the traffic signal condition, front and subject vehicle’s maneuvers (turning, lane change, stopping, etc.). Driver errors were attributed mainly to perception and cognition, errors, driver distraction, decision errors, and performance errors.

**Results:** The results of the crash generating processes for non-freeway rear-end crashes is shown in Figure 1. Roadway characteristics and traffic flow conditions were found to have an influence on the occurrence of critical driving situations and driving errors. The scenario with the highest probability of resulting in a rear-end crash is when a leading vehicle changes its speed due to traffic signs or traffic signals at an intersection on a rainy/snowy day, and the driver following was distracted at the same time. The crash probability in this case could be as high as 33 percent, i.e. every three events that are similar to the abovementioned scenario would result in a crash. It was also found that driving errors increased crash probability by 10 percent. Furthermore, this research sheds light on the interaction between driving errors and driver characteristics. Although a driver’s age does not have a significant impact on the different types of driving errors, female drivers tend to have more action errors than male drivers. Drivers who had a greater number of crashes in the past 3 years were observed to also have more driving errors.

**Conclusions:** This study developed and tested a modeling framework to model the effects of critical driving situations and driving errors on crashes in a crash generating process. It was found that both critical driving situations and driving errors have a significant impact on crash occurrences. Driving errors which accompanied certain types of critical driving situations were identified to have a higher crash risk. With a better understanding of the crash generating process, this research hopes to inform the development of driving training programs and advanced driver assistance systems to help reduce crash risk.

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Background: In the assessment of road user and vehicle occupant safety, physical testing is limited to a few scenarios. To advance transport safety, it is vital to further develop the test procedures and, for example, to consider additional impact conditions. Virtual Testing (VT) offers an opportunity to introduce such additional scenarios and thus to broaden our safety assessment.

The current standards in testing consider very few anthropometries, and population inhomogeneity is not appropriately represented. Future safety assessment procedures should thus aim for a more inclusive approach to better embrace diversity of all road users. VT is likely the most feasible technique to assess safety performance in a multitude of impact configurations. VT incorporating evaluation through advanced Human Body Models (HBMs) has not only the potential to expand the
The VIRTUAL project strives to contribute to the development of VT in the crash safety assessment area. It will develop and provide models and procedures needed to conduct VT in scenarios addressing vehicle occupant and vulnerable road users (VRU) safety.

**Methods:** To prepare and support the introduction of VT, the VIRTUAL is committed to an open source (OS) approach. Consequently, all output will be freely accessible from a dedicated platform. Human body models (HMBs) of the 50th percentile female (50F) and the 50th percentile male (50M) have been developed. The design principles are based on Östh et al. (2017). The VIVA+ models are configured such that they can be used in different safety assessments. Additionally, two versions of a Seat Evaluation Tool (SET) have been developed, representing a 50F and 50M, to be used for physical seat tests.

In VIRTUAL, the benefits of VT for occupant protection assessment will be demonstrated by executing sled tests with the SET using the standardized whiplash assessment methods (Euro NCAP, 2019), in addition to several simulation series using the VIVA+ models. For the VRU assessment, active and passive safety measures, pedestrians and cyclists as well as female and males will be considered in collisions with cars or trams. Finally, a tool for cost-benefit-analysis has been developed to perform analysis based on the simulations. A novel approach is applied in this tool, by using VT results to estimate the benefits of safety improvements in terms of Quality Adjusted Life Years (QALYs) and monetary gains.

**Results:** The OpenVT platform was established as a self-hosted GitLab server. It is an OS repository management system which can be accessed through https://openvt.eu. The setup of the OpenVT platform is designed to facilitate future international collaborative development where scientists and developers can contribute to further developments of OS HBMs and related crash simulation tools.

The baseline models of the VIVA+ family represent vehicle occupants and vulnerable road users (pedestrian and cyclist). Currently, this platform provides the HBMs VIVA+ 50Fand 50M as well as the design of the SET 50F and 50M. The SET has a fully flexible spine in the sagittal plane and an ability to twist around the z-axis. It also contains a shoulder design allowing the arm to move relative to the spine during a crash. The VIVA+ models as seated occupants, pedestrians and cyclists, as well as the design principle and the physical SET 50F are shown in Figure 1.

**Figure 1:** Virtual and physical models of humans and vehicles. Bicycle and tram structures developed within the VIRTUAL project representing vehicle occupants and VRUs, as both average female and male.

Simulations with the VIVA+ models were done in the OS vehicle seat model at the three Euro NCAP low severity rear impact tests. These tests were also conducted with the SET 50F and 50F. Results from the tests will be available for the presentation of this study.

VIRTUAL demonstrates the possibilities and benefits of simulations as a complement to physical assessment for car occupant protection by allowing for more variations in seat and restraint design,
as well as seat positions. This provides essential input for developments towards novel seating in future vehicle crashes.

By means of the holistic VRU assessment, the reduction of crash risk is evaluated. When applying a generic system, collisions were avoided in the majority of the virtual test cases. In the remaining cases, the collision speed and impact location changed compared to the baseline cases. For these remaining cases, a smart design of experiments algorithm is applied and 50 in-crash simulations are performed per road user type and gender. The overall injury risk is then evaluated per body region and compared with the baseline (e.g., before the introduction of an active safety system or without an improved tram front structure. This result is then used in the VIRTUAL cost-benefit calculation tool to evaluate the socio-economic benefits of vehicle and VRU safety improvements in terms of QALY and monetary benefits, as well as the costs and the socio-economic return. The applicability of the cost-benefit tool is illustrated in a few case studies.

**Conclusions:** The VIRTUAL project has developed open source HBMs of both average females and males as seated occupants, pedestrians and cyclists. Furthermore, it has made tools and procedures openly available for conducting virtual safety assessment. Through the OpenVT platform, all these components needed for VT were made publicly available and the platform forms the basis for future open collaborative development of VT tools. Thus, the project has significantly contributed to foster the uptake of virtual testing.

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**Selected references**


9 - A Simulation of Edge Lane Roads and the Impacts of Traffic Characteristics on Road User Interactions

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Background: An edge lane road (ELR) is a road configuration that supports two-way motor vehicle (MV) traffic within a single center lane and vulnerable road users (VRUs), i.e., bicyclists or pedestrians in the edge lanes on either side (see Figure 1). MVs may use the edge lanes to pass approaching MVs, after yielding to any VRUs there. ELRs are also known as Advisory Bike Lanes (ABLs) or Advisory Shoulders. An ELR has no centerline and the center lane is separated from the edge lanes with broken line markings. The broken line markings indicate to motorists their ability to merge into the edge lanes to pass an approaching MV. Motorists must yield to any VRUs already in the edge lane when merging.

Traffic volumes are a primary concern for ELRs. High VRU volumes prevent use of the edge lanes by motorists and high MV volumes create unsafe conditions for VRUs.

There appears to be no evidentiary basis for either MV or VRU volume limits beyond which an ELR produces unsatisfactory results. Dutch guidance provides MV and VRU volume thresholds but this appears to be based on experiential or anecdotal evidence. American guidance provides no VRU limits at all and provides a limit on MV volumes based solely on the required use of center line markings on streets above 6,000 AADT as specified in the Manual of Uniform Traffic Control Devices (MUTCD).

ELRs are rapidly becoming popular in the United States as a way of creating VRU facilities on streets too narrow for traditional facilities or on streets where the intention is for MVs and VRUs to share the roadway. The first ELR was installed in 2011 in Minneapolis and as of early 2022, approximately 60 are known in the United States.

An understanding of how traffic characteristics influence the rate of interactions between MVs and VRUs is crucial for effective use of this new treatment. In fact, a measure of MV-VRU interactions may be the most appropriate metric to use for ELR siting decisions.

Methods: A Monte Carlo simulation program was developed in Python to investigate the impact of various factors on the rate of interactions between MV, bicyclists, and pedestrians on an ELR. Of primary interest were those interactions that involved two MVs passing one another in the presence of a VRU. These interactions are likely the most dangerous and uncomfortable for VRUs and are termed critical interactions. The primary intent of this work was to create a tool that predicts the number of critical interactions on an ELR as a step toward creating evidence-based limits on volumes for ELRs.

The factors allowed to vary in the simulation were road user volumes, road user speeds, length of the
ELR, and MV directional split. Simulations were run for 1,000 to 10,000 hours to ensure that results were free of spurious results caused by the randomness of underlying processes, e.g. introduction of new road users.

**Results:** As expected, the impact of MV volumes on the critical interaction rate is significant. The rate of critical interactions is proportional to the product of the MV volumes in each direction.

The influence of MV speeds was interesting. As MV speeds increased from 20 to 60 MPH, the critical interaction rate was halved. This effect was most pronounced over the increase from 20 to 25 MPH. This creates a dilemma in which higher MV speeds reduce the rate of interactions but increase the severity of any crashes that might occur.

Critical interaction rates were proportional to VRU volumes within the volumes investigated. It is clear that the critical interaction rate would approach the MV-MV interaction rate asymptotically as VRUs began to saturate the length of the facility.

VRU speeds were important. Because pedestrians spent more time on a facility, their rate of critical interactions were much greater than for bicyclists.

MV directional split had a significant influence on the critical interaction rate. This is due to its direct impact on the product of the MV volumes in each direction.

Unsurprisingly, the critical interaction rate was found to be proportional to the length of the facility.

Numeric values for each result depend on the values of other factors that were held constant. It is for that reason that only relationships are presented rather than absolute values.

**Conclusions:** The results generated from the simulator illustrate a number of relationships that are important to understand when dealing with ELRs. The most important is the rapid increase in the critical interaction rate, and the rate of MV-MV interactions, as vehicle volume increases. Volume appears to be the most important factor to consider when evaluating the use of an ELR.

The impact of MV directional split is also significant and could allow for use of ELRs on streets with strong commute patterns where they might otherwise not be considered.

The type of road user being supported by an ELR is significant variable. If one assumes that interaction rate or total interactions while on a facility are held to a fixed limit, then MV volumes for an ELR supporting pedestrians would be much lower than one not intended for pedestrians.

This work is the first step in creating an evidence-based foundation for limits on MV and VRU volumes for the ELR treatment. The simulation accurately represents interactions on two-lane roads as well and could be used to evaluate rates of road user interactions for other facilities such as standard bicycle lanes. Future research is needed to establish the impacts of road user interactions on VRU safety and comfort; this would allow agencies to create guidance for settings in which the ELR treatment creates a safe and comfortable roadway for all users.
Special Session: Advancements in Safe Systems: Research Highlights from the Collaborative Sciences Center for Road Safety

10 - Advancements in Safe Systems: Research Highlights from the Collaborative Sciences Center for Road Safety

Eric Dumbaugh

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Abstract: Advancements in Safe Systems: Research Highlights from the Collaborative Sciences Center for Road Safety

The Collaborative Sciences Center for Road Safety (CSCRS) is a national University Transportation Center committed to the advancement of a safe systems approach to road safety. What distinguishes safe systems from conventional approaches to road safety is the recognition that road users make mistakes, and that safety can be best addressed by ensuring that the system is designed to prevent injury and death. In this session, we highlight some of the key findings on safe systems that have emerged from the center’s work. It begins by identifying the unique characteristics of the system’s most vulnerable users—pedestrians, bicyclists, and motorcyclists—as well as the environmental features that result in injury and death. It proceeds to examine the role of kinetic energy in a crash event and discusses the role of speed management programs in reducing traffic-related injuries and deaths. Finally, it concludes by examining the manner in which road safety issues are framed in the media, which can encourage, or limit, public support for road safety programs.

11 - Safe speeds: Speed, kinetic energy, and the Safe Systems approach to safer roadways

Wes Kumfer

Background: Human beings have a biomechanical tolerance to the amount of energy that is transferred in a road crash. Prioritizing safety in a Safe System Approach requires acknowledging this limitation and managing the various elements of our surface transportation system that expose all travelers to risky levels of kinetic energy. This presentation will highlight the latest research on speed management and latent risks in our roadways to make our roads safer for all.

Methods:
Results:
Conclusions:

12 - Safe roads and safe people: Understanding pedestrian and bicyclist crash risk in low-income and minority areas.

Eric Dumbaugh
Background: Persons residing in lower-income areas are at disproportionate risk of being injured or killed while walking or bicycling. This study examines pedestrian and bicyclist crashes in lower-income areas to identify specific at-risk cohorts, as well as the environmental risk factors that may contribute to traffic-related injuries and deaths. It finds that very few of the pedestrians and bicyclists struck, injured, or killed in lower income areas were under the influence of drugs and alcohol. Instead, the majority of these crashes appear to involve individuals engaging in ordinary activities, particularly during the late afternoon and early evening, in environments that are poorly suited to them. It identifies four pedestrian and two bicycle cohorts at disproportionate risk and concludes by discussing how injuries and deaths are designed into the system—specifically through the production of conflicts of use and errors of expectancy.

Methods:

Results:

Conclusions:

13 - Safe vehicles: How effective are pedestrian crash prevention systems in improving pedestrian safety?

Asad Khattak

Background: Technology can help reduce vehicle–pedestrian crashes, fatalities, and injuries. Emerging technologies such as pedestrian crash prevention (PCP) systems utilized in on-road vehicles have the potential to mitigate pedestrian crash severity or prevent crashes. However, the reliability and effectiveness of these technologies have remained uncertain. This study contributes toward understanding the effectiveness of PCP systems utilized in on-road vehicles with a low level of automation by investigating two crossing and one longitudinal scenario. The Insurance Institute for Highway Safety field test data from 2018 to 2021 is harnessed, where several on-road vehicles and their PCP systems are evaluated in terms of safety. The large-scale experimental dataset is comprised of 3095 tests of 91 vehicles with different sizes, makes, and models. The empirical results indicate that in hazardous pedestrian-vehicle conflict situations, the performance of PCP systems has been improved during recent years.

Methods:

Results:

Conclusions:

14 - Building public support: Factors and frames that shape public discourse around road user safety.

Seth LeJeuness
Elyse Keefe

Background: Across more than 1,000 TV news media frames of traffic crashes in a CSCRS study, the research team discovered that TV news agencies’ Facebook crash-related posts featuring more
vulnerable road users—older adults, pedestrians, cyclists, and motorcyclists—were associated with less audience engagement (i.e., fewer likes, shares, or comments). Additionally, more than a third of the studied posts presented traffic injuries as phenomena that delay motor vehicle traffic. Such framing can orient the public’s attention away from the grim and inequitable reality of road trauma in the US. Promisingly, describing crash victims and using thematic frames were associated with more engagement with posts. Telling inspiring and pragmatic stories about how safety investments can benefit everyone and in copious ways is a promising means of motivating the public and decision-makers to prioritize the safety of all road users.

Methods:

Results:

Conclusions:
Special Session: Non-motorized and human interactions for traffic safety

15 - Non-motorized Safety on High-Speed Corridors

Jun-Seok Oh1
Baraah Qawasmeh1, Sia Mwende1, Valerian Kwigizile1, Ron Van Houten1
1 Western Michigan University

Abstract: In the past decade, there has been an increasing trend in pedestrian fatalities in the U.S. with 6,283 fatalities in 2018 and an increase in the proportion of pedestrian fatalities out of all traffic-related fatalities from 12% to 17%. A recent analysis indicates that 90% of the increase in US pedestrian deaths from 2008 to 2017 occurred at night. Government agencies are concerned about a large number of pedestrian crashes on higher-speed corridors, many of which involve serious injuries and fatalities. In Michigan, there were 772 fatal pedestrian crashes during the past 10 years, and the majority of fatal pedestrian crashes on higher-speed roads occurred during night conditions (83%). Therefore, this study analyzes the causes of non-motorized crashes on higher-speed roads and investigates countermeasures to address this problem.

16 - PREDICTING AND PATTERNING PEDESTRIAN CRASHES USING MACHINE LEARNING

Deo Chimba1
Hellen Shita1, Diana Gomez1
1 Tennessee State University

Abstract: As non-motorized trips are vital to many urban and rural residents, it is essential to identify safety deficiencies in our existing transportation infrastructure to address rising injuries and fatalities among this group of road users. The objective of this research is to identify roadway, environmental and traffic factors associated with pedestrian crash frequency and injury severities in Tennessee. The analysis applies machine learning (ML) approach in predicting and classifying pedestrian injury severities and compares prediction accuracy with traditional categorical data-based modeling using multinomial models, ordered models and binary outcome models. Recently, the use of machine learning has been found to be more accurate in prediction compared to traditional regression analysis, but not many studies have applied it in non-motorized safety. Further, the study analyses through statistical modeling the impact of different variables and factors associated with pedestrian crashes in Tennessee and develop crash frequency models in terms of Safety Performance Functions (SPFs).

17 - Use of Smartphone Apps While Driving: Variations on behavioral and driving impairments

Juana Perez1
Kate Hyun1
Background: The National Highway Traffic Safety Administration states that a total of 3,142 fatalities occurred due to distracted driving in 2019. Since drivers are easily exposed to technology such as in-vehicle entertainment and smartphones in their vehicles, it’s important to characterize behavioral and driving impairments due to smartphone induced secondary tasks and their impacts on driving safety. This driving simulation research will observe the driver’s behavioral change when the driver performs a secondary task using their smartphone using a 13-mile driving simulation. Identifying how visual and physical impairments due to smartphones affect various driving performance measures such as speed control, lane excursion, and reaction time. The research team will primarily focus on smartphone applications like Social Media (e.g., Instagram) as well as texts and GPS to compare the conventional secondary tasks with the non-conventional secondary tasks filling in a gap of distracted drivers that is rapidly increasing among novice drivers. This study recruits 50 participants of all ages from the University of Texas at Arlington to participate in a freeway driving course on a simulator. Participants drive on a short freeway course without any distractions to obtain their baseline driving behaviors and vehicle maneuver patterns. Next, the participants will complete the 13-mile course while completing several secondary tasks using smartphone applications including GPS, texts, and social media. To compare data from these two different conditions (distracted vs. non-distracted) to understand how smartphone applications cause various impairments and consequently impact the driver’s ability to safely control their vehicles and maintain driving tasks.

Methods:

Results:

Conclusions:

18 - Evaluating the Safety Impacts of Green Pavement Markings for Bicycle Facilities

Stephen Mattingly1
Abhinav Awasthi1, Katherine Kam1, Nelson Gomez-Torres1

Background: The research considers Houston and Austin, two major Texas cities with bicycle facilities with and without green pavement markings. This research determines the reactions and resulting impacts of bicycle facilities with green pavement markings for bicyclists and motor vehicle drivers in Houston and Austin. The study examines if bicyclists and motor vehicle drivers exhibit the proper behaviors with green pavement markings because proper behaviors should lead to safety improvements. The study uses the different variable data for the sites with and without green paint bicycle facilities estimate safety and behavioral models. The investigation uses the cost of the construction and marking of bicycle facilities to assess the cost effectiveness of the bicycle facilities based on safety and behavioral impacts. The facilities’ potential to encourage additional bicycling activity and the public health impacts of those trips may be added to the overall benefits of the facilities. This research will help evaluate government investments in bicycle facilities and green pavement markings. This research can help determine the importance and effectiveness of these facilities and markings.

Methods:
Results:
Conclusions:

19 - Prioritizing Bikeability Factors for On-Road Bicycle Facilities Using Analytical Hierarchy Process

Valerian Kwigitizile¹
Sia Lyimo¹, Jun-Seok Oh¹
¹ Western Michigan University

Abstract: Bikeability is an essential element that must be considered in the planning of bicycle facilities. Resource constraints make it imperative for the planners and engineers to identify and prioritize crucial factors that promote cyclists' friendly environment. This study utilized the Analytical Hierarchy Process (AHP), a multiple criteria decision analysis technique, to rank the relative importance of bikeability factors for onroad bicycle facilities. AHP is the most applied multiple-criteria decision analysis technique because of its ability to convert subjective judgment to a numerical value which can easily be incorporated into the decision-making process. The results from this research can give planners, engineers and law enforcement officers the basis and justification for implementing factors necessary to improve likeability of on-road bicycle facilities.
Background: The Safe System movement is gaining momentum. Despite the increase in popularity, an emerging challenge is authorities implementing their own version of the Safe System, cherry picking elements and developing local performance metrics which are not internationally comparable. This dilution of a systematic approach risks compromising safety. Gauging how ‘Safe System-ready’ authorities are will assist with creating consistency in implementation and monitoring and identify where further support is required.

This project set out to determine the potential of a model for assessing how culturally mature organisations are in relation to Safe System thinking and application.

Methods: Organisational culture is based on the shared beliefs, values, and behaviours of its members. An organisation can establish systems and processes for effectively delivering its objectives but if its collective group of individuals does not share its values for the system, then it will not work as intended.

The Safe System is an approach which requires systematic thinking regarding the improvement of safety on roads. An organisation can declare it is ‘Safe System’ but if the culture of that organisation does not support relevant actions and encourage intrinsic motivation towards safety in staff, it will not consistently and methodically deliver a Safe System. A Safe System Cultural Maturity Model (SSCMM) can be used to assess if the Safe System approach is permeating policy and practice.

A SSCMM consists of several components. It includes understanding what the Safe System means and what actions it involves in practice. It demands an understanding of cultural maturity. Finally, it requires a mechanism for linking cultural maturity concepts with Safe System delivery specifics.


‘Change mechanisms’ used for delivery in international Safe System models were collated (PACTS, 2017) (Commonwealth of Australia, 2022) (NZ Transport Agency) (Canadian Council of Motor Transport Administrators, 2016), with the 48 identified actions assigned to these change mechanisms.

An investigation of cultural maturity models from other safety sectors assessed applicability to road safety (Cooper, 2000) (Westrum, 1993) (Hudson, et al., 2000). Whilst existing models did map across to road safety, the SSCCM was strengthened by adding a behaviour change model, explaining
the relationships between individual and organisational behaviour (Darnton & Horne, 2013).

In the SSCMM, ‘Construction’ refers to the underlying beliefs and values that lie at the heart of the organisation’s culture. ‘Application’ relates to the social context of Safe System application. If there are strong Safe System beliefs and values held by individuals, the organisation will use Safe System language and have roles that identifiably relate to Safe System delivery. The outer circle of the SSCMM is ‘Operation’, which is comprised of the change mechanisms used to deliver Safe System actions. Each layer is permeable; there are dynamic relationships between the ‘Operation’ layer of change mechanisms, the ‘Application’ of enacted culture, and the ‘Construction’ of cultural values. The influence is two-way: culture influences action and action influences culture.

To apply the model, 22 questions were created to investigate a road safety organisation’s maturity in applying actions across Safe System pillars and change mechanisms, exploring culture on a five-point scale. In March 2022, the survey was tested with 20 road safety organisations.

Results: Evidence from multiple disciplines has been collated to create and test a SSCMM. The philosophical and practical application of the Safe System have been combined with behaviour change and cultural maturity models to provide a mechanism for identifying where an organisation could be strengthened.

Through testing, the Model was able to demonstrate a level of fidelity and differentiation between and within organisations and their cultural maturity, across the Safe System, and within specific pillars and change mechanisms.

Conclusions: The SSCM is a valid way of exploring cultural maturity of organisations towards Safe System. It can act as a diagnostic tool to identify where Safe System thinking and actions need to be strengthened. There will be small revisions to the question set based on analysis of the test data, making it applicable to road safety organisations operating at local, regional, and national levels. Supporting organisations to strengthen Safe System culture should prove invaluable in increasing its adoption and effective delivery.

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21 - Safety culture and automated vehicles a pre-study

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Background: Safety culture is the common attitudes, values and perceptions that managers and employees have about safety in the work environment (The Swedish Transport Agency, 2014). What characterizes a good safety culture is that management are committed to safety at all levels of the business. Management also rewards safe behavior and communicates safety priorities that engages all employees, which is evident from the behavior one can observe. The basic elements of safety culture according to the survey tool NOSAQ (Kines et al, 2011) are:

- Priorities - know what to do or not to do, to set boundaries
- Leadership – commitment to safety and to reward it
- Communication - clear and rich dialogue
- Engagement- including people in safety work at all levels in the company

When automation progresses, considerations of sustainability and gender equality should be considered with safety culture, to achieve the zero vision and the safe system approach (The Swedish Transport Administration, 2020). For professional drivers and controllers of autonomous vehicles the safety culture is of great importance in working and traffic environment. Companies that develop automated vehicles and machines need to acquire knowledge about how to integrate a good safety culture as part of the design and development processes as well as in the implementation of automated vehicles and machines.

The aim of this pre-study was to explore safety culture in the development of automated vehicles and machines, to identify new risks and to prevent potential accidents. The scope of the pre-study
was to anchor the view of safety culture with industrial partners developing automated vehicles and machines. Through the exchange of knowledge, the need for a model of how to measure and work with safety culture as a factor in the development of automated vehicles, was defined.

Methods: The pre-study was carried out through a series of workshops with experts from research and industry that develop automated vehicles and machines and with expertise in product development and safety culture. Different working models were analyzed concerning safety culture and experiences about safety assessments of automated vehicles and machines. Methods to measure sustainability, gender equality and safety culture, were also presented and discussed. The first workshop analyzed and discussed the theme; Safety Culture - what it is and its relation to automation. The second was about the experiences of how safety culture can be useful in both design and implementation of automated vehicles and machines. The third focused on working models for the development of safety culture. The fourth workshop was a webinar about potential survey tools for safety culture and the possibility of also measuring and comparing cultures of sustainability and gender equality. The model and measurement tool will be further developed in a larger study (both studies financed by Vinnova, FFI).

Results: The initial literature review showed that there are few scientific publications concerning safety culture and automated vehicles and machines. However, studies were found with an indirect focus on safety culture, which showed that there are many factors and complex systems that affect the development of technologies for safe automation. Examples of such factors are new risks, new roles, and responsibilities with automation. Additional factors are, e.g. how priorities should be set, learning, leadership and employee behavior. More studies about how to develop and integrate good safety culture in the development of automated vehicles and machines are needed, to contribute to traffic safety and sustainability. Moreover, in the early stage of design and development of automated vehicles and machines, there is a need for support to understand and explore the safety culture in their own as well as in the customer’s business (Vinnova, 2021).

Safety in automation was found to be technology-driven and the pre-study proposed a systems perspective, from design and testing to implementing the automated vehicle/machine at the customer. A knowledge gap was revealed between how manual vehicles and fully automatic vehicles / machines should be introduced safely. New risks for controllers or workers around automated vehicles should be analyzed. For safe introduction of new automation technologies descriptions and specifications of the new tasks, roles, checklists, training, communication, leadership etc. should be included. To make this development effective and safe a model for the working process is needed and a measurement tool to investigate the safety culture and which parts of it that needs to improve.

Conclusions:
• Safety culture should be addressed when responsibilities and roles will change with full automation and by selling services performed by automated vehicles and machines.
• Safety culture and risk analyses needs to be included early in the design as part of the development of automated vehicles and machines.
• Safety culture has traditionally focused on safety for workers in production, here the focus is on product developers who will design products and their future safety impact.
• Safety culture research needs to use case studies to see how safety culture is practiced, otherwise it may only be written policies and empty words.
• Safety culture need to be measured in order to evaluate existing situation and changes, therefore the most important pillars should be identified and a survey be developed.
• Safety culture is a part of the sustainability goals therefore systems view include gender equality within the transport industry should be analyzed and developed.

Selected references

22 - Saving Lives through private-sector and impact investment in road safety
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Background: Road crashes are one of the leading causes of fatalities and serious injuries (FSIs) worldwide. Continuing with “business as usual” will see more than 375 million mostly young people killed and injured over the next decade resulting in economic losses of more than US$20 trillion by 2030.

Methods: Achieving safer roads, safer vehicles and safer road use is possible. A realignment of incentives across safety outcomes and commercial interests is needed to mobilise and target the estimated $260 billion investment gap needed to halve road deaths and injuries by 2030. Innovative private sector financing and results-based impact investment holds the potential to unlock this win-win outcome to save lives, save money and create jobs worldwide.

New business models and financing instruments to enable greater private investment in road safety have been developed with their viability examined and evaluated across 10 countries in Latin America, Asia, and Africa. A series of solutions have been designed, including eight high-impact project archetypes, a framework for designing road safety projects, and five possible investment structures.

Results: Practical examples of results-based financing to improve road infrastructure safety are shared including examples from New Zealand, Australia and Brazil together with the detailed analysis of road injury types and costs saved across the health and insurance sector. Similar models that address vehicle fleet safety and driver behaviour are also introduced.
The mobilization of private sector investment to address the gap aligns with the recently launched Global Plan for the Decade of Action for Road Safety 2021-2030 to halve global road deaths and injuries by 2030. This includes investment focused on achieving Target 3 for all new roads to be 3-star or better for all road users and Target 4 to see more than 75% of travel in each country to be on roads that are 3-star or better for all.

The Brazil case studies are explored in detail and present the mechanism by which the 3-star or better safety criteria are included in the 30 year concession agreements with associated incentives based on the actual star rating achieved and the timing of those achievements within the concession period. This includes an open and transparent tendering process and the official award of the concessions to successful consortiums that include road industry experts, investors and sovereign wealth funds who support the up-front capital needed to accelerate the provision of safer journeys across Brazil. New emerging case studies from India, Colombia and Senegal are also presented as well as the potential for a "Footpaths for Africa" impact bond.

**Conclusions:** The paper details the steps needed to accelerate private-sector financing of road safety and the role results-based financing can play in achieving the UN Sustainable Development Goal to halve road deaths and injuries by 2030. The launch of the World Bank Road Safety Bond in December 2021 provides a significant turning point for global road safety where socially responsible results-based investment has the potential to emulate Green Bonds and Climate Financing and truly scale the implementation of proven safe system treatments across the world. The establishment of a mobilisation platform for implementation of Impact Investment Bonds and Results-based Financing with public and private capital for road safety will be a key enabler to bring together the various investment, development, safe system and research stakeholders needed to unlock the life-saving potential of the new investment mechanism.

**Selected references**
23 - Method of road safety audit of a high number of unsignalised pedestrian crossings

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Background: In Poland between 2010-2016 there were more than 250,000 road accidents with more than 24,000 fatalities, nearly 83,000 serious injuries [1]. 10.6% of all accidents happened on a pedestrian crossing or cycle crossing and claimed 7.1% of all fatalities. The level of road safety depends on road infrastructure users, the roadside and the technical condition of vehicles [2], [3], [4]. In 2016 there was nothing in the Polish law to regulate sight distance or give guidance for lighting [5].

Between 2016-2020 Warsaw’s road authority commissioned safety audits for about 1,000 pedestrian crossings each year [6]. The authors of this article developed a method for conducting a safety audit on unsignalized pedestrian crossings and then audited over 4,000 pedestrian crossings together with a team of experienced auditors. There were no previous examples of such work in Poland as was established in [7], [8].

Warsaw is one of three final candidates for EU Urban Road Safety Award 2021 for placing pedestrians front and centre with an ambitious Road Safety Audit - an innovative study taking place over the course of five years - to identify strategies and recommendations for urgent and long-term improvements.

Methods: Audit method was developed based on scientific research on the basic factors affecting the safety of pedestrians at pedestrian crossings, such as vehicle speed, visibility, length of pedestrian crossing, location of the pedestrian crossing in the street network. Additional criteria are based on the analysis of experts in the field of road safety. There are many elements that do not significantly affect the safety of the entire population but can be critical for particular social groups such as blind. Another, but equally important aspect is to ensure comfort in mobility. Ensuring comfort, legibility, eliminating architectural obstacles is a facilitation for the general population, but it is extremely important for groups with special needs.

Results: It was assumed that the road authority would apply pedestrian safety management methods to pedestrian crossings [9]. A database had to be built starting with an assessment of the risk and an analysis of the crossings. Hazards should be identified and classified and followed by an action plan of possible treatments. These must then be implemented and monitored for their effectiveness through a repeated risk assessment and database updates. Once updated, the data should be analysed again to capture high risk pedestrian crossings and the steps should be run regularly.

It was agreed that audits can only be conducted by certified auditors [10]. Key to risk assessment is the experience of auditors. Audits were conducted by a team of two people with at least one of them a certified auditor.

- Visit the site and complete a form with data.
- Chose from 30 types of risks were pre-defined.
- Measurement visibility fields.
- Fill out the database to propose pre-defined recommendations designed.
- Auditor’s opinion with a description of the particular risks and suggests a number of recommendations to improve road safety.
- Assigns a general score on a scale of 0 to 5.
- Double-checked by a second Auditor. The Auditors will discuss the issue to reach a common position. If they cannot, a third person who is also an Auditor will be asked to resolve the conflict and they have the final say.

**Conclusions:** Conducted by experienced experts, the audits and the resulting global database of all pedestrian crossings with a summary card for each, help road authorities to manage risk on pedestrian crossings. In addition, the sequence of the work is from the general to the detailed. It is possible to identify pedestrian crossings which require new signs, more speed enforcement or parking enforcement. It is recommended that the low scoring pedestrian crossings should be modernised. This should then be followed with a repeat audit after the treatment. Crossings rated 2,3 should be analysed again in 2 or 3 years. The highest scoring crossings of 4, 5 will not need a repeat audit until 5 years later. To ensure real outcomes and optimal spending on infrastructure, efforts must be comprehensive, successive and cyclical.

**Selected references**

24 - Risk and Contributing Factors of Pedestrian Involved Crashes at Signalized Intersections

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Background: The primary objectives of this paper are 1) to examine the relationship between pedestrian crashes and predictor variables at signalized intersections and 2) to identify the risk and contributing factors that influence the probabilities of a pedestrian being injured or killed at pedestrian crashes and pedestrian’s failure of signal/right-of-way (ROW) compliance to vehicle resulted in a crash.

Methods: This paper analyzed pedestrian crashes from 2011 to 2016 at 276 signal-controlled intersections. A truncated negative binomial regression model was used to estimate the rates of pedestrian crashes per pedestrian crossing volume with predictor variables, and binary logistic regression models were used to examine the probabilities of a pedestrian being injured or killed and pedestrian’s failure of signal/ROW compliance at the pedestrian crashes.

Results: The results show that average daily traffic (ADT) ratio, the number of bus stops, the sum of all crosswalk lengths, and the number of permissive left-turn signal phases are significant and positive variables to predict the pedestrian crash rate. Pedestrian’s failure of signal/ROW compliance, vehicle maneuver turning left or going straight, and high speed limits were found to be associated with increasing the probability of pedestrian being severely injured or killed at the crash. The results also show that younger pedestrian age, male pedestrian, and the number of bus stops at an intersection increase the likelihood of pedestrian’s failure of signal/ROW compliance resulting in a crash.

Conclusions: When pedestrian-involved crashes are compared with all crashes, it is evident that pedestrians are at high risk for injury or death. The identification of the characteristics affecting pedestrian involved crashes can play an important role to improve pedestrian safety. This study provides insight into pedestrian crashes at urban signalized intersections. It considered pedestrian exposure and physical and operational characteristics to identify the risk and contributing factors associated with crash rates and crash severity. The results of this study provides important information that can be used to improve pedestrian safety at signal-controlled intersections. In addition, the results can be used to help formulate studies on the risk and contributing factors at midblock crashes involving a pedestrian in the future.
Session: Equity in traffic

25 - UN’s Sustainable Development Goal for safe, sustainable transport systems for all - do automated shuttles have a role?

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Background: In 2015 the UN launched the 17 Sustainable Development Goals (SDG) and associated targets. The need to “…provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport…” is specifically pointed out in Goal 11 about sustainable cities and communities. Additionally to the SDGs there are numerous examples of national, regional, and local levels targets and visions for safe travel, zero fatalities, and/or no injuries.

There are hopes and expectations that automated mobility can contribute both to improving road safety and increasing the use of public transportation. Automated vehicles are subject of significant development efforts. Several concepts are being tried out, for example shuttle services involving automated electric minibusses. Targets can however only be achieved if users and the public use the solutions that are provided. This in turn requires that users are aware of, have access to and appreciate what is being offered. There is a growing understanding that it is essential to involve people in the further development and deployment of automated vehicles and their use.

Methods: The objective of this paper is to investigate how future mobility concepts, represented by automated shuttles, address safety for “all”. Safety lessons learned from “Ride the future”, a service with minibusses of two brands operating on public roads in Linköping, Sweden, since over two years, are presented. Passengers, road users outside the shuttle as well as the safety driver, i.e. the person operating the shuttle bus, are considered. These “hands-on” experiences are complemented by a desktop benchmark of over 80 ongoing or completed initiatives mainly in Europe with automated shuttles. A comparison is made of how different pilots and demonstrations involving automated shuttles cover different target groups and safety aspects. Furthermore, examples of user and public engagement activities are given.

Results: The underlying reasons for why e.g. a city runs a shuttle initiative have been examined. For the benchmarked shuttle initiatives improved road safety is among the most cited driving forces. However, when looking into the objectives of the individual shuttle operations they tend to be of a more explorative nature, such as learning about the technology, to get experience with the permission process, or finding out what a shuttle may be useful for. Significant efforts are also taken to ensure that the currently available shuttle vehicles can operate on the intended route. Learnings and safety implications from the Linköping operation are shared and show for example that physical infrastructure needs major preparations.

Aspects that need to be addressed by a service aiming to provide safe mobility “for all” are identified and discussed. One key conclusion is that “mobility for all” should enable access to education, work, culture and experience, care (child-, health, elderly), markets and goods – for any person, in cities or rural areas, irrespective of age, gender, ethnic aspects, educational levels and digital experience,
income levels, as well as for persons with disabilities and for those with or without special needs. Safety implications of these aspects are discussed and include considerations for vehicle design and service operations.

Permits for shuttle operation on public roads often require a risk analysis, where one of the key aspects is to ensure that the automated shuttles interact safely and smoothly with vulnerable road users, as well as with other vehicles and their drivers. Given the status of shuttle vehicle technology, this may lead to a hard braking. The paper investigates safety implications considering persons outside the shuttles and the balance with safety of those inside the vehicle. For example, the typical interior layout of autonomous shuttles does not make room for mounting a backrest onto which rearward facing wheelchairs can be mounted. This may compromise the safety of persons with mobility impairments in case of hard braking.

People engagement is important to ensure safe use and interaction with automated vehicles. The paper shares experience for example regarding the role of automated electric vehicle sounds, for which there is no standard today. In the Linkoping site it is noted that persons with hearing problems do not know if the automated vehicle is close behind or if it signals that it is about to stop, and blind persons do not understand what the sound is aimed to solve.

The safety driver is considered as the link to a safe/secure ride, which points towards a role that is different to that of drivers of conventional buses. The Linkoping operation shows how important it is to create awareness about automated vehicles among people outside the vehicle. There is a need to inform and train the different behaviour perspectives among road users that may interact with shuttles along their route e.g. about the possibility of hard braking.

Conclusions: This paper concludes that “safe mobility for all” with automated shuttle services needs further development of sensors and vehicle technology. In the wake of the realisation of these improvements injury mitigation actions for the protection of riders can be taken, such as seat belt usage. Furthermore, avoiding misunderstandings of interactions and intentions is vital. It is highly recommended to develop standards for balancing hard braking, for the use of exterior sound, and for safe and conspicuous interactions with automated shuttles with all - both service users and surrounding road users.

26 - Are 'road safety logics' equally valid across different continents?

Wouter Van den Berghe

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Background: With road safety research expanding globally, including more research being undertaken in LMICs (Low and Middle Income Countries), there is increasing evidence that some models and theoretical frameworks in relation to road safety that had been developed in HICs (High Income Countries) may not be (fully) adequate for LMICs. King et al. (2019) argued that the logics underlying Traffic Safety Culture are not fully transferable to LMICs. Nordfjærn et al. (2011) found that their predictive model of driver behaviour was poorly fitted for the African countries they
considered. Lund & Rundmo (2009) found that social cognition models claiming that attitudes are significant predictors of behaviour are less suitable in low-income countries.

**Methods:** As part of the research for a PhD (Van den Berghe, 2022) associations were analysed between national indicators from different sources, such as the Global Status Report of the WHO (WHO, 2018) and the ESRA database (Meesmann et al., 2021). These analyses have provided further evidence that relationships between factors which are common in HICs - e.g. between behaviour and crash risk - do not necessarily apply to the same extent in LMICs.

**Results:** During the presentation, a number of examples will be provided that illustrate the assertions, such as the associations of traffic volume, alcohol consumption, education level, speeding and confidence in societal institutions with the crash fatality risks and support for policy measures. One example - the relationship between speeding and fatality rate - is shown in the picture. Part of the differences can be explained by culture. The analyses undertaken for the PhD also clearly showed that the support for policy measures in road safety is also considerably higher in LMICs than in HICs. Moreover, ‘supporting a policy measure’ has not the same meaning in collectivistic and individualistic societies, and collectivistic societies are more found in LMICs.

**Conclusions:** HICs and LMICs differ not just in level of wealth but also in terms of culture. The cultural differences impact on behaviour in traffic and hence on the fatality rate, while the economic differences determine the capability to implement (expensive) measures. The combined effects of these differences lead to quite different ‘road safety contexts’, in which some of the models and concepts traditionally used in road safety thinking, developed in the Western world, may become less appropriate. Further research is needed to develop models and frameworks that fit better the road safety context in LMICs.

**Selected references**
27 - Pedestrian and Bicycle Safety Inequities in Texas

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Background: Transportation equity has been an emerging area of research in recent years. Equity in terms of pedestrian and bicycle safety can look at several factors including gender, age, race and ethnicity and location. Additionally, other important factors such as their inherent vulnerability, the purpose of their trip, the safety features found where they walk and bike, the obstacles that prevent them from walking and biking more, and their understanding of safety laws can also be explored for a more comprehensive look at equity in the transportation system for these vulnerable users.

Methods: This data is derived from a survey that specifically looked at how pedestrian and bicycle safety issues differ in urban and rural areas in Texas. The survey included a total of 497 respondents, of which, 88 (17.7 percent) were in rural areas and 409 (82.3 percent) were in urban areas. The survey was conducted online using a survey panel of available respondents. The data for all respondents was combined for an overall look at the state level, as well as broken-down to explore how responses varied by urban and rural status.

Results: Pedestrians and bicyclists face inherent inequities when it comes to their interactions with drivers, with drivers reporting unsafe behaviors that put these vulnerable road users at risk. Results showed discrepancies by demographics as well as in access to safety features to increase pedestrian and bicyclist safety based on their rural and urban status and their reasons for walking or biking (transportation vs. recreational). Rural Texans also reported a lack of infrastructure (sidewalks, bike lanes/trails) and crossing signals and signs as obstacles to walking or biking more at higher rates than urban residents. In addition, black respondents and rural residents reported much lower rates of familiarity with safety laws compared to other groups.

Conclusions: Pedestrians and bicyclists are inherently vulnerable road users and face significant obstacles to their safety. This analysis reveals the inequitable transportation system facing those that
walk and bike. Several factors, such as those discussed here, show that pedestrian and bicycle equity needs to be a priority in the planning of transportation networks in order to meet the goal of zero roadway fatalities.

28 - Does public support in Texas for road safety policies differ a lot from that in other regions in the world?

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Background: It is not easy for policymakers to decide which measures should be taken to improve road safety. Policymakers may be reluctant to implement road safety policy measures because of the expected high costs and/or perceived low public support. Measures that may be effective or cost-effective in one context may be less effective in another. Moreover, policymakers may be reluctant to implement road safety policy measures because of the expected high costs and/or perceived low public support. Opposition to measures is rooted in people’s beliefs about several issues, including effectiveness, costs, burdens, restrictions on freedom, possible discrimination, and so on. An understanding of the factors that contribute to people’s support for road safety measures can enlighten politicians and is useful if one seeks to increase the level of support for such measures. Public support for road safety has been analyzed in several countries for one or more policy measures. Most of these studies were based on national opinion polls and surveys. However, little evidence is available about how countries and part of countries differ in terms of public support for these measures. A limitation of many studies is that they refer to only one country and relate to one or only a few specific measures. So it would be dangerous to generalise the results.

Methods: To understand the arguments used against policy measures for road safety, a survey was conducted in twelve regions and countries (Texas, California, China, Greater London, Austria, Sweden, Greece, Flanders, Wallonia, West of France, Nigeria, and Argentina). Respondents were presented with ten possible road safety measures and asked whether they would support or oppose them, what arguments their opinion was based on, and what the effect of the measure would be on them individually. To allow generalization of the results, the set of policy measures needed to be sufficiently varied. The selection criteria for inclusion were as follows: (1) be implementable (in principle) over the next decade in the countries considered; (2) make sense in all the countries in which the survey were conducted; (3) be neither too controversial nor too obvious and (4) to include at least one dimension of “unfairness”. Over 5000 people participated in the survey. In each country or region, the sample of respondents was representative for the adult population.

Results: The presentation will show the main findings of the research and then zoom in on a number of counterarguments such as restriction of mobility, discrimination, and unjustifiability of state interventions.

Motorists who self-report risky behavior are more opposed to further measures restricting or penalizing that behavior. If people feel safe when using a particular transport mode, they are less likely to see the need for additional or stricter measures affecting their transport mode. People who believe that a particular phenomenon (e.g., speeding or drunk driving) is an important cause of road traffic injuries are more supportive of policy measures meant to reduce this phenomenon. Other
interesting associations were found with personal consequences for individuals. Not surprisingly, if
the perceived effects are negative, people are more inclined to oppose the measure, even if they
consider the measure to be fair. Very large differences exist in the expected personal effects between
the opponents and supporters of a measure, suggesting that such different expectations are decisive
for the willingness to support policy. It was also found that only a small fraction of the respondents
agree with certain arguments that are often used against certain measures—for instance, that
mandating wearing helmets for cyclists would reduce cycling.

The presentation will show how respondents from Texas (and California) differ from the other
regions and countries in terms of the level of public support and the arguments used for justifying it.
Overall the results show that the public support for road safety measures that restrict freedom is
lower in Texas (and California) than in other parts of the world. Such measures are seen as an
unjustifiable state intervention. Much more than elsewhere, such measures are seen as a restriction of
freedom. Interestingly, the differences between Texas and California, are often smaller than those
between Texas and Europe.
One interesting finding was that even if a measure was perceived to be unfair from a certain
perspective (e.g., discrimination), some respondents supported the measure. This illustrates that
other considerations were more decisive in their minds.

Conclusions: Policymakers are notoriously reluctant to issue new regulations for improving road
safety when public support is low. Low public support may be shaped by particular stakeholders and
lobby groups that influence policymakers, especially by stressing particular counterarguments. Our
research shows that even people who recognize that a measure would be effective might oppose the
measure because they think it is not justified from at least one perspective, for instance, an excessive
restriction of freedom—even if in practice, this argument is far less widely used and support
increases once the measure has been implemented and its beneficial effects have been recognized.
People from different countries vary in what they consider fair and unfair, which is linked to the
national culture and organization of society. For instance, many more Americans than non-
Amerians consider the policy measures to be an unjustifiable state intervention; the opposite was
the case in China. In China, the respondents often considered the proposed interventions to be less
restrictive of freedom, privacy, and mobility than in the other countries considered.

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Van den Berghe to University College London (UCL) for the degree of Doctorate of Philosophy
(April 2022)
Special Session: Motorcycle safety

29 - MOTORCYCLE SAFETY CONTRIBUTING FACTORS

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Abstract: The Federal Highway Administration is committed to identifying effective motorcycle safety countermeasures, promoting roadway maintenance and design practices that account for motorcycle-specific safety concerns, and maintaining a research program that supports an improved motorcycle riding environment on American highways. A commitment to Vision Zero will require multiple strategies, including understanding the contributing factors to motorcycle collisions with traffic barriers and designing solutions that will mitigate the consequences of such crashes. Recently, the FHWA Office of Safety has supported research projects to specifically address the Motorcyclist Advisory Council recommendations in the areas of barrier design for motorcyclists' safety, roadway geometry, pavement design, and pavement construction and maintenance practices, as well as intelligent transportation system applications and automated technologies for motorcyclists. As some Department of Transportation are addressing their motorcycle safety needs independently, a pooled fund study was supported to provide a cooperative approach to conducting research to address roadside safety issues specifically related to improving motorcyclist safety. Furthermore, the study is intended to provide participating states collaborative opportunities to stay abreast of best practices, new regulatory issues, risk management strategies, and other research pertaining to roadside safety improvements for motorcyclists.

30 - ADDRESSING THE MOTORCYCLIST ADVISORY COUNCIL RECOMMENDATIONS ON BARRIER DESIGN FOR MOTORCYCLISTS SAFETY

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Abstract: The purpose of roadside barrier systems is to reduce the severity of injuries and number of fatalities by controlling and mitigating crash forces. While barrier systems have been designed and proven to be beneficial for motor vehicles they do not currently address the problems associated with motorcycle crashes. Motorcyclists are more vulnerable than drivers of motor vehicles and that motorcyclists are more likely to be severely injured when they crash into a barrier system. Addressing the challenges associated with barrier systems is critical for reducing the severity of injurious and number of fatalities associated with motorcyclist-barrier crashes. This presentation identifies current needs, on-going research proposals and research gaps that should be considered for future research projects. A significant gap is the lack of testing standards and protocols in the United States to verify the safety advantages of roadside barriers for motorcyclists.
Background: An international workshop on safety for powered-two-wheelers (PTWs), Riding in a safe system, was held as a series of virtual meetings 9–23 June 2021. The workshop was co-organized by the International Transport Forum (ITF), the Swedish Transport Administration, the International Motorcycling Federation (FIM), the motorcycle manufacturers associations (IMMA and ACEM), and the Swedish National Road and Transport Research Institute (VTI). The workshop was a follow-up of the Third Global Ministerial Conference on Road Safety, held in Stockholm in February 2020, but it also built on a previous workshop in 2008 in Lillehammer and the 2015 ITF research report “Improving Safety for Motorcycle, Scooter and Moped Riders” (OECD/ITF, 2015).

Globally the use of PTWs is an important mode of transportation. Improving PTW safety can have a huge impact on reducing fatalities and injuries in the transport system. The aim of the workshop was to gather experts on PTW safety representing all important stakeholders to discuss the nine recommendations of the Academic Expert Group and their application to motorcyclists’ safety. The main goal was to develop a set of priority actions to improve motorcycling safety for the decade 2021–2030, taking regional aspects into account.

Methods: The workshop included six expert sessions, which focused on seven different areas: (i) Sustainable practices, work-related issues and procurement, (ii) Modal shift and urban needs, (iii) Training, education, and licensing, (iv) Vehicle safety, protective safety, and Intelligent Transport Systems, (v) Road infrastructure and road environment, (vi) Speed management, adapting speeds and behaviour to different environments, and (vii) Youth and child safety.

Results: Eight priority actions were recognized by the workshop to achieve the integration of PTWs in the safe system by 2030. These actions build on the Stockholm declaration and its 9 recommendations. The actions are generalized results from the outcome of the expert sessions. The 8 priority actions from the workshop are listed below with a short description of each action.

Move to sustainable practice - Public and private organizations should, in the context of Shared Responsibility, apply best practice in PTW safety and report, separately for PTWs, on their organization’s safety footprint across the entire value chain, in order to improve road safety for professional users, customers, employees and other road users.

Support modal shift - Rethink, redesign, and reallocate infrastructure and urban planning. Cities and road authorities should develop new solutions that include PTW mobility in urban settings for sustainable and safe use of PTWs for efficient mobility. This includes adapting speed in urban areas, where pedestrians and cyclists interact with motorized vehicles, in accordance with the Stockholm Declaration[1].
Adopt safe vehicles and equipment - To accelerate the adoption of PTW safety technologies such as ABS[2] and AHO[3], safe vehicles and products should be promoted by regulation, procurement, and incentives by governments, fleet operators, and insurance companies respectively. Industry should also continue to drive safety performance on all markets. Scientific safety ratings programs should stimulate consumers to choose safe vehicles, helmets and other personal protective equipment (PPE).

Educate safe riders - Promote state-of-the-art rider education and licensing systems. Governments, authorities, rider associations, and industry should accelerate the availability of effective, affordable, and accessible education, training, and licensing programs in all regions, especially in low- and middle-income countries.

Redesign infrastructure - Improve infrastructure safety for PTWs. Governments and road authorities should comply to latest standards and update their road manuals and design and maintenance guidelines to include best practice and safe system principles for PTWs.

Ensure safe speed - Road authorities should set appropriate speed limits that are in line with safe system principles. All stakeholders should promote technology, infrastructure design, enforcement, procurement, information, training, and education to ensure speed compliance.

Protect children - All levels of governments should improve safety by offering suitable transportation alternatives, where possible, to carrying small children on PTWs. If child passengers are carried on a PTW the child should use appropriate safety equipment, and PTWs should have relevant child occupant protection system. Children should be protected in school zones, for example, by infrastructure measures and technology solutions.

Increase knowledge - Governments, industry, and the research community shall fill the gaps in knowledge and develop innovative solutions for the safety of PTW users. Substantial funding is to be quickly devoted to in-depth, epidemiological, and biomechanical research into the mechanisms of PTW crashes and their consequences, as well as the measures to remedy them.

[1] A critical prerequisite to support modal shift is a safe environment for walking, bicycling and low speed powered two- or three-wheelers. The Stockholm Declaration recommends a maximum speed limit of 30 km/h in urban areas unless strong evidence exists that higher speeds are safe.

[2] Anti-lock Braking system


Conclusions: The workshop was a great success in that consensus on important action was reached between different stakeholders and representatives from all over the world. The identified actions point out the direction of how to improve safety for PTW across the globe. However, the need for more knowledge and the possibility for new innovations is also recognised. The potential for finding new solutions is large and should therefore be further explored.

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32 - THE ROLE OF PHYSICAL FULL-SCALE CRASH TESTING AND FINITE ELEMENT SIMULATIONS AS DESIGN AID IN MOTORCYCLE SAFETY

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1
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Abstract: Over the past years, extensive research efforts have been made to improve roadside safety hardware to reduce injury to occupants of four-wheel vehicles and heavy trucks. In comparison, limited research has been conducted to address the safety of motorcycle riders when impacting roadside safety hardware. The vulnerability of motorcycle riders can lead to a high risk of injury for the rider, especially when impacting roadside barriers.

Physical crash testing is essential to prove crashworthiness of roadside safety barriers. In real-world motorcycle crashes there is a wide range of impacts against other vehicles and barriers. Reproducing these different motorcycle crash scenarios through physical crash testing can be considerably costly and time consuming. Computer simulations are a great tool to address the wide range of impacts in real-world motorcycle crashes because they are significantly less expensive and quicker than performing full scale crash tests. Recent efforts have begun to evaluate various new motorcycle-friendly roadside hardware through computer simulations and full-scale crash testing.

33 - UNDERSTANDING PATTERNS OF CONTRIBUTING FACTORS IN MOTORCYCLE RUN-OFF-ROAD CRASHES

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1
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Abstract: In 2020, there were 5,458 motorcycle fatalities in the U.S., which is a 9% increase from 2019. Louisiana has one of the highest rates in motorcycle related traffic fatalities. Due to the unique nature of motorcycle riding and associated safety issues, motorcycle safety is a complex public health concern. In motorcycle crashes, a significant proportion of these crashes are run-off-road crashes. Motorcycle run-off-road crashes can happen due to causes such as self-skidding, hitting fixed objects such as trees and utility poles, leaving the driving lane, and losing control. This study applied association rules mining to identify the patterns of the contributing factors unique to motorcycle operation- geometric variables, operating speed and posted speed limit, motorcycle type, helmet usage, impairment, ejection from motorcycle, rider age and gender, location, license type, weather, season, and roadside fixed objects. In this study, three major severity levels (fatal, serious, and minor injury) were considered for developing rules for each severity level. For each of these severity levels, a set of 30 association rules was developed. The rules provided a wide range of
patterns of key contributing factors associated with motorcycle run-off-road crashes. The findings of this study can be beneficial to the safety professionals, policymakers, law enforcement agencies, and roadside designers.
Special Session: Using road safety performance indicators to support evidence-based road safety policies

34 - Improvement of Road Safety Management Systems in Local Governments in Korea after Evaluating Associated Indicators

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Background: In Korea, more than 90% of all road crashes occur on roads managed by local governments. This means that all 17 local governments should be accountable for the road crashes within their administrative boundaries. However, the level of road safety performance between local governments is significantly different from each other. For example, Sejong shows the lowest number of traffic fatalities per 100,000 population at 2.01 while Jeollanam-do shows the highest at 15.47. It is 7.69 times higher than that of Sejong. This gap may have resulted from the difference in Road Safety Management System (RSMS) between local governments. In this respect, Han & Lee (2020) presented 24 indicators to evaluate the RSMS which is made up of four areas: Institutional Management, Intervention, Intermediate Outcome, and Final Outcome. Then these indicators were used to calculate the overall scores of the RSMS of each local government. The composite scores are the weighted averages of indicators and the weights were derived using Analytic Hierarchy Process (AHP). The evaluation of RSMS indicators has been conducted continuously and now we have results for five years between 2015 and 2019. This study aims at analyzing what has been changed in detail after the evaluation of RSMS indicators during the last five years. The comparison of indicators should have helped local governments to identify the strong and weak points. Then they should have taken appropriate actions to improve the scores of weak points.

Methods: Firstly, the changes in the overall scores of RSMSs were compared during the last 5 years. Then the changes in scores of the four areas as well as the indicator scores were analyzed for the same period. The changes will be compared in various forms of graphs. Then there will be discussions on the effect of continuous evaluation of RSMSs of local governments in Korea.

Results: The national average overall score of the traffic safety performance indicator steadily increased from 77.92 points in 2015 to 83.89 points in 2019. In 2016, the very next year after the first introduction of indicators in 2015, the average overall scores increased by more than 5%. After that, it showed an annual increase rate of 1.1% from 2016 to 2018, and the increase has dropped to 0.02% in 2019. Among four areas of RSMSs, the scores of Institutional Management, Intervention, and Final Outcome areas were increased, but the scores of Intermediate Outcome areas were decreased. In particular, the scores in the Intervention area have shown the highest increase as much as 15.97% in 2019 compared to 2015. However, the scores of the Intermediate Outcome area has been decreased by 1.02% compared to that of 2015. Among the individual indicators in the Intervention area, all local governments received an A in 2019 for the indicator of ‘road safety education programs’. In the area of the Intermediate Outcome, the score of ‘Upload of digital tachograph (DTG) data’ increased significantly, but the scores for ‘ratio of speeding and drunk-
driving violations’ and ‘proportion of aged cars’, which are highly weighted, decreased significantly, indicating that the overall score for the intermediate outcome has been decreased. Among 17 local governments, Ulsan has shown the highest increase in overall score by 14.26% between 2015 and 2019, and Seoul showed the lowest increase in overall score by 2.23%. In the area of Institutional Management, Gyeongsangnam-do showed an increased score of 28.69%, while Gwangju has decreased by 3.97%. In the Intervention area, Sejong showed an increase of 46.57%, and Chungcheongnam-do showed a decrease of 4.17%. In the area of Intermediate Outcome, Jeju-do showed the highest increase of 16.15%, and Incheon showed the highest decrease of 13.14%. In the case of the Final Outcome area, Ulsan showed the highest increase of 13.58%, and Gwangju showed a decrease of 2.36%.

Conclusions: The continuous comparison of indicators of RSMSs in local governments should have helped to improve road safety performance in local governments considering that the average scores have been increased by more than 7.7%. The most distinguishable increase has been identified in the area of Institutional Management. Although there are some indicators whose values were decreased during the last five years, the averages of most indicators have increased. This concludes that the evaluation of indicators of RSMSs for local governments has contributed to improving the road safety of local governments.

35 - The iRAP Global KPIs for Infrastructure Safety and the AiRAP approaches for the future
Invitation only: Using road safety performance indicators to support evidence-based road safety policies
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**Background:** Road trauma is the biggest killer of young people worldwide with an estimated 100,000 people killed and injured on the world’s road each day. In response, the United Nations has developed the Global Plan for the Decade of Action for Road Safety 2021-2030 that includes 12 Global Road Safety Performance Targets that have been agreed by Member States. The Star Rating of the world’s roads has been adopted as part of the Global Plan and Targets.

**Methods:** Governments, development banks, research and civil society partners in over 100 countries have undertaken iRAP related assessments with more than 1.4 million kilometres of roads Star Rated (where 1-star is the least safe and 5-star the safest) and over 1.6 million kilometres of cumulative Crash Risk Mapping completed. The global datasets provide unique insights into the condition of the world’s roads that are periodically updated and shared via the free iRAP Vaccines for Roads resource.

**Results:** To support countries worldwide using the iRAP global standard a set of standard Safe System supportive KPIs have been established. The metrics allow for consistent benchmarking and tracking of performance at the Star Rating and road attribute level in-line with the UN agreed global targets. For example:

- The percent of travel at a 3-star or better standard for each road user
- Percentage of roads where pedestrians are present and traffic flows at 40km/h (25mph) or more have formal footpaths or sidewalks
- Percentage of roads where traffic flows at 80km/h (50mph) or more have low-risk roadsides
- Percentage of roads where traffic flows at 80km/h (50mph) or more have divided carriageways

To accelerate the availability of the data worldwide iRAP is leading the AiRAP partnerships that are focussed on the accelerated and intelligent collection of iRAP data attributes worldwide. Using satellite, LiDAR, aerial, video and telematics source data combined with artificial intelligence and machine learning techniques new big data suppliers are being accredited to deliver the data to the same harmonised and globally consistent iRAP global standard. This provides the critical mass for big data approaches to succeed and ultimately deliver lower-cost data that increases the scale and frequency of road safety data for the mutual benefit of all partners.

With the Transport Accident Commission in Australia, iRAP has also developed insights into the injury burden by age, lifetime claim costs, injury types and gender to shine a light on the true human and financial impact of road trauma. The data provides essential information to inform policy and investment decisions that take into account the true and tragic scale of road trauma with projections to every country on earth.

**Conclusions:** Together the Star Rating, road attribute and injury data provide the foundation of evidence-based knowledge to understand the return on investment of key policy targets (e.g. 75% of travel on 3-star or better roads). This knowledge can then inform the necessary cross-sector discussions with transport, health, welfare and insurance leaders to unlock the win-win investment in safer road infrastructure and speed management needed to save lives and reduce injuries. The link
with results-based financing and public-private sector partnerships can then be enabled with confidence to ensure the 2030 SDG target to halve road deaths and injuries by 2030 is met.

**Selected references**

https://www.vaccinesforroads.org/ accessed on 20 April 2022 - update expected prior to paper submission / conference

36 - Using performance indicators to support evidenced-based behavioral road safety policies.

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**Background:** In 2012, NHTSA convened an expert panel with representatives of State highway safety offices (SHSOs), academia, research and other key safety organizations to develop core performance measures to use when developing behavioral highway safety programs. The resulting publication, “Traffic Safety Performance Measures for States and Federal Agencies,”[1] defines a minimum set of traffic safety performance measures. Prior to this publication, there was a lack of standardization among performance measures.

The States and territories, through their representative organization for highway safety offices, the Governors Highway Safety Association (GHSA), agreed to include performance measures beginning with their fiscal year 2010 HSP submissions. The MAP-21 surface transportation authorization codified this requirement, requiring that States include these measures beginning in their FY 2014 HSPs.

**Methods:** The 50 U.S. States, DC, territories and the Bureau of Indian Affairs submit behavioral safety performance measures to the National Highway Traffic Safety Administration (NHTSA) as part of their annual highway safety plan (HSP) that is required to receive a 23 U.S.C. Section 402. The HSP describes planned highway safety programs and expenditures based upon a State’s problem identification. States forecast and set evidence-based targets from trend analysis, anticipated levels of effort, and situational factors such as economic conditions, demographics, vehicle miles traveled (VMT) and legislative changes known at the time of target establishment.

**Results:** Performance management increases accountability and transparency of actions taken to reduce motor vehicle crashes, which continue to be one of the top 10 causes of death in the United States. Performance management provides a framework to support improved investment decisions that guide States to focus on areas likely to have the most meaningful impacts on saving lives, preventing injuries and reducing traffic-related healthcare and other economic costs.

See: https://www.nhtsa.gov/highway-safety-grants-program/state-performance-targets

**Conclusions:** In a period of rising traffic fatalities and injuries, performance management becomes increasingly important planning and evaluation tool. Performance management will provide objective benchmarks for States to set data-driven targets and measure future successes in reducing motor vehicle crash deaths and injuries.

**37 - From Baseline to Trendline: the European approach to promoting the use of road safety performance indicators**

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¹ TILKON Research and Consulting

**Background:** Continuous and systematic monitoring of road safety performance allows for a better understanding of accident causalities and the implementation of the proper measures and policies in order to prevent these casualties. To measure progress, the most basic and important indicators are the result indicators on deaths and serious injuries. However, in order to gain a much clearer understanding of the different issues that influence overall safety performance, indicators that refer to main road safety challenges are very important as well.

The European Commission (EC) has put forward a new approach to the European Union's (EU) road safety policy for the decade 2021-2030, highlighting also the need of setting new interim targets and establishing a range of road safety performance indicators for road safety at European level. The indicators are referred to as "Key Performance Indicators" (KPIs) and are directly related to factors that contribute to road crashes and injuries. The EC has made grants available for developing and applying a common methodology for the collection of the KPIs in the EU.

In a first project “Baseline”, 18 EU Member States participated. This project, coordinated by Vias institute in Brussels (Belgium) ended in October 2022. A successor project “Trendline” has just taken off, in which almost thirty European countries will take part. This new project is coordinated by SWOV Institute for Road Safety Research in The Hague (The Netherlands).
Methods: Both Baseline and Trendline start from 8 KPIs to be considered which have been defined by the European Commission, following consultation of experts and representatives of EU Member States (EC, 2019). The definition of the KPIs is given in Table 1. For each of these KPIs, a methodology for data collection and analysis has been developed in the Baseline project by a group of European experts, takes into account the best national practices observed in the EU. These methodologies will be reviewed and refined during the early stages of the Trendline project, taking into account the experience gained in Baseline. The methodological guidelines for each KPI are available on the Baseline website (baseline.vias.be) and are listed under the References below. The adapted versions will appear on the Trendline website mid 2023.

In addition, in Trendline a number of new, complementary indicators will be selected. The methodology will be developed and tested in a selected number of EU countries. Following these test, the methodological guidelines for these new indicators will be published. An additional feature of Trendline is its emphasis on the use of the KPIs in national road safety strategies and policy monitoring activities.

Results: At the moment of submitting this abstract, data analysis is almost finished. Most EU Member States will deliver values for 5 to 7 KPIs. The final report on Baseline including all its key results will be published by the end of October 2022. First results on Trendline will become available early 2024.

Conclusions: The Baseline and Trendline projects show that it is possible to develop and apply methodologies for road safety performance indicators that are common, transferable and comparable across different countries. The data collected will constitute the basis for monitoring and evaluating the road safety progress at national and EU level over the decade 2021-2030, and will facilitate the formulation of targets at European an national level. It will also support decision makers in deciding on the most appropriate measures to be taken to improve road safety.

Selected references
Website: https://baseline.vias.be

<table>
<thead>
<tr>
<th>KPI area</th>
<th>KPI definition</th>
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<tbody>
<tr>
<td>Speed</td>
<td>Percentage of vehicles travelling within the speed limit</td>
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<tr>
<td>Safety belt</td>
<td>Percentage of vehicle occupants using the safety belt or child restraint system correctly</td>
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<td>Protective equipment</td>
<td>Percentage of riders of PTWs and bicycles wearing a protective helmet</td>
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<tr>
<td>Alcohol</td>
<td>Percentage of drivers driving within the legal limit for blood alcohol content (BAC)</td>
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<tr>
<td>Distraction</td>
<td>Percentage of drivers not using a handheld mobile device</td>
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<tr>
<td>Vehicle Safety</td>
<td>Percentage of passenger cars with a Euro NCAP safety rating equal or above a threshold</td>
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<td>Percentage of distance driven over roads with a rating above an agreed threshold</td>
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<tr>
<td>Post-crash care</td>
<td>Time elapsed between the emergency call following a collision resulting in personal injury and the arrival at the scene of the collision of the emergency services</td>
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Session: Road user behaviour and risk perception, part 1

38 - The Influence of Drivers Profile on Driving Performance: A Simulator Study

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Background: The triad human-environment-vehicle and its relationship with crashes have been repeatedly discussed over the years, with the human factor being consistently claimed as the leading cause (Dingus et al., 2016; Treat et al., 1979). One tool to study the human element is the famous Driver Behavior Questionnaire (DBQ) (Reason et al., 1990). The DBQ has been replicated several times, and its results have been widely used as predictors of self-reported crashes; however, the relationship between DBQ scores and crash occurrence is small (de Winter & Dodou, 2010). Nevertheless, significant differences in objective behavior measures, such as speed-related measures, have been found between participants of different groups classified based on their DBQ scores (Helman & Reed, 2015; Zhao et al., 2012). In this context, driving simulators can be used to test the relationship between DBQ scores and surrogate safety measures (for instance, speed and trajectory) instead of only relying on self-reported crashes.

Methods: This study used a driving simulator consisting of a fixed-based instrumented car to investigate road risky scenarios based on a crash database from Brazil (Bobermin & Ferreira, 2021; García et al., 2021). Forty-eight participants were recruited considering the predominant characteristics (age and sex) from the database and classified based on their responses to a validated version of the DBQ (Bobermin et al., 2021) through a Clustering Analysis. Surrogate safety measures of speed, trajectory, and acceleration were recorded to analyze their relationship with drivers' profiles based on their DBQ scores. Furthermore, three perceptual countermeasures were tested (peripheral lines in two different locations and delineators), focusing on their effect on the drivers' performance.

Results: Drivers were classified into two groups based on their scores on the three dimensions of the DBQ questionnaire: Errors (E), Ordinary Violations (OV), and Aggressive Violations (AV). The first group (Cluster 1) consisted of drivers characterized by their high scores in all three dimensions, while the remaining drivers were clustered in the other group (Cluster 2). Results of the countermeasure effects will be examined considering the whole sample and the sample divided by groups. Initial results regarding average speed on the countermeasures point out a relevant difference between groups, with Cluster 1 showing a lower average speed than Cluster 2. Moreover, while for Cluster 1, the least efficient countermeasure was peripheral lines placed before the curves, this was the most effective countermeasure considering Cluster 2.

Conclusions: The initial results indicated that drivers with high scores in all three dimensions (Cluster 1) had driven more cautiously than the other group (Cluster 2). This result suggests that the high scores on the DBQ might indicate that drivers are more conscious of their driving skills and have adjusted their performance. Complete analysis, including all the measured variables, and a
thorough study of the relationship between DBQ scores and objective measures with self-reported crashes should enlighten initial results.

**Selected references**


**39 - Evaluation of compliance to school zone and speed limit signs inside a school safety zone in Kigamboni ward, Tanzania**

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**Background:** The research aimed to evaluate the compliance towards the school zone and speed limit signs inside a School Safety Zone (SSZ) in enhancing safer routes to school and schoolchildren road safety in the study area. The scope of the case study area was the three government primary schools located in Kigamboni Ward in Dar-es-Salaam, Tanzania.

1.36 million people have been estimated to die on roads worldwide, while 50 million people are injured, one death every 24 seconds (1,2). Three thousand children and young people are estimated to be killed or seriously injured on the world's roads every day (2). Children have been cited as the most vulnerable road users (3, 4) and most at risk on the streets where they live, play and travel to school (2). Globally, many children are seriously injured or are killed daily in road traffic crashes that sometimes occur a few yards from the school gates (5). Children from Low and Middle-Income Countries are the most affected (6).

Children require safe and secure routes to school as pedestrians and cyclists (7,8). An SSZ is usually aimed to protect elementary (primary) and preschool children (9). A study investigating the causes of traffic crashes in school zones mentioned unfavourable road conditions and the absence of traffic signs as the contributing factors. Even though reduced speeds near schools are reasonably standard, drivers do not always adhere to these limits. Hence high visibility signing in a school zone was mentioned as a helpful treatment that may remind drivers to slow down (10,11).

The Theory of Planned Behaviour (TPB) is commonly used to predict driving violations related to road crashes (12). The TPB proposes that human action is guided by predicting a specific behaviour's occurrence, provided that the behaviour is intentional. Intentions to perform kinds of behaviours can be predicted significantly from attitudes toward the behaviour, subjective norms, and perceived behavioural control. Together with behavioural control perceptions, these intentions account for considerable variance in actual behaviour (13). Using TPB, the study evaluated the road user compliance to the newly established school zone and speed signs in the area.

**Methods:** The research methodology employed a pre and post-intervention survey. The surveys were developed using TPB to examine how its constructs would predict the behaviour to comply with the installed signs. In both pre and post-intervention surveys. Data analysis was done using IBM SPSS Statistics version 26.

**Results:** Findings showed that people agreed that the school zone and speed limit signs were a good intervention in making the routes to school safer and improving schoolchildren's road safety in the area. The means of normative beliefs, perceived behavioural control, behavioural intentions and behaviour regarding the intervention increased while attitude reduced post-intervention. The ordinal regression analysis results showed that normative beliefs and perceived behavioural control significantly predicted behavioural intentions. In turn, intentions predicted behaviour to comply with the school zone and speed limit signs. Respondents who believed that people important to them would find the intervention a good measure, and those who perceived that they had control of reducing their speeds were more likely to intend to comply with the posted signs. Those with higher intentions were more likely to abide by the installed signs.

**Conclusions:** The results showed that creating an SSZ using school zone and speed limit signs as an intervention succeeds in making routes to school safer whilst improving schoolchildren's road safety.
The results also implied that road safety awareness for the Kigamboni ward community was necessary. Hence, it was recommended that the Kigamboni Municipality and other respective road safety actors consider strategies or activities to provide more road safety awareness in the area. In compliance with speed limit and school zone signs, road safety awareness or educational campaigns may focus on the people's normative beliefs, perceived behavioural control, and intentions to comply with the traffic signs inside the SSZ. The other recommendations were the political will to make road safety a priority and continued collaboration among and between government authorities and road safety practitioners.

Selected references


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**40 - Understanding Driver Behavior and Road Safety Perception in Ghana: A Qualitative Study with a Sociocultural Lens**

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**Background:** Human factors contribute to over 95% of global road fatalities (Petridou and Moustaki, 2000); yet, limited research has focused on these factors in developing countries where crashes are most common (Lagarde, 2007). Many human factors identified in developed world crash...
research are also likely to be salient in developing countries. Two forms of risky driving have been identified: inadequate driving skills and dangerous driving styles (Reason, 1990). In developed countries, driver education and licensing are designed to mitigate skill deficiencies. Conversely, in developing countries, several factors potentially influence driver behavior and perception/attitude towards risky driving. This study focuses on understanding driver behavior in Ghana through a sociocultural lens by beginning with the top two regions that experienced the highest crashes and fatality rates over the past year (Road Traffic Crashes in Ghana Statistics Report, 2019).

Methods: This study assesses risky driver behaviors that contribute to road traffic crashes (RTC) through a survey to assess road user behaviors and perceptions. The survey consisted of three parts: demographics, driver behavior, and perception/attitude. The survey was hosted online and in-person for local volunteers to participate, being shared and promoted via social media, academic and professional forums, and word-of-mouth. Study results captured the dynamics between traffic safety culture established by the local community and road user behavior and perception while also providing a typology of behaviors and attitudes that capture variables and stimuli that influence drivers’ responses concerning road safety practices.

Results: This study provides insights into drivers’ perceived danger, perceived risk of apprehension, road users’ social approval, self-reporting of behaviors, and support or compliance of safety laws related to various risky driving behaviors. Upon running perception analysis, 67.6% of survey participants responded feeling “extremely unsafe” traveling on the road in Ghana. While 79.5% of participants responded that they agree more attention and resources need to be allocated to ensuring road safety.

When analyzing driver behavior and the role of socioeconomic status, there is a strong correlation (p-value < 0.05) between a driver who speeds on a two or four-lane road and their level of education attained. After examining driver behavior, it was seen that 53.3% of survey participants admitted to making calls while driving, and of that percentage, 54.3% were employed at the time they participated in the survey. Lastly, it was seen that 53.3% of drivers admitted to making a call while driving, and 60.8% answered a call while driving.

Conclusions: Study results are expected to provide deeper insights into road users’ behavior, perceptions, and attitudes that influence risky behaviors that lead to road traffic accidents while focusing on efforts to improve road safety infrastructure/environment and educate the road user public. The results also seek to reveal any underlying silent effects that influence drivers towards risky driving behaviors. This information can be shared with governing transportation safety agencies such as the Ghana National Road Safety Commission (NRSC) and Building and Road Research Institute (BRRI) as recommendations for innovative initiatives for community engagement. Additionally, this study can also provide a model for other developing African countries, and comparatively, the United States, to better understand how cultural nuances play a role in understanding how road safety can be approached from a global perspective towards decreasing road fatalities. This research attests to Ghana’s significant road safety predicament and the necessity to explore solutions with a goal of a Vision Zero/safe system approach in-line with the WHO’s Road Safety initiative that supports the need for continued future work.

Selected references


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**41 - Understanding the Relationship Between Road Users and Roadway Infrastructure in Ghana: A Quantitative Video-Driven Study**

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4 Council for Scientific and Industrial Research - Building and Road Research Institute (CSIR-BRRI), Kumasi Ghana

**Background:** Road crashes in developing countries pose serious public health challenges, accounting for approximately 85% of global traffic accidents (Lagarde, 2007). Against a global average of 17.5 deaths per 100,000 population, mortality from road crashes is highest in Africa (28.3 per 100,000 population) despite being the least motorized region in the world (World Health Organization, 2015). This research focuses on Ghana, a country located in West Africa with approximately 30 million people (Ghana Statistical Service 2021 Population and Housing Census). Ghana exemplifies the contribution of road crashes to mortality and morbidity in Africa partly due to the growing population and increasing car ownership, fatalities have increased 12–15% annually since 2008 (National Road Safety Commission(NCRS), 2017). About 40% of Ghanaian fatalities involve commercial passenger vehicles that provide public transport services (NRSC, 2017). These include minibusses, commercial coach buses, and shared taxis operated mostly on a hire-and-pay basis.

The Ashanti and Greater Accra regions were reported as the top two regions that experienced the highest crashes and fatality rates, which increased over the past year (*Road Traffic Crashes in Ghana Statistics Report, 2019*). These two regions were the two out of four that contributed close to two-thirds (63.7%) of all the road traffic fatalities in the country. Moreover, the report detailed non-urban sections of the road recorded 61.4% of road traffic fatalities in 2019, resulting greatly in the overall increase in crashes. The report recognizes that in-depth research is needed to understand the current road safety challenges facing the Ashanti and Greater Accra regions and the need for a road user safety improvement plan. In Ghana, limited research studies provide data insight to the interaction between road users and the roadway environment to make adequate planning and
solution-driven recommendations that effectively decrease road traffic crashes (RTC). This study targets one out of the two regions mentioned to understand and assess drivers’ risky behaviors and compliance with traffic calming measures (safety countermeasures) that contribute to the uptick in road traffic fatalities in Ghana.

**Methods:** A video-based approach was taken to understand, identify, and define a typology of road user behaviors (i.e., vehicle braking, vehicle stops, etc.) given the roadway environment. Before any video data was collected, proposed study sites were selected based on specified criteria. A site reconnaissance was performed in-field at each site to validate the site characteristics. Some sites were eliminated upon investigating. Surveillance equipment was set up at each of the selected sites; then video data was collected. Thereafter, the video data was reduced and coded properly to prepare for analysis in R Studio and SPSS.

**Results:** Upon analyzing driver behavior at junctions, 35.9% of drivers did not stop or did not mind the stop sign presence. Additionally, when investigating driver behavior and potential influential factors, the vehicle type and type of stop a driver made at a junction yielded a weak correlation (p-value>0.05). In contrast, the vehicle type and the stop location yielded a strong correlation (p-value <0.05). Moreover, it has been seen that junction characteristics have an influence on vehicle turning movements and vehicle type of stop (made at junctions), both having a p-value < 0.05.

This study provides comparative numerical probabilities that explain the behavioral typologies of road users with the consideration of road safety infrastructure present or lack thereof. It is expected that the data will provide valuable insights on driver braking and stopping behavior at selected sites and their likelihood to respond or adhere to road safety countermeasures. The results are also expected to reveal the effect road safety measures (or lack of) have on driver behavior and other additional factors like the roadway environment (i.e., weather, surface condition, etc.).

**Conclusions:** The results from this research can contribute to the new World Bank Road Safety Calculator to assess present input variables while determining if additional innovative features or variables are necessary. Additionally, the results can assist in determining the predictive and economical effectiveness of the calculator regarding developing low and middle-income countries (LMICs) like Ghana.

Secondly, the results can provide insight and recommendations to the Ghana National Road Safety Authority (NRSA) to utilize in future decision-making towards validation evidence to support proposals for infrastructure funding allocation to improve road safety towards economic growth and development by making the transportation of goods and services easily accessible and safer in support of the African Continental Free Trade Area (AfCFTA) agreement.

Lastly, this research can be used as a launchpad to build a sustainable road safety framework and database, update policy, and establish innovative educational initiatives tailored to the local community to address issues that will spur future work and conversations towards decreasing road traffic fatalities in Ghana.

**Selected references**

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**42 - CRASH DATA ANALYSIS & PREDICTION IN ZIMBABWE: AN APPLICATION OF ARIMA MODELS**

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Cliford Gobo

1 Traffic Safety Council of Zimbabwe

**Abstract:** Based on annual and quarterly data sets, this study employed Autoregressive Integrated Moving Average (ARIMA) models in order to analyze and predict road traffic crashes in Zimbabwe. Our annual data covers the period 1997 to 2020 while the quarterly data spans over the period March 2016 to September 2021. Optimal models were carefully selected using the Akaike Information Criterion (AIC). The most striking feature of our results is that road traffic fatalities have been forecasted to generally increase over the out-of-sample period. This is paradoxical in the sense that we would normally expect the opposite to happen during a pandemic such as the COVID-19 scourge where restrictions and lockdowns limit the volume of traffic on the road. The overall implication of the study is the need for new and or revised road safety policies that take into account COVID-19 dynamics. A number of policy suggestions have been put forward in order to ensure maximum road safety in Zimbabwe and ultimately save precious lives. The study is quite important as it will foster evidence-based decision making with respect to crash data analysis and prediction in Zimbabwe, in order to strategically reposition the country in terms of road safety policy formulation and implementation.

**Selected references**

**References**

Background: Driver fatigue is a contributing factor in about 20% of all crashes. Prevention of fatigue-related crashes is a major goal for the automotive industry. To reach this goal, both robust detection and effective countermeasures are required. The most effective countermeasure for sleepiness is sleep. Studies also show an increased alertness using caffeine intake. Despite this, the most common countermeasure used is to stop to take a walk, turn on the radio/stereo or open a window. Countermeasures for fatigue may be a larger challenge than detection, since the most effective countermeasure, such as taking a nap, are highly intrusive in the sense that you need to make an unplanned stop (or shift drivers if there is more than one person in the car). Finding less intrusive, yet effective, countermeasures that could be deployed without requiring major replanning would thus provide a significant benefit to car makers who wish to deploy this type of technology in their vehicles.

In the current study, the possibility of exposing drivers to odors when they are about to fall asleep has been explored. Previous research has found that specific fragrances can have alerting effects and that certain substances that act on trigeminal nerves can wake people from both light and deeper sleep. Therefore, the aim was to investigate if administration of a fragrance incorporating trigeminal components during fatigued driving can have a significant alerting effect.

Methods: The fragrance was tested on 21 healthy but sleep-deprived individuals while they performed a driving task in a simulator. Each participant performed a monotonous driving task twice. In one drive, participants were exposed to an active fragrance containing a trigeminal component. In the other drive, participants were exposed to an inactive fragrance in a cross-over single-blind design. The order of active/inactive fragrance was randomized between participants and they were not informed about the type of fragrance they received. Both fragrances (active/inactive) were administered either when the participant fell asleep (here defined as eye closure for more than 3 seconds) or after approximately 45 minutes of drowsy driving if the participant did not fall asleep, using a nebulizer placed on the participants chest.

Self-reported sleepiness was assessed using the Karolinska Sleepiness Scale (KSS) every 5 min during the driving task. Speed variability, lateral position variability and line crossing frequency (the
vehicle crossing the lane demarcation line) were logged for each drive to measure driving performance. Physiological measurements in the form of heart rate measurements (ECG), eye blinks (EOG) and brain activity (EEG) were collected to investigate potential arousing effects of the fragrance and to track objective signs of sleepiness. A Psychomotor Vigilance Test (PVT) was used to capture attention and cognitive performance before and after the drives. For analysis, data were aggregated in one-minute segments around the point in time when the fragrance was administrated (five segments before and ten after). The data were analyzed using a mixed model Anova.

**Results:** Subjective sleepiness decreased slightly after fragrance administration, irrespective of whether the fragrance contained the active alerting substance or not, though this effect was not statistically significant. Mean blink duration, which was used as an objective measure of sleepiness, decreased after administration of either fragrance, as did the frequency of line crossings. In summary, the act of administering the fragrance had a small but significant effect on some of the included measures, but there were no significant differences between the active and inactive fragrances.

**Conclusions:** The results for the fragrance administration in itself are in line with the effects found for other countermeasures that have temporary effects on fatigue, like rolling down the window to get some cold air, turn on bright lights or play loud music. These types of countermeasures can buy the driver some time, in the sense that driving performance might be restored for a short while. Whether this is sufficient to support driving performance until the driver can make a safe stop or not in real traffic remains a topic for future studies. It is possible that a different dose or strength of the active fragrance, longer duration of exposure or repeated administration could have given a stronger or longer lasting effect on driver sleepiness and performance.

**51 - Causes of Driver Distraction and Incidents at Signalized Intersections**

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1 UTA, Department of Civil Engineering, USA.

**Background:** Driver distraction causes a major portion of motor vehicle crashes because distractions turn the driver’s attention away from driving the driving task. Intersections represent high-risk environments because many conflict points within the intersection exist. At intersections with signalized traffic control, drivers may be more likely to become distracted than at other intersections. While distraction during the red indication may not seem to be a significant concern, this study investigates the role distraction plays in crashes at signalized intersections. However, the cost of motor vehicle crashes exceeds $1 Trillion a year in the U.S. (1) and forty percent of all traffic crashes occur at an intersection. Using the SHRP2 naturalistic driving study data, this study focuses on investigating the frequency and types of driver distraction, the causes of driver distraction, and factors affecting crashes and conflicts at signalized intersections.

**Methods:** For analyzing driver distraction and influencing factors for crashes, the study examines a total of 4606 events at signalized intersections from the SHRP2 NDS database, and 2,682 events (58%) include a secondary task. The SHRP2 NDS Data Access Website provides 63 types of...
distracted driving behaviors. The dataset includes 51 types of secondary tasks. That the authors combine into 10 groups. About 22% of the total distracted events relate to a distraction caused by a passenger in the car. The second highest distraction events (19.2%) relate to technology/cell phone. External distractions (16%) and talking/singing and dancing (12.8%) also represent frequent distractions. These four distractions account for about 80% of the total distractions.

This paper investigates two dependent variables using Logistic Regression: (a) distracted (labelled as 1) vs. not distracted (labelled as 0) and (b) crash/near crash (labelled as 1) vs. no crash (labelled as 0).

**Results: Distraction Model**

The logistic regression models use the categories with the largest number of occurrences as the reference cases and all independent variables are significant for α = 0.10. Table (distraction model) shows the coefficients and odd ratios of the significant predictors.

The positive coefficients increase and negative coefficients decrease the likelihood of driver distraction. The odds ratio indicates that failure to use a seat belt indicates 2.89 times higher probability of distraction. Level of service C increases distraction (1.58 times higher); this shows that greater levels of congestion likely cause drivers to focus more on the driving task and lower congestion levels may not experience enough signal delay to support secondary tasks. Locations in less dense areas like churches and moderate residential locations increase the likelihood of distraction while urban areas with more external distractions also appear more distracting than business/industrial areas. Driver familiarity and mild congestion levels appear to increase the probability of distraction. Some factors decrease the likelihood of distraction. Drivers appear to focus more on the driving task during rainy conditions because drivers appear about 1.3 times less likely to become distracted. All age groups over sixty years old experience a decrease in probability of distraction, which appears to indicate they focus more on the driving task. The 25- to 29-year old age group appears to be more likely than the 20-24 age group to engage in secondary tasks. The lane the vehicle currently occupies appears to decrease distractions possibly by limiting the external distractions. The reductions in distraction appear to relate to greater focus on the driving task caused by weather, age, or vehicle position. The logistic regression model correctly predicts 504 non-distracted events of 1,545 (accuracy 32.6%) and correctly predicts 1743 distracted events of 2,139 (accuracy 81.5%). Thus, this model works well for predicting distracted events, although the model does not appear as strong at predicting non-distracted events. The testing dataset generates similar accuracies for non-distracted events (accuracy 33.5%), and distracted events (81.4% accurate), which indicates this model is properly fit.

**Crash Model**

Table (Crash model) shows the coefficients and odd ratios of the significant predictors of crashes or near crashes at a signalized intersection. After controlling for the confounding effects related to age groups, traffic density, grade, seat belt use, weather, surface conditions, alignment, grade, contiguous travel lanes, location, marital status, and income, some secondary tasks represent a significant factor in crashes and near crashes at signalized intersection. The odds ratio indicates a 4.10 times higher probability of crashes or near crashes for drivers distracted by an object inside the...
vehicle, which represents the largest causal factor in the model. The model identifies three other secondary tasks as causal factors: technology/cell phone related distraction increases the probability 1.74 times. Adjusting/monitoring devices integral to vehicle and grooming also increase the probability (1.44 times higher for both). The distraction cases that require more individual attention inside the vehicle to complete appear to contribute significantly to crashes and near crashes at intersections while distractions from passengers and outside the vehicle appear insignificant.

The logistic regression model correctly predicts 1,857 no-crash events of 2,248 (accuracy 82.6%); however, the model only correctly predicts 632 crash events of 1,461 (accuracy 43.3%). The testing dataset generates similar accuracies for the no-crash events (accuracy 78.9%), and crash events events (40.67% accurate), which indicates this model is properly fit.

**Conclusions:** This study uses the SHRP2 database and identifies that traffic density, age, driving experience, seat belt use, weather and education have an extensive impact on driver distraction. The level of service on the approach legs and distraction from secondary tasks, especially the presence of an object in vehicle and technology or cell phone related distractions, represent the most influential factors for determining crash/near crash risk at signalized intersection. Adverse weather condition specifically raining decreases driver distraction, but it may increase the probability of crashes or near crashes at signalized intersection. This study can be improved by clearly separating the crash models for those vehicles queued and not queued at the signalized intersection because the crash related factors may vary between these cases. Future research will also investigate the influence of vehicle position in the queue at the signalized intersections on secondary tasks and vehicle conflicts.

**Selected references**

52 - Field evaluation of using Polar H10 sensor to measure heart rate variability for driver state monitoring

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Background: Physiological measurements have potential to complement conventional driver monitoring systems based on driving performance and facial features. Heart rate variability (HRV), a physiological marker reflecting changes of the cardiac sympathetic and parasympathetic branches of the autonomic nervous system, have drawn great interest for assessing drivers’ fatigue, stress, task load, etc. In addition, the popularization of consumer wearable heart rate (HR) monitors makes it possible to assess HR in daily driving scenarios. A previous study compared HR measured with a wrist band based on photoplethysmography (PPG) to electrocardiography (ECG) for fatigue detection, and showed that PPG based HR can be used for this application but with reduced detection performance (Kundinger et al., 2020). The chest strap HR monitor is another type of common wearable HR sensor based on ECG measured by dry electrodes. Studies have shown that it can deliver excellent HR measurement in rest and low intensity activity (Hernández-Vicente et al., 2021). Its accuracy in driving scenarios has not been validated. This work aims to validate the Polar H10 HR sensor for HRV analysis in real road driving, with the application for driver sleepiness detection.

Methods: Dataset

The dataset consists of real road driving data from 89 drivers (36 female and 53 male) with age range 20–59 years. Each participant completed four 180 km long motorway driving sessions. Participants were equipped with Polar H10 sensor (Polar Electro Oy, Kempele, Finland) and Garmin sports watches (Fénix 5 and Forerunner 645, Garmin Ltd., Kansas, US) during driving. The sports watches were used as data logger for the H10 sensor. A reference Lead II ECG was also recorded with a bio-amplifier (eego sports, ANT Neuro b.v., Hengelo, Netherlands) with a sampling frequency of 512 Hz. The recordings were then downsampled and stored with 256 Hz. Every five minutes during data acquisition, participants were prompted by the test leader to verbally report sleepiness according to the Karolinska Sleepiness Scale (KSS) (Åkerstedt & Gillberg, 1990). In this study, KSS<=7 was defined as non-critical condition, KSS>7 was defined as critical condition (severe sleepiness). Details of the experiment can be found in (Ahlström et al., 2021; Lu et al., 2021).

Data Processing

The beat-to-beat intervals were extracted from the ECG measurement and visual inspection was performed afterwards to remove cases with low signal quality that can lead to wrong peak detection. For each KSS reporting, five prior minutes segments were taken for analysis. HRV features were then extracted from the 5-min segments for both Polar H10 and reference ECG measurements.
Extracted time domain features included NN mean, SDNN, RMSSD, and frequency domain features included VLF, LF, HF, LF/HF, and total power. PhysioNet cardiovascular signal toolbox was used for the ECG and HRV analysis (Vest et al., 2018). The description of the features can be found in (Shaffer & Ginsberg, 2017).

Statistical Analysis

Error rate for each HRV index was calculated as the absolute error (difference between H10 and the ECG measurement) divided by the value of reference ECG measurement. Concordance correlation coefficient (CCC) was calculated to evaluate the agreement between two measures. CCC determines how much the data deviate from the perfect concordance line at 45° on a square axis scatter plot (Lin, 1989) which is for comparing two measurements of the same variable.

To evaluate the effectiveness of the two measurements for driver state assessment, we compared the performance for using each HRV feature to discern critical (KSS>7) from non-critical (KSS<=7) segments. The area under the receiver operating characteristic (ROC) curve (AUC) was used to measure performance. All data processing and analysis were performed with Matlab 2021b (MathWorks Inc., MA, USA).

Results: In total, 4110 5-min segments were analyzed. The results of the comparisons are summarized in Table 1. Compared to ECG derived HRV features, measurements with Polar H10 have low median error rates with a range of 0.02–2.7%. CCC statistics among all features show excellent agreement between H10 and ECG. When comparing the performance for discriminating severe sleepy episodes, H10 measurements are on par with the reference ECG measurements.

Conclusions: The results of this study demonstrate that the Polar H10 sensor has high agreement with reference ECG for HRV analysis during driving. With its ease of use, Polar H10 is a good surrogate for standard ECG measurement for driver monitoring purposes and it brings potential for real life usage.

Selected references


Table 1. Comparison between HRV features derived by Polar H10 and reference ECG, analysis based on 4110 5-min segments.

<table>
<thead>
<tr>
<th>HRV features</th>
<th>Error Rate % Median (Interquartile Range)</th>
<th>Concordance Correlation Coefficient</th>
<th>AUC for Discriminating Severe Sleepy Episodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NN mean</td>
<td>0.02 (0.01–0.04)</td>
<td>1.00</td>
<td>0.61</td>
</tr>
<tr>
<td>SDNN</td>
<td>0.37 (0.15–0.87)</td>
<td>0.99</td>
<td>0.68</td>
</tr>
<tr>
<td>RMSSD</td>
<td>1.18 (0.47–2.87)</td>
<td>0.98</td>
<td>0.60</td>
</tr>
<tr>
<td>VLF</td>
<td>0.63 (0.25–1.77)</td>
<td>1.00</td>
<td>0.70</td>
</tr>
<tr>
<td>LF</td>
<td>0.83 (0.35–2.03)</td>
<td>1.00</td>
<td>0.68</td>
</tr>
<tr>
<td>HF</td>
<td>2.52 (1.02–5.59)</td>
<td>0.99</td>
<td>0.58</td>
</tr>
<tr>
<td>LF/HF</td>
<td>2.70 (1.10–5.94)</td>
<td>0.97</td>
<td>0.58</td>
</tr>
<tr>
<td>Total power</td>
<td>0.64 (0.26–1.49)</td>
<td>1.00</td>
<td>0.68</td>
</tr>
</tbody>
</table>

53 - An Exploratory Analysis of Driver Injury Severities Involving Fatigued Driving in Single-vehicle Large Truck Crashes with Unobserved Heterogeneity

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Background: Fatigue is one of the critical safety challenges facing commercial vehicle drivers, particularly large truck drivers. Fatigued driving places heavy vehicle drivers at higher risk of a highway crash, as well as reduced functional performance in their daily work. The decline of functional performance due to fatigue is a complex interaction of circadian rhythm, lengthy time on task (i.e., long drives), extended wakefulness or acute sleep deprivation, chronic insufficient sleep, and poor-quality sleep, with further complications from sleep disorders (obstructive sleep apnea) and medical conditions. Using Florida crash data, the current study investigates the factors that influence the driver injury severity of single-vehicle large truck (gross vehicle weight rating more than 10,000 pounds) crashes, benchmarking fatigued driving against non-fatigued driving (normal driving).
Methods: Crash data for 2011 to 2019 (inclusive) were extracted from Florida’s Crash Analysis Reporting System (CARS) (these are all police-reported crashes). Driver-injury severities in single-vehicle large truck crashes were studied using random parameters logit models that allow for possible heterogeneity in the means and variances of parameter estimates. The available data include a wide variety of factors known to influence driver injury severity, including data related to the spatial and temporal characteristics, vehicle and traffic characteristics, roadway attributes, and driver characteristics. Figure 1 shows the relative driver injury severities. Severe injuries accounted for 5% of fatigued driving cashes as opposed to 3% of normal driving crashes. Minor injuries accounted for 37% of fatigued driving crashes but only 25% of normal driving crashes [See Fig. 1 as attached as .png] .

Equation 1 presents $P_n(k)$ as the probability that single-large truck crash $n$ that will result in driver-injury severity outcome $k$ and $K$ is the set of three possible injury-severity outcomes: severe injury (combing fatality and incapacitating injury), minor injury (combining non-incapacitating and possible injury) and no injury (property-damage-only). To allow for the possibility of one or more parameter estimates in the vector, $\beta_i$ vary across single-vehicle large truck crash observations. Here $f(\beta_k|\phi_k)$ is the density function of $\beta_k$ and $\phi_k$ is a vector of parameters describing the density function (mean and variance) (Washington et al., 2012) [See Eq.1 as attached as .png].

To account for the possibility of unobserved heterogeneity in the means and variances of parameters, let $\beta_{kn}$ be a vector of estimable parameters that varies across crashes defined as in Islam et al. 2020; Islam and Manering (2020, 2021) [See Eq.2 as attached as .png]:

where $\beta$ is the mean parameter estimate across all single-large truck crashes involving fatigue driving, $Z_{km}$ is a vector of crash-specific explanatory variables that captures heterogeneity in the mean that affects fatigued driving injury severity level $k$, $\Theta_{kn}$ is a corresponding vector of estimable parameters, $W_{kn}$ is a vector of single-vehicle large truck crash-specific explanatory variables that captures heterogeneity in the standard deviation $\sigma_{kn}$ with corresponding parameter vector $\Psi_{kn}$, and $v_{kn}$ is a disturbance term.

Results: The model estimates produced significantly different parameters for fatigued and normal driving. The estimated models suggest a fundamental shift in unobserved heterogeneity between fatigued and normal driving crashes. More importantly, the marginal effects of the estimated model parameters show marked differences between fatigued and normal driving crashes resulting in severe injury. These findings add to the growing body of literature that suggests that driver behavior is fundamentally different in fatigued driving relative to non-fatigued (normal) driving. Of the variables that were statistically significant in fatigued and normal driving, only five were present in both models. Of nine variables significant in the fatigued driving model and 12 variables in the normal driving model, differences in the marginal effects of these variables are noteworthy. Roadways with a larger shoulder width (8 to 12 ft) increased the likelihood of severe driver injury more for fatigued driving relative to normal driving. Large trucks registered in Florida were more likely to be involved in severe driver injury in fatigued driving relative to normal driving. Rollover incidents increased the likelihood of severe driver injury more for fatigued driving relative to normal driving.
Conclusions: The model estimation findings add valuable insights to the growing body of literature suggesting that driver behavior is fundamentally different in fatigued and normal driving involving single-vehicle large truck crashes. Moreover, this could have profound effects in the safety performance of large trucks with in-vehicle safety technologies (automated driving systems), as well as various policy-related safety countermeasures. Although the use of police-reported fatigued driving in crash data potentially suffers from under-reporting with possible misclassification of fatigued driving for professional drivers, this study provides a notion of how different characteristics could potentially lead to the severity of driver injuries.

Selected references
Session: Speed management

54 - An online intervention against speed offending: Largescale randomized controlled trial in Denmark (preliminary outcomes)

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⁵ Freelance, Denmark

Background: Speeding is still a key challenge for road safety. The Danish Road Directorate estimates that in about half of all road fatalities excessive speed is a factor. This calls for interventions against speeding.

The understanding of what is on the car driver’s mind when speeding is crucial for the prevention of crashes. Large scale, high-quality experiments challenging the mind set of speeding car drivers are however lacking.

Our aim was (1) to develop an online intervention teaching car drivers with a recent speeding ticket about road safety and (2) evaluate the effect of this intervention on future speeding offences in a randomized nationwide controlled trial approaching all private car speed offenders in Denmark.

Methods: We developed an online intervention based on so-called priming of the mind set of speed offenders, hypothesizing that better knowledge about implications of speeding, consciousness about own behavior, attitude of own behavior and help to development new strategies in trigger situations will prevent the offenders of recurrent tickets. A clear conceptual choice was made of not “scaring off” the offenders but rather encourage the avoidance of a new ticket through positive behavioral change. A change in risk perception and insight into own behavior and attitudes along with new acting strategies is supposed to affect the drivers’ future speed ticket recidivism propensity. The online intervention was built as a 24-question test on relevant and contemporary road safety issues. Based on the participants’ responses to the questions they were divided into three groups of drivers (green=low risk of a new ticket, yellow=middle risk, and red=high risk) and received feedback accordingly. The intervention was pre-tested in a group of 100 drivers who had recently received a speed ticket.

Figure 1 depicts the study flow. The study was initiated through distribution of invitation by digital mail to all private car speed offenders in Denmark during a study period of approximately ten months (fall 2021 to fall 2022). The study period was designed to obtain enough participants to obtain statistical power and thus clear results (20,000-25,000 participants). Contact information of speeding ticket car owners was transferred from the Danish National Police to Aalborg University. Car owners who had not personally been driving the car while speeding were excluded from the study. Participation was voluntary.
Firstly, all participants filled out a questionnaire asking for background information e. g. on their risk perception, attitudes towards speeding and history of speeding tickets. Then, the participants were randomly distributed into a test or control group. Eventually, the test group was exposed to the online intervention while the control group was not approached further until after one year when all participants in both groups received a follow-up questionnaire. The effect outcome was defined as time to a recurrent speed ticket within the follow-up period of one year after randomization. but we cannot give preliminary results on the effect within the time frame of the conference.

We will present the study population at baseline through use of descriptive statistics and latent class analysis segmentation of the participants into homogeneous groups regarding knowledge of, attitudes towards and insight into road safety and the risk of speeding. We will also develop profiles of the green-yellow-red drivers and give an overview of the opinions of the intervention and chosen strategies in the test group through descriptive statistics.

**Results:** The status on this ongoing large-scale study is that by April 11, 2022, 129,802 speed offenders have received an invitation, of whom 16,888 have responded. Approximately 19% were subsequently excluded because they did not drive the car when the ticket was given and additionally 14% did not complete the baseline questionnaire. In total, 11,405 participants were included in the study and subsequently randomized.

Preliminary results suggest that the participants are indeed representative of the total population of private car speed offenders in Denmark with regard to gender, penalty size, and speeding location. The average age of the participants (54 years) is slightly higher than that of the total population (49 years).

Results are limited but suggest that 78% of the test group find the advice that they receive in the online intervention relevant, while 63% find that the program has made them change their opinion about speeding. 51% report to have acquired new knowledge about speeding and road safety, and 74% feel motivated to comply with the speed limit in the future.

Our presentation will explain the intervention and address more about the background e. g. risk perception of the participants at baseline. Furthermore, we will present the test group answers of the intervention quiz including the distribution of red-yellow-green drivers, who are characterized regarding their attitudes and insight into own behavior. We will also present an overview of the new strategies against speeding which are developed by the study participants.

Preliminary results suggest that 45 % of the test group are green drivers, 44 % become yellow drivers whereas 11 % are red drivers with an expected high risk of a new ticket. The red drivers are characterized e. g. by male gender, younger age, many recent speed tickets, self-reports of not being affected by tickets – however oppositely – many of them aware that friends and relatives want them to drive properly.

We will furthermore touch upon the challenges of the study: the relatively low participation rate and speed offenders being intimidated by receiving the invitation unexpectedly.
Conclusions: We expect an effect of the online intervention on the frequency of new speeding tickets within one year after randomization. Our future work will characterize driver subgroups and describe how to build effective online interventions in future prevention of speeding and thus prevention of crashes and fatal and serious injuries on our roads.

The project is funded by TrygFonden.

55 - The Impact of Diverse Speed Management Programs in the Region of Peel

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Background: The Region of Peel (Peel) is located in southern Ontario, within the Greater Toronto Area, and is comprised of the City of Brampton, the City of Mississauga, and the Town of Caledon. The regional road network is encompassed of arterial roadways only, and with a population of more than 1.4 million people, prioritizing road safety is essential for Peel residents. The Region of Peel adopted the Vision Zero framework in 2017 and released their 5-year (2018-2022) Peel Road Safety Strategic Plan (RSSP) in 2018. The plan includes the adoption of the Vision Zero framework originating in Sweden and contains the long-term goal to achieve zero fatalities and injuries as a result of a motor vehicle collision. Additionally, the plan includes a short-term goal of a 10% reduction in fatal and injury collisions by the end of 2022. Through collision data analysis, stakeholder, and public feedback, the RSSP goals, emphasis areas, and countermeasures were developed to achieve this short-term goal. Continuously, the Region of Peel identifies speeding as a major cause of collisions, and as such, has developed multiple speed management programs to enforce the posted speed limits, deter speeding and initiate behavioral change on Peel roadways. Major speed management programs include the Automated Speed Enforcement (ASE) Camera program, the Red-Light Camera program, reductions in posted speed limits through methodological reviews and traffic calming, which include vertical and horizontal deflection. All programs have been shown to be effective in the Region of Peel in addressing speeding through the analysis of pre,
operating and post speed data. This presentation will specifically review and evaluate the methods and results of the ASE Camera program and the installation of bollards with respect to Vision Zero.

**Methods:** Data collection is essential in determining the effectiveness of the Region of Peel’s speed management programs. Collision data, speed data, traffic volumes and resident feedback are all valuable measures of the effectiveness or ineffectiveness of these programs. Specifically, speed data is of interest as these countermeasures are aimed at reducing driver speeds and increasing speed compliance. The Region of Peel retains a contractor to perform speed studies using speed tubes and records speeds before, during and after a countermeasure is implemented. The Region of Peel also has an expanding number of Permanent Count Stations, along with data that can be gathered from Armadillo Counters and data from its fleet of radar signs. Typically, speeds are recorded over the course of a few days and various data is determined, including mean speed and 85th percentile speed. This data is then analyzed and compared to determine if the countermeasure has had its desired effect.

**Results:** Bollards can be installed either with a center bollard with two side bollards or as a single center bollard only. This countermeasure serves as a road narrowing tool to slow drivers down and has been implemented throughout the Region of Peel as warranted. Based on traffic data collection, it has been found that the installation of a center bollard with two side bollards has achieved an average reduction in speed between 5 – 10 km/h and installing a center bollard results in an average speed reduction between 1 – 5 km/h. Please note results vary based on location, but a speed reduction remains consistent.

The Region of Peel is currently operating a Pilot program for the use of Automated Speed Enforcement (ASE) cameras and is rotating one camera around six locations in the Town of Caledon. Since the pilot began in September 2020, Peel has been utilizing speed studies to collect before, during and after speed data. This has allowed the Region of Peel to determine the impact the cameras have on speeding, as analysis can be done to determine driver behaviour before it has been installed, while the camera is active, and if there is any positive impact after the camera has been removed. Currently, the results and findings are still preliminary, however of the three locations that have had full data collection, an average reduction in 85th percentile speed of 11 km/h while the camera is active has been found.

**Conclusions:** Overall, the Region of Peel has been a leader in road safety in Canada through the adoption of their Vision Zero program and strides towards improving road safety. Speeding and lack of driver compliance is a top road safety concern and a common contributing factor to motor vehicle collisions, fatalities, and severe injuries. Through the use and implementation of various countermeasures, Peel is continuously moving towards achieving their Vision Zero goals. In particular, the implementation of bollards and ASE cameras to reduce speeds on Peel roadways and increase speed compliance. Road safety remains a continuous and collaborative effort, requiring partnership with key stakeholders, as well as a cultural change pertaining to poor driving behaviours such as speeding. Although data indicates that Peel’s speed management programs are effective in reducing speed, it is a systemic issue that needs to be addressed at all levels of government, policing and education, to achieve the Vision Zero goal of zero fatalities and injuries as a result of a motor vehicle collision.
56 - Key determinants influencing motorcyclists’ intention to speed and crash risk

Sonja Forward¹
¹ VTI

Background: Motorcycles are more likely to be involved in road crashes than other vehicles. Speeding violations are common among motorcyclists (Swedish Transport Administration, 2020) and in-depth data on fatal crashes show that 30 percent of accidents were linked to speeding (Swedish Road Administration, 2021). The aim of the study was twofold, the first one aimed to increase our understanding of contributing factors leading up to an accident, the second to investigate key determinants influencing motorcyclists’ intention to speed using the Theory of Planned Behaviour. Based on this, both a quantitative and a qualitative approach were chosen divided into four different sub-studies: registry study, questionnaire study and two interview studies. In this presentation the focus will be on the first and the second study.

Methods: The data used in the registry study was from the Swedish Traffic Accident Data Acquisition (STRADA) and a register over owner of a motorcycles. This in turn enabled us to draw a sample from STRADA and then compare this with another sample who had not any registered accidents. The questionnaire study used the same sampling methods including 446 motorcyclists who had been involved in an accident and 415 motorcyclists who had no accidents recorded in STRADA. The questions were influenced by the Theory of planned behaviour (TPB) and included a scenario describing a motorcyclist riding a bike at 90 km/h in a rural area, in which the speed limit was 70 km/h.

Results: The results from the register study showed that about 80 percent of the injured drivers had a valid license. Compared with the control group, the injury group were more likely to have failed their obligatory theoretical test. The survey study showed that the most common accidents were single accidents and that about one-fifth of the injured were wholly or partly to blame for the accident. According to the interview study, with affected motorcyclists who were responsible for the accident, lack of attention and that driver’s behaviour was misinterpreted were the main causes of accidents.

The results from a regression analysis showed that 55 percent of the variables included in the theory of Theory of Planned Behaviour explained their intention to violate speed rules. Those who intended to speed held a positive attitude towards the behaviour, believed that friends accepted the behaviour and felt that they had control over the behaviour. They did not believe as much as the others that they would be involved in an accident, nor that they would be stopped by the police.

The results of the survey study also confirmed that accident involvement could be linked to their attitudes and norms. When those in the injury group were compared with a control group that had not been involved in an accident, the results showed that the first group was more positive about the specified speed violation. The difference between the groups became even more apparent when
consideration was given to who was responsible for the accident. Those who were to blame for the accident were much more positive about speeding and were more likely to ride in this way in the future than the other group who were not to blame for the accident. Those who were to blame for the accident agreed to a greater extent than others that speeding gave them a sense of freedom and that it was fun.

**Conclusions:** The conclusion is that speeding can be linked to violations and that being involved in an accident does not always increase risk awareness. An important conclusion from this is that even if they were to blame for accident, they still found it difficult to believe that they had done something wrong. Based on the theory -Locus of Control, this way of explaining why accidents occur can affect how motivated one is to change.

Hence a number of different educational initiatives are needed. At the same time, it is important to emphasize that the education must be of high quality and that it is student-centred, i.e. based on the student's previous experiences whilst at the same time challenge already established beliefs. The study concludes with a series of recommendations to increase motorcyclists' road safety.

**Selected references**

### 57 - Effectiveness of speed limit and school zone signs in reducing speed inside a school safety zone in Kigamboni, Tanzania

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**Background:** The research aimed to implement a School Safety Zone (SSZ) using school zone and speed limit signs and evaluate the effectiveness of the intervention in reducing speed inside the SSZ to make safer the routes to the school. The scope of the case study area was the three government primary schools located in Kigamboni Ward in Dar-es-Salaam, Tanzania. 1.36 million people have been estimated to die on roads worldwide, while 50 million people are injured (1), which is one death every 24 seconds (2). At the same time, speed has been attributed to 50% of global road crashes (3). Three thousand children and young people are estimated to be killed or seriously injured on the world's roads every day (2).

Several studies mention children as the most vulnerable road users (4, 5, 6) and most at risk on the streets where they live, play and travel to school (2). Globally, many children are seriously injured or are killed daily in road traffic crashes that sometimes occur a few yards from the school gates (7, 8). Children from Low and Middle-Income Countries are the most affected (9). In Africa, the highest
burden of road death is on vulnerable road users, with pedestrians having the highest number (1), which is the case in Tanzania. Many schoolchildren in the country are pedestrians; they walk to school. Road safety challenges such as the traffic mix of vulnerable road users with vehicles, lack of formal sidewalks, etc. (10, 11) make these schoolchildren's journeys unsafe. A study on Road Traffic Injuries (RTI) incidences and crash characteristics in Dar es Salaam established that 43.9% of all injuries occurred on the route to work or school. A study to evaluate a road safety intervention program in Dar es Salaam found that approximately 92% of all injured pupils at selected schools were pedestrians before any interventions. And an estimated 63% of RTI occurred on a school-related journey. Approximately 48% of all injury cases involved a child hit by a motorcycle (5). These discoveries show a need for more road infrastructural interventions to ensure safe and sustainable transport to schools in the region.

Methods: The research design and methodology comprised: selecting an area in Dar es Salaam with a need for the intervention, seeking permission from responsible authorities to carry out the research, data collection and analysis, and establishing the intervention. Data was collected through semi-structured interviews, focus group discussions and speed observations in the selected case study area. The speed observations were designed as a pre and post-intervention study where 309 vehicles were observed pre-intervention and 289 post-intervention. The observations were done during the school opening and closing hours for 90 minutes in each period. Ufukoni Primary School (P.S) was chosen as the treatment site that received the intervention. Kigamboni and Kivukoni Primary Schools were selected as the comparison sites that did not receive the intervention. Data analysis was done using Microsoft excel.

Results: Findings showed both mean and 85th percentile speeds reduced post-intervention at both the treatment and comparison sites. There were 4.12 km/h (16%) and 5.2 km/h (17%) reductions in mean and 85th percentile speeds at the treatment site, respectively. At the comparison sites, the speed reductions were; 5.18km/h (26%) for mean speed and 7 km/h (26%) for 85th percentile speed at the Kigamboni P.S site and 4.78km/h (19%) for mean speed and 5km/h (16%) for 85th percentile speed at the Kivukoni P.S site. The highest speed reductions were observed in motorcycles at the treatment and Kigamboni P.S site, whereas at the Kivukoni P.S site, it was highest among cars, followed by motorcycles. During pre-intervention, twenty-one vehicles travelled between the speed of 30 and 50km/h at the treatment site, five at Kigamboni P.S and seventeen at Kivukoni P.S sites. Post-intervention, this number reduced to eight at both Ufukoni and Kivukoni P.S and zero at Kigamboni P.S. Two vehicles were observed to go at speed above 50km/hr, at Ufukoni and Kivukoni P.S each. Post-intervention, no vehicles travelling above 50km/h were observed in all three sites, as the number of vehicles travelling within 30km/h increased.

Conclusions: The results showed that creating an SSZ using school zone and speed limit signs as an intervention succeeds in making routes to school safer whilst improving schoolchildren's road safety.

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58 - Detecting Traffic Volume and Vehicle Speeds Using Earth Observation Imagery: Innovative Approaches for LMICs

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Background: Following the request of the United Nations General Assembly, on 22nd November 2017, Member States reached consensus on 12 global road safety performance targets (WHO, 2017). Target 4 states that ‘By 2030, more than 75% of travel on existing roads is on roads that meet technical standards for all road users that take into account road safety’. In many countries this target is inaccessible because there is insufficient traffic data to identify where 75% of travel occurs. Additionally, infrastructure quality and vehicle speeds are unknown to assess whether they meet ‘technical standards for all road users’. Costs associated with collecting data can be prohibitive using traditional methodologies.

Utilising an accessible data source with global coverage and consistent quality, this project seeks to explore whether a scalable, replicable and reliable approach to data collection can be developed that will assist nations in measuring performance against this global voluntary target. Earth observation (EO) imagery offers a ubiquitous and dependable route to asset detection and attribute classification when combined with advanced analytical techniques using machine learning.
**Methods:** In order to detect where 75% of travel occurs, a multi-stage process needed to be developed

**Network Selection:** The majority of a nation’s traffic is carried on a fraction of the network. Built from an underlying Open Street Map layer, the network was enhanced to include additional roads that formed continuous routes to large population areas. This process was aided by population raster layers and validated by in-country experts.

**Earth Observation to Detect Traffic Density:** For vehicle detection from pansharpened visual imagery, a neural network with a UNet-VGG16 architecture (Pravitasari, 2020) (first developed for biomedical semantic segmentation) was used. Vehicle locations were snapped to the road network for geospatial analysis. From this it is possible to calculate the number of vehicles on each network link at an instance in time, providing a metric of vehicles per kilometer.

**Earth Observation to Detect Traffic Speed:** During visualization of the multispectral imagery, it was observed that lighter-coloured vehicles are reflective of light in all multispectral bands. Secondly, that the position of these reflections were distinctly different between bands. As such, over the 0.35s time difference the positional change of the vehicle could be calculated between the NIR1 and NIR2 bands providing calculated vehicle speeds.

**Methodological Testing:** An initial trial of this methodology was carried out in Kent, England where additional reference data sets could be used to test and compare the data generated by the models based on EO imagery. Comparison was conducted against both ATCs and high-volume vehicle GPS data to provide alternative sources of speed and flow.

**Results: Vehicle Detection:** The model for vehicle detection was trained using a high volume of labelled imagery. When tested on UK roads, the model achieved F1 scores (measuring completeness of algorithmically matched image to the whole bounding box in the labelled data) of 0.847 (84.7%). When transferred to detect vehicles in Kenya, the model needed additional training which resulted in higher F1 scores of 0.882. The model is therefore categorising vehicles with an exceptionally high level of correlation to human labellers.

**Vehicle Speeds:** As with vehicle detections, bearings for movement were calculated to determine which roads each vehicle was travelling along. The midpoints of vehicle movement paths were matched to the nearest viable road within 15m. These were aggregated over sections to produce average and 85th percentile speeds. EO speed measured using this approach in the UK showed high levels of correlation to speed from GPS and traffic counts. Average speeds had a correlation coefficient of 0.84 between the two metrics, whilst 85th percentile speeds had a correlation of 0.8. To test the methodology in Kenya, comparator data was needed. Uber Movement (Uber, 2022) telematics was used to take trip data in-line with the sun-synchronous satellite imagery to evaluate against. By road length, 62% of roads in Nairobi had an EO-measured average speed within one standard deviation of Uber Movement’s average speed.

**Calculated Traffic Flow:** Once vehicle speeds and densities are known for a road, hourly traffic flow can be calculated as the product of vehicle density per km and average speed in km per hour. It is important to note that WorldView-2 (European Space Agency, 2013) is in sun-synchronous orbit,
resulting in imagery taken at the same time each day. Hourly traffic flow is therefore calculated for a specific time of day.

**Conclusions:** This project represents the opportunity to revolutionise data capture in low- and middle-income countries where data coverage and quality is patchy and poor. Firstly, all data is remotely sensed. This means that no in-country work is required, although local expertise is always valuable in evaluating outputs. There is almost complete global coverage from EO imagery, and image quality is consistent across both space and time. As a result, the speed and flow data are standardised and internationally comparable. Imagery is readily available, with very little time between procurement and delivery, and is regularly updated.

There are also some limitations to this approach that need to be considered. The imagery used in this project comes from a sun-synchronous satellite, although this ensures consistency in imagery, it makes detecting variational trends in traffic and speed throughout the day impossible. The lower resolution of multispectral imagery (1.84m per pixel) means that vehicle speeds below 20kph cannot be detected. However, as higher resolution imagery from satellites such as WorldView-3 becomes more affordable, slower speeds will become more readily detectable.

**Selected references**
59 - Sensor Degradation Detection Algorithm for Automated Driving Systems

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Abstract: Vehicles equipped with automated driving systems (ADS) rely on sensors that provide information about the surrounding environment to make control systems decisions for real-time object avoidance and path planning. The accuracy of the sensor information being passed to the sensor fusion algorithm and the control algorithms greatly affects the performance of the vehicle. Sensor information can be affected by various forms of degradation, such as weather and information corruption due to cyberattack, and misinformation from a sensor can present significant safety concerns. Utilizing the VTTI Smart Roads, sensor data is captured for characterizing sensors and degradation effects. This project explores whether sensor degradation can be identified through algorithm-based detection, and the objective is to develop a sensor degradation detection algorithm through simulation, constructed and validated from physical testing and real-world data. The intent of the algorithm is to improve the reliability of the ADS performance by identifying potential sensor data that is degraded.

60 - Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?

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Abstract: Although home delivery services are highly convenient for the recipients and they increase the business opportunities for logistics service providers, these services result in social costs associated with the increased presence of delivery vehicles (e.g., vans and trucks) in residential areas. With the increasing demand for delivery services and cost-effective delivery options, there have been increases in research, company manufacturing, and usage of autonomous delivery vehicles (ADVs). The goal of this project was to perform safety implication analysis and safety impact analysis on ADVs. This project used five different datasets (two national crash datasets, California ADV collision reports, Waymo open data, and trajectory data from a third party) to perform the analysis. ADV-related operation design domain (ODD) scenarios were determined for the real-world safety implications. This study generated a total of 80 association rules with high likelihood measures by using these datasets. The rules can be used as the prospective benchmark rules to examine how these rule-based risk patterns can be replaced by ADVs with the elimination of human-driven trips. This study also developed a Safe System based ADV related safety scoring matrix, which can be used for infrastructure readiness for the ADVs. The findings of this study can
support constructive thinking into how ADVs may offer benefits that transcend the typical approaches used in vehicle safety.

61 - Crashworthiness Compatibility of Automated Vehicles with Passenger Vehicles

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Abstract: Autonomous vehicles are one of the ever-growing field and various non-vehicle companies are collaborating with traditional car manufacturers to make vehicles fully autonomous. The research study will highlight the crashworthiness compatibility of ADS’s with human-driven vehicles. The Insurance Institute for Highway Safety (IIHS) tests vehicles crashworthiness compatibility during a crash that involves two human-driven vehicles. These tests determine alignment of both vehicles’ energy-absorbing structures. Occupant safety can be compromised if crash partners are not compatible. Vehicles equipped with Automated Driving Systems (ADSs) should provide crash compatibility with existing vehicles. ADSs intended for product or service delivery or other unoccupied use scenarios should consider appropriate vehicle crash compatibility given the potential for interactions with vulnerable road users and other vehicle types. Investigation of the level of autonomous vehicle crashworthiness compatibility with human-driven vehicles can lead to more appropriate vehicle designs, as well as more suitable and better passive protection systems for occupants in such crash scenarios.

62 - Quantifying Alternative Transportation Injury Risk using Health Records and Household Travel Survey Data

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Abstract: Walking and bicycling contribute to reduced traffic congestion, air quality improvements, the development of safer travel routes, and improved population health. A key deterrent to walking or cycling is the difference between the perceived and actual risk of injury associated with these travel modes. A variety of numerators and denominators have been used to estimate injury risk for pedestrians and bicyclists. In this paper, the authors expand crash counts to include pedestrian and bicycle injuries that occur with and without involvement of motor vehicles using data from Emergency Medical Services (EMS) runs and Trauma Registry obtained from the Texas Department of Health Services. The data sources are described with respect to their strengths and limitations and the enhanced dataset compared with the extant available data on injuries to understand the extent to which injury surveillance can be improved from inclusion of health records. The denominator data necessary to estimate relative risk were refined to reflect exposure such as trip duration, trip distance and trip counts using National Household Travel Survey data. Relative injury risk was estimated
using the enhanced numerator and denominator data and specific comparisons were made by mode, stratified by gender and age groups.

63 - Navigating to Safety

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Background: Automotive navigation systems seek the shortest route between a given set of origin and destination points. However, although the suggested routes may help users minimize their travel times, there are certain situations in which the shortest route is not necessarily the safest one. Navigating through local roads that have higher risks of crashes—namely, those with poor geometric designs, drainage problems, lack of illumination, higher risks of wildlife-vehicle collisions, and more interruptions in traffic flow—compared to using higher classification highways is an example of the unintended consequences of routing to ensure minimum travel time. This study is designed to (1) examine the necessity of including safety in route-finding and (2) identify the requirements for developing safe route-finding systems.

Methods: To examine the safety of the shortest routes suggested by navigation apps (routes that minimize the travel time for users), we designed a case study of five metropolitan areas in Texas. First, we identified the shortest routes between origins and destinations and their alternatives. Then, the safety of routes is determined. This study contributes to previous attempts to assess the road network level safety analysis by proposing a new methodology for quantifying route safety. To this end, we suggested estimating the probability of being involved in a crash at a given route, consisting of thousands of road segments, as the complementary probabilities of the union of survival (observing no-crashes) at the road segments. The road segment survival probability was obtained from theoretical probability functions that can be estimated using ubiquitous crash prediction models as a function of weather conditions, traffic characteristics, and road geometry and characteristics. Finally, we compared the safety of the alternative routes for each pair of origin and destination. This study focuses on the rural road network between five cities.

Results: The comparison between the shortest and safest routes between five metropolitan areas in Texas revealed the potential of commonly used road navigation apps to misguide users toward using a road that carries a higher risk of crashes. We showed that reducing travel time by 8% can result in a 23% higher risk of involvement in crashes. Our analysis also suggests that the safest route between a pair of origin and destination points can vary depending on weather conditions.

We proposed a system architecture for the safe route guidance systems (S-RGSs). We discussed ethical controversies in centralized S-RGSs and concluded that the safest route finding should be solved with a decentralized system. Also, given that the S-RGS aims to prevent crashes, predictive algorithms are required to find the safest route. S-RGSs can perform as static or dynamic systems; while static systems are less complex than dynamic ones, this comes at the cost of greater vulnerability to temporal changes, including traffic flow fluctuations, illumination, weather
conditions, work zones, and incidents. According to the proposed architecture, the requirements of deploying S-RGSs are (1) real-time traffic flow and incident information for dynamic S-RGS, (2) accurate crash prediction models, and (3) acknowledging the tradeoff between travel time and safety in order to find the optimal route.

**Conclusions:** This study indicated the necessity of considering safety in RGSs. S-RGSs would guide users to—and through—the safest route, and therefore, can improve traffic safety by preventing crashes in road networks. It is expected that new generations of road navigation tools will become capable of finding the safest route. The proposed system architecture could also stimulate dialogue about vehicle routing in smart cities and the routing of connected and autonomous vehicles.
Session: Road user behaviour and risk perception, part 2

64 - Seat belt usage in buses – An observation study of usage and travellers’ perspectives

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Background: Travelling by bus is one of the safest modes of transport. However, crashes still happen and studies have found that the most severe crashes are related to rollovers, mainly on rural roads. The most severe injuries occur when unbuckled passengers are thrown out through the windows or get stuck under the bus. In Sweden the use of a seat belt and information about seat belt use when traveling by bus is regulated in Traffic Ordinance (1998: 1276) Chapter 4 §10a. In short, all bus passengers three years or older should be seated in a place with a seat belt, if there is such a place, and should use the belt. If there is no seat belt available, it is allowed to stand in the bus (if the bus is approved for standing places). The legal responsibility to inform and make sure passengers under 15 use the belt are on the bus driver. Despite existing regulations there is no clear view on the usage rate of seat belt in buses, or on the travellers’ view of their own usage and the reasons to not buckle up. This study aims to evaluate seat belt usage in buses and to understand travellers’ incentives of seatbelt usage.

Methods: Methods used are observational studies (10 cities, with 328 observations), focus group discussion (7 groups with a total of 32 participants) and a web survey (n=1737 respondents).

Results: The results from the observation study showed that passenger seat belt usage was 92% in order traffic, 50% in commercial traffic and 27% in procured traffic. The bus drivers’ use of seat belt was correspondingly 100% in order traffic, 79% in commercial traffic and 85% in procured traffic. The results from the web survey showed however a lower level of usage for all three types of services.

The focus group discussions show that the decision to use a belt or not vary and factors like how old you are, frequency of safe travelling by bus, what kind of road you travel on, when you travel and how you perceive safety in general plays a part. Those who most frequently use a belt are children. Here is a strong standard of belt use that is encouraged by bus drivers, parents, and other adults. Using a belt is more established in order traffic and in commercial liner traffic. This could be linked to the duration of time, which often is longer, fewer stops and travelling on roads with a higher speed. Although the observations show that the usage rate at such trips is high, it should be noted that travellers themselves state that they often remove the belt if they want to sleep or if it restricts them in any other way. For shorter journeys, mainly in procured liner, traffic passengers rarely use a belt. One reason for this is that passengers worry that they will not have time to buckle up and then remove it before leaving the bus. Other reasons for not using the belt is that the trip usually is in built up areas which the passenger perceive to be more secure and therefore make them less motivated. The belt itself was stated by many to be a problem (dirty, technical problems to roll out, to lock etc.) and difficulties to wear it general contribute largely to not being used. Systematic cleaning and
control of seats and belts is recommended.

From a bus driver point of view, it is difficult to ensure that passengers under the age of 15 use a belt. Even if the driver makes sure that all passengers use the belt at the start of the journey, it is still difficult to check that the belt is used during the whole journey. Some form of driver's support would be helpful, for instance, a red sign in the ceiling that is turned on if the belt is not attached, or seats that cannot be reclined unless the belt is used.

From an enforcement point of view the law about when to use seat belt in busses but also the responsibility of the bus driver to check seatbelt usage is not clear to all. The general view is that the law does not matter if it is not enforced. To increase usage the information to passengers needs to be improved, an information which motivates them, preferably automated. If the bus has a ticket controller this person should also check seatbelt usage and be entitled to fine those who do not use belt.

The logic to require a belt in a belted bus in a low-speed urban environment is not easy to understand, especially if you can have the right to travel 70 km/h on the next trip on a bus with no belts. Regulatory changes so that seat requirements comply with belt usage requirements and that they are adjusted to ensure consistent use of force are recommended. At speeds over 60 km/h seat belt usage should be mandatory, and all passengers should be offered a seat with a belt. At speeds of 60 km/h or less, belt requirements should be investigated further. At lower speed the measures with the greatest safety benefit are to ensure that all passengers are seated, rather than being belted.

Conclusions: The seat belt use among bus passengers can be improved especially in commercial traffic and in procured traffic. It is more common to buckle up on long trips than on short trips. However, even though observations show high usage during long trips, travellers report that they remove the belt after a while if they wanted to sleep or for comfort. For the bus drivers it is not possible to control passengers’ usage. Dirty seat belts and technical mal function might deter some passengers from using them and therefore systematic cleaning and control of seats and belts are recommended. On short trips one reason for not using the belt is related to worries to get stuck and not be ready to get off in time.

Selected references


Background: The technological development in the automotive industry is shaping the future of transport services to meet mobility needs and the provision of the required goods in due time when and where they are needed. Thus, innovative solutions for decarbonisation and economic improvement are being put into practice imposing to truck drivers’ behavioral adaptation and new training needs. Such changes introduce human factors issues that must be studied and put into the new equations towards the service improvement without compromising road safety.

The freight transport sector is requiring new solutions to overcome both the increase of energy consumption costs and the environmental concerns about CO2 emissions. However, new solutions, like automation and truck platooning, have created some personal uncertainty among truck drivers resulting from their fear of a decrease in truck drivers’ employment due to their replacement by automated devices. Thus, this is the right moment to talk to truck drivers to explain them the two main positive effects of the introduction of the platooning technology in the freight transport: 1. the clear improvement of the previous truck drivers’ working conditions, represented by long hours on the road (mostly alone) and the related passive fatigue leading to drowsiness and sleep risk, usually increased by sleep debt resulting from such working schedules; 2. the fact of being assisted by the technology and being a team on the job cooperating in every task on board toward the main task completion.

Methods: New risks and new research needs
Being a new technology linking virtually two or more trucks driving on the road in convoy, truck platooning represents an important change to the freight transport and requires deep research to avoid compromising road safety by the introduction of new risks. Since the introduction of cooperative driving as a way of reducing inter-vehicle distance compared to what is accepted in manual driving, this was considered an immediate target of platooning systems to improve energy efficiency by reducing aerodynamic drag. However, truck platooning systems share the road with a great diversity of vehicles and road users being frequent to see a car or another vehicle cutting in trucks in platooning if they drive at convenient distances for that. This imposes a fast automated adaptation of the ACC slowing down to keep the pre-defined distance between vehicles. According to recent literature, European truck drivers prefer driving at short distances between vehicles in platooning to avoid such interference despite the benefits of allowing more vehicles using the road (Castritius et al., 2020). Differently, in USA, truck drivers prefer driving at longer distances between vehicles in platooning allowing other road users to cut in (Yang et al., 2018).

As a transport system, it is dynamic involving some uncertainty along the trip and leading drivers to deal with the unexpected, having limited time for decision-making. Being composed of two or more vehicles virtually connected in platooning, it requires human-to-human communications, either between drivers or between drivers and relevant entities along the trip. Having some level of automation, it involves human-system interaction and cooperation either when being in-the-loop or
A vehicle in platooning is allowed to leave the platoon and take another road on a junction, and a new vehicle merging the road is allowed to integrate the platooning. Thus, a strong coordination based on V2V communication under a cloud supervision service is required. Truck Platooning is a system of systems requiring coordination rules to keep its integrity while accomplishing its missions having road safety in mind. Thus, some research questions emerge:

1. Which are the impacts of truck platooning systems on road safety?
2. Which are the relevant analysis methods for the study of the drivers’ activity and behavior in truck platooning systems?
3. Which are the drivers’ levels of acceptance and trust in truck platooning systems and how this is reflected on their behavior?
4. What is necessary to ensure safety in truck platooning systems?

Results: The TRAIN Project
Being driven by one driver for each truck (the leader and the followers) adapting their speed and lane position without (or very little) human action, truck platooning use automated driving and vehicle-to-vehicle communication technologies. This highlights the importance of human-to-human communication and the multiple human-system interactions towards the perfect coordination of actions. The automated and coordinated movement of truck platoons has the advantage of reducing traffic jams, but also important, it improves drivers’ working conditions. However, during the transition to full automation, the driver will still be kept “in the loop” or “on the loop”, as he will still be responsible for the driving task or, at least, for its supervision.

A new nationally funded research project (TRAIN - Mapping risks and requirements for truck platooning using a driving simulator) addresses these issues through an integrated approach that will identify the requirements for the development of truck platooning services and assess the risks for a safe deployment in the real world. In a first stage, TRAIN has selected professional truck drivers for Focus Groups (FG) aiming at collecting qualitative data influencing their acceptance of the platooning systems, together with the development of trust, reliance and willing to use. Due to the reduced number of participants in FG, the analysis of the collected data will identify key questions for setting up an extensive survey to be applied to truck drivers working on platooning systems.

Conclusions: The Next Steps
At the present stage, FG are running, and the survey will be launched in June to be collected and ready for analysis early September. Then, the results will be discussed allowing for the parametrization of simulations and tuning for the experimental testing in the driving simulator.

As TRAIN outcomes, the following will be delivered:

- Acceptance model to predict the market adoption of truck platooning,
- Driver behavior model to predict risks of cognitive underload, drowsiness, and distraction in partially automated trucks in platooning,
- Guidelines/recommendations to the truck platooning industry, operators, and regulatory bodies towards
  - safety and usability improvement,
  - provision of regulations and training programs.
Acknowledgement

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66 - Texas Statewide Pedestrian and Bicycle Crash Analysis

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Background: The Texas A&M Transportation Institute (TTI) has undertaken a statewide analysis of pedestrian and bicycle crashes to identify and understand the who, what, when, where, why and how of these crashes. Who is involved in these crashes, what were the circumstances surrounding the crashes, when and where did the crashes occur, why are the crashes occurring and how do we address the issues of pedestrian and bicycle safety in Texas, are the questions researchers considered. This information will guide strategic messaging for outreach and educational efforts and provide data on the problem areas for pedestrian and bicycle safety.

Methods: The analysis included TxDOT reportable crashes involving bicyclists and pedestrians from the Crash Records Information System (CRIS), extracted on 2/3/2022. A TxDOT reportable crash was a crash that occurred on a public roadway and resulted in a fatality, injury or $1,000 in damages. The analysis included at all fatal, suspected serious injury and suspected minor injury crashes (KAB) from 2016-2020.

Results: In pedestrian crashes, most of the drivers were in the 20-39 year age range and most of the pedestrians were in the 15-39 age range. Blacks were overrepresented as drivers and pedestrians in pedestrian crashes.

Failure to yield right-of-way was the most commonly cited contributing factor in pedestrian crashes for both the driver and pedestrian. In fatal pedestrian crashes, driver inattention was the number one contributing factor. Nearly 10 percent of pedestrian KAB crashes involved impairment on the part of the pedestrian and 37.2 percent for pedestrian fatalities. Almost 80 percent of pedestrian fatalities occurred in the dark and over 80 percent of pedestrian fatalities occurred at non-intersections.
In terms of bicycle crashes, the age range of people 10-19 was overrepresented compared to their portion of the population. Males were significantly overrepresented in bicycle crashes, at over 82 percent of bicyclists in crashes. Both Whites and Blacks were overrepresented as bicyclists in crashes compared to their portion of the population. Blacks were also overrepresented as drivers in bicycle crashes compared to their portion of the population.

Driver inattention and failure to yield right-of-way were the major contributing factors in bicycle crashes. Most KAB bicyclist injuries occurred in the daylight, however, the majority of fatalities occurred in the dark. Similarly, most KAB bicyclist injuries occurred at intersections, while most fatalities occurred at non-intersections. Impairment was an issue with 13.4 percent of drivers involved in fatal bicycle crashes and 31.4 percent of bicyclist fatalities.

Finally, while most bicycle crashes were on the TxDOT system and occurred in urban areas, just over 1/3 of bicyclist fatalities occurred in rural areas.

**Conclusions:** Certain demographic groups are overrepresented in pedestrian crashes, which can help focus outreach and educational efforts. Dark conditions and non-intersections are the biggest issues for pedestrians. Impairment is also an issue for pedestrian safety, especially in fatal pedestrian crashes.

Males are the predominant target audience for bicycle safety information. Driver inattention is a big issue for the safety of bicyclists as is failure to yield right-of-way. The high number of bicyclist fatalities that involved impairment is also very alarming. Bicyclists also have increased safety risk in the dark and at non-intersections, especially when looking at fatal crashes.

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**67 - Shuttle operators' attention and fatigue – an explorative study**

**My Weidel**

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**Background:** Experimental activities and studies with small autonomous buses (shuttles) in urban areas are becoming more common. A safety driver who can take over control when the vehicle does not fulfil its task is usually required. In practice, this means that the safety driver is ultimately responsible for ensuring that the journey is safe, both for passengers and for surrounding road users. If they can do so during a full shift is not well known. The aim of the present study was to study the safety driver's work environment, with special focus on fatigue and inattention.

**Methods:** The study was conducted in Linköping, Sweden, in collaboration with the mobility arena "Ride the future" (ridethefuture.se). In total 8 drivers participated in the study. The study was exploratory, and the data collection was conducted in normal operation during normal work shifts. Data were collected during the first and last hour of an afternoon session. The results from these two sessions have then been compared. Drivers' alertness was measured with self-reported drowsiness
(KSS) and via blink measures (blink duration and long blinks) as well as heart rate-based measures (heart rate variability). Furthermore, eye tracker (Pupil labs) was used to monitor the drivers' eye movements in order to describe how drivers search the surroundings while driving.

**Results:** Overall, the results show no difference in performance during the first and last hour of the afternoon work shift. One (1) driver showed high levels of self-reported sleepiness while driving. The results show that there are large individual differences between safety drivers, just as there are individual differences between drivers in general. Drivers' attention shows discrepancies between where it can be assumed that drivers should pay attention and where they focus their gaze. This was primarily revealed by a lack of glances in the rear direction, but also by a lack of glances to the right and to the left. If this is because they have used peripheral vision to acquire this information cannot be determined. Furthermore, it can be noted that much attention was directed towards a display in the bus that shows what the bus knows about its surroundings, probably because drivers want to be prepared for possible hard braking. This diverts attention away from the outside of the bus.

**Conclusions:** The conclusion is that drivers do not show reduced alertness or attention during a work shift. One driver showed signs of sleepiness. This result that is not surprising as individual differences are common. The study shows that drivers do not direct their attention as expected. In particular, the safety drivers neglected to scan towards the rear of the shuttle in many situations. Many drivers also did not look to the left and to the right in situations where they were expected to do so. Whether this affects the ability to intervene cannot be determined. As for any driver, the well-being of safety drivers is important, especially in terms of being rested and well prepared for the work shifts.

**Selected references**
Session: Safety modelling and crash analysis, part 2

68 - Toward the assessment of automated vehicle safety with duration modeling

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Background: Ideally, the evaluation of automated vehicles would involve the careful tracking of individual vehicles and recording of observed crash events. However, due to the low frequency of crash events, such data would require many years to acquire and potentially place the motorized public at risk if defective automated technologies were present. Also, using automated vehicle crash rates reported by manufacturers and comparing them against conventional vehicle crashes rates from police reports (which are plagued by under-reporting) can lead to biased results. Despite the attempts of researchers to extract police-reported crashes of automated vehicles for such an analysis, and to adjust conventional vehicle crash rates for underreporting to overcome this limitation, the analogy between automated and conventional vehicle crash rates can suffer from a false equivalency. Another issue in evaluating automated vehicle safety using road test analyses is the reliance solely on the descriptive assessments of automated vehicle crashes, which provides limited information on the likelihood of crash occurrence. To address the limitations in automated vehicle safety evaluation, this paper demonstrates an approach that uses the collective crash histories of a group of automated vehicles.

Methods: To achieve this, a duration modeling approach is applied where the duration is studied as the number of miles driven between crashes in a group of vehicles. Anderson-Darling and Kolmogorov-Smirnov tests are conducted to statistically assess differences between automated and conventional vehicles. An empirical assessment was undertaken using two comparable sources of data. For conventional vehicles, police, and non-police-reportable crashes were collected from the Second Strategic Highway Research Program’s naturalistic driving study (reflecting both major and minor crashes) and, for automated vehicle crashes, data from the California Department of Motor Vehicles Autonomous Vehicle Tester program is used, including minor and major crashes.

Results: The preliminary analysis of automated and conventional vehicle crash data (based on groups of vehicles) sets indicated that automated vehicles’ crash rates are 20% lower than convention vehicles. On average, automated vehicles were driven 27,399 miles before being involved in a crash which is higher than the 21,634 miles for conventional vehicles. Also, a comparison of automated and conventional vehicles’ empirical distribution of the miles driven between crashes represents the lower failure (crash) probability for automated vehicles. Using the Kolmogorov-Smirnov and Anderson-Darling tests, the hypothesis of whether the automated vehicle failure function is different from the conventional vehicles’ failure function was examined, and it was concluded that the difference between automated and conventional vehicles’ failure functions are different at the 95% confidence interval level. The findings of the proposed statistical analysis herein imply that Level 3 automation testing (which is a system of vehicle automation and human decision-making) in California is safer than conventional vehicles. Also, comparing the crash-free
expectancy between the conventional vehicle and automated vehicle shows a 27% improvement in
150,000 miles of road operation.

**Conclusions:** Despite limited data, this study can be considered a reasonable initial approximation
of automated vehicle safety. With the increasing availability of more complete automated vehicle
data, the proposed methodology has the potential to study future automated vehicle innovations and
upgrades.

![Figure 2. Estimated empirical failure function \( F(x) \), for automated vehicles and conventional
vehicles.](image)

69 - Characteristics of Motorcycle Crashes in Thailand: Evidences from In-Depth Accident
Investigation

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**Background:** During the past decades, motorcycle companies and many research agencies have
tried their best to find the contributing factors causing motorcycle crashes, so that different
countermeasures can be developed to increase motorcycle users’ safety, either in terms of active
safety to prevent or reduce the chance of accidents or passive safety to reduce severity of the
accident. During 2016-2020, Asian Honda Co., Ltd., Honda Motor Co., Ltd., and Yamaha Motor
Co., Ltd. have supported Thailand Accident Research Center (TARC), Asian Institute of Technology
as a leader team collaborating with Chiangmai University, Suranaree University of Technology,
Prince of Songkla University, and King Mongkut’s University of Technology Thonburi to conduct
the comprehensive survey of motorcycle-related crashes under the project of “Motorcycle Accident
Investigation: Micro Study Analysis”. The objective of this project is to conduct the in-depth
motorcycle crash investigation to understand the crash patterns and characteristics of motorcycle
crashes, and to identify the contributing factors causing motorcycle crashes in Thailand. However, to focus on the severe accidents, the case control was selected in this study.

The outcome of this project will enable the related agencies working in road safety to develop countermeasures to increase active safety to prevent or reduce the occurrences of motorcycle crashes or passive safety to reduce severity of motorcycle accidents. In addition, the outcome of this project will be applied to the safety driving training program and approach to the governmental entities to increase the safety awareness in the public.

Methods: The accident investigation is the approach used in this project to determine the causes of crashes and to answer “What happened and how to prevent the recurrence of those types of accident?” The investigation usually starts with an inspection of the crash site and gathering evidences in all contributing factors related to the crashes, including human factors, vehicles, and road and environment. Then, the investigator monitors back the events to figure out the root cause of accident. In this project, a total of 1,200 in-depth motorcycle crash investigations were conducted in all regions of Thailand.

Results:

- The primary accident contributing factor for motorcycle crash is human factor with the similar proportion for both motorcycle riders and other vehicle drivers. The most frequent primary accident contributing factor caused by motorcycle riders was perception failure (49% of all cases), followed by decision failure (32% of all cases), and followed by reaction failure (13% of all cases).
- Motorcycle rider attention failure contributed to the crash in about 25% of all investigated cases. The faulty traffic strategy was considered to contribute to accident causation about 42% of all cases with observed faulty traffic strategy.
- No collision avoidance maneuver was performed for 48% of the time, and up to 60% in fatal cases. Most of the motorcycle riders with no collision avoidance is caused by an inadequate amount of time available to perform any collision avoidance before the crash. These motorcycle riders are those who are in normal riding conditions with no fatigue driving or drunk driving conditions, and most of them were riding between 30-60 km/hr.
- 41% of motorcycle riders do not have licenses at the time of crash, even though it is illegal to ride motorcycle without license. However, among those who have licenses, 50% of them were found to perform no collision avoidance.
- Riders who were involved in the collected accident cases were interviewed about their experiences in motorcycle rider training. More than 90% of riders were trained on how to ride MC by their families or friends, or self-training. And those who have licenses were also trained how to ride MC by their families or friends, or self-training, and of course, without having proper training.
- Most of riders involved in crashes are in age between 15-24 years old. The riders who were below 15 years old and over 64 years old are more vulnerable to have severe injuries and deaths.
- Riders who were involved in the crashes have a higher probability of deaths when travelling with the speed over 80 km/hr, and the probability of deaths significantly increase when the crashes occurred at nighttime.
• Over 50% of all causes of dead for fatal cases in MC riders were head injuries. The results are supported by the fact that greater than 60% of rider involved in the fatal crashes did not wear helmet at the time of crash. In addition, in the fatal riders/occupants due to head injuries, 70% did not wear helmet.
• Road and environment is another major contributing factor to the crashes (40% of all cases). More sever crashes occurred on the roads in suburban and rural areas, and 24 of them occurred at the intersection or access roads.

Conclusions: Based on the findings, the recommended countermeasures and policies can be drawn as follows:

1. Due to the fact that most of motorcycle riders are lack of knowledges and skills on the accident prediction while riding, especially how to assess the risk situations, how to make decision in risk situations, and how to safely control the motorcycle not to have severe accidents, it is necessary to improve the contents of safe riding training by focusing on Risk Perception, Defensive driving, and Collision Avoidance Skill.
2. More strict law enforcement is still needed for motorcyclists violating the traffic regulations, such as the vehicle modification and the use of helmet. In addition, the maximum speed limit of 80 km/hr for motorcycle should be introduced, and the speed management for other vehicles in the traffic should be implemented urgently as the speeding is the major cause of traffic accidents in the country.
3. Policies on safe road/infrastructure design for motorcycle should be implemented urgently, especially how to reduce the conflict points between motorcycles and other vehicles on the roads (at U-turns, intersections, and access roads).
4. More research studies should be conducted to study the safety devices for frontal impacts and the prevention of rear-end collisions.
5. The use of helmet should be continually promoted especially in high-risk groups of motorcyclists such as students and young riders. Advanced technology for helmet use enforcement can be introduced.

70 - Road Risk Disparities in French Overseas Territories

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Background: In France, road traffic accidents in overseas territories (Dom-Tom) have been studied very little, only one epidemiological study on road accidents has been found and is old (Aptel I. et al., 1999). We have tried to compensate for this lack of reference work on the French overseas territories (Dom-Tom) with studies on the overseas territories of other countries, even if these are not always comparable contexts (Heman J., 2012).

This lack of interest is partly explained by the scarcity of data and the difficulty of accessing this
data. Road safety data is collected late and very partially in the Overseas territories and for the autonomous Overseas communities, these data are no longer even available.

Even if these territories represent only 3 to 4% of the road traffic injuries throughout France, their specificities deserve to be underlined. Even if mobility, and therefore exposure to road risk, would be lower in the Dom-Toms, the road risk is as high there, or even significantly higher, than in mainland France.

**Methods:** This study is based on data from the BAAC file, a database of road traffic injuries collected by the police. We have selected the most recent years available for overseas territories, namely 2012-2018. We analyzed the risk of being killed versus injured in a road traffic accident, using multivariate logistic regression models, that took into account all the risk factors available in the data from the Dom-Tom:

- A first global model where metropolitan France was compared to Corsica and to the four overseas departments: Guyana, Guadeloupe, Martinique and Réunion.
- A second model where separate analyzes were carried out in each territory. We were careful to consider only the same risk factors available in all six settings at a time.

Metropolitan France and the island of Corsica were considered in this study as the reference territories for the four overseas departments studied here. The mainland is the general reference territory, Corsica by its size is a useful point of comparison with the overseas territories. Mayotte was excluded from the study because the number of accidents there is too low.

**Results:** The first model reveals that, all other things being equal, in terms of lethality or severity of accidents, Martinique did not present a significant difference, with an Odds-Ratio (O.R.) equal to 0.90 [0.78-1.05] compared to the reference territory represented by metropolitan France. Corsica presented an under-risk, with an O.R. equal to 0.73 [0.63-0.84], significantly lower compared to metropolitan France. All the other overseas territories presented a significantly higher relative risk, compared to metropolitan France, with Odds-Ratios ranging from 1.38 [1.22-1.55] for la Réunion, 1.58 [1.40-1.78] for Guadeloupe, up to 1.63 [1.42-1.88] for Guyana.

The separate models show very different over-risks, for vulnerable road users in particular, in each of the territories. Thus, if we analyze the risk of being killed versus injured in a road accident, we observe that compared to car drivers, for pedestrians, this over risk estimated by the Odds-Ratio (O.R.) is equal to 9.92 [5.95-16.54] in Réunion; 6.65 [2.98-14.86] in Corsica; 5.72 [3.18-10.29] in Guyana; 3.18 [1.95-5.20] in Guadeloupe and just 1.78 [1.0-3.17] in Martinique.

For the elderly, we do not observe the same trends everywhere. Compared to our reference age group of 45-64 years, in mainland France, the 65-74 years and the 75 years and over, respectively present an excess risk of mortality of 1.69 [1.63-1, 76] and 3.33 [3.22-3.45], respectively; in Corsica, these odds ratios are respectively 1.61 [1.07-2.43] and 2.76 [1.83-4.14]; in Guadeloupe these odds ratios are similar: 1.45 [1.02-1.79] and 2.61 [1.79-3.79]; in Reunion, the differences between the two age groups are smaller, 1.71 [1.17-2.51] and 1.77 [1.09-2.89]; in Martinique, on the other hand, the excess risk is not significant for the 65-74 year olds, 1.20 [0.73-1.97] but significant for the 75 year olds and over, 3.23 [2.01-5, 17]; and in Guyana it is the opposite, i.e. 1.98 [1.16-3.79] and 0.94
In the different overseas territories, the differences in excess risk are smaller for men compared to women and for motorized two-wheelers compared to car drivers, they are a little more contrasted for cyclists and car passengers.

**Conclusions:** We did not find any significant effect due to tourist periods as in Crete (Petridou et al., 1997) or in the Balearic Islands (Rosselló J, 2011) or significant excess risk among young people as in the Icelandic study (DennyVC, 2016).

Martinique is the overseas department whose “accidentological” profile seems to be closest to that of mainland France, compared to the other territories, including Réunion, Guyana, Guadeloupe and including Corsica. However, each territory has its own specificities, including in relation to vulnerable populations and issues in terms of road safety. Thus, if globally, vulnerable road users remain a major issue in these territories, the motorization of the population and the aging of the population reveal new road safety issues.

The differences in density of these territories do not explain everything. Further sociological and epidemiological studies should be carried out to explain these differences. For example, mobility surveys would have made it possible to better understand the mobility practices of the inhabitants of these territories and therefore to better take into account exposure to the risk of accident when measuring the risk of road users.

In addition, the recent health crisis due to Covid has revealed the tensions experienced by the emergency services of hospitals in overseas territories. Improving post-crash health care capacities for road accident victims would significantly reduce the number of secondary deaths and injuries with serious sequelae.

**Selected references**
Background: In recent decades, middle-income countries have experienced a rapid increase in the number of cars and motorcycles. According to the WHO, nowadays, the bulk of road accident mortality is concentrated in low- and middle-income countries. The Maghreb is an exemplary case in this regard, including Tunisia. In this perspective, In this study we assessed the determinants of road traffic injuries (RTI) in Tunisia by mode of transportation and compared differences in RTI rates among governorates (district areas).

Methods: We used national road traffic accident data, provided by the Tunisian National Road Safety Observatory, for the year 2019. Beforehand, we selected the best coded and most relevant variables in this database. Then, we adjusted a multivariate logistic regression model to estimate the risk of death compared to the risk of being injured in a road accident, for the selected risk factors. Finally, all other things being equal, we analyzed the differences in the risk of severe accidents between the Tunisian governorates.

Results: Vulnerable road users pay the highest price: pedestrians are 1.75 [1.48-2.20] times more likely to die from a road accident than a car driver is, for motorcyclists, this odds-ratio is equal to 1.71 [1.42-2.06] and for cyclists this OR is equal to 2.51 [1.64-3.84].

The most surprising result of this study is the increased risk of a serious accident on a motorway compared to other traffic lanes. Compared to a municipal road, the risk of a fatal accident is 5.74 [4.03-8.17] times higher on the motorway, whereas it is 2.87 [2.34-3.52] times higher on regional
routes; just like on national roads where this odds-ratio is equal to 2.81 [2.32-3.42].
The territorial inequalities towards the road risk are significant: the interior governorates, the most
deprived, have an over-risk of fatal accident of 3.91[2.01-4.10] times higher than the governorate of
Tunis, the capital. When we take into account the rurality, this odds-ratio remain significant but
decrease to 2.59[1.60-4.22].
Overall, road traffic casualties in rural areas are 2.75[2.35-3.22] more likely to die than those in
urban areas.

Conclusions: There were considerable regional disparities in RTI rates across Tunisia’s regions. We
have underlined the dangerousness of the roads of the most deprived governorates. But, significant
collection biases must be taken into account. They mainly concern the least serious accidents.
Therefore, these results should be viewed with caution. However, these results are consistent with
those of the analysis of accidents involving countries of the same economic level and the same level
of motorization, such as the other Maghreb countries, with the exception of over-risk on motorways,
specificity Tunisian. These findings can help guide interventions to reduce the burden of RTIs in
Tunisia.

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72 - Internet of Things and Road Safety: Challenges and Opportunities for Africa

CLIFORD GOBO
THABANI NYONI
Abstract: Based on Traditional Literature Review (TLR), the researchers explored IoT in the context of Africa. The study resorted to convenience sampling to select a representative sample of the previous studies to be reviewed. The paper specifically explored the IoT challenges and opportunities for Africa. The purpose of the study is three-fold, that is to identify areas where IoT can be applied in the domain of transport in Africa; identify areas where IoT can be applied in the domain of transport in Africa and also showcase the potential role that IoT can contribute to transport management in the continent. The research is important especially with regards to achieving sustainable transport systems across Africa. The study established that IoT challenges in Africa include lack of expertise in IoT, financial problems, power supply, high poverty rates, illiteracy as well as low internet penetration rates. The study also found out that IoT opportunities in Africa include the availability of ubiquitous wireless networks, alternative energy technologies and widespread usage of smartphones as well as the availability of IoT applications in road network management, road safety management, road traffic management and cross-border transport management. The results of the study imply that Africa still has a long way to go in terms of harnessing IoTs for improving road safety and yet there are a lot of opportunities presented by IoTs. Guided by the study, a nine-point policy prescription has been suggested. However, the research focused on the African continent and yet it would have more robust if country specific case scenarios were taken into account.

Selected references

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Poster Session

43 - Situational Child Safety Seat Non-Use

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Background: While public acceptance of mandatory child safety seat laws is strong and attitudes toward use are overwhelmingly positive, the latest national survey (National Occupant Protection Use Survey, 2020) of child safety seat use for children from birth to age seven in the United States is 93.6 percent. A recent survey in Texas (Texas A&M Transportation Institute, 2021) estimated child safety seat use in 18 urban areas at 86.8 percent. This study examines the non-user group. The research focuses on who, where, and why an unacceptable percent of drivers transport children not secured properly in their vehicles.

Methods: Using national and Texas data, observational surveys are analyzed and described, with a look into trends and patterns. Additionally, the study includes a summary review of five years of Texas fatality crash data involving children birth to age seven, comparing use and non-use of child safety seats. Finally, reasons for non-use are examined using telephone interviews and questionnaire surveys of drivers observed with at least one child passenger not riding in a child safety seat. Correlations of sociodemographic variables with risk perception and other factors are included in this analysis.

Results: Child safety seat use, particularly booster seat use, decreases with the age of the child. Misinformation about the benefits of booster seats compared to back seat positioning for children on the higher end of the age bracket is related to non-use. Situational factors, such as short trip destination or perception of low risk travel, were cited as reasons for non-use. Non-use is also associated with the relationship of the driver to the child passenger. Additionally, the study shows an association between driver seat belt use and child safety seat use.

Conclusions: The message of the need for correct child safety seat use on every trip is overridden at times by a perceived sense of safety on short, local trips, with children riding in the back seat. This tendency increases with child autonomy and age. Legal mandates and safety benefits for children under age two are more familiar to parents and child caregivers than safe restraints for children who have outgrown seats used for infants and toddlers. Lack of availability of a child safety seat is less a reason for non-use than lack of understanding of the need for proper fitting restraint systems.

Selected references


44 - Correlates of Self-Reported Driving Behavior and Perceived Traffic Enforcement

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Background: When people get in their vehicles every day, they make conscious and sub-conscious driving decisions based on a variety of different factors that are situational or habitual. One factor of increased interest with the behavior changes noted coincident with the COVID-19 pandemic, is drivers’ perception of enforcement and risk of citation or arrest. This paper focuses on the perceived risk of an intervention by law enforcement for several violations. A primary objective for traffic law enforcement is to disincentivize the public from making dangerous driving decisions – but does the perceived threat impact driving behavior?

Methods: All the data for this survey comes from an annual attitudinal survey conducted by Texas A&M Transportation Institute and funded by the Texas Department of Transportation. This survey sample has over 2,500 respondents in the 2021 survey year and includes respondents from throughout the state of Texas. To augment the analysis of the 2021 time-framed survey within the pandemic period, the responses to the same questions to a statewide sample of Texans in 2019 are provided with a sample size of over 2,400. This demonstrates the cross-sectional differences in self-reported behavior and perceived enforcement risk in the two vastly different contexts.

Results: Speeding, not wearing a seat belt, and driving after drinking alcohol are the three driving behaviors analyzed in this paper. The analysis shows the various correlations between the public’s perception of how likely they are to be penalized for a given behavior versus how likely they are to self-report doing the offense. The analysis also includes demographic and socioeconomic data from survey respondents to describe the drivers with the highest and lowest perceived risk of enforcement. In addition, the data shows who are those who align with the correlation between perceived risk and driving behavior and who are the outliers. The demographic and socioeconomic variables included in the paper for crosstabulation analysis are gender, age, ethnicity, education level, and geographic region within Texas.

Conclusions: The analysis shows that there is a statistically significant relationship between the perceived risk of law enforcement ticket or arrest and self-reported driving behavior. The results provide an indication of the degree of importance that the perception of law enforcement plays in keeping the public from driving dangerously.

Selected references
N/A

45 - Pedestrian Pushbutton Modifications for Improved Pedestrian Compliance

Amy Wyman¹
Background: In the US, pedestrians who want to cross a signalized intersection must often use pedestrian pushbuttons to request the WALK phase for a specific crosswalk—a system which is unlikely to change in the near term (1, 2). When both pushbuttons for perpendicular crossings are located on the same pole, pedestrians may confuse which pushbutton corresponds to which crosswalk or which crosswalk will be served next, and push both pushbuttons. This behavior leads to increased delay for all intersection users, particularly at intersections with split phasing, coordination, or where the pedestrian timing controls the total split length (3, 4). In Washington County, Oregon, United States (US), County engineers repeatedly observed pedestrians making unnecessary button pushes at intersections that meet these criteria. Their desire to mitigate these behaviors motivated a two-part study to: A) Understand where pedestrians are looking for information about which crosswalk will be served next; and B) Evaluate potential modifications to pedestrian infrastructure to better communicate which crosswalk will be served next. Part A was conducted as a small-scale usability study, in which seven participants completed actual crossings at one intersection of interest wearing eye tracking equipment. The results of Part A suggest that participants observed vehicle movements and traffic signals to determine which crosswalk would be served next, and could benefit from additional information which explicitly identified which crosswalk would be served next. Of vehicle movements, traffic signals, pedestrian pushbuttons, pedestrian pushbutton signage, and pedestrian signal heads, participants allocated approximately 50% of their attention to pushbuttons and pushbutton signage, typically just prior to selecting a pushbutton. Researchers used these results in Part B to develop conceptual alternative modifications to pedestrian infrastructure, which were advanced to testing for preference and comprehension via an online survey. This extended abstract discusses the results of the survey.

Methods: The five conceptual alternative designs shown in Table 1 were selected for evaluation in an online survey distributed to adults in Washington County, Oregon (n=202) and across the US (n=415). These designs were selected from a pool of design concepts developed in four categories: pushbutton designs, pushbutton signage, audible pedestrian messages, and pedestrian signal indications. The final five designs were selected to represent a cross-section of the proposed alternatives. Selections were also made based on conversations with Washington County engineers and a pushbutton manufacturer regarding technical feasibility, intuitiveness, and interest in the countdown design concept.

The survey assessed respondents’ comprehension and stated preference of each conceptual alternative, as well as self-reported crossing behavior and understanding of existing pushbutton signalization and signage. It was distributed by Qualtrics to two samples, one from Washington County and one from the US, for two key reasons:

1. Washington County respondents likely had greater familiarity with the local pushbutton signage, signalization, and even intersections depicted in the online survey graphics; and
2. Prior research conducted in Washington County evaluated novel traffic control device designs for different purposes which incorporated similar elements to the evaluated conceptual alternatives, like blue LED lights.
Results: The survey evaluated comprehension by randomly presenting one alternative to each respondent and asking them how they would interpret the design if they observed it at an intersection. Responses to this question were coded as “Correct”, “Partially Correct”, or “Incorrect”. Design 1 had the lowest comprehension for both samples, with no “Correct” or “Partially Correct” responses in the Washington County sample. Comprehension for the remainder of the designs was mixed depending on sample. Design 3 elicited the highest initial comprehension among Washington County sample respondents with approximately 40% of responses “Correct” or “Partially Correct”. Designs 2 and 5 received the highest comprehension among US respondents, with approximately 35% and 38% of responses “Correct” or “Partially Correct”, respectively.

“Partially Correct” and “Incorrect” responses were further categorized by the nature of the incorrect response. Distinct trends in common misinterpretations were observed for each design. For example, respondents commonly misinterpreted Designs 1 and 4 as meaning “push here to cross” or as directing them to cross. Respondents commonly misinterpreted Designs 2 and 5 as indications of how much time remained in the WALK phase associated with that pushbutton. Design 3 was interpreted in a variety of ways, although most commonly as an indication of “push here to cross” or as directing the participant to cross immediately. The majority of respondents, approximately 78% of total respondents, understood that they would still need to push the pushbutton to receive the “WALK” indication with these designs. Approximately 75% of respondents indicated that they “Strongly agreed” or “Agreed” that “Having information about which crosswalk will receive the WALK signal next would be useful to me.” Field testing of these designs will be important to understand how participants interpret them when additional context is provided.

After respondents viewed each conceptual alternative with a description of its intended meaning, they were asked to rank their most-preferred designs on a scale of 1 to 5, with 1 meaning “most-preferred”. Mean preference scores, standard errors, and 95% confidence intervals were calculated for each design accounting for each sample’s size. Design 5 was significantly preferred by respondents in both Washington County and US samples, followed by Design 2. Design 1 was least-preferred in both samples.

Conclusions: Five conceptual alternatives to provide pedestrians additional information about which crosswalk would be served next were evaluated for comprehension and respondent preference. Initial comprehension scores were low for all conceptual alternative designs and varied by sample. Design 3 was best-comprehended by Washington County respondents; Designs 2 and 5 were best-comprehended by US respondents. Persons in both samples preferred Design 5 the most and Design 1 the least.

Selected references
46 - Assessment of the Point-to-Point Speed Cameras to Control Speeding Behavior in Thailand

Kunnawee Kanitpong¹, Mongkol Ekpanyapong¹, Thanchanok Inmor¹
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**Background:** Thailand is currently using a number of technologies in order to control and limit the speed of road users, from fixed speed cameras to mobile speed cameras. These technologies allow stricter enforcement through the detection of speeding vehicles and the reduction of accident occurrences and road casualties. Both types of cameras, nevertheless, have some limitations that affect the enforcement of the law, such as avoiding the vicinity of spot detection cameras and the limits of the working hours at which speed detection is done by the police.

This research examined the information and guidelines of the automatic speed detection system in other countries and has found that point-to-point speed cameras (i.e., average speed cameras) were used. This technology raises the efficiency of speed control in Thailand in terms of law enforcement and increase the capacity for speed detection to reduce the rate of road accidents. The objectives of this research are to evaluate the effectiveness of the point-to-point speed cameras, to compare with the spot speed camera enforcement, and to study the efficacy and cost effectiveness of the point-to-point speed cameras.

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<thead>
<tr>
<th>Design 1 (Illuminated Ring)</th>
<th>Design 2 (Pushbutton Countdown)</th>
<th>Design 3 (NEXT)</th>
<th>Design 4 (Sign Light)</th>
<th>Design 5 (Sign Countdown)</th>
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<tr>
<td>Solid blue ring indicates next crossing to activate.</td>
<td>Estimated wait time in seconds.</td>
<td>Word “NEXT” indicates next crossing to activate.</td>
<td>Illuminated blue light indicates next crossing to activate.</td>
<td>Estimated wait time in seconds.</td>
</tr>
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Methods: This research will compare the speed detection methodologies used by point-to-point speed cameras and spot speed camera enforcement on a variety of measures. The data collection will be divided into two parts: before and after the installation of point-to-point speed cameras. The two speed detection methodologies are compared using the following criteria: Speeding behavior throughout the whole speed control area, Productivity rate of speeding vehicle detection per week, and Speed difference throughout the whole portion of the road with speed control.

Results: After speed detection through point-to-point cameras had been employed together with warning tickets, the 85th percentile average speed in the controlled area decreased by 10 km/hr, with a maximum decrease of 20 km/hr. The proportion of drivers who violated the legal driving speed of 110 km/hr detected by point-to-point speed cameras had also decreased significantly at an average of 15-20 percent.

Comparing the productivity of the two camera models, point-to-point cameras could detect 95 percent of driver’s driving speed, with 45 percent of the detected drivers identified as speeders whose travelling speed exceeded 110 km/hr. This was due to the 24/7 operating hours of the cameras.

The comparison of speed differences at the speed control area revealed dissimilar driving behaviours. Drivers who drove passed the area with spot speed camera enforcement would decelerate abruptly upon noticing the checkpoint ahead. They would then accelerate to compensate for their loss of time from deceleration. On the contrary, drivers commuting passed the area with point-to-point cameras would drive at a constant speed throughout the average speed detection area.

Conclusions: This research investigated the locations and types of roads suitable for point-to-point speed cameras as well as the selection of a proper technology and equipment, the instalment, the public announcement, and the evaluation of the project’s results. The assessment includes the speed control’s efficiency through the observation of the driver’s speeding behaviour on the road; the camera usage evaluation; the comparison with the spot speed camera enforcement; and the cost effectiveness analysis of this measure. In addition, policy proposals were determined to enable relevant agencies to effectively implement the research results on a policy level.

47 - Traffic accident risk among Korean drivers with physical or mental disabilities compared to the general population

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Background: In the Republic of Korea, a medical fitness to drive test is required when licensed drivers become physically or mentally disabled. Noncompliance or failing this test results in license revocation. In this study, the risk of traffic accidents by drivers with disabilities was compared with the general population using the medical fitness test data.

Methods: From 2014 to 2020, data from the medical fitness to drive test of drivers with disabilities and their traffic accidents were obtained from the Korean National Police Agency. Corresponding data on traffic accidents among drivers of the general population were obtained from the Traffic Accident Analysis System of the Republic of Korea (TAAS). Age-standardized incidence rates were calculated using indirect standardization. Standardized incidence ratios (SIR) with 95% confidence interval (CI) were calculated using the indirect method.

Results: Between 2014 and 2020, 3,000 traffic accidents occurred among a total of 43,133 drivers with disabilities. The crude incidence rate of traffic accidents among drivers with disabilities was 69.6 cases per 1,000 people, and the age-standardized incidence rate was 62.4 cases per 1,000 people. The risk for traffic accidents among drivers with disabilities was nine times higher than that in the general population (SIR 9.0, 95% CI 8.7-9.3). In the subgroup analyses performed according to driving environment, drivers with disabilities had a higher risk of traffic accidents during the day than at night (daytime SIR 9.7, 95% CI 9.3-10.1), and had the highest risk on snowy days (snowy days SIR 10.2, 95% CI 5.3-15.1) compared with other weather conditions, including sunny, cloudy, or rainy days. In the subgroup analyses performed according to the severity of injuries caused by traffic accidents, the risk of severe injuries was the highest (severe injuries SIR 9.7, 95% CI 9.3-10.2) compared with minor injuries or death. In the subgroup analyses performed according to the type of disability, the physically disabled had the highest risk of traffic accidents (SIR 9.7, 95% CI 9.3-10.2), while the hearing impaired had the lowest risk (SIR 5.8, 95% CI 4.8-6.9). Visually impaired drivers had a higher risk of traffic accidents at night (nighttime SIR 9.1, 95% CI 7.7-10.6). Finally, the risk of traffic accidents stratified according to the age of drivers with disabilities revealed that the risk was the highest for those in their 20s (20s SIR 15.7, 95% CI 14.2-17.1), and showed a tendency to decrease over ages.

Conclusions: The risk of traffic accidents among drivers with disabilities was significantly higher than that in drivers of the general population and was influenced by various factor, such as driving environment, type of disability, and age. Therefore, to reduce the occurrence of traffic accidents among drivers with disabilities, it is necessary to improve the policy of the driver's license system in detail, such as adjusting the driver's license issuance standards according to the type of disability or ages (i.e., conditional driver’s license).
Abstract: Autonomous vehicle (AV) technologies hold the potential to improve traffic safety and operation and transportation networks' sustainability. With the global interest in deploying AV technologies, government agencies are compelled to reassess the safety of existing infrastructure for AV operations. Several recent initiatives and studies surveyed the key physical and digital infrastructure aspects that infrastructure owners and operators (IOOs) must address to prepare existing roads for AVs. Following these recommendations, our research provides a novel methodology for simulating AVs in digital twins built using large lidar and image sensor data crowdsourced from probe mapping vehicles. In our method, AV sensors and vehicle autopilot parameters are used to simulate AVs in a shared environment with different road users. A combination of semantic segmentation variants of deep neural networks and advanced mathematical models are used to study the interaction between the generated road users and query/score locations with unsafe conditions for AVs. We finally developed a framework for the countermeasures to be applied at detected locations. This work can help IOOs make performance-based decisions regarding smart physical and digital infrastructure upgrades.
49 - Assessing the Impact of Bicycle Infrastructure on Traffic Operations and Safety Using Microsimulation

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Background: A transportation system designed to prioritize the mobility of automobiles cannot accommodate the growing number of road users. The Complete Streets policy plays a crucial part in transforming streets to accommodate multiple modes of transportation, especially active modes like biking and walking. Complete streets are referred to the streets designed to accommodate safety and mobility for all transportation user modes. A strategy of complete streets transformation is to connect isolated complete street segments to form a complete network that improves active mobility and public transit ridership.

The study area of this research consists of the entirety of downtown Atlanta and the southern part of Midtown (4.015 square miles). Within the study area, freeways like Interstate 85 (I-85), Interstate 75 (I-75), Route 10, and Route 154 serve as important routes of entry and exit into the downtown area. The study focuses on the bike network in Atlanta metropolitan region due to multiple factors. The first being as such that biking and shared micromobility are rapidly growing as modes of travel in Atlanta and both modes of travel benefit from dedicated bike lanes. Secondly, having dedicated bike lanes will ensure safety and comfort for all road users, not just the bicyclists. Third, cycling infrastructure is typically the least well developed amongst other facilities and services dedicated to various modes of transportation. The last factor would be behaving improved cycling infrastructure to encourage people to ride a bike, which promotes clean energy, better public health, and a cleaner environment.

In summary, this study addresses the Complete Streets policy which is aimed at transforming streets to accommodate multiple modes of traffic such as active modes like biking and walking. The project looked at the effects of complete streets by analyzing the existing bike networks and the potential connections and implementation of new bike infrastructure to form complete networks that improve active mobility.

Methods: This research assesses the impact of efficiently and equitably connecting and expanding the biking network using dedicated lanes on the safety and operation of the network in Atlanta, Georgia. These connections are aimed at increasing the multimodal use of the streets in midtown and downtown Atlanta and achieving the mobility and public health goals through the integration of various modes of travel. The evaluation was done by modeling a well-calibrated and validated network of Midtown and Downtown Atlanta in PTV VISSIM using existing travel demand and traffic design conditions (i.e., the baseline or Scenario 0). A total of three different conditions: existing, proposed, and alternative conditions, were modeled to see the effectiveness of bike
infrastructure design improvement and expansion. Three scenarios were then modeled as variations of modal demand of the different condition models. Scenarios modeled are based on input from the City and Community stakeholders. Using the trajectory data from microsimulation, the surrogate safety assessment model (SSAM) was used to analyze the safety effect on the bike infrastructure improvement and expansion.

**Results:** Results of this study showed a positive impact of complete streets transformation on the streets of Midtown and Downtown Atlanta. Figure 1 visually summarizes the impact of bike infrastructure improvements within the study area.

**Figure 1. Average Delay and Safety Impact of the Various Conditions and Scenarios**

From the figure, the average delay for the proposed and alternative conditions was very similar. However, when comparing SSAM results of all conditions and their scenarios, all conditions showed a decrease in conflicts per vehicle. This may be a result of the bike networks being more complete, which decreases the interaction between vehicles and bicyclists. By having more complete bike networks, decreasing number of vehicles can be expected as people shift from driving to the cycling mode. The decreasing number of vehicles on the road will decrease the overall conflict per vehicle.

**Conclusions:** To the broader research community, the work will provide a framework to evaluate combinations of strategies aimed to improve active mobility and build more “complete” streets. For the existing baseline model, the speed for the VISSIM model landed within or near the range estimated on Google Maps during PM peak hour on Friday. Travel time through key corridors within the network was also well-validated to ensure that the model is capturing real-world driving behaviors within the base network model. The evaluation of the alternatives was based on Georgia Institute of Technology and the City’s input on the planned extension and implementation of bike infrastructure. The scenarios were evaluated to see the effect of the existing and potential bike infrastructure on the vehicles within the study network. These scenarios and alternatives account for the Complete Streets policy objectives. As a result of the output data from the microscopic traffic simulation models, the project team encourages the potential implementation and extension of bike networks throughout Midtown and Downtown Atlanta.

This project provides a framework to examine the design of complete streets by connecting isolated complete street segments to form complete networks that improve active mobility. Most of the previous research studies focus solely on the impact of automobiles from complete streets transformation. For the broader research community, this study shows an alternative way of evaluating complete networks, not just complete streets. Some future work that can utilize this method of evaluation includes using SSAM results for admission analysis or evaluating specific conflicts, such as bicycle conflicts, at selective locations, links, or intersections.

**Selected references**


![Figure 1. Average Delay and Safety Impact of the Various Conditions and Scenarios](image-url)
The foundation of the RS5C conference is in state-of-the-art research and good practice. The conference aims to be a leading source of research results and interaction in the transport area with focus on safety and health associated with road transport. By providing a platform for sharing knowledge and a forum to discuss mutual problem and their solutions, researchers, officials and other stakeholders can learn from results, experiences and success stories. The aim is accomplished by cooperation with local as well as global organisations to ensure that the RS5C conference meets local needs with global state-of-the-art.