



**International Co-operation on  
Theories and Concepts in  
Traffic Safety**

**31<sup>th</sup> ICTCT Conference in Porto, Portugal  
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on

**On the track of future urban mobility:  
safety, human factors and technology**

**Book of abstracts**

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The conference will be organised in close co-operation with the Research Centre for Territory, Transports and Environment of the Faculty of Engineering of the University of Porto.



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# CONTENTS

What is ICTCT? .....4

## Abstracts

Keynote Sessions:..... 7

Session I: Automated driving .....9

Session II: Safety impacts..... 17

Session III: Accidents and prevention ..... 27

Session IV: Policies and implementations..... 35

Session V: Surrogate safety measures ..... 43

Session VI: Naturalistic driving ..... 55

POSTER SESSION ..... 63

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## What is ICTCT?

**ICTCT** is an association developed out of an international working group of safety experts with the aim to identify and analyse dangerous situations in road traffic on the basis of criteria other than past accidents, analogous to the methods of air and industrial safety.

### Our Goal

International co-operation in the identification and analysis of potentially dangerous situations in road traffic, and their causes, on the basis of relevant safety data derived from observations and surveys.

The aim of **ICTCT** is to achieve a deeper understanding of problems in the area, to harmonise future research activities, and to provide for means for an optimal utilisation of research results from different countries.

To fulfil these aims **ICTCT** has been involved in a number of co-operative research efforts (conferences, calibration studies, formulation of international guidelines, clearing house for reports, etc.).

**"WE DON'T NEED ACCIDENTS  
IN ORDER TO PREVENT ACCIDENTS!"  
because we are aware of "danger indicators"**

Danger indicators are, for example, traffic conflicts and near-accidents, as well as the behaviour and interaction patterns in which they are rooted. To improve knowledge about these events and behaviour patterns, which in the long run lead to accidents, is to be collocated within the **ICTCT's** sphere of activities.

### Today's activities and future plans of ICTCT

- Information and co-ordination service for the international exchange of information
- Production and distribution of a regularly-published research journal ("Newsletter")
- Encouragement of international co-operation by the organisation of conferences and other events
- Development of research structure for the planning, realisation and implementation of projects
- Organisation and administration of an archive and a library ("Clearing house")
- Establishment of advisory centres for the identification, analysis, and solution of safety problems in line with the present state-of-the art
- Advice on the development of facilities for the training of safety experts in the identification of risk indicators in traffic
- Publishing of material (e.g. handbooks, brochures, guidelines...)
- Public relations work

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## Keynote Sessions

Title: **Road Safety and Automation**

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Road accidents constitute a major social problem in modern societies, accounting for more than 1.2 million fatalities worldwide and 25.500 in the European Union in 2016. The European Union has made substantial progress in improving road safety and reducing traffic fatalities: in the last decade, the number of fatalities and injuries decreased by 45% and 30% respectively. However, there are still several important road safety problems, namely those related to human factors, which are particularly complex and challenging to evaluate. Within this framework, the automobile and technology industries have made significant effort in a technology that has the potential to impact both road safety and driving behaviour, aiming to change the whole transportation system.

After decades of research, autonomous vehicles (AVs), connected vehicles (CVs) and all relative technology have been in the spotlight, being intensively researched and developed. There is high anticipation on the benefits of automation and the overall reform it will bring throughout the transport sector, with some optimistic estimates considering it a reality within the next few years. However, since it is still an emerging technology, its impacts on several aspects are still unclear. One such aspect, probably amongst the most critical from a social, economic and scientific point of view, is road safety. There is considerable uncertainty regarding the repercussions that will occur when AVs and CVs start operating in real traffic conditions, and several pertinent questions have reasonably arisen.

Autonomous vehicles operations are inherently different from human driven vehicles and have the potential to offer several important benefits. The artificial intelligences that would drive AVs and CVs would not suffer from distraction, emotions, fatigue, poor or clouded judgment, or cognitive impairments, and would have enhanced perception of the road environment and of each other. Their calculating and decision-making skills would take a very small-time fraction in comparison to human ones, and they could aid in not only avoiding an accident but even after it happens (for instance e-call functions). It is highly likely that increased application of AV and CV mechanisms will grant increased self-sufficiency to older drivers, and even allow non-drivers, such as underage passengers or people with mobility or visibility impairments, to travel by car on their own. The benefits of automation are expected to gradually materialize in the more imminent future through implementations of Connected Vehicles that will aid human drivers with advanced sensor technology with easy to access and process information about the road environment.

Focusing on road safety, a very important issue is generated by the fact that for decades autonomous vehicles and human drivers will likely share the roads. Although autonomous vehicles have several advantages presented above, they would do well to imitate some human habits, otherwise the probability of an accident between an autonomous vehicle and a human driver will remain quite high. Morespecifically, an autonomous vehicle that behaves more like a human driver could provide a sense of familiarity with the technology and reassure passengers who might be reluctant to surrender control. Moreover, it could interact with traffic and finally it might be more suited to handling situations where human intuition can be more useful than fixed algorithms. Based on the above, autonomous vehicles should not behave robotically, in a mechanical way that is different from the way that other human drivers would react, but instead behave like a human.

Autonomous vehicles are more than a new package of automotive technology features. They are a disruptive technology that will upend traditional auto industry structures, usher in new cross-value chain models and change the nature of the transportation system. In conclusion, it is likely that someday, the era of human driving will end, and our descendants will chuckle at the idea of us using a steering wheel and pedals. But there is a long way off, and before the coming autonomous vehicles fully take over, they should learn to interact with human drivers.

# Session I

## Automated driving

Title: **An incremental approach to study driver-vehicle interaction in the context of progressive automation**

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keywords: Automated vehicles, Collaborative technology, Driver-vehicle interaction, Driving simulator

## BACKGROUND

Human errors are the main cause of 75% of road crashes. Additionally, human errors are involved in some way in 95% of crashes. Much effort has been made to understand the behavioural factors affecting driving performance, and consequently, crash risk. Distraction, fatigue, and drowsiness are examples that led to the development of detection and warning systems already featured by some vehicles currently in the market. Conversely, the large-scale launch of automated vehicles (AV) is seen as a key instrument to fulfil the ambitious goals of the European Commission's "Vision Zero" strategy, aimed at eliminating road crashes caused by human errors by 2050. Researchers, industry and policy-makers currently agree that a successful transition to automated driving relies not only on people's adaptation to new technologies, but also on automated systems that comply with the society's expectations in terms of usability and safety. Therefore, the development of collaborative systems between humans and technology is crucial to the acceptance of AV and the progression towards a fully automated road transport.

## AIM

The main objectives of this research are (i) to provide a complete mapping of drivers' expectations, interactions and risky behaviours towards the use of automated driving systems of different levels, classified according to the SAE scale, and (ii) to deliver best practices for future design of AV technology, promoting safe and intuitive operation of AV through enhanced driver-vehicle cooperation. The study of driver-vehicle interactions is a relevant part of broader efforts to follow a user-centric approach in AV research, which include the interactions with other vehicles and with vulnerable road users.

## METHODOLOGICAL APPROACH

The first stage of this research is currently in progress under the AWAREE project. This project is focused on the impairing effects from driver inattention on road crashes. For that, a driving simulator study will be conducted to characterize driver-vehicle interactions in scenarios of no automation, allowing to isolate the effects of human errors from the intervention of driver assistance technology during regular and critical driving events.

In a second stage, a comprehensive survey will be carried out to assess current acceptance of AV technology and derive the requirements and use cases of different groups of drivers. The survey results will be used to design driving simulator scenarios, which will be followed by an incremental analysis of driver-vehicle interactions for successive levels of automation. Relevant driver-centred issues of AV technology will be investigated, including the improper use of driver assistance, the takeover of vehicle control, and the compliance with the driver's behavioural intentions in regular and critical situations.

## EXPECTED RESULTS

Three main contributions are expected from this research: (i) a comprehensive mapping of risk factors associated to different groups of drivers and levels of driving automation technology, (ii) a set of recommendations to improve the design, safety and usability of driver warning and automated driving systems, and (iii) the rise of public awareness of automated driving from the users' standpoint.

#### CONCLUSIONS

This research follows an emerging user-centric approach, benefiting from strong receptivity among the scientific community, industry, and policy-makers. The incremental study of driver-vehicle interaction across different levels of automation will allow to identify relevant safety issues associated to each level, distinguishing between the contribution of drivers and vehicle technology. The results will be aimed at enhancing the development of new, safe and collaborative concepts of Human-Machine Interfaces and Advanced Driver Assistance Systems, as the industry is keen on bringing human factors into the design process and embedding human cognitive capability into the control path of autonomous systems. Collaborative systems will more effectively address the requirements of different groups of users, promoting social inclusion and boosting the societal acceptance and market adoption of AV. Through this impact, this research will also contribute to the "Vision Zero" strategy by reducing the frequency and impact of road accidents caused by human errors.

Title: **The deployment of automated vehicles in urban environments: traffic strategies in a safety perspective**

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Author keywords: Automated Vehicles, Transport Planning, Traffic Operation, Road Safety

Pulling off the human control from vehicles and converting it into a reliable automated driving task is the reason for numerous changes in the whole mobility system. How citizens will adhere to this technology and how automated vehicles (AVs) will penetrate into the vehicle fleet are just two of the various questions that have an immediate impact on transport systems performance throughout the process.

At a strategic level, governments need to look at this technology as an opportunity to improve the efficiency of mobility systems and consequently the social welfare. Technology development usually means more information and operational control. In this sense, it is expectable to assume that AVs in urban regions should be designed to grapple with urban problems, thus improving traffic congestion and road safety.

Road traffic safety has a key role in the social welfare as it is a basic claim to the mobility system performance because it directly affects all travellers, before, during and after their trips. Road safety itself varies on the environment (e.g. type of roads) and the variables involved (e.g. pedestrians, bikes, vehicles, etc). A hierarchy composed of three levels of action involves: the prevention of serious injuries and fatalities, the real time prevention for specific users, and the road design standards application. All combined impact the efficiency of the road safety, thus the mobility system. As AVs enter the picture, new strategies of control can be put in practice to improve road safety to levels of efficiency never thought before - but not without its challenges.

The future of urban road traffic requires a compromise between public authorities and citizens perspectives. On one hand traffic operators' will is to increase the social welfare through AVs traffic operation control, but on the other hand citizens want to keep their benefits, such as road safety, comfort and reduced travel times, while keeping the liberty of vehicle ownership.

In the light of the problem, transport planning in urban centres is therefore vital to leverage the AVs potential benefits. For this reason, traffic management for AVs operation is the main focus of this article, given an angle of the road safety risks and practical incompatibilities that might occur in reality.

Our study overviews several traffic strategies to be designed in metropolitan areas throughout the deployment of AVs. Each strategy is accompanied with pros and cons regarding road safety, human factors and technology. We sought to help public authorities with a general assessment of traffic solutions for this promising traffic. Thereupon, hypothetical scenarios are inevitably created based on the AVs deployment visions defined a priori.

In theory, there are two main visions to foresee the deployment of AVs. The geographical envisions an implementation of highly automated vehicles in one step that will gradually and geographically expand. The functional assumes incompatibilities during the process, so the deployment cannot be performed suddenly and intermediate functional steps must be identified and optimized throughout the process. The level of automation can be considered a discernible functional increment from one level to the next as technology matures.

Hitherto investigation have looked to potential scenarios that involve the progress from mixed traffic through separate lanes which evolve from links to network to dedicated roadways for AVs only within the network. Also, the technology factor is present with regions that have V2I communication and others that don't. The present research gap are the safety and human factors that still do not find enough support in literature.

At first glance, the main methodological issue of the following study is the fact that AVs are not deployed in reality yet. Nevertheless, we believe that this shall not be seen as limitation, but rather an opportunity to install the debate and discussion about AVs traffic operation in a safety new perspective.

The main conclusion of this essay is that traffic strategies will only have some credence if road safety is a considered topic at first. Furthermore, although some traffic strategies remind the current transportation panorama, they gain another perspective with AVs deployment. Traffic operation has indeed an infinite number of solutions to tackle AVs circulation. Moreover, it embraces pedestrians' interaction and how this new technology shall be included in our city centres in the best possible way.

Title: **Recognition on trigger condition of autonomous braking system**

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Author keywords: autonomous braking system, Recognition, multivariate analysis model

#### Background

Automobiles carrying autonomous braking system are prevailing. More than 40% of vehicles sold in Japan in 2016 have been equipped with the systems. While the reduction of traffic accidents is expected due to the widespread use of the system, there are concerns that many drivers are using the system without the proper understanding of the trigger conditions. Ambiguous recognition of such "trigger conditions" can also have serious adverse effects, such as promoting dangerous driving.

#### Aim

We grasp the degree of recognition of the trigger condition of the autonomous braking system of the driver holding the vehicle equipped with the system. And the influence factors on that recognition are shown.

#### Method

In this research, we develop a multivariate analysis model with the degree of understanding of the trigger condition of the autonomous braking system as the objective variable. The explanatory variables of this model are "personal attributes" and "contact opportunities of information on the autonomous braking system". "Personal attribute" is composed of age, gender, driving frequency, type of vehicle in possession, the ability of own activity, and driving style. "Contact opportunities of information on the autonomous braking system" is composed of "experience of the autonomous braking system before purchasing" and "information provided by various mediums" such as TV commercials and magazines. The trigger condition of the autonomous braking system was referenced from the automaker's website.

This analysis is conducted on a characteristic group holding an autonomous braking system. Therefore, we collected the data through a web research company (Rakuten Research) with a large population that can be screened. The population of this survey is 1.22 million people holding cars. We sent a survey sheet for screening to 9,999 monitors randomly selected by gender and age group for this population and confirmed own vehicle with autonomous braking system ownership status. Subsequently, the main questionnaire was sent to the respondents who passed the screening. The survey was finished at the stage of obtaining answers of target number by gender / age group. The number of answer targets was 200 for each of 4 groups divided by elderly / non-elderly and gender (male and female).

#### Result expected

Many respondents referred to "explanation by car dealer" and "explanation in maker catalog" about the autonomous braking system. On the other hand, "automobile specialty magazine" and "the result of performance evaluation in public institutions" were not well consulted. Among the trigger conditions of the autonomous braking system, there are a relatively large number of respondents who said "knew it now" especially regarding pedestrian detection. By considering the constructed multivariate analysis model, it is expected that what "personal attributes" and "contact opportunities of information on the autonomous braking system" will affect the recognition of the trigger condition.

#### Conclusion

From the viewpoints of 'personal attributes' and 'contact opportunities of information on the autonomous braking system', influence factors on recognition of trigger condition of the autonomous braking system are clarified. In the future, we are planning to analyze how the recognition difference of trigger condition affects driving behaviors.

Title: **Influencing factors on the acceptance of Advanced Rider Assistance Systems (ARAS)**

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Author keywords: advanced rider assistance systems, motorcycle, powered two wheeler, crash simulation, safety measure acceptance

The risk of being killed in a traffic crash is 3.5 times higher for riders or pillion passengers on Powered Two Wheelers (P2W) than for drivers or passengers in motor cars. That is not only due to a higher risk exposure, but also because consequences of a crash are much more severe for P2W riders: 16.5 out of 1,000 P2W crash victims die, in comparison to 4.7 out of 1,000 for motor car crash victims.

In addition to passive crash security features like crumple zones, reinforced passenger compartments, seat belts and airbags that protect motor car occupants, active security systems like ABS and ESP are ubiquitous in motor cars. More advanced driver assistance systems like blind spot monitoring, lane and distance keeping assistants are trickling down from top-of-the-range to economy models, helping prevent crashes in the first place. While passive security is hard to achieve due to the lightweight and minimalistic construction of P2Ws, manufacturers are increasingly providing Advanced Rider Assistance Systems (ARAS) in order to achieve gains in active security.

In the project moTFas the potential of selected ARAS (blind spot monitoring, curve warning, forward collision warning, Cornering ABS, traction and wheelie control, autonomous emergency braking) to avoid/mitigate the consequences of typical P2W crashes was analysed. This was done using methods ranging from the simulation of real crashes – collected in the CEDATU crash database – with and without the specific ARAS engaged, as well as focus group discussions and an online survey (n=400) about the acceptance of such systems, to the analysis of data obtained by logging the activation of the ARAS in racetrack as well as riders' safety training scenarios.

In the follow-up project MOKABS, the same methods will be applied to an in-depth analysis of Cornering ABS with a stronger focus on its use by real riders in different scenarios, from racetrack riding and riders' safety training manoeuvres to more naturalistic riding on specific motorcycle routes and individually chosen routes. First results from focus groups about the acceptance of Cornering ABS among motor bikers can already be presented.

In the crash simulation it was found that the efficiency of the forward collision warning and autonomous emergency braking ARAS, to avoid or mitigate typical P2W crashes, is between 38 and 58 percent. In the online survey important findings show participants' scepticism about technical feasibility of ARAS on motor bikes, which is significantly reduced for riders who had the chance to test the ARAS in practice. Analysis of manoeuvres in riders' safety training carried out with motor bikes equipped with Cornering ABS showed that – after some getting used to – riders trusted the ARAS enough to employ the brakes as hard as possible, thereby reaping the full benefits of the systems.

The research project moTFas was funded by the Austrian Road Safety Fund (VSF) of the Austrian Ministry for Transport, Innovation and Technology.

Title: **Road safety in an uncertain technological future**

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Author keywords: road safety, autonomous vehicles, human driver, automated system, accidents

The exponential technological evolution of the past decades suggests the future will not be a simple extension of the present, as it was not in the past. The invention, discovery, and adoption of new technologies in societies will again change the logic and hypotheses of today's thinking. Automation in road vehicles will begin by affecting the choice of transport mode, but will later impact urban planning, the "sharing economy" and ultimately society. Many researchers, from academia to the industry, are debating the pros and cons of autonomous vehicles in this transition period. One of the pros of SAE International Level 5 autonomous vehicles mentioned most frequently is the reduction of traffic accidents.

This research analyses and discusses the arguments relating road safety to autonomous vehicles based on extensive literature. We compare the factors underlying mistakes and road unsafety, and the following dimensions are put into perspective: (1) the influence of human factors in driving; (2) the decision-making process and reliability of autonomous vehicles; (3) the uncertain interaction between human and autonomous drivers in the transition years.

This study aims to explore how the diffusion of autonomous vehicles might impact road safety based on the literature. The different variables contributing to the probability of an accident, both for human drivers and autonomous drivers are analyzed. Also, the known statistics for road safety in Portugal are discussed.

Age is frequently correlated with experience. In the context of driving, experience leads to a better prediction ability on the road. On the other hand, age also brings a cumulative number of physical and mental constraints. Likewise, drunk or fatigue affect cognitive and motor function negatively and the probability of having an accident increases. The literature suggests human error is the cause of 90% of all traffic accidents. A preliminary analysis of the statistics known on Portugal suggests a lower number, but still close to 90%. The literature suggests that the introduction of autonomous vehicles in the market may lead to fewer road accidents and may yield fatality levels comparable to those in the aviation industry. SAE Level 5 autonomous vehicles will be prepared and tested to handle different traffic, weather and pavement conditions. Nonetheless, statistically "proving" autonomous vehicles to be safer than human drivers may take longer than ten years (with a fleet of 100 autonomous vehicles navigating the roads 24 hours a day). If we also take into account the evolution of autonomous vehicles technology in this time frame and the variation of fatality rate each year, the problem quickly becomes unmanageable. Alongside the technological evolution, there's the issue of perception of safety: as autonomous vehicles are perceived as safer, carelessness might follow in both pedestrians and drivers. While both systems co-exist - i.e., autonomous vehicles and human drivers - autonomous driving may yield a false sense of safety, misleading humans into additional risks. For some cohorts, road safety might deteriorate, but overall, it is believed that it would improve.

## **Session II:**

# **Safety impacts**

Title: **A controlled trial to allow motorcycles on bus lanes in Tel-Aviv: an assessment of mobility and safety impacts**

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Author keywords: motorcycles, bus lanes, controlled trial, behaviour indicators, accidents

### Background

Over recent decades, an increasing use of motorcycles of various kinds or powered two-wheelers (PTW) is observed, throughout the world and in Israel, mostly in metropolitan areas. Motorcycles provide mobility benefits in densely populated areas but belong to vulnerable road users due to the high risk of riders' injury in road accidents. One of the measures for improving motorcycle safety in urban areas is seen in allowing the use of bus lanes by PTWs. This measure was introduced in various European cities, whereas the detailed examinations of its impacts are not common and were reported mostly in the United Kingdom. In Israel, the use of bus lanes by motorcycles was introduced in Tel-Aviv, initially in the form of a controlled trial that comprised two streets - major traffic routes, with a total length of 5.5 km. Both streets are divided roads with a built median, curbside bus lanes and two-three lanes of general traffic per direction. The trial took place in 2016 and was accompanied by an evaluation study.

### Aim

The purpose of this study was to examine the mobility and safety impacts of the new measure – a permission for motorcycles to use the bus lanes on two traffic routes, in Tel-Aviv.

### Method

To assess the impacts, before-after comparisons of behaviour and accident indicators were applied. Based on the international experience, the new measure was supposed to improve the PTW mobility and to reduce conflict occurrences between PTW and other vehicles. Besides, it should not harm the travel times of buses and the safety level of the streets involved. All these implications were estimated in the study based on field observations of traffic components and road user behaviours, during the trial as opposed to a before period.

The observations were collected by means of video-recordings including special cameras installed on five road sections, four cameras of the Tel-Aviv traffic control center that filmed traffic movements at junctions and mobile cameras attached to the motorcycle helmets in a group of PTW volunteers. The video-records were coded by the study team providing a database for estimating behaviour indicators, which included: percent of using bus lanes and other travel lanes by motorcycles; keeping the travel lane by motorcycles; conflict occurrences between PTW and other vehicles, with a particular focus on bus lanes and motorcycle-other vehicles' interactions near the bus stops; passing times of buses and motorcycles through the pre-defined street sections. Before-after comparisons examined the extent and the significance of changes.

In addition, road accident changes were examined during the trial related to previous years, with regard to total injury accidents, severe accidents and accidents involving buses and motorcycles.

### Results

The results showed that during the trial, the rate of using bus lanes by motorcycles increased by 4-5% under the conditions of moving traffic and by 6%-8% under traffic congestion. However, PTWs continued to be observed in other traffic lanes. On the street sections, the amount of interactions between motorcycles and other vehicles did not change, whereas the conflict occurrences near the junctions decreased. Despite

the initial concerns, the amount and the severity of conflicts between motorcycles and other vehicles near the bus stops did not increase. The passing times of buses and motorcycles through the pre-defined street sections did not change significantly. Accident numbers did not change substantially on both streets during the trial, yet signs of a decrease were observed in motorcycle-involving accidents.

#### Conclusions

Allowing PTWs on the bus lanes produced slight improvements in motorcycle mobility, without harming bus travel times or detrimental changes in safety. The absence of substantial behaviour changes during the trial indicated that the new measure “regulated” the situation that was previously present in actual traffic.

Title: **Safety of mobility scooters: lessons learned from in-depth accident investigations**

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Author keywords: Mobility scooters, Accident causation, In-depth study, Measures, Road safety, Older road users, Vehicle design

### Background

People with motor impairments are often dependent on mobility scooters for independent mobility. In the Netherlands, most of the mobility scooters are provided by municipalities as part of the Social Support Act. The ageing of the population has led to an increase in the number of mobility scooters. Between 1999 and 2009 the number of mobility scooters in the Netherlands has almost tripled: from 51.000 to 146.000. Since 2010 the number of mobility scooters has stabilized. However, the number of road fatalities among the users of mobility scooters has increased from 19 traffic fatalities in 2010 to 38 in 2016. This has led to major concerns about the safety of mobility scooters. Similar concerns have been raised in other countries such as the United Kingdom and Australia.

### Aim

The aim of this study was to gain more insight into the factors and circumstances that influence the occurrence and consequences of accidents involving mobility scooters. A second aim was to select promising measures to prevent these accidents and reduce any resulting injuries.

### Method

A dedicated team for in-depth road accident investigation collected and analysed detailed information on 35 accidents involving mobility scooters that occurred between February 2015 and November 2017 in The Hague (NL) and the surrounding area. This resulted in a description of the course of events for every accident that was analysed, including a list of factors that contributed to the occurrence of the accident and possible injuries. Accidents with a similar course of events and a comparable combination of contributory factors were grouped into (sub)types of accidents involving mobility scooters. A prototypical scenario was written for every identified type of accident, based on the common characteristics of its accidents, including a description of the road users involved, where and how the accidents typically occur, what injuries result from them, and contributory accident and injury factors. Based on the contributory factors to the identified types of accidents, measures will be selected to prevent similar accidents from occurring in the future. These will include measures to improve road user behaviour, road design and vehicle design.

### Results

Four types of accidents were identified, varying from single-vehicle accidents in which vehicle design played an important role to accidents in which the mobility scooter fell over after contact with an obstacle, and collisions with cars. This paper contains the prototypical scenarios of these types of accidents, common contributory accident and injury factors, and the injuries of the road users involved.

### Discussion

Study results will be compared with those of other accident studies carried out in the Netherlands and in other countries in- and outside Europe. Any differences in study results will be related to differences in

legislation and use of mobility scooters in these countries. In addition, promising measures will be discussed to prevent similar accidents from occurring in the future.

#### Conclusions

This in-depth study and the development of prototypical scenarios give insight into the contributing factors to specific types of accidents involving mobility scooters. Based on this knowledge, countermeasures can be developed to prevent these types of accidents and to improve the safe mobility of older road users.

Title: **A comprehensive and unified framework for analysing the impactson road safety of measures influencing speed**

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Author keywords: Speed, Speed distribution, Exponential model, Impact assessment

This paper proposes a comprehensive and unified framework for analysing the impacts on road safety of measures influencing speed. The key tool for analysis is a specification of the speed distribution, which in most cases closely approximates a standard normal distribution. Skewness in the distribution can be introduced by making one or both tails of the distribution fatter or thinner than the standard normal distribution. The validity of assuming a normal distribution should be tested prior to analysis.

It will normally be sufficient to identify sections representing one half of a standard deviation of the distribution and assume that the entire distribution is contained within the limits of plus or minus three standard deviations from the mean speed. The speed distribution will thus be made up of thirteen sections: the mean speed, six half standard deviations below the mean (-0.5, -1. -1.5, etc) and six half standard deviations above the mean (+0.5, +1.0, +1.5, etc).

The exponential model of the relationship between speed and the number of accidents or injured road users is then applied to estimate the expected number of accidents or injured road users for any part of the distribution. The upper part of the distribution will be associated with a higher expected number of accidents or killed or injured road users than the lower part of the distribution. It can be shown that the shape of the risk curve as applied to the speed distribution according to the exponential model is consistent with studies of how individual driver risk varies as a function of speed. Thus, the results of microlevel and macrolevel studies of the relationship between speed and road safety are consistent.

By relying on an exponential model fitted to speed distributions, a more comprehensive analysis of the impacts of road safety measures influencing speed becomes possible. In particular, road safety impacts of the following changes in speed can be analysed:

1. Shifting the whole speed distribution, as usually happens when new speed limits are introduced.
2. Compressing the upper end of the speed distribution, as usually happens when speed cameras or other means of enforcement are introduced.
3. Enlarging or reducing the variance of the speed distribution, while keeping mean speed constant.
4. Selective changes in upper regions of the speed distribution, for example as a result of changes in fixed penalties for speeding.

The paper illustrates how to test the validity of the assumptions made in analysis and how it can be applied to different sorts of data. Examples are given of how knowledge of the impacts of measures on speed or compliance with speed limits can be translated into expected changes in the number of accidents or killed or injured road users by relying on the exponential model.

## **Session III**

# **ACCIDENTS AND PREVENTION**

Title: **The severity of pedestrian crashes in Lisbon**

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Author keywords: Pedestrian safety, Injury severity, Build environment, Multinomial logit model, GIS

#### Background:

Spatial organization in cities has often taken a special attention to motor vehicles requirements, and neglecting pedestrians and cyclists' needs. Current emphasis in city planning for health and sustainable development has led to shifting local transport policies emphasis to the promotion of active transport modes and to the reassignment of urban space to these modes. However, to increase the share of active transport modes while meeting road safety policy means improvements in the safety of vulnerable road users are needed.

Accident occurrence in urban environments represents a critical safety issue for all countries in the world, as the opportunities for crashes involving pedestrians or cyclists and motorized vehicles increases with urbanization growth and those occurrences tend to involve severe injuries. According to the CARE database (the European Union's injury road accident database), in 2015 21% of European road accident fatalities were pedestrians, of which 69% occurred inside urban areas and only 31% occurred in rural areas.

In the same year, in Portugal pedestrian fatalities corresponded to 24% of all road accident deaths, a percentage that is slightly below the corresponding European value. However, when analysed in detail, 76% of these pedestrian fatalities occurred in urban areas, which highlights a higher relative importance of the pedestrian road safety challenges in Portugal than in Europe.

A safe environment is indispensable to promote walking and cycling. However, motorized vehicle priority urbanization created a built environment unfriendly for pedestrians, making walking activities too much vulnerable, even in developed countries.

Improved knowledge on the underlying factors involved in crash occurrence and elements influencing the severity of resulting injuries are needed to improve pedestrian safety. The consideration of variables describing build environment in explaining crashes and injury outcomes may help to improve urban planning and street environment design. Several studies have examined the relationship between built environment factors and pedestrian crash frequency and risk.

#### Aim:

This study aimed at investigating factors associated with injury severity levels that pedestrians experienced in the city of Lisbon, Portugal, such as urban infrastructure, population and other exposure indicators, and urban characteristics. To accomplish this analysis, a geocoded database on road accidents and victims that occurred in Lisbon between 2008 and 2011 was used. The analysis was conducted using the multinomial logit (MNL) model to estimate pedestrian and driver injury outcomes, by severity level.

#### Method or methodological issues

In crash severity analysis, several models can be applied; MNL being a frequently used one. MNL models are traditional discrete outcome models that may consider several outcome levels and that do not explicitly consider the ordering that may be present in these outcomes. These models require the assumption that the unobserved terms are independent of the injury severity level. If there are injury severity levels that share unobserved terms (so being correlated), coefficients and severity probabilities would be erroneously estimated; in this cases, these models should not be used.

The data collected for this study concerns Lisbon municipality. This study uses four data sets, namely pedestrian crash data, land use information, population census data, and pedestrian exposure proxies. Land use information is disaggregated by area type: industrial, green, residential, historical, services, special uses, mixed-use, railways, roads, and buildings. Census data includes the number of housing units, number of families, and number of inhabitants per gender, age group, and main activity. Finally, pedestrian exposure proxy data were calculated using a numeric scale conversion of the pedestrian potential maps (MAPPe) developed within the Pedestrian Accessibility Plan of Lisbon.

Results obtained or expected:

A MNL model was fitted to identify the possible street geometric, road user, environmental, vehicle, and land use predictors of pedestrian injury severity in Lisbon. In the analysis, data were used, from 2006 pedestrian crashes that occurred in Lisbon in the period 2008 to 2011.

Altogether, 19 variables were calibrated and used to identify the potential effects of different factors related to the categories listed above.

Conclusions:

Significant severity predictors from the model included driver injuries, drivers' maneuvers before crash, driver gender, pedestrian age, crosswalk type, land use characteristics, lighting conditions, and time of day.

Several factors were found to influence the probability of pedestrians' injuries in motor-vehicle crashes, by severity class. For instance, business areas and drivers' abrupt maneuvers were found to increase the pedestrian's fatality probability by 350% and 1750%, respectively. Pedestrians severe injuries were 44% less likely for female drivers, compared to male drivers. It was also found that residential areas are associated with a modest increase in pedestrian's minor injury probability (1%).

Title: **Driver visibility assessment on urban crossing environments based on point clouds**

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Author keywords: Safety assessment, spatial analysis, urban environment, obstacle detection, occlusion, Mobile Laser Scanner

## 1. BACKGROUND

The assessment and improvement of traffic safety is crucial for the development of contemporary and humanized cities. In spite of the fact that accident rates were highly reduced during the last decade, traffic accidents still cause large number of human injuries and economic losses. Enhancing traffic safety is an ongoing request and efforts are needed towards a zero accident concept (Shinar, 2012; COST, 2014).

Poor visibility is highlighted as one of the most important causes of road accidents, and a 3D realistic model of the as-built environment is essential for an accurate analysis. Nowadays, LiDAR based mobile mapping technology is able to collect 3D data of urban environments in a very reliable and accurate way, allowing the automatic and semiautomatic extraction of geometric and semantic parameters and thus, avoiding the manual collection of required assessment data based on on-site inspections and time-consuming surveys.

Point clouds have already been used for determining the area of visibility for drivers in interurban environments (Iglesias et al, 2016). Weather conditions were considered correct visibility areas obtained from point clouds (González-Jorge et al, 2016). And a similar approach was implemented by (Soilán et al, 2018) to safety assessment on pedestrian crossing in urban scenes.

The aim of this research is to develop a methodology for the automatic analysis of visibility in urban crossings based on point clouds. As-built geometry of urban scenes often differ from the as-designed ones due to changes during construction, growth of vegetation, inclusion of traffic signs or new constructions in the road surroundings. In this context, the methodology will be also used for stop signalling diagnosis'.

## 2. METHODOLOGY

Visibility is a common measure to describe the spatial properties of an environment related to the spatial behaviour. The isovist theory has been proposed several decades ago in the field of cognitive science and it defines an isovist as a polygon representing the space that can be seen from one observation point. In this research, a visibility approach based on a ray-tracing algorithm will be implemented to obtain isovists of the crossing scene from a driver point of view – observer-. The algorithm consists on creating a Line-of-Sight from an observer to the objective point, checking if there are obstacles causing occlusions between the beginning and the end of the LOS. The detection of obstacles in the point cloud defines the isovist polygon. The visibility analysis is evaluated considering the driver field of peripheral vision.

The isovists will be used in last instance to assess urban crossings in terms of signalling, and more specifically to evaluate stop and yield situations.

## 3. EXPECTED RESULTS

The methodology will be implemented in Python and will be tested in real case studies from the city of Porto (Portugal). Data has been acquired with a Mobile Terrestrial Laser Scanner (LYNX Mobile Mapper by Optech).

As it has been already proved in interurban environments, a visibility analysis can be directly performed from point clouds to extract isovists. Expected results from this work are very detailed isovists of urban crossings. The isovists will be also used to assess stop signalling.

## 4. CONCLUSIONS

Point clouds can be used to automatically obtain very accurate isovists from the real state of an urban environment. Street slope and objects in the crossing surroundings such as vegetation or parked cars are considered in the study as long as they were acquired in the point cloud. This makes the use of point clouds and this methodology a very effective approach for safety assessment.

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Title: **Estimating the potential of warning system, which prevents road accidents at pedestrian crossings**

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Safety of vulnerable road users is one of the main traffic safety issues today. Modern vehicles offer high level of protection to both drivers and passengers, but pedestrians and cyclists are left with significantly lower chances to survive in a road accident. Vehicle-pedestrian collisions at uncontrolled pedestrian crossing remain one of the most serious unsolved road-safety problems, where the focus must be set on prevention rather than mitigation of consequences. Along with traditional measures, such as rebuilding pedestrian crossings and installation of traffic lights, one can apply contemporary cooperative intelligent transport systems (C-ITS) that would warn both the vehicles and the road users of potential danger. This article aims to estimate the potential of such a warning system as well as to draw recommendations for its design.

Efficiency of the system would very much depend on the timing of warning signals. The main question that needs to be answered is whether such signals can be provided early enough to prevent collisions without the necessity of giving false positive signals just in case. To answer this question, in Tallinn, Estonia there is held a case study, which aims to determine typical road accidents at uncontrolled crossings, propose warning signals' timing and model road users' possible reactions to the signals.

The case study consists of three stages. The first stage determines the typical behavioral patterns of driver and pedestrian, which lead to road accidents. It helps to understand, in which situations the warning system should function. For this, researchers carry out traffic conflict studies at uncontrolled crossings with traffic filmed both in winter and summer seasons and video analyzed with the help of semi-automated software. Research select and describe serious conflicts as well as validate them in accordance with vehicle-pedestrian accident data from police and traffic insurance databases. Thereafter, the validated traffic conflicts are grouped according to similarity in behavioral patterns of road users and thus typical traffic conflicts are determined. These conflicts represent typical vehicle-pedestrian accidents at uncontrolled pedestrian crossings.

The second stage of the research analyzes road users' behavior in typical conflicts to determine parameters like speed, trajectory, distance to potential collision point, time to collision, etc. Among other factors, the research estimates reaction times and potential stopping distances, based on road conditions and peculiarities of different braking systems. The work results in proposal for optimal warning signal timing for prevention of each typical road accident.

The third stage of the study models typical accidents based on each typical conflict. Warning signals are added into the road accidents models and behavior of road users upon receiving the warning is simulated. This simulation assumes giving warning signals to vehicles as well as to drivers and pedestrians. Researchers play through different scenarios, try various vehicle types and imitate different road conditions. As a result, the group draws the conclusion as to whether it is possible to give warnings in adequate time to prevent collisions under different circumstances. According to the findings, researchers give recommendations for optimal warning signals' timing as well as to the design of the system, which would be capable of detecting and preventing typical vehicle-pedestrian conflicts by giving warning signals.





## **Session IV**

# **POLICIES AND IMPLEMENTATIONS**

Title: **Road safety benchmarking in Dutch municipalities: theoretical framework, implementation and webtool**

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Author keywords: benchmark, municipality, data collection, implementation

Municipal policy makers regularly have questions about the efficiency and effectivity of their policy. Benchmarking can provide a method for this assessment: comparing the performance of their municipality with similar others, identifying learning points, and applying them in one's own environment. Although municipal benchmarks have been present in the Netherlands for many years on various policy fields, and in recent years, road safety benchmarks have been developed on international level to compare the achievements of EU countries, a municipal road safety benchmarking for the Netherlands has never been developed.

SWOV has developed and implemented a road safety benchmark together over the last few years, in close cooperation with nine municipalities, the Dutch Traffic Safety Association and the Dutch Cyclists' Union. The benchmark consists of a process framework, a 'golden standard' for indicators to be used in the benchmark and a webbased benchmarktool containing available data for benchmarking municipalities.

The framework of the process steps starts with determining the need to benchmark and forming a benchmarking team, then determining the benchmark topic and relevant indicators, collecting data and identify the best in class before finally identifying success factors and lessons to be learned.

For the 'golden standard', we used the input-throughput-output-outcome cycle and defined items for each level. For instance, on the input level, budget and ambitions were measured, problem analysis and monitoring were measured for the throughput level, the output level consisted of road safety measures taken by the municipalities and the outcome level contained speed and quality of the infrastructure as well as the more traditional measure for road safety: fatalities and serious road injuries.

After implementing this golden standard in nine pilot municipalities, the municipalities were positive about the benchmark, especially about the exchange of success factors on road safety and lessons to learn from each other. The data collection in the benchmark, carried out mostly by the municipalities themselves, appeared to be a severe problem. On the input and throughput level, the long term data (2000-2013) of most indicators could be collected. However, the data on measures taken (output level) was in most cases only available through the memory of the municipal policy makers and not in databases. On the outcome level, data on speeding and quality of the infrastructure was hardly available at all, and available data was not collected in a comparable way. Data on fatalities and serious injured were available from national databases. The implementation of the benchmark increased the awareness of the lack of data in the four municipalities.

To identify key success factors for implementing the benchmark on a larger scale, a document analysis on twelve Dutch benchmarks in other policy fields, (such as benchmarks on sewage systems, domestic waste, home care and the welfare system) was held. The results show that most successful municipal benchmarks, defined as benchmarks with many participants (more than one third of the municipalities participating), used data readily available through mandatory municipal accountability processes. Such mandatory accountability process is not (yet) available for road safety. Furthermore, these successful benchmarks compare mostly executive tasks on which municipalities hope to save money. The results of the document study were validated for the road safety field through interviews with stakeholders.

The above mentioned key success factors are not present in the road safety field: road safety has no mandatory accountability process and it is not a mainly executive task, but a policy task. Therefore, to implement the road safety benchmark on a larger scale, we developed a webbased benchmark tool based solely on nationwide available municipal road safety data, ranging from road deaths to cycling

infrastructure and from civilian complaints on road safety to budgets. In the coming years, cooperation with other partners will be sought to improve and extent the incorporated data and to investigate effective implementation methods.

Title: **A foresight exercise into urban mobility**

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Author keywords: Urban mobility, Urbansafety, Foresight, Inequalities

Technology seems to be the current answer to mobility and safety problems. However, too little thought is given to what urban mobility of the future will be like. The purpose of the paper is to discuss some probable evolution patterns in urban mobility and their implications for research and the development of adequate technology. Thus this is not a research paper, but a presentation of some hypotheses and of their probable effects and suggestions for further discussion.

Among the hypotheses presented, the following will be included:

- urban growth, densification and spatial and social diversity;
- the need for environmental protection (limiting global warming, reducing urban pollution) and its implications for traffic and vehicle use;
- the programmed end of fossil energy reserves, the ensuing increase in oil prices, and their effects on urban mobility and social inequality (with reference to a previous paper from the Pedestrian Quality Needs project);
- the development of new technologies ("automatic cars") or lack of (technologies addressing vulnerable road users, elderly people, etc.) and the possible safety problems involved.

Title: **Spatiotemporal Variation of Bicycling Collision and Injury in Berlin: Implications on Local Transport Policy Making**

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Author keywords: infrastructure for bicycles, urban road safety, crash, collision, injury, road treatments types, facilities, urban bicycling system, Berlin

This paper explores relationships between spatiotemporal location of bicycling road collision and injury in Berlin and its variation among different districts and road infrastructure treatments within the whole city territory. Though in the city the bicycle mode share expanded (from 8% to 13%), and the private motorized trips share shrink (from 38% to 30%) recently, the total number of road crashes, fatalities and injury dropped along the last 2 decades, it did not affect the number of a specific road users group: bicyclists. As social pressure for investments in bicycle road infrastructure rise – often armed with the argument that bicycle road treatments will improve bicycling safety - and local and national politicians declare that more could be done - promising higher (but limited) budget for bicycling infrastructure, we investigate the distribution and relationship with spatiotemporal attributes of the 37,097 bicycling road crashes (2011-2015), using the police reported records. First, we made a cross-sectional analysis of collision density at intersections and on-road sections, and frequency of collisions by bicycle road infrastructure facility (bicycle road path type). Second, we proceed the same analysis, but focusing on selected districts where bicycling mode share is larger. Third, we made a multiple regression using a comprehensive set of traffic volumes and demographic variables at the city's districts level, pointed in literature to influence bicycling crash and injuries. We conclude by informing prioritization criteria in local transport policy making, as arguing the limits of the transferability among cities of findings on what concerns bicycling road infrastructure safety.

Title: **Can an experience with no car use change a future mode choice behaviour?**

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Author keywords: modechoice, habits, traffic psychology, automobile dependency

#### Background:

In today's world we are socialised to use the car. Our parents did so, and we do it. When we grow up and reach the age when the driving licence can be obtained, it is usual to do so. Then to get a car. At least this is how it used to be in the last decades. Nowadays, this trend might slowly change. Young people are not getting driver's licenses so much anymore. In fact, no one is. According to a new study by Michael Sivak and Brandon Schoettle at the University of Michigan Transportation Research Institute, the percentage of people with a driver's license decreased between 2011 and 2014, across all age groups. For people aged 16 to 44, that percentage has been decreasing steadily since 1983 (Sivak & Schoettle, 2012).

So to say, our world is telling us from the very beginning that it is a normal thing to use a car. That it is a first choice. And only if something goes wrong (no money, car is broken, alcohol use), we think of other possibilities. I.e., we have developed a habit. We don't think about our decisions and their consequences; we do not think or consider which mode of transport we choose, but we more or less "instinctively" use the car. As it is very well known from psychology, habitual behaviour is rather complicated to change. Often, it is not rational and sometimes based on prejudices. One of the problems when changing habitual behaviour is the so called "problem of starting point" or "endless circle". This means, that the human needs a positive experience, something that he or she can experience in order to adopt certain behaviour or a change. We need to see and to feel that such behaviour is good and enjoyable, but we will experience this only if we adopt or change certain behaviour. So as we can see, we need something as a starting point, but our behaviour so far does not provide such a starting point – a vicious circle. In this research work we focus on breaking this circle. Once this is done, we assume that choice of walking as a transport mode will rise.

#### Aim:

Main aim of this work is to experimentally verify how the induced experience of not using a car for some time will change car use in the future. The point is that in an experimental setting, and with incentives, we encourage people not to use the car for one month. This will enable them to get an experience of not using car but other modes of transport. Thereby, they will have to change their daily routines (e.g. shopping near house instead of in a shopping mall in the suburb). The main strength of this approach is that unlike in other studies, we won't work with "what people think they WOULD do in a certain situation", but we experimentally let people experience it and then see if this experience changes their real future behaviour. Literature supports the usefulness of such an approach.

#### Method:

Experimental design, 10 families (different families as couples without and with children, low/high income, education, with an older family member, living in the city/ country side) in the experimental group. The requirement is that the family so far used their own car on a regular basis. To recruit families, a convenience sampling method was used. At the beginning of the experiment, each family member (over the age of 10) completed the WHO – Quality of life questionnaire (WHOQOL-100) and a questionnaire containing items regarding the attractiveness and functions of car use (as perceived by the member) and other transportation modes such as walking, cycling or public transportation (Steg, 2005). Then, families were interviewed about their attitudes towards car use and asked to keep a "travel diary" and a log-book/ Google Maps application with daily entries on approximate distance travelled via different modes of transport. For the first week, they were asked to travel "as usual", and next, the one-month period without

car use began. After this month, the families were interviewed again about their experiences and asked to fill out the questionnaires again (WHOQOL-100, attractiveness of car use and other transportation modes). A final interview and questionnaire collection was planned 3 months after the experimental period's end (e.g, March-April 2018) to assess the habitual change in car use.

#### Results:

Most families in our study used their car for taking their children to/from school, shopping and leisure time activities, incl. trips and visiting relatives; not all of them used a car to get to work. For most of the families, "planning and organizing" was the most difficult on the experience with life without a car. When asked about the changes in everyday-life, six of the families reported "more planning ahead", probably with more cooperation (not just within the family itself, but also with the grandparents, friends and neighbors) in coordinating the different activities. The other four families focused more on the changes in their routine trips. Overall, it seems that providing a starting point – the experience of living without a car – can be beneficial largely for people who have already been thinking of cutting back on car use, but did not find the right incentive before. These seem to exhibit the potential of a long-term change; even if they do not give up car use completely, they may maintain some of the newly developed habits (which, in turn, take longer to form and may seem difficult in the beginning, so having the right incentive may help overcome this phase). Living without a car may also be easier for single adults (if they don't have too many activities outside of work) or families with older children, especially if there is good public transport connection and/or good infrastructure for cyclists to the city centre, the workplace and the children's school. Based on our results, the choice of walking as a transport mode did not rise with living without a car, but the participants reported increased use of public transport and, in some cases, cycling as well. This might be partly due to the "ceiling effect" and scaled used (the participants indicated high frequency of walking in the beginning of the experiment already, although they were probably thinking of shorter trips during the day), and partly due to the weather during the study period (fall-winter, with the participants mentioning bad weather as one of the main reasons to use "covered" and "warm" transportation modes).



## **Session V**

# **SURROGATE SAFETY MEASURES**

Title: **Comparison of two nearness-to-collision surrogate indicators at a signalized intersection in Minsk using Extreme Value Theory**

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Author keywords: road safety, surrogate measures of safety, extreme value theory, nearness-to-collision

### Background

In order to overcome the shortcomings of safety analyses based on crash data (underreporting, quality issues and rare nature) a number of Surrogate Measures of Safety have been developed and proposed by various researchers. One of the most widely used temporal indicator is time-to-collision (TTC) which can be calculated for any moment as long as the road users are on a collision course. Previous research has proven that road users that are strictly speaking not on a collision course actually might behave and take evasive actions as if they were, thus indicating that such near-miss situations might also be relevant for safety analysis. To account for this, a more flexible indicator, T2 was proposed describing the expected time for the second road user to arrive at the conflict point. This indicator is more flexible than TTC as it does not require the two vehicles to be on a collision course, and it allows a smooth transfer between collision and no-collision course interactions. Thus, T2 seems to be more suitable for detecting potentially dangerous situations, but it has not been explicitly tested and validated so far.

### Aim

Recently the Extreme Value Theory (EVT) to estimate crash probabilities using surrogate measures of safety has been more frequently applied. This theory offers two approaches to sample extreme events, in this case near crashes, the block maxima (or minima using Generalized Extreme Value distribution) and the peak over threshold (using Generalized Pareto distribution). In the former case the maximum (in this case the minimum) values over time are considered, whereas in the latter case values over a certain threshold are used. In this paper univariate models are used with an intention to investigate the differences in using T2 versus TTC.

### Method or methodological issues

A regular signalized intersection with two-phases in Minsk (Belarus) was recorded for three days (from 6 AM till 9 PM). The video footages of two cameras were then analyzed in the software T-Analyst allowing the manual tracking of straight going and left turning vehicles as well as the calculation of various surrogate measures of safety. For this study approximately 1600 interactions were detected and subsets were created where T2 and TTC values were available. For both indicators the minimum values are used (TTCmin and T2min) representing the moment in time when the two vehicles are closest to each other. These subsets then are analyzed using EVT applying both the block maxima and the peak over threshold approaches.

### Results expected

This is an on-going research, it is expected that by testing the efficiency of both EVT approaches comparing the two surrogate indicators we can make conclusions on 1) the differences in the applicability of the two surrogate indicators and 2) the differences in the two EVT approaches based on their yielded results.

Title: **Evaluation of Surrogate measures of safety for vulnerable road users- results and lessons from InDeV project**

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Author keywords: Surrogate measures of safety, Evaluation, Validation, InDeV

Surrogate measures of safety (SMoS) can provide a method for reasonably quick and easy risk assessments in many different traffic situations. Instead of relying on accident data, SMoS uses predefined safety indicators to identify safety critical behaviour in traffic. SMoS have several advantages compared to more traditional safety analyses based on accident data. It is possible to make a risk assessment before any accidents have occurred and it is also possible to make risk assessment in locations with lacking accident history data.

However, the main concern regarding surrogate measures of safety is the accuracy of risk assessments made with the various safety indicators. While previous research has shown a strong relationship between the frequency of safety critical events and police reported accidents, this research is quite old and was mainly focused on events between motor vehicles (1).

This work aims to provide a new evaluation of SMoS with a focus on vulnerable road users. The aim is also to provide a solid comparison between the most commonly used safety indicators using several different threshold values for the various indicators.

The data used for this evaluation are video recordings made at 26 signalized intersections in 7 different European countries within the InDeV Eu project. At each location, encounters between left-/right-turning motor vehicles and vulnerable road users (both cyclists and pedestrians) have been studied for a period of three weeks. Also, to provide an approximate risk assessment based on accident data, accident data from 50 similar locations in each country have been gathered.

The main safety analysis contains two separate evaluation approaches. The first approach estimates the daily frequency of safety critical events and correlates them with an estimation of the accident frequency using the gathered accident data. Several different indicators with different threshold values are compared to find the best performing safety indicator. This approach also accounts for exposure by estimating the frequency of relevant meetings (or encounters) at the recorded locations and estimated ADT values from manual counts for the 50 similar locations in each country.

The second approach focuses in more detail on the relationship between the frequency of safety critical events and encounters. This approach includes data from only 1-day at each location but can in turn provide a more detailed analysis. The main aim of the second approach is to study how different threshold values affect the number of safety critical events per encounter. By investigating how this relationship changes, it is possible to find a suitable threshold value that provide a "good enough" risk assessment while maintain a relatively high frequency.

This twofold approach provides two important outcomes. Firstly, it offers two different approaches to evaluate the effectiveness of SMOs which makes potential agreement between the methods decidedly significant and secondly, it can also provide some insight into the benefits of expanding the observational period from 1-day to 3-weeks which is important when applying SMOs in a more practical setting.

Results from both approaches and an in-depth discussion regarding the most suitable safety indicator and threshold as well as the benefits of an extended observational period will be presented at the conference.

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Title: **Framework for analysing cyclist safety per movement: Case study at discontinuity locations along the cycling facility**

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Author keywords: Surrogate safety, Motion prediction, Video analysis, Cycling network discontinuity, Cyclist safety

Road safety assessments use two main categories of data to evaluate the safety of a given location: accident data and other safety related events and behaviors directly observed in traffic. Typically, results are summarized for the specific location: total number of accidents or other events per intersection or road link. This provides a general picture of the location's safety; however, these do not pinpoint specific maneuvers that have a higher risk of collision. It is however possible to study safety at the more microscopic level of road user movements at the site. Few maneuver-specific studies have been carried out. The safety of through cyclists and turning vehicles was specifically evaluated in (1, 2) , which is a step towards understanding risks of specific maneuvers. Our study aims to go further and evaluate the relative safety of all cyclist movements based on their interactions with other vehicles using surrogate measures of safety. To achieve this, a trajectory clustering algorithm is adopted to combine similar trajectories into sets of distinct movements (motion patterns) for cyclists and vehicles.

The Time-to-Collision (TTC) is a surrogate measure of safety that relies on the concept of collision course, defined as a situation in which two or more road users approach each other to an extent that a collision is imminent if their movements remain unchanged. However, the assumption that vehicles will continue straight does not accurately represent real-world behavior where users perform slight steering or major maneuver changes such as turning. Furthermore, this traffic conflict definition is inapplicable in situations where the road user does not have the option to continue along a straight path, for example at a T-intersection. Instead, one can learn motion patterns from observed user trajectories and use them to predict the road user's future positions and compute more realistic and robust TTC. Our study makes use of this Probabilistic Surrogate Measures of Safety framework to measure the safety of the cyclist-vehicle interactions.

Past studies show that at cycling network discontinuities (interruptions in the cycling network such as changes of cycling facility type, end of the cycling facility, change in location of cycling facility on road, etc.), cyclists perform a higher number of movements compared to similar sites without a discontinuity (3). This provides an ideal condition for movement-based safety evaluation. Video data is collected at two intersections with discontinuities, one with a change in cycling facility type and one with a change in cycling facility location on the road, as well as two control sites. Road user trajectories are extracted using the automated traffic intelligence tool on a sample of 2 hours for each location. After automated tracking and classification, the trajectories are further verified and classified manually for safety analysis. Using a clustering algorithm, similar trajectories are combined based on the longest common subsequence providing their percentage of similarity to obtain the main movements, or motion patterns.

Our results summarize the surrogate measures of safety for each movement and compare the safety across movements at the discontinuity site and with movements at the control site. Results are expected to show large safety variations among cyclist movements at the discontinuity locations compared to the control sites.

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Title: **Contribution of a Novel Speed Reduction Equipment to Promote Road Safety**

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Author keywords: Road safety, Speed reduction, Pavement energy harvesting, Intelligent Safety Systems

The World Health Organization states that road accidents are responsible for more than one million deaths and eight million injuries worldwide every year, being the leading cause of death in children and young adults aged 5 to 29 years old. Also, road accidents cause substantial economic loss for society, estimated by the World Health Organization to be up to as much as 3% of gross domestic product in any of the countries studied.

Most fatal accidents occur in urban areas and mostly involve vulnerable road users, especially pedestrians. Approximately 70% of these fatal accidents with pedestrians occur in crosswalks, the place where these should be safe, and the main causes are the excessive speed and inappropriate illumination. When a vehicle hits a pedestrian at 50 km/h, the probability of killing the pedestrian is higher than 50%, but when the vehicle is moving at 30 km/h, this probability is reduced to only 5%. An effective vehicle speed control in urban areas can contribute significantly to reduce the number of accidents, especially the fatal ones.

Nowadays, the most effective solutions to this purpose are based on speed bumps and traffic lights. However, both of these solutions depend on the drivers' behaviour - if the driver doesn't break or reduce voluntarily the vehicle speed, this will not change significantly, although the consequences for the vehicle, its occupants and for the driver. Existing equipment and solutions are not sufficiently efficient and new solutions are needed.

This paper deals with the development of a new speed reduction solution to be implemented on road pavements and which extracts kinetic energy from vehicles, depending on their travelling speed while minimising the impact on the vehicle and its occupants. The main goal is to create a uniform solution that effectively reduces vehicle speed and promotes road safety in an effective manner, without affecting ride comfort and without depending on any driver breaking action. This solution establish a link between vehicles, infrastructure and road users, consisting of an Intelligent Safety System that operates without depending on the drivers' behaviour.

A study is performed to identify the optimal design in order to autonomously reduce the vehicles speed by 20 km/h, making it possible to reduce their speed from 50 km/h, an acceptable speed in the urban environment, to 30 km/h, a safer speed in terms of vehicle-pedestrian interaction. The solution is designed to harvest the maximum amount of energy from vehicle, maximizing its speed reduction, with a minimum impact on its occupants, maximizing the ride comfort.

Besides the system design, an experimental validation of the solution is presented, with a prototype being built and tested. The main goal is to validate the results achieved through computational simulations using the experimental results, proving the concept and feasibility of the new proposed solution. A comparison with typical speed bumps is also performed, in order to technically prove the higher effectiveness of the new proposed solution when compared the most used solution of the present moment.

Conclusions are presented, emphasizing the importance of an effective speed control near crosswalks and the potential contribution of the new proposed system, as well as the expected impact, both in terms of accidents reduction as well as the social and economic cost reduction related to these accidents, demonstrating the contribution of this technology to a safe systems strategy.

Title: **Safety effects of traffic calming on roads through villages: proactive evaluation using GPS data**

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Author keywords: road safety, evaluation, speed, GPS data, traffic calming

Background: Speeding is an international road safety problem; a set of potential measures include physical speed management devices (also known as traffic calming or local area traffic management). However, the safety effects (i.e. expected reductions of speed, and/or frequency/severity of accidents) of these measures are not always known; in addition, they may be highly variable, given the differences in design, configuration, or surroundings conditions. Given these challenges, the presented research focuses on two-lane road sections through small towns or villages. These roads are characterized by high speed prior to built-up area, mixed local and through traffic, and high share of heavy vehicles. These characteristics lead to overlap of commuter/through traffic with local traffic leading to interruptions, dispersions in speed and in result changes in road safety levels. Traffic disruptions and speed changes may also be caused by: intersections located along the road section (with low traffic volumes on entries), numerous accesses (entries and exits to/from the main road), bus stops or pedestrian crossings. As a result, there are more collision points, and the need for speed reduction, stopping, accelerating, etc. In addition, the frequency of the disruptions depends on the land use character, which mainly generates additional traffic.

Aim: The aim of the study is to test a proactive safety evaluation approach, based on GPS data collected from vehicles on selected roads through a sample of small towns or villages in two Central European countries (Czech Republic and Poland), using various measurement techniques. The approach will be applied to compare the effects of selected traffic calming measures; the effects will include impacts on speed, speed variations and safety.

Methods: The collected GPS data will be used to obtain representative speed profiles. These will further enable estimation of speed changes, induced by the studied traffic calming measures, as well as other influential variables, related to cross-section, road surroundings, access, etc. However, while GPS data present a valuable emerging big data source, they have also limitations, e.g. sampling rate, uncertain estimation of free-flow speed, or generalizability to driving population. In order to collect data on drivers' behaviour, test drives for each section will be conducted and analyzed. The measurements will be based on necessary number of vehicle passages through the villages in both driving directions.

Results: The results are expected to show:

- Feasibility (and challenges) of using GPS data for safety evaluations.
- Estimates of speed changes and their relationship to accident changes and/or changes in severity (via so called Power Model).
- Variability of these estimates across different traffic calming scenarios.

Conclusions: If successful, the developed method will enable using GPS data to obtain speed-based metrics. If these prove to be valid against accident changes, they will in turn provide a valuable surrogate safety measure, applicable for proactive safety evaluations.

Title: **Parameters and statistical modeling for comparison of simulated and observed traffic conflicts. A case study on 2+1 road sections.**

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Author keywords: Traffic Conflicts, 2+1 Roads, Surrogate Measure of Safety, Microsimulation

### Background

The literature points out that additional passing lanes and 2+1 roads improve significant road safety. Studies indicate sections with additional passing lanes (relief or alternately), which may cause reduction in the number of accidents by 50%. However, how geometric design affects the safety performance of such sections is not in depth investigated. Previous studies are carried out with two approaches, i.e. the most often, based on analysis of observed crashes and more rarely by using microsimulation study. In the case of microsimulation research, traffic conflict theory can be applied as a Surrogate Measure of Safety (SMofS). By using simulated traffic conflicts, the use of the Surrogate Assessment Module (SSAM) estimates a set of parameters which have to be considered in observed data if a fair comparison has to be carried out. Furthermore, the measure of risk when traffic conflicts are considered as measure of exposure to risk instead of SMofS does not necessary resemble the crash statistical distribution. This was validated in several studies considering traffic conflicts within a certain threshold of Time To Collision (TTC) and considering the largest extreme value theory or the Lomax distribution.

### Aim

One of the main problem in simulated conflicts study is the validation of simulation results against real world conditions. In the field of passing lanes and 2+1 roads microsimulation is in an early phase of application. The aim of the paper is to assess the reliability of traffic conflict measures obtained by microsimulation against real world observations. Besides, given the easiest identification of PET in observed conflicts (instead of TTC), one of the aim of the present research work is, by fixing a threshold value of PET, to study if some distributions can better describe the relationship between observed and simulated traffic conflicts.

### Method or methodological issues

Conflicts were detected and classified from video recording and analysis of vehicle trajectories in the merging area on 2+1 roads in Poland. Starting from that data, trajectories were extrapolated and conflicts detected and analyzed. Conducted studies focus only on lane changing conflicts, locations and PETs values of observed conflicts between vehicles were primarily identified. Particularly their values need to be further corrected. Observed conflicts are than used as dependent variable to estimate the expected number of conflicts using as covariate the microsimulated one, to assess if there is a correlation in the two. Simulation is carried out in VISSIM<sup>®</sup>, calibrating models with experimental data related to traffic operation parameters, and trajectories are analyzed using SSAM. To estimate the probability of observing a traffic conflict conditioned on the occurrence of a simulated one with a certain value of PET, different statistical distributions will be tested. Simulated and observed traffic conflicts will be selected setting different PET thresholds.

### Expected results

The validation of the microsimulated traffic conflicts as SMofS is one of the main objectives of the present research work. The ground truth provided by observed traffic conflicts will be used either for the validation of the microsimulation analysis or for the study of other possible distribution in the relationship between observed and simulated traffic conflicts when a PET threshold is selected.

#### Conclusions

The paper presents an in-progress research work to define a new approach to the validation of microsimulation models with observed conflicts. As first step in the analysis it represents a good starting point for future analysis by taking into account that a perfect validation of a microsimulation model will allow to apply a proactive approach to evaluating road safety at the end of passing lane for 2+1 roads using microsimulation approach. Furthermore, the use of observed traffic conflicts to estimate safety, requires an established connection between observed and simulated conflicts, with the right statistical inference and approach to estimate the risk of observing a traffic conflict given the occurrence of a microsimulated one with a certain PET value.



## **Session VI**

# **NATURALISTIC DRIVING**

Title: **Using naturalistic driving data to evaluate speed limit reductions: energy, environmental and safety assessment**

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Author keywords: vehicle monitoring, driver behavior, speed limits, drive cycle adjustment, energy impacts

Driver behavior is intrinsically connected with vehicle performance, directly influencing its energy, environmental and safety outcomes, which is particularly relevant at urban level. This research work focuses on exploring naturalistic driving data to evaluate the possibility of adjustable speed limits and assessing its impacts regarding energy, environmental and safety outcomes. For this purpose, a sample of 10 drivers was monitored for a period of one month in the Metropolitan Area of Lisbon using an on-board data logger. A numerical tool was developed to modify the sample's second-by-second vehicle power requirements and by imposing lower speed limits based on the hierarchical street levels. The application of the developed numerical tool to the collected sample confirms the possibility of using adjustable speed limits to improve safety. As example, for the 120 km/h drive cycle limitation, results show potential average speed reductions of up to 8%, coupled with an energy consumption reduction potential that can reach 15%. Further analysis will be explored in the full paper.

## 1. Introduction

Driver behavior is intrinsically connected with vehicle performance, directly influencing its energy, environmental and safety outcomes. This is particularly relevant at urban level, due to health impacts associated to air quality, as well as driver and pedestrian safety. Also, influencing driver behavior constitutes a very difficult task, due to deeply rooted habits and perceptions associated to the activity of driving. However, emerging technologies can play an important role in this framework, by providing useful information regarding vehicle use that can be used to provide tailor-made feedback to the user, as well as by forcing or limiting driver behavior. Having this in mind, one alternative solution can include adjustable speed limits according to factors such as time of day, traffic, weather, among others, with consequent impacts in terms of road safety improvements. This research work focuses on exploring naturalistic driving data to evaluate the possibility of adjustable speed limits and assessing its impacts regarding energy, environmental and safety outcomes.

## 2. Methods and data

To accomplish the objectives of this work, firstly, a sample of 10 drivers was monitored for a period of one month in the Metropolitan Area of Lisbon using an on-board data logger, the i2D device. The i2d device acquires 1 Hz data on vehicle dynamics (speed, acceleration, etc.), engine data and also location information. This dataset was coupled with data regarding the road type (defined by hierarchical street levels, from level 1 –arterials – to level 4 – local streets).

Secondly, to assess the impacts of adjustable speed limits, a numerical tool to adjust real world drive cycles was developed. This tool was developed in Matlab® to modify the sample's second-by-second vehicle power requirements and by imposing lower speed limits based on the hierarchical street levels the vehicle was circulating.

The outcomes in terms of total driving time (for the same distance), average speed (km/h), energy consumption (g/s and l/100km) and energy consumption reduction potential (%). Also, the possible safety gains of implementing such measure are also discussed.

### 3. Preliminary results and conclusions

The application of the developed numerical tool to the collected sample confirms the possibility of using adjustable speed limits to improve safety. Additionally, for the 120 km/h drive cycle limitation, results show potential average speed reductions of up to 8%, coupled with an energy consumption reduction potential that can reach 15%. Further scenarios will be explored and assessed in the full paper. Summing up, using naturalistic driving data brings new opportunities to characterize and to evaluate driving behavior, which can be easily translated in road safety improvement.

Title: **Using naturalistic driving data to model crash risk at a city level**

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Author keywords: naturalistic driving data, driving behavior, crash risk, binary logistic regression

1. Introduction Research suggests that driving behavior is a contributory factor in over 90 percent of crashes. Consequently, identifying the driving behavior that represents greater risk of involvement in a crash brings significant benefits to reduce road accidents. A number of methods have been applied including focusing in demographic profiles, self-reported behavior and risk preferences and personality and risk perceptions. However, results from these methods generally are based on small number of observations and may be under or over-predicted. In contrast, data collected during real world driving (naturalistic driving data) provides information on driving behavior across time and space, generating a great amount of observations for each driver. Considering this, the aim of this research work is to explore the association between driving behavior and crash occurrence, using naturalistic driving data to model the crash risk at a city level.

## 2. Methods and data

To accomplish the objectives of this work, firstly, a sample of 46 drivers was monitored for a period of at least six months in the Metropolitan Area of Lisbon using an on-board data logger, the i2D device. This device allows acquiring 1 Hz data on vehicle dynamics (speed, acceleration, etc.), engine data and also location information. With this data an extensive database was built, including data on the road type (defined by hierarchical street levels, from level 2 – minor arterials – to level 4 – local streets). To integrate the extensive database with crash data the authors followed a method focused on the city rather than on the driver. Therefore, driving data from all drivers were aggregated per street allowing to characterize driving behavior for each street at a city level. This database, with average driving parameters per street, was then merged with the crash database which is also street-based. Afterwards, a binary logistic regression was performed to model the crash risk as a function of several driving behavior parameters. The factors that were included in the model ranged from percentage of time spent in different speed bands, average acceleration and deceleration, percentage of time drivers accelerate or decelerate in different acceleration values, vehicle specific power (VSP) distribution, percentage of time spent in aggressive driving, among others.

## 3. Preliminary results and conclusions

Preliminary results reveal the existence of an association between driving behavior at a street level basis and crash risk. It was found that deceleration related parameters, such as percentage of time spent in VSP mode 1 (which occurs either for higher negative slopes or for more extreme deceleration events) and average negative VSP (comprehending all situations with negative slopes and deceleration events), are influential in predicting the crash risk. Furthermore, as expectable, the likelihood to have a crash in level 2 and 3 streets is higher than on more local ones (level 4). However, oppositely to authors' beliefs, even if non-significant, an increase in aggressive driving (defined by acceleration thresholds as a function of speed) was found to decrease the odds of outcome being crash. Higher percentages of time spent in aggressive driving are typically found for level 2 and 3 streets (comparing with level 4 streets); therefore, an increase

in aggressiveness was expected to increase the odds of crash outcome. Further analyses must be performed to assess this result.

Concluding, naturalistic driving data provide detailed data allowing performing in-depth analyses that were not possible until these large databases become available. This data will give a better knowledge on driving behavior allowing a more efficient selection of the measures to focus on future training assets in order to improve driving behavior and, consequently, reduce crash risk.

Title: **Quantitative analysis of rear-end crashes and near crashes in a commercial fleet in Shanghai**

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Author keywords: Glance behavior, Looming, Naturalistic driving study, Road safety, Time Headway

#### Background

Previous research conducted in Western countries concluded that rear-end conflicts occur due to a combination of off-path glances (e.g. towards in-vehicle devices or mirrors) and the simultaneous rapid change in the situation kinematics, manifested by an increase of visual looming. More detailed quantitative analyses – conducted to better understand the factors behind rear-end crashes and to develop countermeasures – reported the following results:

The mean duration of last off-path glances before driver's reaction (e.g. braking) was 1.84 seconds for crashes and 1.51 seconds for near crashes.

The mean time headway to the lead vehicle at the start of the last off-path glance was 2.62 seconds for crashes 2.54 seconds for near crashes.

The mean value of inverse time to collision or looming increased from 0.17 seconds to 0.52 seconds for crashes and from 0.07 seconds to 0.19 seconds for near crashes, in the time elapsed between the start and the end of the last off-path glance.

#### Aim

Similar quantitative analyses have not been conducted yet for rear-end conflicts in China. To fill this research gap, this paper aims to: 1) assess drivers' off-path glances and kinematic relevant parameters (e.g. looming) in rear-end conflicts occurring in a commercial fleet in Shanghai; 2) compare the results to previous studies conducted in Western countries. Those analyses will provide interesting results for the development of active safety systems and autonomous driving in China.

#### Method

The dataset analyzed in this paper includes 51 rear-end near crashes and crashes (CNC) collected during a 12-months naturalistic driving study, involving 47 commercial vehicles in Shanghai. All vehicles were equipped with a Video Event Recorder (VER) which integrated a variety of sensors and stored safety critical events every time a strong longitudinal or lateral acceleration was triggered. The safety critical events had a duration of 12 seconds – 8 seconds before and 4 seconds after the trigger – and the collected information included videos of forward and driver view cameras (4 Hz sample frequency), longitudinal, lateral and vertical accelerations (20 Hz sample frequency) and speed (1 Hz sample frequency).

The videos of the front and driver view cameras from the 51 rear-end events were coded to extract the following variables:

On-path and off-path glances

Kinematic parameters such as the optical angle  $\theta$ , optical expansion rate  $\dot{\theta}$ , the inverse time to collision and the time headway (THW)

## Results

The results reported in this section consider together crashes and near crashes – referred as CNC – given the small number of crashes available in the dataset.

The cumulative distribution of time spent by drivers to look at different locations shows that on-path glances occurred for almost 80% of the time in the overall dataset. However, looking at each event individually, the results illustrate that drivers' off-path glances were present in 70.8% of CNC and, for those events, the mean duration of the last off-path glance was 1.16 seconds.

With respect to the time headway, the results show that its mean value was 1.29 seconds at the start of the last off-path glance. So, most drivers (87.5%) started to glance off-path despite the THW was short, defined as smaller than 1.75 seconds.

Finally, smaller values of mean inverse time to collision were found at the start of last off-road glance (0.03 seconds) compared to its end (0.10 seconds). This result indicates that, in average, the criticality of the situation increased while the drivers were looking away.

## Conclusions

The analyses show that, among Chinese drivers, off-road glances are rare and when they occur, their mean duration (1.16 seconds) is lower compared to previous values found for near crashes in Western countries (1.51 seconds). Besides, those off-path glances start at an average value of time headway (1.29 seconds) which is much shorter than the corresponding one found for near crashes in Western countries (2.54 seconds). Finally, the mean value of inverse time to collision in the present dataset assumed smaller values both at the start (0.03 vs. 0.07) and at the end (0.10 vs. 0.19) of the last off-path glance compared to the results reported for near crashes in Western countries.



# Poster Sessions

Title: **Effectiveness evaluation of in-vehicle warning system under reduced visibility conditions: a driving simulation study**

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Author keywords: driver's behavior, driving simulator, ADAS assistance, low visibility, foggy conditions

Background: There is wide state of art that addresses the issue of reduced visibility due to fog. Many researches use the correlation between traffic and the wear data to study this phenomenon, other employ the real-time data to investigate how foggy conditions affect the driver's behavior up to lead to accidents. In recent times, the progress of technologies in this field allowed to develop more and more tools to support the driver in the driving task under reduced visibility conditions.

Aim: In this regard, the main objective of this research aims to evaluate the effectiveness of in-vehicle warning systems in low visibility conditions due to fog by means of a driving simulator study.

Thus, this study will test ADAS assistance influence on driving behavior in foggy weather, in particular by using the Head-Up Display (HUD) technology (a type of in-vehicle HMI).

The driving simulator experiment is conducted employing an intersection and pedestrian detection assistance to send warnings to the driver when approaching respectively an intersection and pedestrian crossing. A combination of both audio and visual warning will be employed to alert the drivers during the experiments (based on literature findings that shows greater efficiency in double signal instead of single signal). The objective will address the assessment of effectiveness of HUD under reduced visibility condition, compared to no warning system.

Method: Thanks to the driving simulator, an advanced tool able to record all the driving parameters of a sample of drivers in a virtual reality environment, it is possible for this research to explore crash risks of specific drivers' behaviors, such as car following, lane departure, approaching to intersections and pedestrian crossings, keeping same wear foggy conditions for all the drivers.

In fact, the scenarios, designed according to the Italian rules and regulations, have the following weather characteristics:

§ Scenario 1: clear visibility condition;

§ Scenario 2 and 3: the same reduced visibility condition characterized by an initial clear zone (approximately of 300 m length), followed by a constant 85 fog zone, in which the level of fog was alternately moderate (such as 100 m) and heavy (such as 50 m).

The data analysis is composed by two phases in order to enable a comparison firstly between drivers' behavior under reduced visibility conditions and clear visibility conditions, and further between drivers' responses under reduced visibility conditions with and without in-vehicle warning system. Each comparison was assessed related to different road sections: one consists in approaching an intersection and pedestrian crossing element, and the second one is simple section where the participants have to drive under normal and free flow conditions, that means no external conditioning (due to the presence of critical road elements) and low vehicle interference. All the analyses are conducted for two different bibliographical

indicators, i.e. kinematic and dynamic, which are able to measure the potential alterations in driving performance.

Summarizing, the data analysis is develop in three steps listed below:

- Analysis 1: NO FOG and FOG “no interference” on road segments;
- Analysis 2: NO FOG and FOG in approaching to pedestrian crossing and intersections;
- Analysis 3: FOG and FOG+HUD in approaching to pedestrian crossing and intersections.

Results: Due to progress in the areas of information and communication technologies, it is expected that in-vehicle warning information can play such a helpful role. Once established that fog conditions affect drivers' behaviors in terms of speed reduction (around -15%), headway distance reduction (-42%) and with a significant decrease in time to arrival to critical elements, the results shows also the effects of in-vehicle warning system, considering in particular HUD technology, in case of approaching to intersections and pedestrian crossings.

Conclusions: The in-vehicle warning information provides by HUD (image and audio) before approaching to intersections and pedestrian crossings may help drivers get better prepared by harmonizing their speed. In particular regarding drivers' braking process, it was found that HUD assistance in approaching to intersections produces the effect of controlling the use of the brake pedal better than in approaching to pedestrian. Thus, it suggests that drivers are more sensitive to visibility reduction when they are driving in approaching to pedestrian crossings, then to intersections.

Title: **Using data from a smartphone app to analyse distraction and drowsiness of drivers**

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Author keywords: Drowsiness, Distraction, Smartphone, Safety, Human factors, Driver monitoring system

## BACKGROUND

Driver distraction and drowsiness have received increased attention during recent years due to the rapid increase in vehicle automation technology that impact on the driver behaviour. Driver distraction and drowsiness contribute to approximately 5–25% of all crashes (European Commission 2015) and around 20% of all fatal and severe crashes (Connor et al. 2002, Kecklund et al. 2011), respectively. These types of driver behaviour are associated to a degraded driving performance as well as to a significant detrimental of the cognitive performance (e.g. reaction time) and therefore, to a negative impact on road safety (Sweeney et al. 1995, Atchley et al. 2017, Fitzharris et al. 2017). Traditionally, safety research is supported on traffic crashes and/or traffic conflicts data. However, reports from traffic crashes and conflicts do not always capture the full dynamics and the conditions under which an event has occurred, particularly if the driver behaviour is the focus. Consequently, other research methods have been applied namely naturalistic (Hanowski et al. 2005; Socolich et al. 2013) and driving simulator studies (Oviedo-Trespalacios et al. 2017; Papantoniou et al. 2015). However, these studies are both complex and costly to conduct and as a result are frequently of small size.

## AIM

In this context, the present study introduces a novel approach by exploring data of driver-monitoring systems (DMS) vendor supported on a smartphone camera-based application freely available for the general drivers' population. The DMS solution emits an alert when detects distraction or drowsiness of the driver, storing a set of information of that event (timestamp, a GPS position, the instant speed of the vehicle and the type of the alert). Moreover, information about the journey (e.g. date and time of the start and end of the journey), the driver age and sex were also collected. Deidentified data were extracted from the DMS vendor' database. It should be noted that the research team did not supervise the DMS implementation process, neither data collection and management. Retrospective data obtained under these circumstances, we named 'opportunistic' data.

## METHOD

In order to full explore the retrospective data, two distinct analyses were performed: 1) clustering analysis to identify drivers' profiles and 2) a generalized linear model (GLM) to identify risk factors associated to alerts. A data treatment and rearrangement were performed and at the final, a dataset was obtained including 489 drivers to which correspond 1008 observations when aggregated the alerts by driving record. These 1088 driving records correspond to the observations modeled by the GLM, in particularly a binomial negative model. To this analysis, variables such as the number of alerts per journey (dependent variable), journey time, journey breaks, breaking duration time, age and sex of the driver were used. On the other hand, several measurements were created to be used as inputs for the clustering analysis which was based on the Hierarchical Clustering Approach (HCA) and the K-means (KM) method.

## RESULTS

The application of the hierarchical approach led to the plausible number of significant clusters between 3 and 10. Additionally, the Silhouette validity index suggests three clusters (S.C. = 0.292). A separation among the three clusters with respect to the number of inattention events is evident. One cluster is composed of all the drivers in the dataset that did not raise any alert (39% of the drivers), meanwhile another cluster is

composed by 23% of drivers with the greatest number of alerts and the highest values respect to the exposition variables (time and distance related variables).

Using the number of alerts separated by distraction and drowsiness as dependent variable of the two models, distraction and drowsiness models, we found that journey time has a similar effect on both distraction and drowsiness alters, indicating that increasing 10% of the time of the journey, the distraction and drowsiness alerts increase 6% and 5%, respectively, *ceteris paribus*. Additionally, increasing the number of stops during the journey, the distraction and drowsiness alerts decrease however, the elasticity of this impact is not constant, being the alerts frequency sensitive to the magnitude of the number of breaks. Results show that age and sex variables have different effects on alerts of distraction and drowsiness.

## CONCLUSIONS

This study explored 'opportunistic' data to investigate driver behavior and profile. The findings show that this type of data has potential to be explored to road safety studies. The data and its analysis should be seen as complementary to other studies using controlled methods of data collection (e.g. naturalistic and driving simulator studies), at least at this early stage of data exploitation gathered from emerged technology.

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Title: **The use of alternative transport means in city centers: insights from an observational survey**

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Author keywords: Alternative transport means, urban intersections, presence, behaviour

## Background

Alternative transport means (ATM) such as e-bicycles, electric scooters, mobility scooters and segways - were designed to improve mobility of individual road users. ATM are suitable for short trips in urban areas, with associated benefits of improved accessibility, reduced traffic congestion, lower energy consumption, etc. However, the urban space is not adapted to incorporate the new means. The ATM use traffic settings built for other road users and not always in accordance with traffic rules, which leads to conflicts between various road users and increases injury. There is a need to characterize the current situation and to consider solutions for the ATM integration into urban space.

## Aim

This study collected empirical data aiming to estimate the scope of ATM use in Israeli cities and to characterize their behaviors in interaction with urban settings and other road users.

## Method

The data were collected by means of an observational survey at 50 representative urban intersections, in nine cities. The sample included 10 roundabouts, 10 signalized intersections on urban arterials and 30 on collector streets; all in vicinity of city centers. The survey was conducted during the main hours of urban activities, 8 AM-8 PM. Three layers of data were collected: (1) full counting of the ATM entering a junction; (2) periodic sampling of background data – motor vehicles, pedestrians, regular bicycles, from each direction; (3) main characteristics of the ATM users (age group, gender, place of riding, etc.). The data were collected manually, by two trained observers, who stayed 6 hours at each site.

The count data were processed to produce hourly figures, per site and per type of sites. The indicators of presence of various ATM were estimated relative to vehicle and pedestrian traffic. Pearson correlations were examined and statistical models were adjusted to explore the relationships between the presence of various road users. Characteristics of the ATM users were analyzed to create their profiles, at various types of sites.

## Results

The average hourly numbers of e-bicycles at signalized intersections were around 50, at roundabouts – 23, but vary widely; at some sites, about 80 e-bicycles were observed, per hour, on sidewalks or on the roadway. The average hourly numbers of other ATM types were lower, in the range of 1-3. The extent of e-bicycle traffic was generally similar to that of regular bicycles. At all types of sites, the presence of regular and e-bicycles was low related to motor vehicle traffic, with average ratios of 0.5%-0.6% for regular bicycles, 0.7%-1.3% for e-bicycles. The presence of both bicycle types was more tangible on sidewalks: related to pedestrian traffic, they constituted about 2% at roundabouts, 6%-8% at signalized intersections on urban arterials and 4% - on collector streets. As found, more e-bikers choose to travel on roadways at roundabouts and on collector streets, while on arterial roads they prefer to travel on sidewalks. Also, more mobility scooters were observed at roundabouts than at signalized intersections. Apparently, such results reflect a tendency to choose "safer" travel conditions.

The correlation analysis and the models for predicting the ATM presence showed that regular bicycles, e-bicycles and all ATM together appear at the same sites of the city as motor vehicles and pedestrians, i.e. indicating a direct relation between the presence of “traditional” and new road users. A difference was found for mobility scooters, which mostly appeared at the same sites as pedestrians, but their numbers dropped at sites with higher vehicle traffic. In addition, at sites with higher traffic volumes, more e-bicycles rode on sidewalks.

Among the users of e-bicycles, scooters and segways, children up to 18 presented about a third, while the majority were young adults aged 19-34 (similarly to some European studies). As expected, the age groups of mobility scooter users were different, with the majority being 65+. Most ATM riders did not use helmets, thus increasing injury risk.

#### Conclusions

The ATM volumes in the cities are not negligible. ATM are used for the same travel destinations as traditional transportation means. For safer ATM integration in the cities, more bicycle facilities and wider sidewalks are needed, together with enforcement and publicity.

Title: **Quality of pedestrians' mobility: exploratory study in Coimbra**

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The literature on human factors and road user behavior in road and transport design is extensive (Papadimitriou, Lassarre, & Yannis, 2017). Compared to other road users, human factors related to pedestrians have received somewhat less attention in the literature. This prevalence stands out although it is often underlined that road and traffic factors alone may explain only a small part of pedestrian walking and crossing behavior in urban areas (Papadimitriou, 2012). Increasing the share of walking and cycling instead of using the car on short trips contributes to sustainability: It is cheap both for the individual and for society (economy), and it helps to protect the environment (ecology) and it supports the quality of urban life and health.

Despite the improvement in road safety in recent years, road accidents and their consequences remain a serious social problem (Ribeiro, 2010). In 2015, 5.435 pedestrians were killed in road accidents in the EU (excluding Lithuania), which is 21% of all road fatalities. On 27th of January 2017, the Portuguese Social Communication (Jornal de Noticias) reported that between 2015 and 2016, in Portugal, there were 3,618 pedestrian accidents with an average of five road deaths per day. Data published by the Portuguese National Road Safety Authority indicate that in 2016, 5 537 were pedestrian victims of accidents of whom 82 were killed.

The need to face off pedestrian is growing as a central element of the urban rail system. As a principal actor, the pedestrian deserves to see spaces where can circulate freely, practice activities and calm walks. It is known that the behavior of road users is influenced by a wide range of factors such as their personality, physical and emotional state, culture, social status and mobility options (origin and destination of their journeys, mode of transport). These aspects must be considered when design and planning urban mobility systems, that should be fair and universal, sufficiently flexible and adaptable to the needs and desires of everyone (Ribeiro, 2010).

Some already studied factors that influenced the ambiently capacity of the road are, for example, the probability of abusive parking as well as the quality of the sidewalk (Buchanan, 1963; Ribeiro, 2010). It is only accounting for all risks associated with conflicts between them and motor vehicles that it is possible to try to provide greater safety and comfort to the pedestrian circulation (Buchanan, 1963; Ribeiro, 2010).

The main purpose of this study is to describe pedestrian' habits and characterize subjects' perceptions of pedestrian quality in Coimbra. We also aimed to study the difference of perceptions between group age and by high lightening the main reasons why walking is a very little practiced activity and what changes are needed to make to increase pedestrian quality. Coimbra is a Portuguese city in the Center Region of Portugal. Is a historically university town and currently has more than 30,000 students that make walking a way of life.

For the purpose, the questionnaire -Life Quality of Pedestrians-LQP was adapted from the work of Ausserer, Fuessl, Risser & Chaloupka-Risser (2013) entitled "What makes walking attractive and what keeps people from walking". It was filled by 130 subjects. Descriptive and frequencies analysis were carried out, revealing that 67.7% were woman and 24.6% men, between the age of 18 and 85 years old ( $N=129$ ;  $35.40 \pm 13.32$  years old). Most of the subjects were employed (48.5%) and studying (26.2%), were natural of Coimbra (67.7%) and resided in the periphery of the city (60.8%).

The results show that most subjects reported like walking, with 18.5% reported they like very much and 4.6% reported they didn't like it at all. Regarding the frequency of walking during the week, it was higher than on the weekends, which can be due to the transportation to and from the workplace/study. It also seems that students walk more frequently than employed subjects, which can be due to the lack of driver's license or lack of car ownership.

When inquired about the main situations that disturb walking, most relevant complaints were: cars travelling too fast, dirty sidewalks (e.g., dog excrements, garbage...), drivers that do not stop at crosswalks, cars parked on sidewalks, insufficient green areas for rest in public spaces, public roads with little or no lightening, high amount of car traffic, among others.

Our study lead us to the conclusion that there a strong need for socio-cultural change in walking habits, as such an increase of actions, combining human, engineering, psychological, social and economic fields leading to the consideration of the pedestrian as an important road user and the increase of its quality of life and reduction of their vulnerability. The Traffic-safety work of the future will have to focus more on specific traffic safety problems of pedestrians and their involvement in the city

Title: **The interface of Transport and Health Engineering for the understanding of Brazilian urban mobility from the perspective of the elderly person**

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Author keywords: seniors, equity, senility, urban mobility, social inclusion

#### Background:

From the middle of the 20th century, Brazil began to experience a new social geography due to the migratory flow, causing people to seek the transition from rural zone to urban. As a result of this migratory movement, a marked urbanization process was observed, often in a disorderly way, and also demanded the expansion of the transports supply. Depending on the mobility model, inequities can be intensified considering the value of tariffs or when there is a restriction of the supply of transportation in peripheral areas. The challenges of mobility are still accentuated by insufficient investment or poor public management. Other factors that impact mobility are the demographic transition and the morbidity and mortality profile. In Brazil, public transportation is free of charge to those over 65, but it is emphasized that the transportation is basically funded by the paying passenger and the with gratuitous the expense ends up having a tariff impact inflating the value of the tickets. Although it is the result of social conquest, gratuitousness is a challenge for managers. It stands out the close relationship between urban mobility and social development and, considering public transport and its supply as social goods, recruits the theory of the spheres of justice, perceiving justice as the creation of a political community in a given understanding an egalitarian society oriented by an egalitarianism linked to freedom in which no good can serve as a domination. Based on the assumption that people have differentiated needs and expectations regarding mobility and that transport is a basic condition for access to services, it is inferred that the theme needs to be approached in the light of citizenship, equity, social inclusion and life.

#### Aim:

To argue as to the need to carry out studies that deal with urban mobility from the interface of Transport and Health Engineering, including the right to the city, road safety, transport behavior, traffic epidemiology and life cycle.

#### Method or methodological issues:

Theoretical study using as a method the review of the literature and, additionally, the reference chain technique extensive to scientific articles having as inclusion criteria articles from the areas of Transport Engineering and Health (Gerontology), institutional documents and normative letters. For the treatment of the findings, the content analysis was used.

#### Results obtained or expected:

There are several ways of perceiving and experiencing old age. From the point of view of legislation, reading is chronological, however, when taking into account subjective variables, it is not an easy task to demarcate when the age-old phase begins in the life cycle. There is also the distinction between senescence and senility. The first is a sequential, cumulative and non-pathological process and occurs for all; the second is related to the aging marked by physical decline and mental disorganization.

The aging process is sensitive to social determinants. Considering the intersection between Transport Engineering and Health, urban mobility and traffic are perceived as social determinants impacting on access to services, possibilities for social interaction, belonging to the city and epidemiology inherent to the elderly segment

It is important to point out that technological advances in the daily life of the elderly, considering the characteristics of the age group, can create barriers in their interaction with the urban space, in this way the knowledge of the physiological and cognitive components inherent to the elderly population can contribute to the decisions regarding the urban setting.

Considering the transit, the high prevalence of the elderly population in the accident outcomes stands out. Even if death is not verified, an elderly victim who survives an accident is temporarily or permanently disabled, so it is important to create protective measures aimed at this segment, especially in the case of pedestrians.

Conclusions:

When addressing the theme of urban mobility from the perspective of the elderly, it is necessary to consider the specificities of this population. Studies that establish the interface between Transport Engineering and Health can favor the understanding of this universe, its demands and challenges in the attempt to mitigate them. It is intended, in addition to this study, the application of surveys with the reference population in order to obtain more robust results in addition to the theoretical appraisal.

Title: **The tale of two pedestrian deaths : A first of sorts**

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Author keywords: Pedestrians, self driving vehicles, accident information

The death of Bridget Driscoll (44) was the first recorded case of a pedestrian being killed in 1896 with a motor car in United kingdom. She, along with her teen aged daughter and a friend were crossing a road in palace grounds in London was stuck by a demo ride car with a low-speed engine belt that can travel at 7.2 km/h belonging to Anglo-French motor carriage company. The Jury after a long inquest returned a verdict of an accidental death. The Coroner in whose jurisdiction the death occurred said he hoped such a thing would never happen. Even though a century and two decades passed by since the first death, about half a million persons got killed in UK roads and 30 million persons in the world.

In 2018, the current state of art is self driving autonomous cars. Long list of tech companies and car makers expand their testing and Uber is one of them. When Elaine Herzberg (49) purchased her kitchen items, filled her bags and was walking her bicycle on a Sunday night at 10 PM in a clear and dry weather, she would have never thought that in her city of Tempe, Arizona in US, where robots roam, the self driving vehicle will silence her to death that night. She is the first recorded case of a pedestrian killed by a self driving autonomous vehicle.

There are several similarities and differences surrounding these two pedestrian deaths happened 120 years apart, in these days of growing citizen journalism , provides rich insights into accident information that is intended to be captured in this paper.

Title: **Pedestrians behaviour at unsignalized crosswalks: comparison of results based on simulated urban environments with field observations**

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Author keywords: Pedestrians behaviour, Pedestrians trajectory, Crosswalk, crossing speed, Simulated environments, Virtual environments, Urban areas, TTC

Studies addressing Vulnerable Road Users, particularly pedestrians, are relevant to increase safety in view of the tragic safety statistics and the increasing focus on accommodation of non-motorized road users in our transportation systems. In the EU, 21% of all traffic fatalities are pedestrians. The largest share of these are 65 or over and occur in urban environment. Therefore, questions about pedestrian safety, the interaction of pedestrians and motorized traffic, as well as their operational effects, need to be explored. A thorough understanding of pedestrian behaviours in urban environments and the risks faced by them, especially at unsignalized street crossings is lacking. The analysis methods of the pedestrians' behaviour pass through sophisticated simulation methods, due to their ability to replicate variability, to consider system effects, and to allow the analysis of extremely dangerous scenarios. However, the consideration of pedestrian behaviour in simulation is currently limited and is recognized as one of top ten key research needs in traffic simulation.

This research is a part of the project AnPeB - Analysis of pedestrians' behaviour based on simulated urban environments and its incorporation in risk modelling and aims at comparing the pedestrians' behaviour on simulated urban environments with field observations.

Therefore, two intersection crosswalks with different traffic and pedestrian flows were selected for describing pedestrians' behaviour and traffic characteristics in real environments. This information was used to parameterize the inputs of two simulated environments, to replicate the real ones. Preliminary experiments with real pedestrians were run and their results were compared with real data for their own validation.

To characterize the pedestrians' behaviour and vehicles' operational conditions the software Traffic Intelligence, developed in the scope of an European project, was adapted and used. This software uses video images to identifies pedestrians and vehicles through the automated analysis of video recordings and registers their trajectory in time allowing the calculation of speed, acceleration and also several surrogate safety indicators which relate vehicles with pedestrians, such as Time-to-Collision (TTC).

The behaviour of the drivers when a pedestrian approaches a crosswalk was categorized by stopping, slowing down and continuing. For each category, speed-time models were developed to be implemented in the virtual environments. The pedestrians' behaviour was characterized by their speed and acceleration before, during and after crossing the street. Finally, the TTC was calculated at several pedestrians-conflicting vehicle positions.

Meanwhile, the urban environments were constructed to replicate with reliability the two selected intersection crossings and their surroundings. BlenderTM 2.79 was used to construct the virtual scenarios, while BlenderTM 2.69 was used alongside with BlenderTM VR to project the scenarios on the CAVE system. This system is composed by 3 chip DLP projectors Christie Mirage S+4K with resolution up to 1400\*1050

pixels, with frame rates locked at 96 Hz and stereo projection using active shutter 3D glasses. Additionally, the experiment stimuli were constructed to replicate the behaviour of the drivers.

Ten pedestrians participated in the experiment, five females and five males, all voluntary participants, recruited via academic institutions. The experiment was composed by two parts: one static and another dynamic. Therefore, for the same stimuli, pedestrians were asked to indicate when they would start crossing by pushing a trigger and, afterwards, they were asked to actually cross the simulated street and their movements were recorded with Vicon<sup>®</sup> motion capture system.

From this experiment it is expected to be able to replicate the pedestrians' behaviour by comparing crossing speeds and TTC. If not, suggestions will be made to improve testing protocols. With this tool validated, further experiments will be carried out to identify with reliability pedestrians risk factors when crossing a street.

Title: **The relative impact of cyclists' appearance and infrastructure layout on speed and lateral distance while overtaking bicyclists: a simulator approach**

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keywords: overtaking bicyclist, proximity, stereotypes, salience, infrastructure layout

For most cyclists, being overtaken by a car feels uncomfortable. In recent years though, cycling infrastructure is brought from the pavements onto the streets to prevent accidents between straight-cycling cyclists and right-turning drivers. In the present two studies, we examined the influence of infrastructure layout on drivers' speed and lateral distance while overtaking bicyclists in urban scenarios. Gaze behaviour of drivers will be analysed as well. Two within-subject design studies are at the moment conducted in a static driving simulator. In the first study, lane markings for cyclists were varied in three conditions: no marked cycling infrastructure, dashed lines (where German drivers are allowed to drive on the marked cycling path; Radfahrerschutzbereich), and solid lines (where German drivers are not allowed to drive; Radfahrstreifen). In this study, we also attempt to replicate the effects of cyclists' appearance on overtaking manoeuvres, reported by Walker and colleagues (Walker, 2007; Walker, Garrard & Jowitt, 2014) in their naturalistic observations. In the second study only infrastructure, especially street and lane width, as well as lane separation, is varied. As data collection is still ongoing, results and implications are presented at the conference. To our knowledge, this approach to examine the effects of infrastructure layout on cyclists-related behaviour in a controlled experimental setting has not been used before, but is rather promising as new layouts as well as assistance systems may be tested in the simulation before (expensively) building them in reality.

Title: **Exploring cyclist behavior at signalized crossing: perspective of cyclist-pedestrian conflict analysis**

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Author keywords: Cyclist behavior, Cyclist-pedestrian conflict, Dedicated bike lane, Signalized crossing, Video-based analysis, Mixed logit modeling

To develop safer and friendlier environments for cycling and walking has received increasing attention to foster sustainable transportation, particularly from the perspective of transforming street design. The growing popularity of cycling also induces the argument over the right of way for cyclists: sharing lanes with motorized vehicles exposes cyclists to the risk and pressure of interacting with those faster-moving vehicles, while riding on sidewalks leads to potential conflicts with pedestrians. Hence, many cities have deployed dedicated bike lanes to separate cyclists from other traffic flows in light of the described development trend and safety concerns, aiming to establish well-connected cycling routes or networks and thereby encouraging the use of greener mobility.

However, the effectiveness of dedicated bike lanes is questioned in terms of their utilization rates. Especially, for those built on sidewalks, it is frequently observed that some cyclists still ride on the areas of pedestrian walkways; on the contrary, there are also pedestrians walk on dedicated bike lanes. As cyclists and pedestrians have different movement characteristics, conflicts between them seem to remain. Nevertheless, such cyclist-pedestrian conflicts are comparatively minor in general, and therefore few records of them are made, which presents the challenge to better comprehend the behavior of cyclists and pedestrians. Likewise, current design guidelines are primarily based on conceptual principles but lack theoretical understanding and explanation from the perspectives of road users.

This research seeks to explore the behavioral patterns related to cyclist-pedestrian conflicts against the presence of dedicated bike lanes, to provide both empirical and quantitative insights for the current design guidelines. Upon the consideration of data collection, this research focuses on the cyclist-pedestrian conflicts occurring at signalized crossings, where higher frequencies of conflicts are expected. The design of flow separation at signalized crossings can affect the performance and safety level of the associated network, while how to effectively manage intense interactions between heterogeneous flows within limited space de facto depends on how road users respond to the presented environment.

In this research, we film video streams over the signalized crossings around a university campus in Taipei, Taiwan. Heavy cyclist and pedestrian traffic can be observed at the selected signalized crossings, as college students can be one of the major cyclist groups; among some of these crossings, the average crossing traffic can attain nearly 100 bikes and more than 150 pedestrians per minute for one direction during peak hours, which can result in a great degree of flow weaving and probably the consequence of collision.

Based on the recorded video, we abstract the trajectories of individual cyclist and pedestrian flows to identify the behavioral pattern of crossing streets with the presence of dedicated bike lanes. Both actual and potential conflicts related to cyclist flows are specified and classified into different types of conflicts and evasions. The spatiotemporal characterization of each conflict is analyzed against signal timing, road geometry, and the separation of the designated right of way. The mixed logit model is employed to investigate the behavior of cyclists and pedestrian, respectively, in terms of whether they ride or walk on the designated right of way or intrude the space of other modes. Such a behavioral pattern is further associated with the types of conflicts by factoring the trajectories before conflicts into right-of-way usage and flow characteristics. Risky crossing behavior is distinguished thereupon, and conflict-prone areas over crossing walkways and bike lanes are delimited. Finally, we retrieve further insights regarding the interactions between heterogeneous flows by comparing the associated flow patterns with those of homogenous flows (all-pedestrian), so as to highlight the effect of deploying dedicated bike lanes for signalized crossings.

Collectively, this research re-examines the current design of dedicated bike lanes at signalized crossings based on the derived behavior patterns of cyclists and pedestrians in the context of conflict analysis. The derived research findings may feedback to the current design guidelines and following policy making. Ultimately, we are seeking to extend the relevant insights to the problem of flow separation on sidewalks and provide the capability to develop better urban design for cycling traffic management.

Title: **Incremental and disruptive innovations in the modal cycle: an incentive factor for sustainable mobility?**

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Author keywords: cycling mobility, Innovation, Disruptive Innovation

Accelerated technological advancements and increasingly valued innovation processes on a global scale have led to the creation of new products, services and market niches, causing deep changes in regional and global competition structures (Santos et al. 2014). Disruptive innovations arise when new levels or references are defined for the performance of a particular sector, causing the (a) rupture with the old business models (Christensen, 1997). In this context, disruptive innovations in the urban transport sector, such as UBER (Ma et al., 2018), electronic ticketing (Payeras-Capellà et al., 2015) services and autonomous vehicles (Berrada, 2017), among other alternative proposals, have revolutionized the provision of urban transport services, as well as introducing new concepts in this area, such as the intelligent transportation systems - ITS (Festag, 2014) and sharing economy (Puschmann et al., 2016).

Yet cycling, which is considered as one of the essential modalities that composes the sustainable urban mobility, plays a secondary role in the modal distribution of brazilian cities. There is no evidence that the development of innovations regarding this subject, such as electric bicycles (e-bikes), the bike-sharing systems with dockless technology and Internet of Things (IoT) applications in bicycle, have been effective in promoting this modal as a mean of transportation in a national range.

This paper aims to investigate, inside the context of Curitiba city and its metropolitan region, the potential set of innovations aimed at the cyclist or the potentially cyclist public, in order to know its impacts on sustainable mobility development. Thus a review of the bibliography on the subject has been carried out initially, as well as an initiative survey of the many sectors of society (first, second and third sector) facing innovation in cycling modal. Right after that, with the aim of knowing the limitations and impacts of the innovation proposals focused on cycling mobility, an exploratory research regarding the subject has been carried out, in which professionals and specialists who work in these areas were interviewed, has been carried out (delphi method). Finally, incentive and limitation elements collected by this exploratory research were used to formulate a questionnaire with the purpose of identifying the impact of the studied innovations, when it comes to mobility from the perspective of those who live in the cities.

The literature review has made it possible to acquire a better understanding of the currently studied innovations, such as electric bicycles (e-bikes) (Ruan et al., 2014; Gruber & Kihm, 2016), the bike-sharing systems (Otero et al., 2018; Zhang et al., 2018; Zhang et al., 2015; Bullock et al., 2017) and Internet of Things (IoT) applications in bicycle use (Behrendt, 2016), among other proposals and concepts which were further used in the exploratory and descriptive research. An innovation survey facing auxiliary maintenance services of bicycle and cycle lanes was also fulfilled, as well as business models based on provision of cycling mobility services. These initiatives were organised according to the agents responsible for their implementation, which are divided into public, private and third sector. The identified agents in this phase were later included as interviewed subjects for the application of the delphi method.

ased on the presented methodology, results indicating a greater attractiveness of the cycling mobility system by means of the implementation of the studied innovative proposals are expected.

Title: **Attitudes and behavioural preferences of bicyclists using smartphone app: a comparison in two urban areas in Italy and USA**

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Author keywords: Bicycles, Survey, Safety, Smartphone, App, Statistical method,

### Background

The number of people using bicycles as a primary mode of transport has increased over the past 40 years. Higher growth has been attributed to infrastructure improvements and the introduction of programs that advocate bicycling. These efforts have included the addition and expansion of bicycle facilities (lanes and paths), implementation of traffic calming measures, improved bicycle-transit integration, establishment of bike sharing programs, and promotional events. Along with large-scale mail and phone questionnaire-driven surveys, a variety of other tools have been leveraged to collect quantitative and qualitative data on bicycling and walking behavior and preferences. New cycling apps are constantly introduced to record ride, monitor training and also for route planning.

### Aim

Although surveys are used routinely to understand bicycle usage in the USA and Europe, no comparative studies have been performed that systematically compare the preferences and attitudes of bicyclists across various contexts taking into account impediments to bicycling and what features bicyclists would like to find in a smartphone app. This study provides much-needed insights into bicyclist preferences and how they vary between countries.

### Method or methodological issues

Researchers developed a web-based survey to solicit responses about bicyclist attitudes, opinions about bicycle infrastructure, and preferences for a smartphone app that would assist bicyclists with route selection. The survey targeted audiences in two cities: Lexington, Kentucky, in the USA and Catania, Sicily, in Italy. Survey questions were developed after reviewing previous surveys given in both the USA and Europe to catalogue bicyclist attitudes. The survey contained five parts: demographic questions, questions about bicycle usage and impediments to bicycling, a list of items that would help increase the use of bicycle as a transport mode, and a series of elements that could be useful in a smartphone app. Researchers statistically analyzed survey results to determine whether there was a consensus in the rankings of each group of participants and compare responses from the two cities. Kendall's coefficient of concordance (W) was used to estimate consensus on the rankings within each group of participants, and the U Mann-Whitney test was selected to detect differences in the rankings between the survey participants from each country.

### Results obtained or expected;

Survey results could reflect the presence or absence of bicycle infrastructure. Respondents in Lexington tend to bike more miles per week than those from Catania, possibly due to a more robust bicycle network, which accommodates longer trips and greater commute frequency. Another item that indicates the effects of infrastructure or how local governments support bicycling is modal connectivity.

Survey participants in both cities overwhelmingly said that lack of quality infrastructure is a major impediment to bicycle usage mirroring results of previous research. Respondents expressed a strong desire for a smartphone app that contains information on route safety along with other typical features. Current

apps do not provide this; they include data on route geometry and distance between origin-destination pairs, but little else.

#### Conclusions

The survey's findings demonstrate that bicyclists around the world hold similar opinions on what improvements are required to promote cycling and enhance their experiences. Agencies wanting to increase bicycling in their jurisdictions must improve infrastructure. The wealth of information and data that can be collected through smartphone apps can provide transportation agencies with the means to identify needed improvements on their networks and develop targeted solutions that encourage bicycling as a transportation alternative. While respondents were not unanimous in their opinions about the importance of different app features, they agreed it is critical for it to contain information regarding the safety level of the route.

**Title:** **The perception of the operational efficiency, by the user of the collective transportation of the metropolitan system of public transport network of the metropolitan region of Goiânia, Goiás, Brazil.**

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**Author keywords:** public transport, operational efficiency, urban transport

The perception of the quality observed by the passengers in the operation procedures of the public transport service systems is related to a set of conditions created and proportioned, so that the population of a determined urban region can move between different zones, considering attributes that go back to the satisfaction or not of the standards of the supply of these services. The Public Transport System by Bus of the Metropolitan Region of Goiânia is the only means of transportation to and from work, study, leisure, shopping, health, among other reasons of travel. It has two basic characteristics that guide its operation: the first is that it is structured according to a network of main lines and feeder lines and the second is that the interfaces between the main lines and the feeder lines take place in most of the operation, through Stations of transshipments - terminals, which allow such procedure without effecting payment of another ticket, accesses and exits out of the system, distributed in three operational regions. This work has as its general objective to present an analysis of the efficiency of the system according to the passengers, based on a research carried out inside the Transshipment Stations, relating it to the integrated public transport network and its influence on the environment. Based on these premises, what possibilities are there to observe any differentiated results between services provided and operational regions? In order to answer this question, direct investigations were carried out in the Transshipment Stations - Terminals of the Service Network, the first in order to draw a socioeconomic profile of the user and their opinion about the quality of the services in general; and another observing the physical characteristics and location in the urban soil of this infrastructure. As a result, we can observe some of the hypotheses listed below: that the production of the physical space of the infrastructure is directly influenced by the socioeconomic characteristics of the surrounding population; that the socioeconomic profile of the user population of the Transshipment Stations - the analyzed terminals influence the perception of the quality of the provision of the services offered; and that there is no influence between the two variables.

The present work dealt from the basic concepts and a subjective and superficial systemic marginal approach of the user perception of the public transportation by buses of the Metropolitan Transit Transport Network of RMG, of problems evidenced in the daily use of Stations of Transshipments - Terminals. It is emphasized that the main object is perceived as the ability to interpret the stimuli that were received by the senses and that enable individuals to identify objects and events, or the act, effect or ability to perceive something in a visual way, where the individual in question obtains some kind of information through their eyes, as well as adopting a bias of social perception, which consists in the ability to see and interpret the behavior of other individuals and is essential for social interaction. Measuring human feelings is an attribute of psychology, which does not fit the intention of the work developed. However, the planning of activities that impact on the feelings and attitudes of users of the urban transport systems reflect the satisfaction condition attributed to the consumption, in this case, of a good service, which must meet the minimum needs for social and health well being and that relates to the constitutional right to come and go.

As can be observed in the research results, each investigated aspect portrays a characteristic that differs and at the same time confronts social, cultural, purchasing power, educational level, among others, that

can be distributed in an urban region delimited by conjunctural characteristics , for example the operational region, Transshipment Station - the terminal and the population of the region in study and that makes use of the services of the public transportation system. This is clearly demonstrated when one observes the level of satisfaction of the users of the Transshipment Station of the South Region and the level of satisfaction of the northwest region. Whether it is the observation of building installations, the saturation of the quantity of users accessing the services at the same time, the comfort of the services portrayed in the stocking of the vehicles, or even the urbanity demonstrated by the system operators.

It then emerges as recommendations for any new work, which cover topics such as the investigation of business culture regarding administrative and operational management; supervision, control and operational monitoring by the public power; the use of other technologies in simultaneous services in transport networks, and more. Finally, it is left as an incentive to further research the understanding that perception provides positive indications of warnings about the efficiency and operational effectiveness for the provision of these services, in the specific case of urban transport and consequent of the mobility of passengers in urban regions.

Title: **Home-school travel: a path analysis of factors underlying the choices of the Italian parents**

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Author keywords: Child safety, home-school path, transport mode, path analysis, pyramid diagram

## Background

Children are vulnerable road users in the community travelling to school, parks and other neighborhood destinations. Pedestrian injury is a major hazard to the health of children in most developed countries. Pedestrian accidents are one of the first causes of injury-related deaths for children aged 5 to 14 years old in industrialized countries. Accidents in Italy are the main cause of death and disability in the ages after the first year of life, and most of those with death (about 50% of the total) are on the road. While the number of children dead in road accidents is overall decreased from 2010 to the present date, the number of children dead as pedestrian is almost stable. As for the children injuries, both the number of children injured in road accidents and the number of children injured as pedestrian are almost stable. A very high percentage of road accidents involving children occurs on the home-school path which is the first and most important use of children of the urban areas.

## Aim

This study has a dual objective: to identify and analyze the factors that affect the parents' propensity to use private cars to accompany their children to school; and to analyze the availability of Italian parents to send their children to walk to school alone. In order to identify of these benefit factors both for the preparation of more effective information campaigns, and the definition of calming traffic interventions to be carried out on the home-school paths.

## Method

The observational survey was focused on parents who were taking their children to school. The survey was conducted in front of 9 primary schools in Catania (Italy). The data reported in this study were collected from 1482 parents (953 mothers and 529 fathers) of children between 3 and 11 years old. The methodology used in this paper was path analysis, for which the following hypotheses were made:

- hypothesis 1: "Driver instead of walking" is influenced by variables of type "Socio-demographic characteristics";
- hypothesis 2: the variables of the type "Socio-demographic characteristics" also influence "Parents' availability";
- hypothesis 3: the parents' perception of the safety of the home-school path played a role in conditioning the parents' choice of the mode of transport;
- hypothesis 4: the parents' perception of the safety of the home-school path also influence "Parents' availability";
- hypothesis 5: "Driver instead of walking" is influenced by exogenous variables belonging to the category "Parents' reasons for choosing the car";
- hypothesis 6: the variables of the type "Road safety measures" influence "Parents' availability"; and
- hypothesis 7: "Parents' availability" is a mediator variable for the "Driver instead of walking".

## Result

The results of the present study show that just same variables of the type “Parents’ choice motivations” are statistically significant for variable “Driven instead walking” (Car-use habit, go to work by car, child too young and excessive distance). All variables of the type “Socio-demographic characteristics” are positively associated with the variable “Driven instead of walking”; the most significant role is played by the following two variables: Home-school distance; Park. The variable “safety perception” is statistically not significant, in none of the cases. About the variable “Parents’ availability” only 4 variables of the type “socio-demographic characteristics” are statistically significant (child’s age, Home-school distance, working parents, and number of sons). 2 out of 4 variables of type “Road safety measures” are statistically significant (traffic reduction and pedestrian crossing). Finally, there is a negative correlation between the variable “Parents’ availability” and the variable “Driven instead of walking”, this means that parents who are more inclined to have their children walking to school are also predisposed to using less the private vehicle.

#### Conclusions

The safety of home-school paths can be improved by reducing vehicular traffic in the roads near schools and increasing parents' availability to send their children walking to school. This is a goal that can be reached through information campaigns aimed at both children and parents and through infrastructural interventions.

Title: **Using real-time information to improve Emergency Medical Service response: A vehicle dispatching analysis**

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Author keywords: EMS, Emergency Medical Service, Real-time information, Simulation, Vehicle dispatching

## Background

In an era of fast technological improvements and easy access to real-time data from various sources, intelligent transport systems emerge. Emergency medical services (EMS) response is one of the transport systems that can take advantage of these technological advances. Moreover, cities present themselves as dynamic environments where traffic flows change during the day as well as people's location. Therefore, a static overview of urban drivability is inappropriate and unable to fully support EMS tactical decisions, i.e. chose which vehicle will be dispatched to an active medical emergency call. At the present, most of the EMS entities still rely on the closest idle vehicle policy to decide which vehicle to dispatch. Many of these, chose the closest idle vehicle using distance based or average based calculations. This leads to a solution that disregards real-time drivability conditions, resulting in a bad use of the available resources (i.e. emergency vehicles).

## Aim

This study assesses the use of real-time traffic information or estimations in the EMS dispatching decisions to achieve higher system performance. Furthermore, errors might exist in the real-time estimations, thus these errors are forced in the study to measure how big they can be till performance starts to drop when compared to practices that do not use or estimate this real-time information.

## Method

We propose the use of a simulation model to measure EMS response performance. This performance is measured in terms of average response time and victims' survival. The simulated EMS agent has direct access to real-time travel times from the road network and makes decisions upon this information. Several test cases are computed where an error component is added to the information accessed by the EMS agent. This error is obtained randomly from a normal distribution with parameters mean = 0 and stander deviation = Maximum Error/ 2, i.e. A Maximum Error in the obtained information is ensured with a confidence of 95%. Several Maximum Errors are tested and then compared with a control case where EMS uses average travel time for dispatching decisions (i.e. no access to real-time information or estimations)

We apply our methodology to a case study, Porto city, to validate it and assess the impact of real-time information in dynamic environments for EMS response.

## Results

The use of real-time information when deciding which vehicle to dispatch leads to an average response of 4.45 minutes while without real-time information the value rises to 4.50 minutes when emergency vehicles are homogeneously distributed through the city. If vehicles are concentrated in the higher demand areas, the values drop to 4.32 and 4.36 respectively. The same happens when analyzing the emergencies responded within 8 minutes. For homogenous vehicle distribution the use of real-time information leads to a total of 95.24% calls responded within 8 minutes, whilst without real-time information the value drops to 94.55%. Similar relative results were observed when vehicles are concentrated in the higher demand areas. When performance is measured by victims' survival, the simulations show that with the use of real-time information for a period of one year, the system can achieve an increase in its survival by a magnitude of 10

(i.e. the accumulated survival gain adds up to 1000%, where 100% means a victim has a 100% chance of survival), and 50 life-threatening victims assisted within 8 minutes.

In terms of error in the real-time estimated information, the simulations shown that in terms of average response time, if a maximum error of 35% (deviation from the real value) is ensured the system still outperforms the non-use of real-time travel estimations. This value drops as the number of vehicle stations increases.

#### Conclusions

This study shows that efforts should be made to introduce available real-time drivability tools in the EMS vehicle dispatching decisions. It was shown that significant survival improvements can be achieved with the use of real-time information, and that even estimations that deviate up to 35% from the real values can still bring improvements to the EMS response performance.

Title: **Winter road maintenance in Portugal: The case study of Bragança**

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Author keywords: Winter, Road Maintenance, Snowplow, and Cost/Benefit

The present work aims to evaluate the winter road maintenance resources and the methods used in reference countries to support and develop the resources and methods used by the EP in the district of Bragança, through a cost/benefit analysis of investment in Road winter maintenance or closing roads.

A bibliographic was conducted in order to search and compare the winter road maintenance resources and methods used in reference countries. Through personal knowledge and EP data, we performed a case study centered on the winter road maintenance in the district of Bragança, based on Marshal Theory of supply and demand.

The objectives are common to all road operators. First, road traffic conditions are kept to ensure circulation on the roads and the safety of users, giving preference to main itineraries roads, ensuring the highest level of service on de highways, with specific levels according to the variety of the roads. Another goal is the road users information, using roads signs and agreements with radio stations and newspapers, in order to inform the status of the roads.

The most ambitious goals are providing the reestablishment of services in the main roads connections as soon as possible.

The case study resulted from an analysis of a section of the main itinerary road IP4 in the district of Bragança, where it was possible to quantify the variables provided for the micro-economic analysis. In the present case, collected data includes the number of vehicles, flow rates and travel duration, in order to analyze and manage snowplowing and spreading salt.

The hypothesis were: to keep or to close the IP4 between the nó sul (Bragança) (A) and the nó oeste (Vinhais) (B), open to the traffic safely after the cost/benefit analysis. This analysis confirmed that snowplow and spreading salt reflects an increase of social benefit on the road users.

For future studies, we proposed to identify details and quantify the costs and benefits involved in winter road maintenance, in order to determine the sustainability of the business road operators.

Title: **Road crashes and meteorological conditions in Porto, Portugal: An analysis with lagged effects**

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Author keywords: Road crashes, Rainfall, Temperature, Lagged effects, Urban environment

## BACKGROUND

Meteorological conditions are widely referenced as a major factor affecting the operation of transport systems. In general, the performance of road, rail, water and air transport decreases under adverse weather, as the systems become more exposed to the risk of congestion, delays, and accidents. In the context of climate change, the research community has been focused on the impact of adverse and extreme weather on diverse modes of transport. However, the weather effects on road transport has received a special attention, given that this model of transport accounts for the highest share of fatalities, injuries, and property damages among the whole transport sector. In urban settings, the increase of crash frequency is particularly accentuated, since the higher number of conflict points and heavier traffic represent a higher exposure to risk.

## AIM

This study is focused on the impact of meteorological conditions on the frequency of road crashes in urban environment, using the city of Porto, Portugal as a case study. The analysis includes the evaluation of current and lagged weather effects on the frequency of property-damage-only and injury crashes.

## METHOD

First, an analysis of property-damage-only crashes, which represent the great majority of urban crashes, is conducted, distinguishing between single-vehicle and multi-vehicle crashes. Then, injury crash counts are also investigated with the aim of evaluating the contribution of adverse weather to the occurrence of more severe crashes. The analysis is based on negative binomial regression models that consider the effects of daily precipitation and average temperature, as well as the lagged effects of the precipitation accumulated during the previous month. Those variables were selected to characterize weather conditions in the day of the crash and the accumulated precipitation during the previous 30 days. The hierarchical classification of urban roads, divided into four categories, is used as a proxy for traffic exposure.

## RESULTS

The results show that rainy days are more prone to the occurrence of traffic crashes, but such effect may be attenuated by the precipitation accumulated during the previous month. The average daily temperature tend to present a negative effect. The results are consistent for single- and multi-vehicle property-damage-only crashes, as well as for injury crashes.

## CONCLUSIONS

The results obtained in this research comply with the majority of previous studies, demonstrating that inclement weather increases the risk of road users being involved in a traffic crash. Particularly, being Porto located on one of Europe's wettest regions, the rainfall effects on road crashes are aligned with those

observed in other wet regions. However, the lagged effects of precipitation show that the effect of a rainy day may be smaller if it was preceded by a wet month. This may be essentially attributed to two factors associated to wet periods: (i) the precipitation washes the road surface, cleaning the oil and grime accumulated during dry spells, and (ii) drivers have enough time to readjust their behaviour to wet conditions. The temperature effects denote that less accidents occur in hotter days, being aligned with the rainfall effects in the context of the Portuguese climatic characteristics.

Title: **The work dynamics of professional drivers of Brazilian cargo transportation and the potential risk factors for road safety and worker health**

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Author keywords: professional drivers, road safety, risk factors, occupational health, transport behavior

Background: The factors that contribute to the occurrence of a transport accident can be categorized into: human, road-environmental, vehicular, institutional and socioeconomic. Based on this principle, the present study, in a prevention perspective, sought to recover the worker's reality, socioeconomic perspective, and its potential impacts on driver's health and road safety.

Aim: To characterize the work dynamics of professional drivers of Brazilian cargo transportation and to identify the potential risk factors for road safety and worker health.

Method or methodological issues: This study adopted as a method the literature review using as techniques the steps defined by Soni and Kodali applied to scientific articles and the snowball technique covering scientific articles, institutional documents and legislations related to public policies that regulate the activities of professional drivers and programs governmental organizations related to road safety and worker health surveillance in the Brazilian context. The institutional data were constituted by physical documents made available exclusively for the study, collected in official sites of open consultation or requested to government bodies with the help of the Law of Access to Information. The historical series defined was from 2007 to 2017. The related languages for the research were Portuguese, Spanish and English. The inclusion criterion adopted was "peer reviewed journals", in the case of scientific articles, and related to road safety and worker health surveillance, in the case of institutional documents and legislation.

Results obtained or expected: The results showed similarities in the work dynamics of professional drivers of cargo transportation. In the Brazilian context, the professionals who have an employment relationship with carriers, experience a better job situation than the autonomous colleagues, propitiated by the technological increments of the vehicles, transport logistics strategies and even laws that regulate the profession. Technological advent has required of professional drivers new skills for vehicular driving causing some professionals to become obsolete for the job market. Long periods away from home, absence of family ties, adverse ergonomic conditions and pressure for productivity may contribute to risk factors for worker health or risk behaviors to road safety such as: inadequate feeding, sedentary lifestyle, musculoskeletal system overload, psychoactive drugs, alcoholic beverages, unprotected sex and little time for rest. Vulnerability to cargo thefts, fragility in work relationships, shifts in activities or reversal of the biological clock, as well as types of cargo under the responsibility of professional drivers, are considered to be factors of insalubrity and precariousness of the work, being able to favor the manifestation of stress frames. It is also highlighted as threats to the health of professional drivers the high consumption of caffeine and energy drinks, low water intake, long hours overloading organs and the habit of driving with open windows and sunroof exposing the driver to exogenous agents. In Brazil, the social security reform process, which will increase the time for workers' retirement, is also highlighted, reverberating also in the work dynamics of the subjects of this study, considering the conditions inherent to the life cycle.

Professional drivers can make short or long journeys, and can present different work dynamics. Professional drivers can concomitantly travel on highways and urban roads and in the Brazilian context the increase of cargo thefts in the vicinity of the municipalities has been observed, being a risk factor and suggesting the incorporation of public safety and its relation with labor dynamics as a variable of analyzes.

The present study integrates the thesis titled Methodology of evaluation of governmental programs directed to the road transport in development University of Brasília - UnB, for this reason, in addition to the literature review the findings were complemented by means of field observation in the context of

coordinated actions by the Federal Highway Police (PRF), which deal with occupational health and road safety surveillance for professional drivers.

Conclusions: Although studies carried out in other countries have revealed similarities with the work dynamics and risk factors inherent to Brazilian professional drivers of cargo transportation, it is necessary to equalize the realities, contexts, labor relations and respective legislation, otherwise it may jeopardize the analysis of the phenomena studied.

Title: **Exploratory study of motorcyclists' risky behavior at an unsignalised intersection using the Swedish Traffic Conflict Technique**

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In Malaysia, annual crash records involving motorcyclists account for more than 60% of the total number of crashes. However, the crash records are typically based on the police records that suffer from severe underreporting (according to a recent study, approximately 5% of traffic-related injuries are reported to the police). This is particularly a problem for vulnerable road users, including motorcyclists, as they tend to be under-reported to a higher degree compared to car occupants and thus the true scale of the problem is not visible. Moreover, the available records are very scarce on the information about the factors that contributed to a crash, making the task of finding good counter-measures very difficult and based on guesses rather than empirical knowledge.

In this study, we explore the behavior of motorcyclists at an unsignalised urban intersection in Malaysia, their involvement in traffic conflicts and the contribution of certain behavior and other factors to conflict situations. Video recording was performed during three months with the ambition to be able to record both conflict situations. Only daylight traffic (7am to 7pm) was recorded. The conflict situations are selected and classified by a human observer trained in the Swedish traffic conflict technique. Even a sample of "regular" encounters of motorcyclists and other road users is analysed to provide the baseline for the "normal traffic" conditions. Factors such as motorcycle speed, trajectory type, looking behaviour, use of the turn indicator, use of helmet, etc. are coded for each analysed encounter.

The initial results indicate that it is very common that motorcyclists perform "strange, unexpected maneuvers" which, in turn, seem to be over-represented in conflict situations. Several collisions have been observed, though they seem to belong to the 'everyday life' as the road users did not even stop after these collisions. Once the video analysis is completed, a negative binomial regression model will be developed that will hopefully help to explain which factors contribute to increased conflict probability and, ultimately, to the crash risk.

Title: **Are the safety benefits of the treatments at pedestrian crossings still valuable in presence of autonomous vehicles?**

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Author keywords: Autonomous Vehicles, Pedestrian Crossing, Surrogate Safety Measures, Vulnerable Road Users, Microsimulation model

## Background

One of the main concern when Vulnerable Road Users (VRUs) safety is considered, is the interaction with vehicular traffic. In case of pedestrian it is related to the interaction at the pedestrian crossing, and it mainly depends on design and the control strategy for the crossing itself. Designing pedestrian crossing is a complex problem which must involve the consideration of various factors. The basic criterion deciding the choice of a particular type of pedestrian crossing is road safety. To improve this, typical 'zebra' crossings are being reconstructed, usually by implementing refuge median islands or traffic signals. At the same time the introduction of Autonomous Vehicles (AVs) is opening new questions based on the effective of the different type of pedestrian crossing based on different levels of penetration of AVs in traffic flow.

## Aim

The introduction of the refuge islands in the pedestrian crossings resulted to be highly effective in providing safety benefits for VRUs. On the other hand, the increasing consideration of AVs is changing the perspective mainly from the VRUs point of view. The safety effects of treatments implemented to solve safety problems can become ineffective or even can worsen the safety conditions in presence of AVs. The main objective of the research study is to evaluate the influence of different levels of penetration of AVs in traffic flow in the safety benefit delivered by the implementation of the refuge island in pedestrian crossing.

## Method

To evaluate those safety benefits, a simulation model was built in VISSIM<sup>®</sup> and calibrated on the basis of research results on observed data about drivers and pedestrians behavior. The vehicles flow was modified considering different levels of penetration of AVs. The AVs behavioral parameters were chosen based on previous research on the topic, and in general considering a less aggressive driver behavior. The comparison between before and after conditions (based on the share of AVs) was based on Surrogate Safety Measure (SSM) such as the conflicts frequency, the Time to Collision (TTC) and Post Encroachment Time (PET). Those parameters were estimated using the Surrogate Safety Assessment Model (SSAM).

## Expected results

It is expected that the penetration of AVs in traffic flow can able to considerably increase safety at pedestrian crossing till make the effects of any classical countermeasure negligible. In other terms, it is expected that based on the share of AVs the effects of the treatments change till to become negligible for the higher levels penetration considered, with a sensible reduction of severe conflicts (lower values of TTC).

## Conclusions

The different driving approach introduced with the AVs points out new questions about the effects of the classical countermeasures on safety. In the period of transition between a fully automated driving in each vehicle (from 0 to 4 in the Society of Automotive Engineers (SAE) Automation Levels), but also the traffic mix made up by vehicles with different automation levels, the safety benefit of treatments is function of the penetration level of the AVs which can sensibly get worse or better the safety conditions. That is particularly true when the interaction between vehicles and VRUs is considered. VRUs are generally not connected users this make them vulnerable not only from a physical point of view but also unable to get I2V information and to elaborate them based on their choices. The present research work is a first step in

identify safety benefit for refuge island for pedestrian crossing in presence of AVs. The microsimulation model was calibrated on observed behavioral parameters and simulate the observed traffic operation conditions of the real site. Unfortunately, model validation is not possible when even a small share of AVs is considered in traffic flow. More research is needed on the topic before the introduction of AVs in the operating network above all when the interaction with VRUs is considered.

Title: **Can micro-simulation help in getting better exposure measures?**

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Author keywords: Exposure measures, Traffic microsimulation, Vulnerable road users, Safety analysis

The total number of accidents of a certain type in a certain location is a product of the accident risk and the exposure. The exposure is often defined in terms of AADT, which is known for having non-linear relation to accidents (safety-in-numbers phenomenon). Some researchers argue that the simultaneous presence in a certain location of two conflicting road users, has much stronger theoretical grounds for being a unit of exposure compared to single passages. An encounter can be seen a statistical "trial" that either results or not in a collision with a certain probability. That probability represents a characteristic value for that specific site and can be used for comparison between sites with different schemas and layouts or even for similar sites in different Countries. Moreover, since the process of encounter generation is relatively complex, it might be able to explain at least some part of the safety-in-numbers effect.

Obtaining the encounter data requires much efforts as, unlike the flow counts, it is not collected on a regular basis and thus must involve either manual counts or use of sophisticated tools like automated video processing. In this study, the use of microsimulation was tested as virtual environment for getting encounters. As a starting point, data on flow and encounters between motor vehicles and bicyclists collected manually within the Horizon 2020 project InDeV (2015-2018) are used. The same intersection is then modelled in VISSIM software and various operational definitions of an encounter are tested and compared to the field data.

The trajectories obtained by microsimulation are then analyzed with the Surrogate Safety Assessment Module (SSAM) and compared with observed encounters. The input traffic volumes of the simulation are measured in the real world and in the same time frame of the observed encounters. The variability of the flows, and as a consequence the encounter frequency, is taken into account considering the hourly variation of the daily observed volumes. This condition implicit considers the non-linear relationship between flows and encounters frequency which resembles the shape of the non-linear relation between the flow and crashes. The comparison between the observed and simulated encounters is carried out considering, for the simulated one, different range of Time To Collision (TTC) and Post Encroachment Time (PET). For this, the use of SSAM offer the advantage of estimating different surrogate safety measures for each interaction in the trajectories of two road users. The shape of the distribution of the simulated encounters allows to assess which range of TTC or PET values is the more appropriate to estimate the expected encounters in a simulated environment just considering, as dynamic parameter, the hourly distribution of daily traffic flows. After this first validation step with observed data, a testing phase is performed by changing the drivers behavior or the intersection layout to estimate the value of the threshold of PET and TTC, in estimating encounter frequency obtained by SSAM and counted manually from simulation by using the encounter definition. The results allow to extend the traditional use of microsimulation and SSAM for the estimation of conflicts, which under certain restriction represent a surrogate safety measure, to a measure of exposure to the risk, such as the encounters. The result also indicates a maximum threshold for the tested indicators since they at that threshold can be reliably used to estimate exposure and are therefore not suitable to estimate risk and to be used for safety analysis.

Title: **Evaluation of the safety effect of bike boxes**

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Author keywords: Bike Boxes, Safety effect, Conflict study

A big safety problem on roads with cycle paths is accidents where cars are turning right at signalised intersections and run down bicycle or moped going straight ahead. Throughout the years, a number of different physical designs of the cycle path in the intersection have been tested, but without finding a safe design.

In 2016 initiated the Danish Road Directorate a before / after trial in seven at signalised intersections that should clarify if a bike box in front of in the right-turn lanes stop line can prevent these accidents. Bike boxes are an additional waiting area for cyclists. A bike box is placed in front of the cars stop line in the right-turn lane and clearly marked with eg blue paint or with white bicycle symbol (see: [https://www.cyklistforbundet.dk/~ /media/Images/Aktuelt/Cykelboks%203\\_vejdirektoratet.ashx?w=700](https://www.cyklistforbundet.dk/~ /media/Images/Aktuelt/Cykelboks%203_vejdirektoratet.ashx?w=700))

The seven intersections are located in different city sizes and have different geometric design and traffic volume.

Aalborg University has conducted an evaluation of the trial for the Road Directorate. This extended abstract presents this evaluation.

The evaluation is made through a before-after study of the number of conflicts through Hydens conflict theory

The conflicts were found by video footage for a month before and after the bike boxes were made. After this potential conflict in the video footage were found using the image analysis software RUBA which identifies potential conflicts. Subsequently the potential conflict were analyzes and it was decided they were conflicts in accordance with the Swedish conflict technique.

Only the effect of accident types right-turning car in front of straight ahead cyclist and left-turning cars in front of straight ahead cyclist were studied.

In the seven intersections over 3600 hours of video were recorded before and after the establishment of the bike boxes, and in total 644 conflicts were identified.

When looking at right-turning car in front of straight ahead going cyclist, the number of conflicts has decreased overall by 9% during the 7 intersections, but the fall is far from statistically significant. Looking on the left-turning car in front of straight ahead going cyclists is the number of conflicts increased by 17%, but this result is also far from statistically significant.

Looking at the effects of the seven intersections individually, the results point in different directions, in some intersections the effect is positive and in other negative. The box has had a significant effect on right-turn accidents in three of the intersections, in two of the big cities the effect is positive, and in one of the minor cities the effect in negative. Why that's the case, the study can't say anything about.

A counting of the rate of use of the bike box's has not been part of the evaluation, but consistent feedback from the observers who have analysed all the potential conflicts is that they rarely have seen cyclists in the boxes. Thus, a contributory explanation of the lack of effect may be that the box has not been used.

Title: **The "go-along" approach to study the relationship between the environment and residents of Brasilia.**

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Author keywords: Go-along, person-environment relationship, pedestrian and cyclist interactions

Urban mobility is related both to human behavior and to physical and social context. In one hand, people choose the mode of transportation they will use, considering their needs, preferences and the activities they need to perform. On the other hand, the transport system and the urban infrastructure available compel the residents to avail themselves of modalities that do not always corroborate their preferences. This relation between human behavior and the physical and social environment is at the heart of the studies of environmental and urban psychology and is the focus of this work. Through a qualitative study using the "go-along" approach, the present study investigated the relationship between the available urban infrastructure in the city of Brasília and the travel behavior of its residents. 9 women and 7 men, aged between 21 and 54 years, participated in the study. The "go-along" approach was used to accompany the participants in their daily trips, recording reports of their space perception and the relationships they establish with space and other users, through videos, audios, maps, and photographs. During the accompanying trip, the researcher requested that the interviewee maintain their daily habits, without changing their behavior due to the presence of the researcher. During the trip, the researcher asks unstructured questions to explore how the person-environment relationship occurs. The equipment used were: a) GoPro 5 Black camera, affixed to the researcher's vest; b) Zoom audio recorder; c) Strava smartphone application to capture GPS data with the location of the researcher, maps and travel time. Data from video, audio, photographs, and maps were analyzed using the technique of content analysis. 16 trips were accompanied on foot and two by bicycle. The data showed that the interactions between different public road users do not occur in a peaceful way. In all modes of transportation, participants reported dissatisfaction with the available urban infrastructure (sidewalks, bicycle paths, or road gutters). Sometimes this lack of infrastructure and urban maintenance seems to elicit

inappropriate behavior by cyclists and pedestrians. Cyclists, for example, report that they travel on sidewalks when there are no bike paths. Pedestrians report walking on bicycle lanes, due to better conservation, accessibility and continuity conditions, in comparison with the sidewalks. They feel forced to transit along the road with vehicles that travel above the permitted speed, because drivers constantly park on the sidewalks, making it impossible to walk. It was also observed the behavior of crossing outside the pedestrian tracks, as a way of avoiding longer routes. The lack of accessibility on the spot was also pointed out as a risk factor for pedestrians with special needs, who risk by sharing space with cars. Cyclists also reported that there is a lack of respect for cyclists in the city, stating that the high speed of cars on the roads contributes to road insecurity and crashes. By evaluating the relation between person and environment in Brasília, it was noticed that different people interact in different ways in the same space, depending on their perception of the environment and their local involvement. However, environmental aspects such as the lack of maintenance of public spaces and inadequate urban infrastructure serve as an affordance for users to engage in inappropriate behavior while sharing the same space. The high speed of cars in the roads seems to be one important risk factor, giving a strong sense of insecurity for those who use nonmotorized transportation modes.

\* This paper is based on data collected from the international collaborative project, Healthy Urban Mobility, conducted by the University of Brasilia, Federal University of Rio Grande do Sul, and Federal

University of Santa Catarina, Brazil, with funds from FAP-DF; and Oxford Brookes University, United Kindon, with funds from ESRC.

Title: **Incorporating road safety concerns into pavement maintenance management**

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Author keywords: Road safety, Accident frequency prediction models, Pavement performance prediction models, Pavement quality, Skid resistance, Macrotexture

Worldwide, more than 1.25 million people die annually in road traffic accidents and between 20 and 50 million more are injured. By 2030, highway-related crashes are projected to be the 5th leading cause of death in the world. Road accidents have a number of contributing factors, including roadway conditions, vehicle conditions, and factors related to the road users. While some of these factors have been studied extensively by researchers very few focused on quantifying the relationship between accidents frequency and pavement quality. Before 1990s, due to the lack of pavement data collection technology, it was very difficult to carry out state-wide scale studies relating pavement quality and road safety. However, in the past decades, there has been a huge growth and awareness in the importance of road safety as a public health issue, leading to a significant increase of research in the topic. Researchers started to study other contributing factors to accidents occurrence such as the pavements quality. Nowadays, the management of road pavements is a challenging task. On one hand, the economic crisis imposed a reduction of the available budget and, on the other hand, the demand in terms of quality, comfort and safety is higher than ever before. Therefore, the road agencies are investing more in new techniques, which allow them to find the most effective and cost-efficient solution to the management of the entire network. Moreover, with the development of high-speed friction measurement tools, agencies can now include friction into network level Pavement Management Systems (PMSs). Therefore, incorporating safety concerns is one of the urgent needs of PMSs, not only in order to optimize the management of the resources but also, and above all, towards the reduction of road fatalities and injuries. Despite the fact that there is limited research on the topic, important results were already achieved proving that there is a correlation between the frequency of traffic accidents and variables, which state the condition of the pavement such as macrotexture and skid resistance. This article aims to contribute to the incorporation of road safety concerns into pavement maintenance management. Therefore, the system includes the HDM-4 pavement prediction models and accident prediction models. Moreover, in order to provide alternatives to the decision maker, different scenarios of M&R operations and the corresponding cost analysis, which includes the costs related to road accidents, are performed. Finally, the conclusions and recommendations are presented.

Title: **Adverse weather and vulnerable road users' casualty in some European countries**

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Author keywords: road casualties, road fatalities, adverse weather, trend analysis, vulnerable road users

Background: Weather conditions are known to impact mobility, especially on the roads, and consequently road accident and casualty outcomes. Adverse weather in particular is known not only to reduce exposure but also to increase the level of the road risk. But it is not clear whether the combined effects of a reduced exposure and an increased risk result in a reduction or an increase of the number of road casualties, measured at aggregate level. Vulnerable road users (pedestrians, bicyclists, mopedists and motorcyclists), which are the most weather-sensitive road users, rise up to about half (40 to 60% according to the country) of the total of casualties in Europe and this share continuously increases while on the opposite the respective share of car users, which are very little weather-sensitive, decreases. It is therefore of great interest to measure the impact of inclement weather on VRU's casualty, and its changes depending on the climatic configurations in Europe.

Aim: This paper aims at presenting a tool for monitoring, on a monthly basis, road casualty short-term trends for VRUs (pedestrians, cyclists, mopedists and motorcyclists) in relationship to a short number of explanatory variables measuring adverse weather. A comparative analysis of the results obtained for a group of European countries (Austria, Belgium, France, Germany, the Netherlands, and UK) is expected to highlight similarities and differences in behaviours of each type of VRU among these 6 countries.

Method: In practice, three steps were achieved. Collecting the casualty data (totals and fatalities alone) from the Care database, building the adverse weather predictors (the number of days in the month with rainy, resp. cold, resp. rainy and cold weather, computed from equidistant meteorological measures taken from the Agri4Cast database), fitting a generic model that could be applied to each dataset of casualties considered. Structural (the so-called "state-space") time series analysis techniques were chosen and applied to the monthly number of casualties, whether totals or fatalities alone, disaggregated per road user type for a number of European countries and for the 16-years period 1999-2014.

Results: Correlations between VRU's casualty numbers in general and the numbers of days with adverse weather are highly significant with a globally negative sign. The weather sensitiveness of VRUs to adverse weather is much larger for motorcyclists than it is for bicyclists and mopedists. The same result applies regarding the correlations between fatalities alone and adverse weather, but the weather sensitiveness is generally larger.

When analysing the 16-year period in terms of road safety performance, it is clear that some years have been favoured (favourably impacted by adverse weather conditions): 2001, 2010 naturally, and 2013 which had more days with adverse weather than in average, whereas some others have been disfavoured: 2000, 2007, 2011 and 2014 which had more normal days than in average.

Finally, the results of the analysis are coherent among countries, and the size of the adverse weather's impact is large: when measured at the scale of the year, it may reach 3 to 4% of the total of VRU's casualty, and even 6% of motorcyclist's casualty.

Conclusions: This work demonstrates that the number of days with adverse weather measured through rainfall and cold (itself measured through snowfall and frost), in deviation to their seasonal averages, computed from equidistant meteorological measures taken over seven countries' areas in Europe are significantly correlated to casualty numbers for the 16-year period 1999-2014. These results highlight the demand for an additional source of weather data complementing the information registered by the police on the spot of the accident. The large size of the adverse weather impact on casualty numbers should lead decision makers, in particular, to analyse trends corrected for this impact. In terms of prevention, a number

of actions could be taken or reinforced, at urban level in particular, for reducing the added-risk by rainy and/or cold weather (information and alert, lightning and speed reduction). National authorities and research bodies, municipalities and industry can help addressing this issue.

Title: **Analysing the relationship between freeway flow parameters and safety, through the functional form of a crash prediction model. The case of run-off-road crashes.**

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Author keywords: crash prediction model, functional form, modified Ricker model, run-off-road crash, level of service

Crash prediction models (CPM) can be used for various purposes in highway safety analysis. The most common are the quantitative prediction analysis of road crashes and the establishment of relationships between these crashes and different covariates.

The relationship between safety and traffic flow parameters (flow, speed, and density) of freeways may also be explored by examining the functional form of these CPMs. This relationship has significant consequences for transportation planning, freeway design, and management policies.

The conventional functional form of CPMs is based on the assumption that the traffic flow model component continuously increases over the covered range of values. However, the crash phenomenon does not necessarily have to follow a simple monotonous, mathematical function. In the case of run-off-road crashes, using a functional form that shapes the curve between crash frequency and traffic flow in a concave way, the modified Ricker model, shows better quality model fit than a functional form under the assumption that the model component for traffic flow continuously increases with traffic flow.

Run-off-road crashes on freeways may be considered as a by-product of traffic flow; therefore, variations in flow parameters may produce changes in the probability of crash occurrence and differences in crash frequency.

This study first examines the relationship of traffic flow parameters, such as volume, density, and speed, to safety, using a calibrated CPM developed with the modified Ricker model and fitted to Portuguese freeways run-off-road crash data. A possible explanation of the effect on road safety of traffic volumes is formulated and discussed.

Empirical examination of the relationship between traffic flow, density, and speed and the expected crash frequency on selected freeways in Portugal suggests that, when traffic density is low the number of crashes increase at a high rate with an increase in traffic. The mixture of density and speed of traffic is such that the probability of a run-off-road crash increases substantially and thus a steep reach of the function. However, once a critical density is reached (at an Average Daily Traffic of approximately 25,000 vehicles) the function begins to level off, the number of crashes almost stabilizes, and accident rates decrease significantly, due to higher traffic volumes and lower operating speeds. It is also worth noting that the number of crashes reaches its maximum for a density between 11 and 16 passenger cars per kilometre per lane (Level of Service C). Under these circumstances, vehicles speeds are near the freeway Free Flow Speed (FFS), and drivers have restricted freedom. However, lane changes are still possible but requiring more care and vigilance on the part of the driver.

Further examination of the function suggests that past the point of maximum density (for an Average Daily Traffic of approximately 35,000) the function begins to decrease at a slower rate with an increase in traffic. Under constant perception–reaction time, vehicle and roadway characteristics, and speeds, it is highly plausible to expect a decreased probability of run-off-road crash occurrence as a result of 50% more cars in the same space (Level of Service E). The decrease in the number of crashes may be explained by the fact that compression of flow and speed reduction produces headways so small that it becomes difficult or impossible for an errant vehicle to encroach the roadside without previously hitting another car.

Title: **Identification of potential relationships between road safety and design and operation of roadside elements**

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PROGRESS – Provision of Guidelines for Road Side Safety is a project funded within the CEDR 2016 Safety Call, in which the results of a status quo review of available EU roadside safety standards and guidelines are combined with the experiences from National Road Authorities in applying these in the design, operation and maintenance phases of EU high-speed roads (speed limits higher than 70 km/h). A special emphasis is put on the six funding countries (Belgium-Flanders, Ireland, Netherlands, Slovenia, Sweden, and United Kingdom), plus Germany and Portugal, which are included to increase the geographic representation of the results

Existing safety projects and international literature related to the application of guidelines and standards in the improvement of roadside safety have been analysed in detail, in order to describe and assess their findings and to summarise the potential relationships between the design and operation (including maintenance) of roadside elements and safety. The main conclusion is that the effect of the application of guidelines and standards on roadside safety has not been sufficiently studied or reported in scientific journals both in Europe and in the rest of the world.

Following an examination of current national standards of eight European countries for roadside design, management, maintenance, and operations, a matrix was developed to illustrate the relationship between different roadside design features and road safety elements in general and crashes in particular. This provides a benchmark of roadside safety performance in those eight European countries, namely resulting from a combination of crash data analysis and an examination of roadside severity ratings for countries where these were available (for example, from EuroRap inventories).

Additionally, crash data from the eight participating countries over the past ten years were analysed to determine the extent of the single-vehicle crash problem on their rural roads (both motorways and single carriageway roads with general speed limits above 70 km/h). The analysis defines the scope of the problem and provides a perspective on differences between the participating countries, related to both single-vehicle crashes and the involvement of road workers, during roadside maintenance duties. This qualitative analysis was complemented by fitting crash prediction models to the EuroRap and crash data, which allowed for a thorough quantitative assessment of significant crash risk and severity covariates. In this paper, the outcomes of this assessment are presented, with the results from their combination with the conclusions of the qualitative analyses.

Title: **Systemic approach for the preventive road safety incidence assessment of cycle rickshaw**

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#### ABSTRACT

Cycle rickshaw is an activity that offers an alternative of mobilization to people, in and out of cities. However, its operation can trigger negative road safety incidents. In this research, we present the progress and results in the formulation and application of a methodology, with preventive approach, that seeks to respond effectively to the road safety incidence assessment of cycle rickshaw in Bogota (Colombia). The above, under a systemic approach, framed within the five pillars established in the National Road Safety Plan (2011-2021).

#### OBJECTIVE

To estimate the incidence of cycle rickshaw in road safety under a systemic preventive approach, in Bogota city, to recognize the effects that may arise from the practice of this activity.

#### METHODOLOGY

The methodology comprises four stages: A. Systematic literature review and information gathering by local, public and private entities. B. Debugging of the information focused on the characterization of the operation of cycle rickshaw and the motivations that led to the appearance of such phenomenon. C. Identify tools for the road safety assessment of cycle rickshaw, under a systemic preventive approach, which would allow incorporating all the variables of interest that could have influence in the achievement of the study objective. D. Establish methodologies and selection criteria of variables, for an assertive information collection, within each one of the five National Road Safety Plan pillars (NRSP, 2011-2021).

#### RESULTS

The literature review allowed to establish the knowledge of the general context under which cycle rickshaw currently operates and how it is found in terms of road safety and regulation, both in Bogotá and in other parts of the world. Also, it allowed to establish the methodology and processes under which the research is being carried out from each of the five NRSP pillars (2011-2021).

Regarding the five pillars, we have:

[i] Institutional management: currently, the intention of regulation that has been taken for the provision of the service is recognized, although it has not yet been possible, mainly due to motivations associated with road safety. However, this institutionality is not only given from the need for legal regulation. Cycle rickshaw pullers, have formed associations that self-regulate the operation to provide an efficient and comfortable service to the users. Therefore, the evaluation of the pillar will include both the management carried out by the public sector and the private sector.

[ii] Human behavior: it will be carried out through the analysis of individual places, based on behavioral observations, which involve qualitative variables identified as risk factors. Additionally, there will be the accompaniment of professionals in psychology and sociology. [iii] Victim care and rehabilitation: given that cycle rickshaw is an informal transport in Bogota, there is no official information regarding road accidents. Therefore, it was defined that, through surveys in hospitals, collision centers, bicycle workshops and insurance companies, it will be possible to establish, in a general manner, the severity of the incidents presented and the procedure to attend victims. [iv] Infrastructure: will be evaluated through road safety

audits in three high demand areas and [v] Vehicles: their characteristics and conditions will be evaluated under NTC 5286 standard.

## CONCLUSIONS

In the local and national context, the cycle rickshaw operates from the informality. At the international level, this situation is also recurrent, which leads to a negative impact on road safety, whose magnitude is unknown. Therefore, it is necessary a systematic assessment of road safety, which allows establishing the main risk factors, the possible solutions to mitigate the negative impacts and, in the best of cases, allow regulation in the provision of the service.

During the study it was established that, although previously, the incidence of cycle rickshaw in road safety has been evaluated, those evaluations have not been systematic, which could lead to biases in the definition of variables and risk factors, reaffirming the need of the present study.

Finally, a method for information collection and road safety assessment of cycle rickshaw, from the pillars, is established. In the future, it will be possible to include new processes and investigative techniques, in case of find an advance regarding the information collection, seeking to obtain more precise results.

Title: **Modeling to assess gender and age influence on traffic injury severities in Brazil: urban vs. rural environment**

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## BACKGROUND

The growth of the road transportation system has brought some externalities, including a significant increase in traffic accidents. Therefore, safety of the system users became one of the main objectives to be addressed during road transport planning and management.

Traffic accidents represent high socio-economic costs to the developing countries. In Brazil, a survey conducted by the Ministry of Transport, Ports and Civil Aviation (MTPA) shows more than 1,134,800 accidents on federal highways supervised by the Federal Highway Police (PRF) between 2010 and 2016, resulting in more than 55,850 deaths. These data stresses that measures to improve road safety are urgently needed on both type of road environment - rural and urban.

In general, engineering actions of road safety are focused on the reduction of accidents and their severity through the implementation of reactive measures at hotspots (locals with a high concentration of accidents). However, the adoption of preventive strategies also contribute to improve safety by decreasing accidents and/or reducing the consequent severity.

It is worth noting, among the proactive strategies, the importance of road safety modeling as a tool for road safety management (RSM). Usually, models are developed and applied to study the relationship between road infrastructure and operation features, and the accidents frequency and/or severity. However, the analysis of the relationship between road user characteristics and accidents is also important, enabling to guide actions focused on road user such as the promotion of targeted educational campaigns and thus enlarging the scope of RSM actions.

## AIM

In this context, the aim of the present study is to investigate the influence of road users characteristics on traffic accident severity modeling data of Brazilian highways provided by the Federal Highway Police. Due to the scarce and/or incomplete accident data usually available the analyzed characteristics are gender and age data of the users involved in the accident, reflecting in some way, the heterogeneity of users behavior.

## METHODOLOGICAL APPROACH

Data from PRF, which is the agency responsible for traffic accident records on Brazilian federal highways, will be used. The database consists of records throughout the country's road network, between the years of 2010 and 2017, corresponding to a total of 1,224,233 accidents. In order to consider the type of road environment (urban vs. rural) where accidents occurred, a previous analysis was conducted to identify the local of the accidents.

Statistical modeling techniques have been traditionally employed for accident prediction and severity analysis, using appropriate models to the data's specificities. Nevertheless, limitations are recognized in this type of approach, since each statistical model has its own assumptions and a pre-defined relationship between dependent and independent variables.

On the other hand, considering that Artificial Neural Networks (ANN) has shown on past studies similar or superior performance compared to traditional modeling and overcoming the need of a pre-defined relationship between variables, this technique was adopted for modeling the described data.

In this sense, ANN modeling will allow the analysis of the influence of the included variables on each level of accident severity (without victims, with injuries, with fatalities). Firstly, two datasets are created and analyzed by separating rural and urban accidents and aggregating by each user. Secondly, each dataset (rural and urban) are subdivided into three subsets, each one associated with a level of severity (without victims, with injuries, with fatalities), providing the association of users characteristics depending on the type or road environment and accident severity.

#### EXPECTED RESULTS

At the final of the modeling process, it is expected to be possible to establish the relationship between age and gender and the accident severity under two distinct road environments. Through the study results, it will be possible to infer about the impact of the behavior of each age or gender group on accident severity. In addition, the results will allow the comparison between rural and urban roads, which may reveal how the user behavior diverges depending on the road environments.

Title: **Intermodal Mobility Hubs and MaaS Solutions**

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Author keywords: intermodal mobility, multimodality, usability, transport planning

#### Background:

Technological innovation in the mobility and transport sphere is still strongly focussed on vehicle or infrastructure based systems. In view of ITS aimed at vulnerable road users technology is mainly addressing the comfort aspect (i.e. routing and traffic realtime information in public transport), while the general dimension of mobility demand and usability in public space remains a rather untouched topic in many European regions. In a row of consecutive Austrian research projects every element in the chain of intermodal routes has been addressed, starting from the user centred features of public transport stops in both urban and rural transport systems, to the planning tasks involved in providing demand-driven public transport. The current iteration focusses on establishing a typology of intermodal mobility nodes including a differentiated view of the potential users of a multi-modal transport system.

#### Aim:

While previous steps in the development of a dynamic transport management in urban and rural areas based on a complex accessibility model have focussed on the intermediate aspects of accessibility and usability of transport stops and multimodality in general, here the main goal is to interlace recent findings on acceptability and user demand with current developments in systemic traffic planning.

#### Methods:

In the early stages of the ongoing project a user centred design approach involving all relevant stakeholders will ensure that potential users, planners and system relevant public actors are activated early on in the development process. Potential end-users from different mobility related backgrounds, with varying needs, living areas and access demands will be involved in course of focus group discussions. Expert workshops with planners, engineers, responsible actors on regional and federal level will ensure that the final planning tool fits professional demands.

#### Expected results

As a result, a typology of intermodal mobility nodes will be established based on aspects such as regionality, type of usage, user demand, seasonality and the information demand at these traffic connection points. Based on user input from potential end-users, mobility as a service (MaaS) solutions will be proposed and needed functions will be sourced to the later development stages of the project. These findings and the outcomes of the expert workshops are the basis for the establishing of a dynamic traffic management.

#### Conclusions:

While data sources for mobility demand assessment are available today, there remains a lack in knowledge on which factors influence uptake of certain transport services on the intersections of rural, suburban and urban areas. Provided public transport options are often neglected and hence terminated without further research into cause and effect. Here the ongoing research projects Mobility Integrator steps in to provide the basis for the intermodal mobility node of the future.

Title: **Sustainable mobility for irregular settlements**

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Author keywords: sustainable mobility, inclusive spaces, irregular settlements

#### Context and proposal of research

This article brings an academic experience and stresses the issue of mobility on irregular settlements arising from industrial activities. The current pattern of disorder and the heavy traffic derived from industrial use, directly affect inhabitant's movement safety and bring substantial impact on quality of life as well as on natural environment (PLANMOB 2015). To give students skills to tackle this problem, a project was conducted on the region called FERCAL, aiming at defining a more sustainable model and finding strategies to promote quality of life and reconciliation between economic development and local environmental support capacity.

FERCAL is the first operational town of Federal District (FD), emerged along the axis road of the DF-150, as the main channel of production flow towards the capital. This spontaneous occupation happened in a longtime process and gained economic importance along time. Today its urbanization consists of 14 communities, from which six are rural, while the others are urban, concentrating approximately 30,000 inhabitants in the region.

Despite the size of industrial activity, resources from tax revenues are not reinvested on local public services or benefits to the community. Moreover, the production process of cement and asphalt triggers a number of factors that directly affect urban environment and life quality. All of this creates a conflict scenario, with highlighted problems such as air and aquifers pollution, followed by lack of infrastructure and public services.

Urban mobility is one of the main local problems, once settlements got spread without any planning along the highway DF-150, leading to a framework with great risk of accidents, as attests the large number of pedestrian injuries. Broad topic to be discussed, the debate about transport covers issues of urban development, such as land use and occupation, in addition to health and quality of life, intimately linked to the conditions of daily locomotion.

#### Methodological issues

The assessment method, on which the research is based, started on learning about the fundamental principles of inclusive spaces. These principles were presented by Christopher Alexander (1965) in his studies of ordered overlapping systems, and by Stanford Anderson (1986) in the field of urban ecology, where the latter defended the constitution of spaces as sympatric environments ; both authors suggested a place in which the coexistence should be outlined by natural settings. A bibliographic review enabled the identification of principles and criteria associated to the street evaluation related to the demands of pedestrians movement. It is expected that such criteria indicates the efficiency of street as an inclusive space.

#### Results obtained and expected

During the analysis process it was possible to identify the major connection crossings between communities of DF-150, by surveying conflict points between pedestrian movement and motor vehicles traffic. Such points represent spaces of urban life's convergence, unfortunately, they turn to be completely deprived of infrastructure.

The main objective is to overcome the logic of a car oriented design and transform hostile spaces into pedestrians inclusive places, favoring social exchanges and communities quality of life. The idea of DF-150

transformation counts on the support of Federal District transit department (DER-DF), which attests to the current model exhaustion related to the industrial production flow in this highway, unsuitable to the urbanization level of that region.

#### Conclusion

The premise of a new mobility plan should be to protect urban environment from impacts generated by freight vehicles traffic, and develop a model oriented to rebalance the functioning of vial space by privileging pedestrians and promoting the social content of the streets.

It is expected to extract from this research tools that assist the promotion of an urban design capable to generate more integrative spaces, through a participatory process with the involvement of community.

The triad established by Teaching – Research – Extension makes possible the formative process of academic community, and can also enable the necessary transformations of society. It also brings the opportunity to demonstrate the ability of university centers to contribute on social demands, in a more inclusive and participatory way.

Title: **Proposition of mitigating measures to minimize the impacts implaced by a travel generator pole of church type: a case study in Goiânia, Goiás, Brazil**

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keywords: Urban infrastructure, Travel Generator Pole (PGV), Urban mobility, Road user safety

The urban infrastructure surrounding a Travel Generator Pole (PGV) is directly linked to the quality of the mobility of road and enterprises users, whether they are pedestrians, drivers or cyclists. Impacts on mobility caused by a pole can be observed, for example, in traffic, with congestion in the surrounding roads; in the physical space of the PGV, with the lack of parking spaces; in road safety, with high accident rates. These points present significant relevance, since they induce feelings of discomfort and vulnerability to the user, which, of course, tends to avoid the region. According to some criteria for the characterization of enterprises as Travel Generator Poles established by the Missouri City Design Manual - MCDM (2004), a church can be characterized as a PGV since, besides its nature and size, it contemplates the minimum travel demand indicated in the characterization. The region where the "Luz Para os Povos - Serrinha" church is located, located in the city of Goiânia - Brazil - was not planned to meet the intense flow of vehicles in the region. There are problems such as congestion, lack of parking spaces and inadequate spaces for pedestrians. With the implantation of the church in this place, these problems were potentialized due to the attraction of the travel demand disproportionate to the urban space available for parking, access and capacity of the surrounding roads, which directly implies the safety of users. The purpose of this study is to evaluate the infrastructure of the "Luz Para os Povos - Serrinha" church, located in Goiânia, in order to identify the problems faced by pedestrians and drivers and to propose interventions to minimize them. To meet this objective, the study was based on the method proposed by Cardoso (2005), which contemplates several steps. In the first stage, the study area is characterized and defined using the parameters defined by the MCDM. The second stage involves the survey of the supply and demand of the PGV performed through surveys of volumetric counting of vehicles, pedestrians and cyclists in loco. The third stage refers to the bid and demand analysis, based on studies of traffic capacity, traffic flow, number of trips generated and parking spaces. The last step consists in the proposal of mitigating measures that aim to minimize the impacts identified in the region from the implementation of a new Travel Generator Pole. These measures aimed at improving user safety are mainly related to the road infrastructure, the position and geometry of the accesses to the project, the accessibility of pavements road signs and parking. As a result, it is expected to indicate measures of improvements in the infrastructure of the critical area of the Travel Generator Pole that contribute directly to the mobility and accessibility of the users of the surroundings and space of the enterprise. It is concluded that the PGVs that have specific characteristics in their operation, especially those that have demand outside of business hours, also need studies aimed at the quality of the users' displacement in their environment. The studies are relevant contributions to the urban mobility of the region as a whole and the improvements pointed out increase the quality of life of the population, providing safer trips in the place, be they destination or passage.

Title: **The effect of urban design on the pedestrians' safety perception: lighting, vegetation, and roadway lanes.**

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## 1. Background

Walking, the most common form of transportation, is a risky activity. Although in recent years the trend is the reduction in the number of traffic victims, a considerable percentage of the deceased are still pedestrians. Studying the factors involved is fundamental.

Many studies have focused on identifying objective risky situations related to urban design. However, along with the objective risk there is a perceived sense of risk that has been less studied despite its impact: pedestrians modify their behaviour seeking an accepted level of risk, increasing the accident rate in places where the objective and perceived safety do not match. Therefore, quantifying the safety perception is of vital importance.

## 2. Aim

The objective of the present study was to analyse the effect that certain configurations of urban design parameters have on the pedestrians' safety perception.

## 3. Materials and methods

Methodology consists of a field study, in which the safety perception of participants before urban stimuli was quantified.

### 3.1. Stimuli

Stimuli were virtual reality environmental simulations. This allowed to apply different configurations of design configurations on the same basis, a visual-auditory replica of a real street that was considered representative and apt for the study.

Specifically, parameters were: (1) "natural lighting", (2) "artificial lighting", (3) "vegetation", and (4) "number of roadway lanes". For each of these, different configurations were considered. Thus, for natural lighting, "day" and "night" configurations were applied; for artificial lighting, "2800K", "4500K", and "10500K"; for vegetation, "trees" or "non-trees"; and for number of roadway lanes, "1" or "2". These were studied individually and in combination, giving 18 environmental simulations.

Technically, the scenarios were generated by Unity3D (v5.6; [www.unity3d.com](http://www.unity3d.com)). This included a three-dimensional model and an audio clip recorded in the base street. The model was produced in Rhinoceros (v5.0; [www.rhino3d.com](http://www.rhino3d.com)), and the clip (24-bit at 96 kHz) using the ZOOM H4n Pro recorder ([www.zoom-na.com](http://www.zoom-na.com)) in conjunction with the binaural microphone Free Space XLR ([www.3diosound.com](http://www.3diosound.com)).

### 3.2. Participants

Sample consisted of 70 participants. Within this, two age groups were considered in order to discern specific needs: 50 participants between 18 and 50 years, and 20 participants over 65. The sample was balanced in sex. All of them, were placed on a pedestrian crossing of the stimulus, in order to quantify the safety perception.

### 3.3. Quantification of the safety perception

Quantification of the safety perception was made through psychological and neurophysiological records.

On the one hand, psychological record consisted of the self-assessment, using a Likert scale from -4 to 4, of the following concepts:

- "Safety perception".
- Perception of Dominance. Seven concepts related to the perception of Dominance: six concepts that describe it, according to Mehrabian & Russell (1974); and the global perception of Dominance, through SAM pictograms (Bradley & Lang, 1994).

On the other hand, neurophysiological records completed the quantification. They have the advantage of not being limited in the consideration of unconscious processes and the real time study of these. The records, of which metrics related to the safety perception were calculated, were:

- Electrodermal activity (EDA), which measures variations in skin sweating.
- Heart-rate variability (HRV), which measures variations in the interbeat intervals.
- Electroencephalogram (EEG), which measures variations in the electrical activity of the surface of the scalp.

## 4. Results

Preliminary results show that it is possible to improve the pedestrians' safety perception through the design of the urban environment. Thus, the presence of trees positively affect the safety perception, both at the psychological and the neurophysiological level. The number of roadway lanes also affects, although with less weight. On the other hand, there are important differences in the diurnal versus nocturnal environments, which confirms the need to carry out these studies differentiating this context. In addition, dissimilarities are observed according to the age profile of the participants, with those over 65 years showing, in general, more extreme behaviors.

## 5. Conclusions

Different urban design configurations can affect the pedestrians' safety perception. In addition, at the methodological level, the present study suggests that the combined use of virtual reality and psycho-neurophysiological record are a useful design tool. The results are of interest to the agents involved in urban design, as urban planners and policy makers, in their work towards a safer city for pedestrians.

Title: **The influence of a bypass road on road safety**

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Author keywords: Bypass, Road safety, Arab towns, Land use

### Background

One of the principal reasons for the construction of bypass roads in towns is the removal of through-traffic from the center of a town or city to the periphery, for the purpose of improving the flow of traffic, reducing travel times, and decreasing road accidents. Bypass roads, however, also have environmental and economic consequences. On the one hand, they reduce noise and pollution emissions along the previous route. On the other hand, such projects are often accompanied by concerns on the part of local proprietors and businesses regarding the scope of their business revenues, the value of their properties, and the impact of the road on land uses. These changes in land use arise the question whether the construction of the bypass decrease road crashes and improve road safety or shift the problem from site to other sites?

### Aim

This paper analyzes the effect of bypass construction on road safety, specifically crash rates on bypass segments and in bypassed communities. It further investigates the effect of bypass construction on those communities' economic development through changes in the number and spatial distribution of businesses and residential development, and examines whether these changes affect the road-safety level.

### Methodology

A descriptive longitudinal analysis approach is conducted investigating changes that have occurred over a length of time both previous to and subsequent to the construction of the bypass. The descriptive longitudinal analysis investigates changes that occurred over time in relation to the construction of the first bypass road in 1952 and the second bypass in 1996. The research period for this case study is 1945-2018. The study focuses on Arab cities in the Galilee region of Israel.

### Results

A summary of the findings of this study reveals that the construction of the two bypass roads had significantly affected the town in all areas examined: the land spatial distribution of residential housing and business activities, land uses and road crashes.

The results show that bypass construction does not necessarily reduce overall crash frequencies or crash rates. It merely shifts road crashes from the highways (the bypass roads) to inner roads (bypassed) and from there to local traffic, with no significant reduction.

Title: **Construction and validation of the public bus passenger safety evaluation scale**

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keywords:

Scale development, Public bus passengers, Safety evaluations, Psychometric properties

Public transport (PT) passengers make safety evaluations, yet to the best of our knowledge, there exists no instrument to measure these evaluations. What exists is a generalised service quality scale (SERVQUAL). Unfortunately, this scale does not adequately capture the content domain of personal safety which is important to PT users, especially in developing countries where PT vehicle accidents are both frequent and severe. This study discusses the development and validation of the public bus passenger safety evaluation scale (PBPSSES), for measuring public bus passengers' safety evaluations. The results of two independent studies suggest that the PBPSSES measures three facets of public bus passengers' safety assessments: driver-related, transport operator-related and vehicle-related safety assessments. Through both exploratory Principal Component Analysis (PCA) and Confirmatory Factor Analysis (CFA) (using IBM SPSS Statistics and AMOS respectively), we demonstrated that the new scale is reliable, psychometrically sound and can be utilised to assess public bus passengers' safety evaluations. The 3-factor model observed through PCA was confirmed using CFA, indicating that the same factor structure existed in both datasets. The final 3-factor, 17-item model exhibited an acceptable model fit and evidenced convergent validity. However, we recommend further studies to establish the scale's predictive validity (the extent to which public bus users' safety assessments would inform future bus use and transport operator choices).

