SESSION 4A :

DIVERSITY AND SPECIFICITY OF DIFFERENT ROAD USER GROUPS

ANALYSIS OF HUMAN FACTORS IN KHUZESTAN PROVINCE ROAD ACCIDENTS

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ABSTRACT: Khuzestan province is the most important economic and geopolitical area Islamic Republic of Iran. Its geographical location, economic potentials of natural oil, gas and water resources has created considerable effect on the mobilization and road use. Insufficient capacity of railway system has increased the dependency of passenger and transport on road use. According to data recorded by Iran Road Maintenance & Transportation Organization the traffic increase in Khuzestan has much higher than increase rate road development; therefore it results in an increase of road accidents. Although there is no significant study of accident causes on Khuzestan roads, but highway analysis findings indicates a %43 human error of all accidents and by contributing factor it is over %97.In contrast the technical factors only contributes one percent of all accidents. This article is to conduct the first research of its kind in Khuzestan on aiming to identify human factors contributing accidents. The motor vehicle accidents statistics used in this study are derived through the highway police reports also known as COM113. The study is based on the collection of data of all motor vehicle accident fatality which has occurred in Khuzestan highways during a three year period of 2006 to 2009. The police report contains such information as: The driver characteristics (age, gender, education, number of fatalities and casualties); Type of vehicles; Types of crash; Causes of accidents; Air conditions; Road, vehicle and human factors and other less effecting factors.

1. INTRODUCTION

Every year the lives of almost 1.3 million people are cut short as a result of a road traffic crash. Between 20 to 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury [1]. The losses associated with these accidents include not only the lives of those involved, but also the time spent in stopped or slowed traffic, excess fuel consumption, the cost of health care, and tax dollars spent on emergency response.

There are few global estimates of the costs of injury, but an estimate carried out in 2000 suggest that the economic cost of road traffic crashes was approximately US$ 518 billion. National estimates have illustrated that road traffic crashes cost countries between 1–3% of their gross national product, while the financial impact on individual families has been shown to result in increased financial borrowing and debt, and even a decline in food consumption [1].

Khuzistan province is the most important economic and geopolitical area in Islamic Republic of Iran. Its geographical location, economic potentials of natural oil, gas and water resources has created considerable effect on the mobilization and road use. Insufficient capacity of railway system has increased the dependency of passenger and transport on road use. According to data recorded by Iran Road Maintenance & Transportation Organization (RMTO) the traffic increase in Khuzistan has much higher than increase rate road development; therefore it results in an increase of road accident to as much as annually 52 percent for a three year period of 2006-2009.

In order to determine the best way to allocate limited funding to programs that effectively and efficiently work toward the goal of highway safety, it is important to understand the significant factors leading to car accidents. This article is to conduct the first research of its kind in Khuzistan on aiming to identify all factors contributing accidents. The contribution of this research to road safety is provide dependable analyzed data for future transport planning and engineering studies or any related researcher on safety issues.

2. DATA AND METHODS

The motor vehicle accidents statistics used in this study are derived through the highway police reports also known as COM113. The study is based on the collection of data of all motor vehicle accident fatality which has occurred in Khuzistan highways during a three year period of 2006 to 2009. The police report contains such information as: The driver characteristics (age, gender, education, number of fatalities and casualties); Type of vehicles; Types of crash; Causes of accidents; Air conditions; Road, vehicle and human factors and other less effecting factors. In next step all of data registered in a special data bank and finally, according to different subjects and accidents factors these data are analysed.

3. ROAD ACCIDENTS FACTORS

The road transport system include three main physical components; the road users including pedestrians and drivers, the vehicles including bicycles as well as motorcycles, and the roads including their immediate environment. These components and their interaction through the movement and behavior of the road users are influenced by and have an effect upon a variety of social, economic, and technological factors. Some factors such as vehicle licensing and inspection, land use in the immediate vicinity of the roads, and traffic legislation and its enforcement are directly related to the three components. Other more external factors such as education and medical services which are linked to other sectors of the economy are still affected by and have an influence on the operation of the road transport system [2].

Though all these factors contribute to higher accident risks and give a lead on where corrective actions may be taken, it is clear that any countermeasures need to be undertaken as a part of a comprehensive program to be effective. In-depth studies in British and US have found that the road users alone were responsible for 65 and 57 percent of the crashes in Britain and US respectively; that the road environment alone could be held responsible for 2 and 3 percent respectively, and that the vehicles themselves were solely responsible for only 2 percent of the crashes. Road users and the road environment together were found to have caused 24 and 27 percent of the crashes respectively, the road users and the vehicle together for only 4 and 6 percent, and that errors by the road users were a contributing factor in 95 and 94 percent of the crashes respectively [2]. In addition according to P.I.R.A.K reprts in 57 percent of word traffic accidents human factors were major causes. Road and vehicle factors were responsible of 34 and 13 percent of word traffic accidents. Figure 1 shows traffic crashes contributory factors according to P.I.A.R.C studies [3].

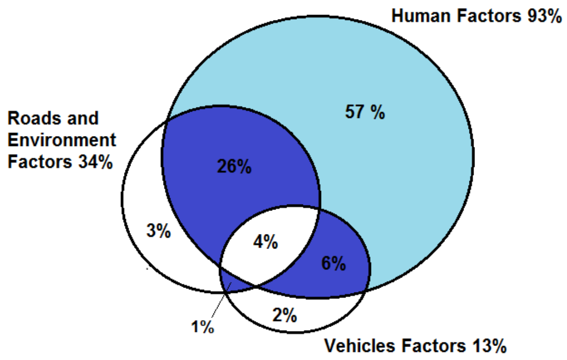


Fig. 1 Results of world traffic accidents factors in P.I.A.R.K study

Although there is no significant study of accident causes on Khuzistan roads, but highway analysis findings indicates a %43 human error of all accidents and by contributing factor it is over %97.In contrast the technical factors only contributes one percent of all accidents (Figure 2) [4].

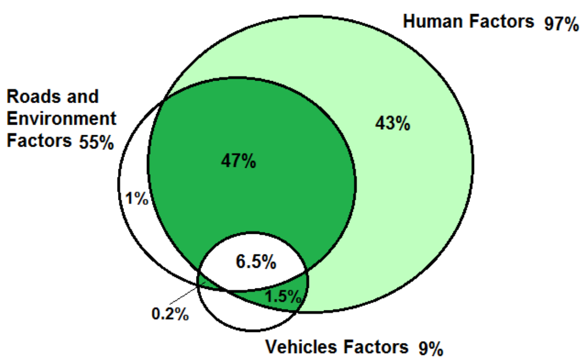


Fig.2 Khuzistan Road accidents contributory factors

4. HUMAN FACTORS IN KHUZISTAN ROAD ACCIDENTS

The road users is clearly the critical element in the system, their behavior has to be addressed if significant gains in safety are to be obtained. Key factors are a basic understanding of the traffic system, an ability to recognize and avoid danger, and to exercise safe behavior. Knowledge on the traffic system and how to behave in traffic can primarily be improved through better education and publicity campaigns, and through better screening, training and testing of drivers.

The Figure 2 indicates that 97 percent of all road accidents can be attributed by human behaviors alone or combined with other factors. This means that the majorities of accidents are caused by the actions and behaviors of individuals and are therefore largely preventable.

4.1. Risk Drivers Age and Sex

Driver age is a significant contributing factor in fatal accidents. Younger and older drivers are expected to increase, and these groups have the highest risk of becoming involved in an accident. In the next 20 years, the number of drivers over 70 will double, and these drivers often have poor vision, medication side-effects and slower reaction times. Drivers under 25 are most likely to be killed in crashes because they have the highest intoxication rates and the lowest seat-belt use [5].

Figure 3 shows age of drivers in Khuzistan road accidents. According to this figure drivers with 25 to 30 years old are most risky age. This means that these drivers group are very important in safety programs.

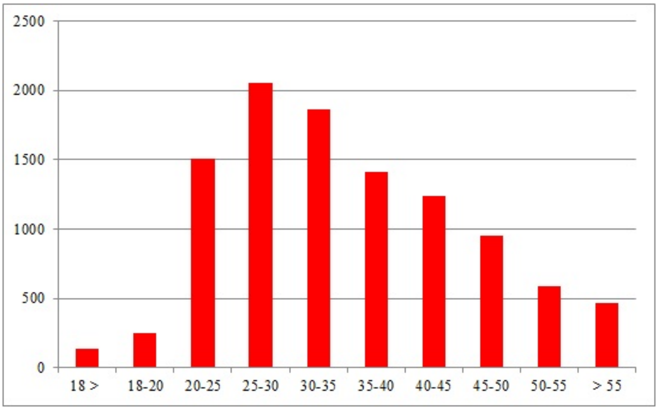


Fig.3 Age of drivers in Khuzistan road accidents

According to WHO reports from a young age, males are more likely to be involved in road traffic crashes than females. Among young drivers, young males under the age of 25 years are almost 3 times as likely to be killed in a car crash as young females [1]. Men are primary roads usre in Iran and specially in rurla roads almost all drivers are men. Khuzistan road accidents analyses indicate that the men were in 98 percent of road accidents and women were only in 2 percent of all accidents.

4.2. Behaviors Factors

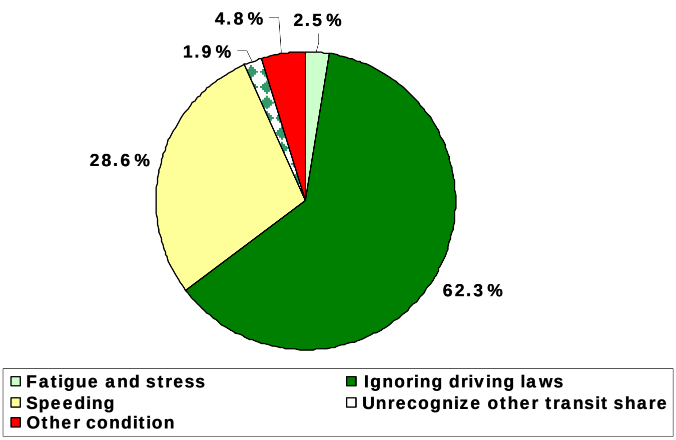
In order to determine the most effective approaches to reduce highway deaths, injuries, and related costs to acceptable levels, it is necessary to have an accurate and complete picture of the causes and circumstances of traffic accidents and especially driver behavioral factors and condition. The last comprehensive study on the causes of highway accidents was conducted in the 1970's, and much advancement in road and vehicle safety and changes in driver attitudes have changed transportation safety issues in the past three decades [3].

Alcohol-related traffic accidents are very important and serious problem in many countries, for example in U.S Alcohol-related traffic accidents claimed nearly 18,000 lives in 2002, and driver impairment due to alcohol is the single most contributing factor to accidents [6].

Speeding is another leading cause of fatal accidents. Driving faster than posted speed limits or what safety would dictate reduces the diver's ability to negotiate curves or steer around objects in the roadway, extends the distance required to stop the vehicle, and increases the distance the vehicle travels during the driver's reaction time.

Driver distraction is other important human factors in road accidents. There are many types of distractions that can lead to impaired driving, but recently there has been a marked increase around the world in the use of mobile phones by drivers that is becoming a growing concern for road safety. The distraction caused by mobile phones can impair driving performance in a number of ways, e.g. longer reaction times (notably braking reaction time, but also reaction to traffic signals), impaired ability to keep in the correct lane, and shorter following distances.

Khuzistan road accidents analyses show that the major behaviors that contribute to accidents are identified as inattention to driving laws, unseasonable speed. It is important to realize that there are other factors that contribute to these behaviors.The figure 4 indicates a comparison of the four major behavioral factors contributing to road accident fatalities.



5. CONCLUSION

It is generally acknowledged that human error is an underlying cause of almost all accidents; human error in observation, decision making and response to the situation at hand. Research in several countries conclude that human error is involved in over 90 percent of all road accidents and that only a small proportion of accidents can be directly attributed to vehicle defects or faults in road design or maintenance.

Analyses indicate that human factors alone are the major contributors (43% of crashes) in Khuzistan road accidents. In addition human factors alone or in combination with other factors consist of 97% of road crashes contributory factors. Also analyses show that the major behaviors that contribute to accidents are identified as inattention to driving laws, unseasonable speed.

Results of this study show that it is very important to have a good plan and program to manage road user bevaiuors to reduce share of this factor in road accidents. All activities with significant impact on road safety risk factors need to be monitored and appraised at regular intervals to assess status, gain experience and knowledge, and provide basis for remedial actions as seen necessary. Important aspects are safety audits of road maintenance and construction programs, and monitoring of speeds and other traffic behavioral patterns to assess the sufficiency of traffic surveillance and control.

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DATA COLLECTION METHODOLOGY FOR STUDYING DRIVER BEHAVIOUR FROM FREE FLOW SPEED PROFILES ON RURAL ROADS

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ABSTRACT: Methodologies based on naturalistic observation provide the most accurate data for studying driver behaviour. This paper presents a new methodology for getting naturalistic data related to drivers' behaviour in a road segment. It is based on the combination of using pocket-size GPS trackers and drivers' surveys. Continuous speed profiles along a road segment and social characteristics for a great number of drivers can be obtained. It has already been successfully used for several studies, such as the development of models to estimate operating speed profile in two-lane rural road segments; or the characterization of driving styles. Those models have been the key for the development of a new geometric design consistency model, making the road safety evaluation easier.

1. INTRODUCTION

Multiple factors typically combine to produce circumstances that lead a vehicle to crash. The main concurrent factors are human factors, roadway environment factors, and vehicle factors. Human factors are the most prevalent contributing factor of crashes, followed by roadway and vehicle factors. However, due to its characteristics, it is also the most complicated factor to study. The best results in this area have been achieved by using methodologies based on naturalistic observation. This kind of methodologies is based on subjects driving the way they usually do, in their own vehicle and without any specific instructions or interventions. Projects such as *100-Cars Naturalistic Driving Study*, *SHRP2-Vehicle-Based Study* and *2 Be Safe* use this data collection methodology.

The main aims of those studies are drivers' behaviour at crash situations and the interaction between drivers and inside car devices. Besides, in most studies, drivers are volunteers who know the scope of the research project, so their behaviour may be biased.

In order to study drivers' behaviour at different road alignment elements (curves, tangents and spiral transitions), it is necessary to collect data from a huge sample of people driving along a sample of elements.

For characterizing drivers' behaviour, the most studied variable is the speed at which they drive. Speed data collection may be based on spot or continuous data.

In most cases, data collection device is a manually radar gun or similar [1]. The use of radar gun has three important problems: human error, cosine error and drivers' behaviour affection. Pavement sensors are also used for collecting speed data [2]. Although they solve those problems, they only collect data in one location, as well.

With those methodologies, the study of acceleration and deceleration phenomenon is not possible. Therefore, several research projects [2] complemented data collection by using lidar guns. This way, speed data is collected in several spots in a road segment location. However, even with lidar guns, starting and ending points of acceleration/deceleration cannot be accurately determined.

These deficiencies in data collection may be avoided by other methods based on continuous speed tracking, such as instrumented test vehicles or different methods based on digital video recording and processing. Last one is only suitable for local studies at short road segments.

Other researchers [3, 4] studied drivers' behaviour from speed data collected using instrumented vehicles. However, the results may be conditioned by the equipment of the vehicle and the number of observations. Moreover, the sample may be biased and it may not be enough representative of the actual driver behaviour because research volunteers know the research objectives and they are not used to drive the instrumented vehicle.

2. OBJECTIVES

Considering the shown deficiencies on speed data collection, the Highway Engineering Research Group of the Universitat Politècnica de València (Spain) has developed a new data collection methodology, as an adaptation of usual naturalistic methodologies.

The main objective is getting naturalistic data in order to study drivers' behaviour in a road segment. The researchers should be able to get enough sample size of drivers along road segments.

Collected data should be both drivers' individual continuous speed profile along a road segment and data related to their social conditions, trip characteristics and vehicle type.

Besides, data collection shouldn't be the cause of drivers' behaviour change, so that it may be considered as naturalistic data collection methodology.

3. METHODOLOGY

This section describes the application of developed data collection methodology on 10 two-lane rural road segments. Data about path and continuous speed profile of actual drivers, their social characteristics, their trip characteristics and type of their vehicles were obtained.

3.1. Data collection

For data collection, two checkpoints were located at the beginning and at the end of each road segment, controlling both directions. Two or three people stayed at each checkpoint. Two members were at the starting lane, while the other one was at the final point. The general diagram of the data collection system is presented in figure 1.

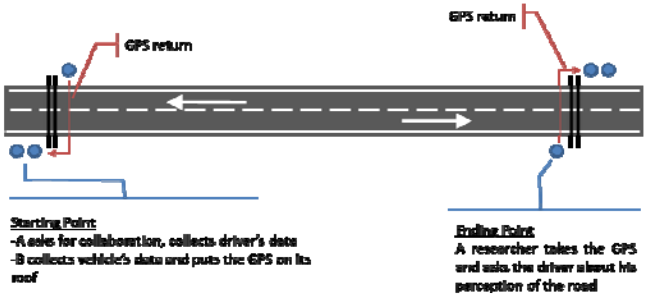

Fig. 1 Data collection diagram

When there was an incoming vehicle, one member of the checkpoint team took care of stopping it and asked the driver about collaboration in the research project, emphasizing that he/she was part of the University. In order to avoid data biasing, the scope of the research was not explained at the beginning. After driver's agreement, he was asked about some general questions about his driving experience, previous knowledge of the road segment and the purpose of the trip. Another member of the group placed the GPS device on the vehicle and wrote down some data, such as the number of passenger or type of vehicle. Driver was also encouraged to not change his usual driving behaviour.

This process took around 1-2 minutes. After this time period, driver was allowed to continue along the road segment.

When the vehicle arrived to the final checkpoint, a member of the team took the GPS device out of the vehicle and asked the driver some questions about his perception of the road segment. At this point, the driver was informed about the research project, by means of a leaflet, in order to be as fast as possible and not slow down the traffic flow.

The average sample size of drivers involved in data collection was 180 drivers by road segment (considering both directions). The total data sample of the research project was 11876.5 vehicles·km.

After described data collection, some recommendations can be made.The sample of drivers who take part in the research will depend on the considered variables for the analysis. Thus, an estimation of the duration of the data collection has to be carried out before it, considering the AADT and the amount of data needed. It is also needed to consider at least one hour before and after the test in order to set and pick up all the equipment placed on the road.

GPS devices provision is always needed at checkpoints. Depending on the traffic flow balance by direction, it may be needed to transport devices from one checkpoint to the other one, in case of lack of devices at one checkpoint.

It is also recommended to select roads with balanced traffic flows for both directions.

Some equipment is needed in order to perform the test, besides of GPS devices. The safety of the people involved in the field data collection is very important. Thus, some traffic guidance elements have to be used for warning drivers about the presence of the checkpoints. A safe area must be created at each checkpoint for allowing their members to work. They also have to wear safety vests.

3.2. Naturalistic data test

GPS devices contain the information about position and speed of all drivers along the road segment under study. The main goal of this field data collection is to obtain accurate, naturalistic and disaggregated data from actual drivers. Thus, it is important to ensure that drivers perform their driving task without being influenced by the presence of GPS devices, by means of a naturalistic data test.

The test was carried out during the first two field data collections, comparing data obtained from drivers who were driving the day of the experiment and drivers who were driving the day before of the experiment. Speed data from both types of drivers was obtained at the same spots.

Some video cameras were set at some spots along the road segment, hidden from driver’s vision. They were recording the traffic flow, for calculating the operating speed of individual drivers. Operating speeds of drivers involved and not involved in the field data collection was compared, for checking if they were influenced by the presence of GPS devices. The analysis was performed by means of LSD intervals, finding no statistical difference between people with and without GPS devices [5].

Recorded traffic was also used for determining the operating speed at those spots. By comparing speeds obtained from video cameras and GPS devices, data obtained from last ones was validated.

3.3. Free-flow condictions test

In order to analyze the influence of the infrastructure on drivers’ behaviour, involved vehicles are supposed to drive at free-flow conditions. Different vehicles are released from the initial point of the road segment at free-flow conditions, but they may be disturbed by other vehicles along the road segment. In this case, there is no an easy option to determine if the registered data is under free or non-free flow conditions. A methodology was developed in order to determine the road segment where a driver drove under non-free flow conditions.

Each driver behaves in a particular way, approaching to certain operating speed percentiles. This behaviour is similar under free-flow conditions, but should be different when the driver is disturbed due to traffic flow. By means of comparing different aggregate operating speed percentiles and individual operating speed profiles, it is possible to determine when drivers' speed is constrained.

4. APPLICATIONS

Described data collection methodology allows obtaining data on several road segments about vehicle paths, individual continuous speed profiles, social characteristics of drivers, of their trip and the type of their vehicles.

Those data allows performing new and more accurate research.

4.1. Operating speed profile models for geometric design consistency evaluation

Previous operating speed determination methodologies were based on spot speed data collection. Some hypotheses had to be made in order to develop operating speed profiles construction rules, such as considering constant speed at curves. Other example is the determination of acceleration and deceleration rates. Spot speed data collection is only able to determine the speed at two previously located spots. Thus, deceleration length is unknown and the hypothesis of considering it constant for all drivers has to be assumed.

With this new methodology both problems are fixed. The continuous operating speed profiles help the researchers to check the behaviour of all drivers at different alignment elements, so the previous hypotheses can be considered or rejected based on naturalistic data. Also, deceleration length is known for all individual drivers, so more accurate analysis can be done.

Taking into account these considerations, it can be concluded that operating speed and acceleration/deceleration rates models calibrated from continuous naturalistic speed data fit better drivers' behaviour than those based on spot data do.

According to this assumption, operating speed models for tangent and curve sections have been developed based on operating speed profiles. Besides, other models have been calibrated for estimating the 85^{th} percentile of acceleration/deceleration rates, instead of the acceleration/deceleration rate of 85^{th} percentile speed profile [5].

Those models have been the key for the development of a new geometric design consistency model [6]. It allows the estimation of the crash rate of a road segment. Thus, this data collection methodology has turn into a tool for road safety evaluation on both road design phase and operation phase.

4.2. Human factors analysis

As a result of data collection and treatment, individual continuous speed profile is available for each single vehicle and for each road segment. Besides, the different questions asked to drivers before and after the test allow the characterization of some variables, such as: driver's characteristics (age, gender, driving experience); characteristics of the trip (distance, regular or not, number and type of passengers); and vehicle type.

Therefore, it is possible to study the relationship between both types of variables, instead of performing aggregate analysis. The obtained results may be used for studying: drivers' speed perception; driving styles characterization; and consistency of drivers' behaviour between elements, between roads and along the time. It may also be the base for the validation of driving simulators that have the purpose of drivers' behaviour study.

The analysis about the influence of those variables in the developed speed on curve sections has already performed. The results show that men drive faster than women and that the older driver is, the slower he/she drives. Driver's experience is also a significant variable, so people with less driving experience drive slower. Besides, people drive faster in a regular trip and/or when they are alone in the car.

The knowledge of the influence of those data on driver behaviour may be useful for road safety media campaigns and education programs designers.

5. CONCLUSIONS

An adaptation of previous naturalistic data collection methodology has been developed for studying driver behaviour on rural roads. The obtained data consists on individual continuous speed profile and data related to driver, his/her trip and the type of vehicle he drives. With those data, aggregated and disaggregated analysis may be performed. In fact, it has been successfully used in order to calibrate the models and construction rules for getting operating continuous speed profile of a rural road segment. This model, based on aggregated data, allows road design consistency evaluation and road safety improvement.

Disaggregated data have been used for studying the influence of driver's characteristics and the characteristics of trip and vehicle on chosen speed and acceleration/deceleration rates.

Therefore, this data collection methodology turns into a new tool for drivers' behaviour and road design evaluation.

6. AKNOWLEDGEMENTS

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RIDERS' RESPONSE TO ASSISTANCE FUNCTIONS – A COMPARISON OF CURVE AND INTERSECTION WARNINGS

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ABSTRACT: Addressing the two predominant crash scenarios for motorcyclists, a Curve Warning system and an Intersection Support system have been developed and tested with users. This paper reviews the results on the riders' response to these two assistance functions, starting from the key differences in the characteristics of their target scenarios and the expected compatibility of the warnings with riding. The review shows that both systems are adapted to fit rider needs, provided that thresholds and warning signals are suitably chosen.

1. INTRODUCTION

The characteristics of a motorcycle and the way the riders use their vehicle lead to typical crash scenarios, which differ from those of other road users. The most common crash scenario for motorcycles is the single-vehicle crash in curves due to inappropriately high speed and consequent loss of control, followed by the front-side crash at intersections, usually due to a right-of-way violation of another road user [1-3].

The challenges of riding arise from the high level of necessary motor-skills, coordination and balance [4] and the constant hazard-monitoring task [5]. The high manoeuvrability of motorcycles allows for an expressive use of the vehicle, which can lead to intense sensations of dynamics and control [4, 6, 7]. Accordingly, passion for motorcycles, performance and the experience of sensations are predominant motivations among riders [8].

The conception of riding as a performance involves that a majority of riders appreciate risk up to a certain threshold [9]. When the risk level of the activity matches the riders' skills, they can achieve a flow experience, an optimal sensation of high concentration and control [10]. However, the expressive use of the motorcycle increases the risk of losing control of the vehicle, especially when the rider chooses a high speed in order to enhance riding sensations [e.g., 11]. Accident analyses and rider statements reveal that the most common error underlying curve crashes is the misjudgement of the appropriate speed by the rider [12], leading to fall after overbraking or running wide of the curve [1].

Right-of-way violations at intersections may be associated with inattentiveness, driving errors and risky driving [3]. In about two thirds of the intersection crashes, the driver of another vehicle infringes upon the right of way of the motorcyclist, having overlooked the rider or misjudging the approach time of the motorcyclist [e.g., 13, 14]. Those errors occur more frequently when the rider is speeding [15].

Within the European project SAFERIDER, two advanced rider assistance systems (ARAS) have been developed, which target the above mentioned crash scenarios. In the following, the assistance functions are presented and the different characteristics of their target scenarios (curves vs. intersections) are highlighted. Consequently, expectations on how these differences might affect the riders' experience of the assistance function are deduced.

2. ASSISTANCE FUNCTIONS AND TARGET SCENARIO CHARACTERISTICS

The Curve Warning (CW) system aims at avoiding single-vehicle motorcycle crashes by warning the riders if their speed is inappropriately high for the curve they are approaching. The Intersection Support (IS) system gives guidance to the rider regarding the appropriate approach speed to an intersection. It supports the rider in anticipating possible right-of-way violations by other road users. The ARAS do not only consider the scenario characteristics but also the appropriateness of the motorcyclist's riding behaviour when facing a potentially critical situation, and they only warn the riders if their behaviour critically differs from the safe reference manoeuvre calculated by the system. The CW and the IS are combined with two alternative rider interfaces: a force feedback throttle which alerts the rider by increasing the stiffness of the gas-throttle handle, and a - less intrusive - haptic glove which applies a vibration signal on the rider's wrist.

Both ARAS aim at increasing the riders' safety in hazardous situations, but the target scenarios of the CW and the IS have considerably different characteristics. Firstly, riding through curves is a key aspect of the expressive nature of motorcycling. By riding well around a set of curves riders can experience positive riding sensations, which may even include flow - provoked by the application of their skills to meet the challenge [16]. Correspondingly, curve crashes are more often associated with riding pleasure than other types of crashes [12]. Safely managing intersection situations, in turn, does not compete with such riding motives. Rather, it implies potential conflicts with other road users, especially the failure by car drivers to give way. As a consequence, the CW is more likely to interfere with riding sensations than the IS. The riders may feel annoyed because the warning interrupts their experience of flow and the satisfaction of riding motives is altered. It can be expected that the design of the rider interface is crucial in this context. The riders may reject an intrusive warning because it disturbs the riding activity, particularly in curve situations.

Secondly, curve crashes are mostly single-vehicle accidents, where the rider is responsible of the misjudgement of the appropriate riding manoeuvre. Given that riding is often considered as a performance, where the riders match their skills with the risk level of the activity, using the CW could conflict with the riders' feelings of control and autonomy. It can be expected that riders tend to reject the CW, at least if thresholds employed by the system differ excessively from the riders' accepted levels of risk. On the other hand, there seems to be an awareness of errors in judging the adequate approach speed to a curve [12], which may be favourable for the acceptance of the CW. Intersection situations, in turn, are characterized by the possibility to be put at risk by other road users. Given that the consequences of a right-of-way violation by another road user are particularly injurious [17], the riders should welcome the IS as an assistance function that helps them compensating for other road users' errors.

Thirdly, the scenarios differ in the behavioural options that exist for managing the situation safely. The only option to compensate for excessive speed in a curve approach is to slow down, which corresponds to the reaction suggested by the curve warning. Likewise, this reaction appears to be the most appropriate for intersection approaches, since it allows the rider to come to a stop in case of a right-of-way violation and mitigates judgement errors of the motorcyclist's speed by the other driver. However, alternative behavioural choices exist, which are opposed to the one suggested by the IS. When approaching an intersection with the presence of another road user, the riders may just as well intend to quickly pass the intersection or to perform an evasive manoeuvre. In these cases, an intrusive warning, such as the one provided by the force feedback throttle may be especially incompatible and not appreciated by the riders as a consequence.

The aim of this work is to analyse whether the described differences between the assistance functions affect the riders' response to the ARAS according to the expected implications mentioned above. With the objective of comparing the riders' behavioural reactions and attitudes towards curve and intersection warnings, this paper reviews the results of user tests that have been carried out on the CW and the IS [18, 19].

3. USER TESTS

The CW and IS were tested from a human factors perspective in two separate simulator experiments [18, 19]. In each experiment, N=20 participants rode on a virtual test track specifically created for testing the system functionality. Riding with a system setup was compared to baseline riding. The evaluation included the effects of the system use regarding objective changes in the riding behaviour, measured in terms of speed reduction in response to a warning and in terms of warning avoidance through more cautious riding behaviour, as well as the subjective appreciation of the system, comments on possible disturbances and acceptance measures. Both ARAS were consecutively tested with the two alternative interfaces. The results of the user tests on the CW are reported in detail in [18] and those on the IS in [19]. They are reviewed in the following, in order to obtain a comparison between riders' response to assistance in curves and intersections.

4. COMPARISON OF RIDERS' RESPONSE

The warnings of the CW provoke a better adaptation of the riding behaviour in the curve (speed reduction) compared to riding without support, and so did the IS function in right-of-way situations. The fact that warnings occurred in curves and at right-of-way situations confirms that the riders can both benefit from support when negotiating a curve and when other road user could get into the rider's trajectory at an intersection.

The use of the CW with the haptic glove leads to a reduced frequency of warning situations, showing that this kind of assistance function can have an educational effect and thus prevent the emergence of potentially critical situations. When using the IS, in turn, the riders did not anticipate and avoid the warning situations in right-of-way intersections. This may be due to the fact that a right-of-way situation is only potentially critical if another vehicle is present and the riders rely on the IS to detect this hazard.

Although the CW intervenes in a situation characterized by riding fun and autonomy, the riders' reactions to its warnings are clearer than the reactions to the IS warnings. Fig. 1 shows that after the warning onset (at 1s) the riders release the throttle more when using the force feedback throttle than when they are warned by the haptic glove. The adaptation of the riding behaviour to the critical curve situation is far less pronounced in the baseline condition.

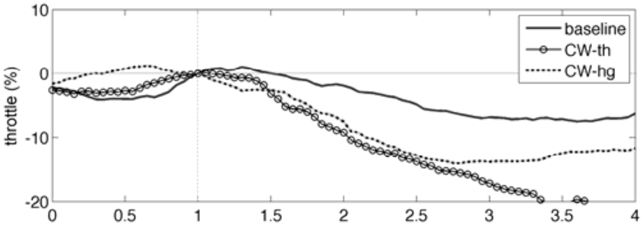

Fig. 1: Comparison of mean value of throttle variation [%] over time [s] after curve warning onset (at 1s), from [18]

In the critical intersection approaches, a clear speed reduction only appears in higher speed environments (rural roads). The warning thresholds for lower speed environments might need to be better adjusted so as to efficiently support the rider here as well (Fig. 2).

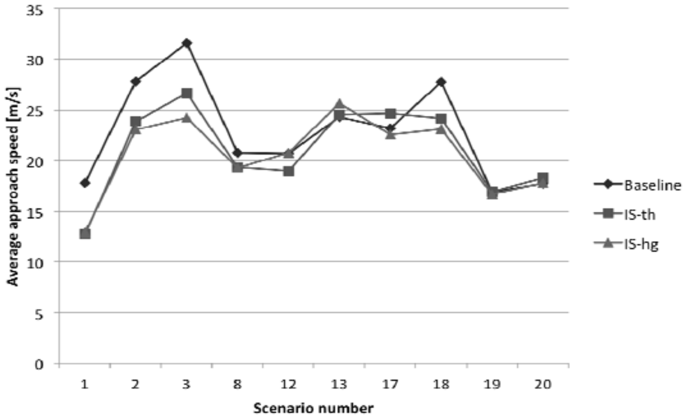

Fig. 2: Comparison of average approach speed to right-of-way intersections, 1-3 and 18 are rural or higher speed scenarios, from [19]

It is however arguable whether a reaction to the extent as induced by the force feedback throttle is appropriate or necessary to safely manage curves, and whether the avoidance of critical curve situations provoked when using the haptic glove outweighs this. It has to be considered that the majority of the participants chose the ride with the haptic glove as the safest one in the user tests of both systems. The subjective assessment of the interface and its effects by the riders reveals the downsides of the force feedback throttle (Fig. 3). Regardless of the assistance function, the haptic glove is clearly better rated than the force feedback throttle, which is rejected due to its invasive character. Against expectations based on the positive experience of riding as a performance in curves, the riders' annoyance by this intrusive interface appears more clearly for the IS than the CW. The riders fear an interference with their behavioural intention at intersections. Although intersections are not associated to the experience of riding pleasure, the riders feel disturbed by the intrusive interface. This finding calls the force feedback throttle in question as an appropriate interface for the transmission of warnings, especially in situations where the interaction with other road users might allow for several choices of appropriate behaviour. Both the evaluation of the CW and the assessment of the IS point towards a considerable influence of the interface design on the overall appreciation of the system (Fig. 3).

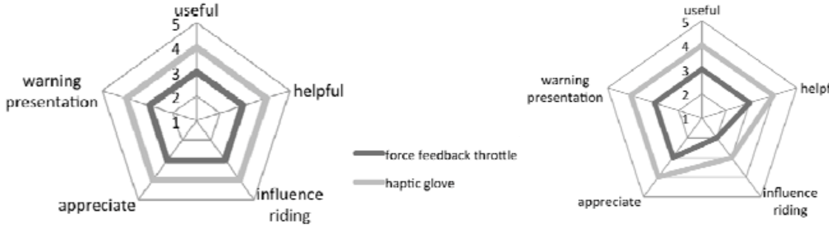

Fig. 3: Example items of the subjective evaluation of the CW (right) and

the IS (left), median values [1: not at all – 5: a lot]

The subjective measures on the CW and the IS reveal a receptive attitude of the riders, but the acceptance is limited by restrictions in the preparedness to acquire the systems and to permanently use the systems.

5. CONCLUSIONS

The review conducted in this paper confirms that the systems successfully address the two most prominent crash scenarios, by provoking a speed reduction in potentially critical situations. The results on a reduced warning frequency when riding with the CW using the haptic glove show that ARAS can cause a more cautious behaviour in the situations they are designed for and thus prevent the emergence of potentially critical situations. In turn, the IS did not generate such an adaptation effect. The riders rather seem to rely on the system to detect the hazard before modifying their behaviour. This raises the issue of a possible over-reliance on the IS by the riders. By contrast, the behavioural adaptation generated by the CW is opposed to a system misuse (testing the limits).

Although riding is an activity that mainly comes across as a performance rather than a pure means of transport and that is characterized by high levels of autonomy, the motorcyclists seem to be generally willing to use support for specifically risky situations and react appropriately to the warnings. The receptive attitude towards the systems demonstrates that such types of support are compatible with riding motives and the riding experience motorcyclists are seeking. Against the concerns regarding possible interferences with riding pleasure or feelings of autonomy, in the present work the curve warnings lead to clearer adaptation of the riding behaviour than the intersection warnings and the curve assistance system does not receive any negative evaluation. This favourable assessment may be attributable to an appropriate choice of the warning threshold.

The findings suggest that special attention should be paid to the riders' subjective view on the effectiveness of a system rather than solely relying on the effects that are measurable in the riding behaviour. In this context, an appropriate design of the interface that transmits the warning to the rider has proven essential. The results show that assistance does not necessarily interfere negatively with riding sensations if the warning thresholds are properly chosen (curves), and that an invasive interface is rejected by the riders, especially when it is not sufficiently compatible with the rider's behavioural options to manage the critical situation (intersections). The assistance systems need to be optimized in order to enhance user acceptance, e.g. by customizable thresholds and warning designs.

The conditional usage intention expressed by the users in both experiments still represents a clear limitation for the systems' potential to improve the riding safety. It might be due to the fact that the riders need to get more familiar with the system, that the tests were carried out with first prototypes, which still need to be improved, or that the transfer from the simulated environment to the real world is not straightforward for the participants. Nevertheless the findings support that it is worth to further develop ARAS with both types of functionalities reviewed in this paper. They indicate that ARAS can prevent human error in the situations they are designed for, both by inducing appropriate reactions to warnings and by provoking an avoidance of warning situations. The systems seem to be compatible with the nature of riding and rider needs, as long as warning thresholds are carefully chosen and warning signals are appropriately designed.

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