# NATURALISTIC DRIVING STUDIES (NDS): International lessons learnt and the implications for South African driver behaviour studies

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**ABSTRACT**

Naturalistic Driving Studies (NDS) is a novel approach to the way that road safety research can be conducted in South Africa. The term "naturalistic driving studies" refers to the unobtrusive approach to study specifically driver behaviour. This new methodology will enable researchers to study driver behaviour in context of the driving task, road environment as well as inform driver actions preceding crashes or near crash events. The underlying assumption of this approach is that driver behaviour will not be significantly altered by being observed over the long term and that such studies would therefore reflect natural driver behaviour over time. The image material recorded in the vehicle along with other in-vehicle technologies that also collect data about the road environment and other vehicles will give valuable insight into driver behaviour in different driving situations. The first studies of this nature have been undertaken within the U.S Federal Highway Administration programme and a second study is underway for 2010. It is imperative that South Africa is part of this study.

Human error has been highlighted as the most significant contributor to road traffic crashes in South Africa. Yet little is known about the human factors that are seemingly the main contributory factor attributing to the carnage on our roads. South Africa also has the unique opportunity through participation in the International NDS project to contribute to this important research study by delivering data that reflects the nature of intrinsic road safety aspects from a developing country's perspective. This paper takes into account the lessons learned from international NDS studies that have been successfully completed. The paper then considers the implications of an NDS approach for South African driver behaviour studies.

## 1. INTRODUCTION

### 1.1. Setting the stage for NDS in South Africa

In December 2008, South Africa boasted a vehicle population of approximately ten million registered vehicles. This estimate includes both motorised and towed vehicles.

Between 1999 and 2008, the type of vehicles represented in the registered motorised vehicle category, has stayed fairly the same (http://www.arrivealive.co.za. accessed 21 January 2010). Vehicle representation in December 2008 was predominantly made-up of cars which constituted for approximately 62% of the registered vehicle population. Light delivery vehicles had the second largest share of the vehicle population namely 23%, followed by trucks (4%), buses (1%), motorcycles (4%) and an 'unknown' category of 3%.

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The high percentage of registered cars reflects the preference of drivers in South Africa for their own transport as a result of, amongst other, a lack of accessible, efficient and safe alternative modes or public transport. Registration statistics related to light delivery vehicles, trucks and busses on the other hand paints a possible picture of the number of vehicles as well as the number of drivers that "drive for work".

According to the RTMC statistics for 2008 (http://www.arrivealive.co.za. accessed 21 January 2010), the highest number of fatalities per type of vehicle (46%), were sustained by occupants of cars. Light delivery vehicles had the second largest share of fatal crashes (22%), followed by minibuses (9%) and trucks (6%). Busses and minibus taxis each contributed to 3% of the fatal crashes occurring on SA roads in 2008. Motorcycles constituted 2% and in 8% of the fatal crashes the vehicle type was not indicated. Driver error is a contributing factor in 90% (Botha and Van Der Walt, 2006) of crashes yet little is known about the driver behaviour/performance and interactions with the road. Even more so in South Africa where very little driver behaviour research has been conducted for the past 15 years.

A January 2010 news report, issued by the Automobile Association of South Africa (http://www.aa.co.za/home/press_room/itemid/147/whose-fault-is-it-anyway.aspx. accessed 21 January 2010), states that one in ten South Africans are at risk of being involved in a road traffic crash on South African roads. This is a staggering realisation when compared to a 1 in 5000 risk per annum in other parts of the world (Khan, 2007).

The question at hand: What do we know about these road users that either fit the profile of offender and/or crash victim on South African roads?

## 1.2. Study of driver behaviour

Driving is an ordinary task, undertaken by ordinary people everyday. Driving is something which anyone can do, providing the person meets the license requirements. The ability to drive and owning a vehicle constitutes a symbol of freedom in modern society (Ward, Hancock, Ganey and Szalma, 2003). This freedom though comes at a price. The *price* is the *risk* of being involved, being seriously or fatally injured as well as the financials and socio-economic costs associated with being in a road traffic crash. Driving a motorised vehicle is therefore potentially dangerous not only to the driver, but also to pedestrians, cyclists and fellow motorists. Ward et al (2003) believe that drivers receive minimal training and that the training they do receive, occurs under conditions which are manipulated to resemble real world driving and roads and that the training provided might not be adequate for the new driver to meet the demands under real driving conditions. In South Africa, it is not compulsory to attend a K53 driver training class or make use of a driving school, before obtaining a license. In the case of professional and hazardous goods drivers the law requires a different type of license, which implies different, perhaps more advanced driver training, in order to safely drive a truck carrying goods or minibus taxi/bus carrying people.

The rate at which technology, especially in-vehicle technologies, is developing is overwhelming. In future, the driver will have to negotiate sensory input from various different sources, receive and process information originating from the simultaneous use of devices that aim to make the driving task safer. Navigational, infotainment and hand-held devices such as cell phones and in-vehicle systems are common devices and aids, now becoming more and more to the avail of drivers. Although aimed to improve road safety and the driver task, these technologies is increasing the potential for cognitive overload and is sure to increase driver risk in terms of road traffic crashes, especially within a unique and complex road environment such as that of South Arica.

## 2. NATURALISTIC DRIVING STUDIES

### 2.1. NDS defined

"Human factors, driver behaviour and traffic psychology" is a subject that internationally receives a great deal of attention. Ward et al. (2003) state that to date most human factor research have been executed in a laboratory or simulated environment. Limited aspects of cognitive, perceptual and motor demands that drivers face have been researched in this simulated environment, isolating variables from real world situations and behaviour.

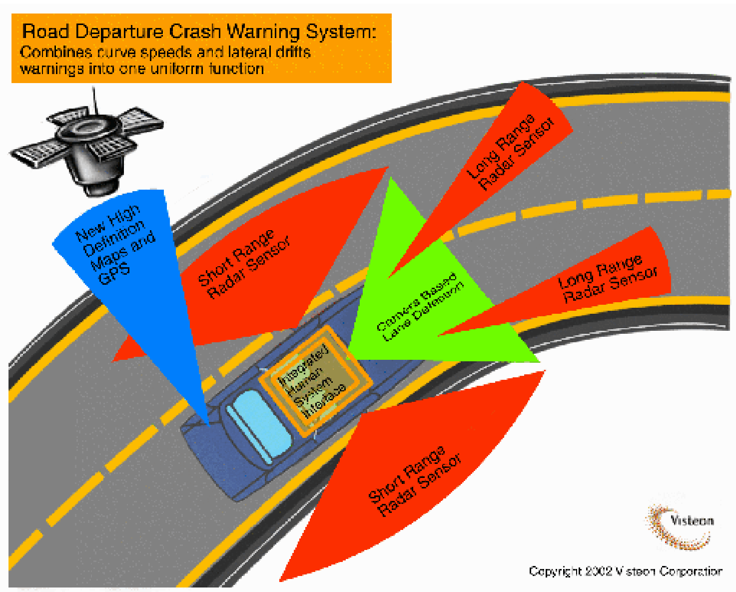


**Figure 1: Lane departure warning system and NDS (Sayer, 2005)**

Naturalistic driving studies can be defined as a research methodology that is used to unobtrusively observe driver behaviour and events that take place in a natural driving setting (Shankar, Jovanis, Aguero-Valverde and Gross, 2008). Fitch and Hankey (2008) state that the collection of vehicle and driver behaviour data through naturalistic driver studies have far reaching implications for understanding driver behaviour and road safety than ever before.

Naturalistic driving studies used as a methodology to study driver behaviour, aim to bridge the gap between laboratory and real-world driving. NDS will also narrow the gap in terms of studying driver characteristics, driver behaviour and attributes such as perception and cognition in isolation. Incidents can be measured in terms of the socioeconomic and attitudinal factors related to the driver. NDS therefore provides an integrated approached to the studying of driver behaviour within the context of the human, the environment as well as the vehicle.

## 2.2. NDS methodology


**Figure 2: NDS in-vehicle recording instrumentation (Sayer, 2005)**

Use is made of video instrumentation in vehicles and this instrumentation captures driver behaviour immediately before a crash, near-miss or other incident. Data is also collected through vehicle-based sensors and radars which record environmental and vehicle factors at the same time. Naturalistic driving studies are longitudinal experiments, which imply that the notion behind the methodology is that the driver, over a long-term, will not try to significantly alter his driving behaviour. The expectation is that the behaviour observed over this period of time will be reflective of behaviour over a longer time which will provide more insight into factors associated with crash causation, near-misses and incidents. The primary objective thus is to record events of varying degrees. In other words, the result is accurate, real-time data that gives insight into driver behaviour over a long term. The benefit of this methodology is that, in addition to “big” events such as crashes, near-misses and so forth, data pertaining to mostly unreported or seemingly insignificant events is also recoded and available for analysis.

## 2.3. International NDS research: lessons learnt

### *2.3.1. The United States*

The Naturalistic 100-car study undertaken by the National Highway Traffic Safety Administration (NHTSA) in the United States, in 2005 aimed to obtain driver behaviour and performance data of events that lead up to a crash (Hanowski, Olsen, Hickson and Dingus, 2006). This study was a joint operation between the National Highway Traffic Safety Administration, the ITS Joint Programme Office from the Federal Highway Administration (FHWA), the Federal Motor Carrier Safety Administration and the Virginia Traffic department. The Virginia Tech Transportation Institute (VTTI) was contracted to do the research. An important consideration in the utilisation of this methodology was the fact that no similar data from traditional road safety research existed in any other databases. Although crash databases in such as the U.S are considered resourceful in terms of the information that can be derived at, the information in the databases give poor insight into driver behaviour and performance. The study consisted of 100 vehicles, which were fitted with the appropriate instruments. Of the sample population, 80 vehicles were privately owned and 20 were leased. The test subjects were monitored and evaluated and they drove the instrumented vehicles for a period of one year. The study informs the design criteria for a second, similar project that will be embarked on in 2010. The findings from the first study will inform the development of new driver, vehicle and road way treatments to reduce the deaths and injuries associated with the crashes. Findings will be used in the modification and improved targeting of existing treatments. The study also provides a rich database of naturalistic driving data, which is linked to roadway data as well as other diverse factors. The NDS data holds the potential for the development of tools for monitoring and evaluation of potential crash prevention or countermeasures based on the naturalistic driving data. Road safety researchers participating in this project developed a range of analysis tools such as validated crash surrogates; research protocols, specifications for monitoring and recording of incidents as well as encoded instrumentation for the vehicles. Later developments include the compilation of Naturalistic Driving Study and data dictionary. The successful completion of the first project provided the opportunity within the second project to focus more closely on hazardous locations or particular areas in the road environment such as intersections where there is a known problem. The second study under the banner of the Strategic Highway Research Programme will be much larger, delivering much more needed driver behaviour and performance data. Canada and Europe is following suit in 2010.

### *2.3.2. Canada*

The Canadian Naturalistic Driver Study is a controlled study focusing on elderly driver behaviour and on drivers driving on rural roads. The study is expected to start in September 2010 for a period of one year. A sample population of 250 drivers will be interviewed, screened and their vehicles instrumented. Use is made of volunteers giving consent to participation in the study. According to the Engineering and Research Support Committee in Canada (2009) the benefits of such a study will include real world data that will inform licensing policies; roadway design; operations and maintenance practices; vehicle safety standards. The study will support the Country's research base and capacity as well as contribute to the Canadian Road Safety Vision 2010 and successor plan. It was indicated in this report that a 1% saving on crashes will save the country 200 times the research costs. The current proposal to the Canadian Government was that the Government fund 75% of the total estimated cost and the remaining 25% by partners in the project.

### *2.3.3. Europe*

In Europe (http://www.eurofot-ip.eu/; Accessed 21 January 2010) a consortium of twenty-eight government, academic and private industry partners are collaborating to implement euroFOT, Europe's first "Field Operational Test". The aim of the project is described as being "to make road transport safer, more efficient and more pleasant". The project is based on the same principles as described in the U.S and Canadian studies, although 1000 vehicles will be utilised in the European version of the Naturalistic driving study. The studies' vehicle population will consist of cars and trucks equipped with a range of ITS technologies which include different sensors and devices that monitor every aspect of individual driver behaviour in real-world traffic conditions. Ultimately, the naturalistic driving study in Europe will focus on 8 distinct functions that assist the driver in detecting hazards, preventing accidents and make driving more efficient. It is envisaged the results of this project will significantly contribute to supporting the decision-making process in the deployment of new transport technologies. Furthermore the analysis of the data gathered in real-world traffic conditions with ordinary drivers is expected to highlight several crucial aspects of the intelligent vehicle systems.

## 2.4. NDS-informing international research and development

### *2.4.1. In-vehicle systems*

Smrcka (2007) indicated that practical design work has traditionally been the responsibility of engineers, trained to understand technology, and not the human factor per se'. Internationally there has been a focused drive to integrate the fields of engineering and psychology in order to facilitate the effective and safe interaction of humans with computers.

Technology is having unavoidable and fundamental impact on the way that a person drives (Carsten, 2008). This in turn has an impact on road safety. Vehicle design across the world is becoming more and more complex and is accelerating at an astonishing pace. Carsten indicated that most of the advances made within this field have been in the areas of vehicle electronics and associated systems. It is (Carsten, 2008) estimated that by 2010, 40% of a vehicles' cost base would be around the electrical systems and electronics. These developments have implications for research in terms of primary safety such as vehicle handling and crash avoidance as well as secondary safety research in the form of injury protection through seatbelts, airbags, and other in-vehicle systems. Technology creates enormous opportunities for research, engineers and designers. Carstens (2008) summarises the major developments, internationally, in the vehicle electronic field for the pass four decades as follows:

- 1971: ABS which prevents wheel-lock-up to maintain friction between wheel and road surfaces
- 1995: Electronic Stability Control (ESC) which maintains directional controllability through break intervention
- 1999: Adaptive Cruise Control (ACC), which replaces the driver in the car following task by driving at a set headway
- 2000: Lane departure warning
- 2006:Lane keeping systems which applies corrective steering responses to steer the vehicle back into a lane
- 2007: Forward Collision Warning systems
- 2007: Stop and Go, which extends ACC to stop and start traffic

Vehicle manufacturers and researchers have high hopes for new and improved designs for in-vehicle systems that will contribute to road safety in the long-term. Some of the innovations that are expected include autonomous vehicles where autonomous refers to the vehicle operating in terms of support from infrastructure and from other vehicles in the traffic stream. The alternative version on this refers to a cooperative future where vehicles are integrated into the road environment and with other traffic through infrastructure to vehicle (I2V) and vehicle to vehicle (V2V) communications.

Traditionally, the driving task is represented as involving interaction between the driver, vehicle and environment. With Advanced Driver Assistance Systems (ADAS) the interaction between the driver, vehicle, in-vehicle systems and environment becomes more and more complex. New in-vehicle systems can adapt to a drivers' current driving style or current driving performance, many of these systems are designed to communicate with each other. The driver has to anticipate and respond to the systems, as well as in some instances, interact with the in-vehicle manager or "supervisor of those systems. At the same time Carsten (2008) indicates that above and beyond all of the in-vehicle demands the driver has to negotiate, the driver also still needs to anticipate and respond to the road traffic environment. Carsten argues that vehicle designers are faced with decisions such as to “hide” in-vehicle systems, which may result in the driver failing to understand what the in-vehicle systems are doing. On the other hand, the in-vehicle systems can be displayed, which again could contribute to driver distraction in the form of additional workloads that could lead to driver stress. ADAS is aimed at helping the drivers to make informed choices about their anticipated behaviour on the road ahead.

A recent study (Lindgren et al, 2008) compared the influence of culture and how the application of ADAS differs in western and eastern countries. This particular study compared the driver behaviour and application of these technologies in Sweden and China. The research findings clearly indicated that although the traffic rules and regulations for both Sweden and China are similar, driver behaviour itself is culturally mediated. Lindgren et al. (2008) found that the type of driver assistance that is needed for, on the one-hand western and on the other hand for eastern drivers depend very strongly on the driver behaviour that is exhibited by the different drivers from the different countries. This finding might have important implications for a country such as South Africa. South Africa as a developing country is becoming more and more motorised. Africa also has a unique transportation system with large numbers of the population having to rely on public and non-motorised transport alternatives. Nevertheless, all of the road users still need to interact with each other. The type of ADAS that is implemented in vehicles in South Africa might prove to be considerably different from those of other countries.

The HASTE project, a collaborative research project on distraction was conducted over a period of four years, (2002-2005), investigated the effect that in-vehicle systems have on driver distraction, since at that stage no universal standardized test existed for assessing the safety of in-vehicle information systems. The project outcome provided a system for the assessment of Human Machine Interface and the Safety of Traffic in Europe (HASTE). This system assessed the following attributes:

- Was technology independent? (Does not depend on specific technology being employed in a system)
- Did the system have safety criteria?
- Was the system cost-effective?
- Was it appropriate for IVIS systems?
- Was the system validated through real world testing?

All experiments were conducted within a simulator with a limited amount taking place on real roads while a person was driving. This project distinguished between two major types of distraction: visual and cognitive distraction. Visual distraction had an impact on the lateral control of the vehicle. Visual distraction was manipulated by increasing the demands on the visual search task on a screen. Cognitive distraction, increased cognitive demands through auditory experiments. Significant results were found for two age groups, namely the age group 25-50 years and the group over 60 years. Younger drivers seemed to have a decrease in their ability to handle more cognitive demands and reach a plateau when realising it is not appropriate to engage in the most demanding task first. In the older driver group, a constant decline was seen in their ability to deal with the cognitive overload.

The most important outcome from this study includes the fact that an IVIS assessment test was drafted. Testing of IVIS can be done by making use of a relatively small number of test subjects; assessment of a rural two lane driving simulation takes approximately 1 hour. Assessment should take place at a pre-determined level for the specified task on IVIS. Lastly, it was determined that a small number of dependent variables were needed in order to test IVIS.

### 2.4.2 Speed adaptations

Carstens (2008) states that it is not surprising that the focus of new technological applications is in looking at ways to adapt speed. Speed is still considered as one of the biggest contributors to and a major factor in the increased risk of accident occurrence, as well as severity of crashes that occur. Many studies have looked at the relationship between increases and decreases in speed as well as the impact, severity of injuries as well as the increased number of fatalities that occur due to speed related road traffic crashes. In-vehicle technology aimed at preventing over-speeding, known as Intelligent Speed Adaptation. Carstens (2008) indicated that the in-vehicle devise uses existing GPS satellite positions to position the vehicle on a particular road, the route information is compared to speed and speed limit information and the in-vehicle technology assists the driver in automatically adjusting to the speed according to the speed limit information on the route. When operating a vehicle with ASA, the driver can decide to activate or de-activate the system. This particular in-vehicle technology has sparked a wave of positive as well as negative reactions to it.

### 2.4.3. ITS and NDS

The euroFOT (http://www.eurofot-ip.eu/: Accessed 21 January 2010) project commencing in 2010 will focus on addressing research questions related to ITS technology such as:

- What are the performance and capability of the systems?
- How does the driver interact with and react to the systems?
- What are the impacts on safety, efficiency, and on the environment?

### 2.4.4. Driver distraction

Driver distraction has been the focus of the 100-car study by Virginia Tech. The longitudinal naturalistic driving study, of which the vehicles were driven by volunteers for a year, provided valuable insight into driver distraction. The vehicles were highly instrumented and provided video feedback with regards to crashes, near-crashes and conflicts. According to the research study, 65% of near-crashes and 80% of crashes (mostly damage only), involved drivers looking away from the roadway, just prior to the crash or incident happening. Use of cellular phones and Personal Digital Assistants (PDA) while driving, was major contributing factors in the incidents. According to the research study, the incident rate increased with age, which has significant implications for the older driver population.

Drivers involved in concurrent cognitive tasks (secondary tasks) exhibit adaptive behaviour to enhance immediate safety despite the fact that other aspects of safety might be compromised. It was concluded (Horrey, Simmons, Buschmen and Zinter, 2006), however, that studies reporting on findings in terms of these behaviours, are often not representative of real-world traffic situations. They found no indication that drivers adjust their safety margins to account and manage additional demands of performing a cognitive task in simulated experiments.

Criticism against the use of naturalistic driving studies relates to the sheer volume of information pertaining to complex cognitive processes and skills that need to be analysed for even one driver, over a period of time. Ward et al (2003) though indicate that this barrier can be overcome with the use of Cognitive Task-Analysis (CTA). According to the researchers, the success of CTA-techniques used to study naturalistic driver behaviour lies in the retrospective interview technique that makes use of cognitive probes to extract knowledge and strategies used in complex decision-making processes while driving. These techniques can also be used to type of decisions made by drivers as well as the nature of challenges encountered by drivers when faced with a particular decision on the road. Cognitive task analysis and methods for analysing Naturalistic Decision Making are powerful tools to be applied in transportation research (Ward, Hancock, Ganey and Szalma, 2003). According to the researchers when NDS is used in conjunction with simulators, these methods allow for an increased understanding of the decision-processes involved in the operational aspects of driving, navigating and using infotainment in a vehicle. This approach makes the investigation of driver performance under a range of workload and stress factors more feasible. This approach also supports the development of future prototypical models which will encapsulate both cognitive and perceptual-motor demands of driving in the presence of situational stressors under both high-and low workload conditions.

Sayer, Devonshire and Flannagan (2005) investigated the frequency and conditions under which drivers engage in secondary tasks while driving. This Naturalistic Driving Study found that drivers engaged in secondary behaviours in approximately 34% of the video clips that were obtained from the in-vehicle recordings. The data from the video recordings were correlated with information from the in-vehicle sensors to calculate factors such as the mean variable speed, mean variability throttle speed, steering angle and lane position. Contextual factors such as road type, curve and condition were also brought into account. The most common secondary tasks that drivers engaged in were talking to a passenger (15.3%), grooming (6.5%) and using cellular phones (6.3%). The findings from the study indicated that engagement in particular secondary tasks while driving affected particular vehicle mechanisms. The research study also suggested that drivers perform differently when participating in different secondary tasks and that their decisions to engage in secondary tasks relied on the road and traffic conditions where they driving Younger drivers were found to more easily engage in secondary tasks while driving.

#### *2.4.5. Collision avoidance systems*

McLaughlin, Hankey and Dingus (2008), based on the 100-Car research study, describes a method for evaluating the performance of a collision avoidance system (CAS) using the naturalistic driving data collected during crashes and near-crashes. The methodology described minimizes the interpretation of the driver’s perception and response levels. This in return allows for generalisation of the findings beyond the driver’s performance. The method involves four parts of which the first is aimed at input of the naturalistic data into alert models to assess when alerts will occur. Secondly, kinematic responses are analysed to determine the response required avoiding collisions and thirdly, the translation of the amount of time available estimated into a percentage or proportion of the population, who will be able to avoid the collision. Lastly, an evaluation of the frequency of alerts generated by the collision avoidance system was done. It was found that this evaluation methodology could assist in especially the development of forward collision avoidance systems.

## 3. IMPLICATIONS FOR SOUTH AFRICAN DRIVER BEHAVIOUR RESEARCH

Currently little driver behaviour research is conducted in South Africa. It has been inferred that the human factor is the most important contributor to road traffic crashes resulting in the high death toll on South African roads. Still, no definite attempt seemed to be made to address the human factor. Very little is known about South African driver behaviour. By incorporating Naturalistic Driving Studies as a methodology to study driver behaviour in South Africa, there will be for the first time in many years, the opportunity to verify the quoted statistics, pertaining to the human factor as a contributory factor in fatal crashes. By actively participating in the global NDS studies, South African researchers' academics and practitioners will have the opportunity to contribute driver behaviour data from a developing country perspective. This will add a third world perspective to an international driver behaviour research study.

Tried and successfully tested by the international road safety research community, the research findings clearly show the potential benefits of advance driver behaviour research that has the potential to change the way we think about road safety in South Africa forever. One of the main objectives of this type of study is to understand the driver and standard driving behaviour in an everyday context. South Africa is unique in its make-up; with a vast array of cultures, languages and perceptions that shape and influence behaviour on the road. Naturalistic Driving Studies provide the medium through which researchers, practitioners and implementers at national, provincial and local level can begin to understand the road safety situation holistically. Naturalistic driving studies present an opportunity for road safety professionals to understand the South African dynamics of interaction between the driver, vehicle, environment as well as other road users.

Coupled with the much needed behavioural research is the development and expansion of current and new future Intelligent Transportation Systems that will assist in the collection of data in intelligent and innovative ways. As the need for more intensive and comprehensive data develops, NDS will contribute to the development of unique and innovative new ITS systems and methodologies to capture analyse and interpret the data into meaningful research findings. This will in turn inform strategic decision-making at the highest level. Another benefit of developing the field of NDS in South Africa is that the findings and solutions emanating from the research will be uniquely tailored for South Africa as country.

Naturalistic driving studies offer the prospect of a new academic and research field, with the possible development of bright new minds not only in the fields of road and computational engineering, but also in the fields of research, psychology and forensics.

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