TOWARDS A DEDICATED TRANSPORT SAFETY RESEARCH FACILITY FOR SOUTH AFRICA

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ABSTRACT

The establishment of a dedicated CSIR research facility for transport safety has been a topic of discussion for several years. In 2020 the CSIR embarked on a process to establish a facility dedicated to transport safety research to be known as the Transport Safety Lab. The aim is to address transport unsafety by conducting experimental projects that provide insight into the mechanisms and contributory factors that cause risk and incidents in the transport environment.

This paper provides feedback regarding progress made with the Transport Safety Lab project to address the Research Development and Innovation (RD&I) gap by enabling experimental research (evidence based and data driven), promoting, and advancing initiatives and opportunities that encourage the use of local data and methodologies in support of local transport safety solutions. In addition, the article provides a review of current experimental projects that support capability development and the building of a portfolio of evidence to be used to display the type of work that the Transport Safety Lab can do.

The experimental projects revolve around specific topics that contribute to addressing accidents and incidents and are considered medium to long-term projects or research programmes that are evidence-based and that will in future inform the development and implementation of relevant, targeted policies, regulations, and interventions to effectively curb transport safety issues responsible for crippling the South African economy.

1. INTRODUCTION

1.1 Background

The role of transport as a catalyst for economic growth and job creation is widely accepted. Efficient transport networks contribute significantly to reduced cost of doing business in the country and improves the competitiveness of products and operations across all industries. Transport, after education has been cited as the single most crucial factor for economic development in South Africa with land-based transport playing a primary role in meeting people’s mobility and accessibility needs. The South African transport system however remains complex and exists within an institutional, spatial, environmental, and social context. All the components of a transport system are designed to facilitate the movements of people, goods, and information, either as separate or joint components. Within this context there is a need to address institutional matters (governance regulations, compliance, risk etc.) as well as monitor the processes, outputs

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etc. In addition, there is a need for focus on managing, coordinating, improving (inventions, approaches, ideas) and to provide feedback in support of achieving results.

The 1996 White Paper on Transport defines the different subsectors in the transport sector to include infrastructure and operations of rail, pipelines, roads, airports, and harbours, as well as the cross-modal operations of public transport and freight. Transport safety is a key indicator of how well the transport system function and although it is acknowledged that it is not possible to fully eliminate incidents, the severity of impacts can be addressed. A safe and efficient transport system, as envisaged in the 1996 White Paper, has not yet been realized in South Africa. Transport safety in South Africa is a long-standing issue with safety and security issues, negatively influencing social and economic progress and in urgent need of attention as:

- Safe, and efficient movement of people and goods is a basic constitution right (Constitution of South Africa Act 108 of 1996).
- The safe and efficient transportation of goods is an important differentiator between successful and less successful economies.
- Ethically, the road crash death and severe injury toll is far too high.
- Added to the losses in human lives and wellbeing, are the considerable monetary losses incurred in medical expenses, infrastructure repair, and production downtime.
- The socio-economic cost of these events, to the welfare and prosperity of the country is unacceptable for a low- or middle-income country such as South Africa which is struggling to eradicate poverty and inequality.

The purpose of transport safety research is to prevent or reduce the occurrence of injuries and fatalities. Transport safety research is concerned with understanding the underlying or contributory factors (four elements) that result in unsafe transport systems. By better understanding the causes or contributory factors it becomes possible to design topic specific programmes, policies, and interventions to address unsafety in the transport system. The Safe System Approach (or similar frameworks that address transport safety holistically) forms the focus of most efforts as it facilitates an understanding of the interaction and impact on safety of the different elements that comprise the transport system. No meaningful change towards sustainable transport will be evident in South Africa unless there is a dedicated effort (political will) to acknowledge the inefficiency of the safety paradigm as transport planning is not matched with existing challenges such as pro-poor job creation and basic service delivery (Kane, 2010).

1.2 CSIR's Response to Address Transport Safety

The CSIR has been involved in road and transport safety research since 1965, spanning a period of more than fifty years and continue to contribute to road transport research outputs and is extensively involved in the preparation of national policies, strategic plans, technical methods and guidelines, legislation, capacity building, as well as road and traffic behaviour and engineering studies aimed at addressing road transport safety challenges. Throughout the years, due to reduced financing from government and other investors, the transport safety research function dwindled. The result was that the focus on safety research narrowed significantly resulting in less outputs and almost no contribution to national knowledge regarding transport safety. The impact from this reduced investment, clearly manifesting as the high road death toll as well as the rising number of incidents on railways. Given the extent and cost of the transport safety problem in South Africa as well as the rest of the Continent, there is an undeniable need to invest in research, development, innovation, and activities that build capacity to address this socio-economic burden across all modes of transport.

In 2017 the CSIR embarked on a process to purposefully position the CSIR to contribute to the socio-economic development of South Africa. During this process, the organisation streamlined the different CSIR functions to leverage the Science Engineering and Technology (SET) capability base, in line with the 4IR expectations, build on current industrial development opportunities, while creating the right balance between scientific development and industrial development in its innovation portfolio.

With the move to align the organisation to support 4IR activities, transport safety was highlighted as a key national concern. The establishment of a dedicated CSIR research facility for transport safety has been a topic of discussion for several years. In 2018/2019 a process to establish a facility dedicated to transport safety research was started. This process entailed:

- Establishing a motivation (business case) for the establishment of the Transport Safety Lab.
- Initial investment in the development of the concept and strategy (this business plan and subsequent research strategy).
- Investment in the building of capabilities and the sourcing of human resources, that are aligned not only with transport and transport safety but with 4IR skills and application of technologies.
- Incubating, framing, investigating, designing and delivery of context specific transport safety solutions.
- Measuring impact by evaluating implementation on a project, social and investment level.

These processes were executed in a phased approach over the last three years and will continue to evolve in the next two to three years.

1.3 Transport Safety Lab Objectives

The Transport Safety Lab aims to contribute to safer transport environments by conducting quality research in support of solving fundamental transport safety problems. Currently there is no dedicated transport safety research facility on the African Continent. Although South Africa continues to learn from international best practices, there is a need for local solutions tailor-made for South African transport and related safety problems. The Transport Safety Lab aims to:

- Enable data driven and evidence-based research in support of local transport safety solutions.
- Develop research, implementation skills and capabilities to ensure safe, sustainable future transport solutions and implementation.
- Foster and facilitate sustainable relationships between government and industry in support of transport safety research.

2. AIM OF THE PAPER

This paper provides feedback regarding progress made with the Transport Safety Lab project to address the Research Development and Innovation (RD&I) gap by enabling experimental research (evidence based and data driven), promoting, and advancing initiatives and opportunities that encourage the use of local data and methodologies in support of local transport safety solutions. In addition, to provide a review of current experimental endeavours that support capability development and the building of a portfolio of evidence to be used to display the type of work that the Transport Safety Lab aims to do.

3. OPERATIONALISING THE TRANSPORT SAFETY LAB

3.1 Skills and Capacity

The changing and increasingly complex transport environment requires a shift in focus where multidisciplinary teams with a range of specialised skills execute projects within a given time, at competitive cost and at the set-out quality. However, it also means that there is a need for generic capabilities that cut across transport disciplines, research activities and projects to deliver transport solutions that sufficiently address new and existing challenges through better organisation, project management and knowledge transfer. Current skill sets encompass disciplines of transport engineering, transport economics, structural engineering, vehicle dynamics, and data science.

3.2 Data Driven and Evidence Based Research

3.2.1 Data Capabilities

The CSIR has developed capabilities in remote sensing and data collection techniques, developed methodologies and frameworks for the analysis and interpretation of the data collected and have made advances in the storage, management and sharing of big data sets. Expertise in computer vision and machine learning offer substantial benefits to data processing and analysis tasks skillsets are distributed among multiple research groups which operate independently. In addition, existing data collection techniques and technologies are proprietary, resulting in limited flexibility and added costs. They have a narrow set of measured parameters and require extensive manual processing to extract useful research data. There is a need to introduce newer technologies and techniques, to conduct research that matters.

Through the consolidation of the current skill sets a high impact transport safety research centre that will be viewed as the transport safety nerve centre not only in Sub-Saharan Africa but on the continent can be established. This will increase the scope and effectiveness of current transport research capabilities and enable participation in new and upcoming research efforts relating to human factors and technology development, human/machine interface; several types of system dynamics as well as autonomous systems in managing a safe and sustainable road and traffic environment. Development of skills pertaining to:

- Imagery (Photogrammetry).
- Imagery equipment.
- AI (machine learning for drone, video/ image material).
- Processing algorithms / software to add intelligence to the machine learning outputs.
- Post processed data usage/application development.
- Cloud data storage - need to identify suitable options for Cloud storage of this image data.
- Centralize and control access to image data.

3.2.2 Dedicated Data Collection and Data Consolidation Platform

3.2.2.1 Remote Sensing and Big Data

Data are integral to safety decision making, both in prioritizing investments and in identifying analysing the most effective techniques and interventions. The more comprehensive and accurate the data, the better the resulting decisions. Quality safety data are at the core of any successful effort to improve road safety. However, current data collection mechanisms are outdated. With the move towards 4IR thinking, including emphasis on connectivity, cloud computing, open access and interoperability, there is a strong motivation to explore alternatives that will enable real-time data collection, use of artificial intelligence to analyse and interpret data and to provide the relevant decision-makers with accurate and real-time information. In support of these initiatives, it should be noted that South Africa has recently seen data centre investments by large multinationals, including Huawei, Microsoft© and Amazon©, in addition to a much smaller local data centre ecosystem. Establishing local cloud bases allows for lower costs and higher speeds of data transfer; an important development for the Southern African countries, where local development may not be economically feasible (Markowitz, 2019).

Sensor telemetry has been used for several years to assist with fleet management, monitoring driver behaviour and to assist with behaviour change as systems provide real time location and load of freight vehicles and buses (Innovation Group, 2015). Sensor technologies that collect data to enable the monitoring of driving, routes and the vehicle's health had a positive impact on both safety and efficiency (Innovation Group, 2015). Sensors can assist with preventive maintenance actions on the vehicles therefor enabling the owner or operator to address vehicle safety concerns timeously. There are also telematics products that can be purchased by parents to monitor their teenage drivers although currently the private adoption of telematics does not appear to be well supported and there still exists some concerns over privacy (Innovation Group, 2015). Sensor technologies also have application for road traffic and safety data collection using drones to inspect infrastructure, road works and lane repairs, which makes it safer for road workers (Wordsworth, 2020). New intelligent mobile signage solutions are reported to be more reactive than before and can be integrated within a broader smart motorway network. With the incorporation of GPS tracking into new variable message signs (VMS), they can now be remotely monitored from any internet device and important safety and road condition information portrayed to motorists (Wordsworth, 2020).

3.2.2.2 Subtask: Expansion of Survey platforms

One of the deliverables of the data platform is the identification of a suitable survey platform that will be used for the collection of various survey inputs. However, to provide flexibility in the collection of survey responses, a need was identified to expand the use of additional survey platforms. For the mobility as a service project, a requirement was for a survey to be developed to collect responses relating to motorcycle delivery rider behavior. A survey questionnaire was developed on the ESRI Survey 123 platform (platform 1), and some sample data was entered. The questionnaire was then replicated on the MicroSoft (MS) Forms platform (platform 2) and some sample data was entered. ESRI Survey 123 offline capability is also being investigated. MS Forms doesn't have any offline capabilities and thus only suitable for where internet connectivity is available.

3.2.2.3 Subtask: Data Visualization

Another deliverable is the display of results from data surveys. The open-source metabase data dashboard system is being researched as one of the possible web-based dashboard tools. Metabase connects to a server PostgreSQL database that has been populated with previously collected anonymized naturalistic driver data and two dashboards have been created on Metabase for review. Research is continuing to further investigate additional data dashboard tool as well as data analysis options.

3.3 Research Topics, Approaches and Methodologies

3.3.1 Human Factor Research

User experience methods including eye-tracking, getting participants to verbalise their thoughts (verbalisation and participatory techniques), and wearable biosensors to track physiological indicators of stress such as heart rate, skin conductance response and movement.

3.3.1.1 Simulated Transport Environments

Traditional experimental research was faced with a choice between experimental control and environmental validity (Loomis, Blascovich & Beall, 1999). With a simulator, limited aspects of cognitive, perceptual, and motor demands that drivers face are researched in these isolating variables from real world situations and behaviour. Simulator research provides detailed information about specific behaviour. Simulator research can be conducted with a variety of demographic diverse groups and provide insight into specific behaviour in specific settings or contexts.

For this behavioural research, the Transport Safety Lab is investing in a static driver behaviour simulator that utilises gaming theory to assist in experimental work related to transport user behaviour, conducted in a simulated and safe environment.

3.3.1.2 Virtual (and Augmented) Reality Programmes

Virtual environments are considered sufficiently representative of reality. Virtual reality research entails the reconstruction of a real environment in a virtual reality. Surveys and observations are used to accurately construct this reality making use of appropriate software (e.g., Autocad, Adobe Photoshop, Autodesk 3DStudio.Max 8) to prepare the 3D reconstruction of the environment taking cognisance of specific lay-outs, characteristics, and common elements. Animations are added with simulator software. The difference between a virtual reality and a traditional simulator is the quality of the experience, in particular the perception and dynamic vision required to study dynamic behaviour. Virtual reality research and applications are used for:

- Studying at-risk populations (disabled and elderly).
- Road environments (road safety audits, assessments, and risk analysis).
- Education of transport users such as learners, inexperienced or novice drivers and so forth.

Virtual environments have been used extensively to train pilots. This is an emerging area and although South Africa might not yet be ready to apply virtual reality programmes in specific areas, the initiative has merit to study behaviour in specific transport (rail and road) contexts and environments. The Transport Safety Lab will collaborate with amongst others, universities, to develop this capability and to validate research approaches and methodologies, using simulated and real-world findings to augment the way transport safety and user research can be conducted.

3.3.1.3 Expanding Real World Investigation with Instrumented Vehicles

The Naturalistic Driving Study (NDS) approach to the study of driver behaviour in context, over time, bridges the gap between real world investigation with instrumented vehicles.

The experiment is controlled for different influences pertaining to the driver, vehicle, and environment using different sensors collecting several types of data during the study. NDS narrows the gap in terms of studying driver characteristics, driver behaviour and attributes such as perception and cognition which in the past years were studied in isolation from the "real-world". NDS uses an array of sensors, images, audio, and computer equipment, to simultaneously investigate various aspects of human (road user) behaviour and human interaction with vehicles, in-vehicle systems, as well as the road and transport environment. To assist in this research the CSIR Transport Safety Lab is investing in a dedicated experimental vehicle that will be equipped with NOLDUS© drive lab technology and software to assist in the analysis of real-world driver behaviour research.

Incidents can be measured in terms of the socio-economic and attitudinal factors related to the driver. NDS provides an integrated approach to the studying of driver behaviour within the context of the human, as well as the vehicle environment. Naturalistic driving studies provide rich naturalistic driving data, that can be used to understand behaviour in many different real or near-real time contexts. NDS provides real-time driver behaviour data over a specific period. NDS affords new opportunities to make use of modern and efficient image processing algorithms, which coupled with increasingly efficient computational power, made the technology accessible and effective in numerous transport tasks. By applying machine learning techniques video/image material can be scrutinized to identify and investigate vehicle and pedestrian behaviour, vehicle classification, collision/crash detection, congestion detection, stopped/stationary vehicle detection, wrong way driving detection, and licence plate recognition. Recently, progress has been made with the identification of surrogate crash measures, which is becoming important in the South African context, where crash data is lacking.

The CSIR has been actively promoting the use of Naturalistic Driving Studies as a tool to understand the context of driving in South Africa. In support of real world behavioural research, the Transport Safety Lab is investing in a Drive Lab with a dedicated experimental vehicle with observer capabilities including eye and physiological performance of the driver.

3.3.1.4 Active Vehicle Systems

Active vehicle systems refer to in-vehicle safety systems that protect occupants from the force of crashes using intelligent and adaptive technologies. Examples include Advanced Driver Assistance Systems (ADAS), brake and skid resistance, electronic stability control as well as assistance systems that use sensors such as forward collision warning and lane departure warning, along with adaptive cruise control. Most of this research is sponsored by manufacturers of vehicles and the research that is done to investigate behaviour under specific conditions, are conducted in developing countries.

The Transport Safety Lab will investigate the impact that these systems have for prevention of crashes in local settings and scenarios. This will enable driver state sensing, interior sensing, and user experience solutions, allowing for an improved understanding about driver attentiveness and will assist in determining future actions for making local environments and vehicles safer.

3.3.1.5 Communication Technologies

Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication is not yet a full reality in South Africa. However, efforts should be made to ensure that in future these technologies and applications are relevant and safe for South African conditions. The

Smart Roads initiatives hosted by the CSIR and UP are potentially collaboration projects whereby safety aspects of the future technologies can be assessed.

3.3.1.6 Connected Vehicles

Connected and automated driving promises a future where humans are (largely or completely) out of the driving loop and as such may seem to suggest that the foundational premise of the Safe System – human fallibility – is no longer an issue in achieving safe traffic performance (International Transport Forum/OECD, 2019). Human-centred intelligent vehicles hold a major potential for industry and across the world, systems have been included to provide for more complex functions to help people drive their vehicles safely and efficiently (Labuschagne, 2010). The advancements in research have provided the basis for the development of Autonomous Vehicles (AVs). Connected vehicles have the potential to reduce carbon emissions (Chandra, 2020). Distraction while driving however remains a concern, and there is a need to have an equal focus on safety and increasing connectivity as well as autonomous driving features (Innovation Group, 2015). With automotive telemetry advancing, it seems plausible that in future it will be possible to plug vehicles into the Internet of Things, while will also allowing vehicles to "see" their immediate environment (for example, through LIDAR systems).

Autonomous vehicles will become an element of road traffic (Maurer et al., 2016). The degree of vehicle automation is rising in all modes of transport both on public transport infrastructure and in-house transport within company grounds, to improve the productivity, reliability, and flexibility of transport. With the growing of information density and the complexity of the geographic division of labour, the idea of autonomous, decentralized local units is gaining momentum. However, the focus, up till now has been on private passenger vehicles, however, public, and scientific debate has until now neglected about one third of traffic on public roads, i.e., commercial traffic (Flämig, 2016). Data is provided by cameras and sensors and processed in real time by a computer in fractions of a second (Maurer et al., 2016). These vehicles permanently exchange information with one another and with the transport infrastructure (Maurer et al., 2016; International Transport Forum/OECD, 2019). The Innovation Group (2015) state that fully autonomous vehicles will not need steering wheels or driving aids (no driver), air bags or side impact bars, highly engineered accident crumple zones or seat belts (no chance of crashing), nor powerful engines or associated componentry, such as large brake disks (they will drive at exactly the speeds specified by law). Driving robots are employed to successively relieve the driver of individual tasks and this rise of fully autonomous vehicles is driving discourse around the world, with a push for increased vehicle automation on both the industry and policy side (Ryan, 2020). Nonetheless there are scepticism about the practical feasibility, especially in Africa where the infrastructural limitations (roads, electricity etc.) hold back the vision, for now (Innovation Group, 2015). Ryan (2020) however argues that self-driving vehicles (SDVs) offer the potential to improve efficiency on roads, reduce traffic accidents, increase productivity, and minimise our environmental impact in the process (Ryan, 2020).

It is not clear, if "human-free" driving will be safer than conventional driving in every context though there are strong reasons to believe that it will deliver better safety outcomes in some cases. (IRTAD, 2019). Part of this uncertainty stems from the original premise – that human errors are linked to over 90% of all fatal crashes (International Road Traffic Information and Data Group, 2019). Hancock et al (2020) state that designers should therefore not assume that automation can substitute seamlessly for a human driver, nor can they assume that the driver can safely accommodate the limitations of automation. Designers, policy makers, and researchers must consider what role the person should have in highly automated vehicles and how to support the driver if the driver is to be responsible for vehicle control as driving safety increasingly depends on the combined performance of the human and automation, and successful designs will depend on recognizing and supporting the new roles of the driver (Hancock et al., 2020).

The Innovation Group (2015) research indicated that self-driving cars may only become a reality in South Africa in 20 or more years and that this may spur innovative advances in infrastructure, energy services and the look and feel of roads and cities. However, a substantial investment in vehicle-to internet communications, along with cost effective sensor and radar-based solutions, would be required along with safety evaluations fit for the African context (Innovation Group, 2015).

3.3.1.7 Connected Road Environments and Infrastructure

Connectivity will extend to the road and traffic environment as there will be a need for intelligent roads (Road Innovations for the Future, 2018). Intelligent and responsive roads (interacting with connected and autonomous vehicles) will be a requirement for road traffic operations. Intelligent roads of the future include glowing roads, that enable the vehicle to recognise road markings. This development has road safety implications that will need to be investigated as the vehicle will have autopilot functions that rely on these markings (traditionally guiding the human driver) to help centre the vehicle on the road (Davis, 2018).

3.3.1.8 Additive Manufacturing and New Materials

Additive manufacturing could change the established way vehicles are manufactured as well as the uptake, as modern technologies are permitting the manufacturing of vehicles. This has the potential to reduce conversion costs, and to provide the public with the option of designing their own motor vehicles using standardised computer aided design tools and then 3D printing the designs while simultaneously permitting the manufacturing of thinner steel sheets required for weight reduction in more fuel-efficient vehicles (Innovation Group, 2015). However, within the road safety paradigm (Safe System Approach), the aim is to ensure that vehicle as well as restraint systems are designed in a manner that absorb kinetic energy upon impact, to protect humans. This means that even if new and innovative technologies are more cost-effective and mass produced, there will still be a need for localized testing and standards to ensure that the materials are able to withstand the collision.

4. WAY FORWARD

The CSIR has transport safety experience, mostly related to road-based traffic systems, however the intent is to, in time, expand the research offerings to include other modes of transport. The Transport Safety Lab will collect transport data (historic/traditional; real-time as well as near real-time) in support of an improved understanding of the elements that contribute to unsafe transport.

On-going road safety research in the CSIR includes performance-based standards for heavy vehicles and naturalistic driving studies. The work enables an improved empirical understanding of road and transport safety. Short-term research will entail a continuation of the application of these methodologies. The current focus areas are centred on investigations that promote public transport, freight operations and safety. Future focus areas will revolve around public transport and freight with an emphasis on enabling research with transport data, generating information on user behaviour, traffic flow and performance measures.

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