THE USE OF FIFTH GENERATION NETWORKS (5G) TO IMPROVE ROAD SAFETY IN SOUTH AFRICA: A COMPARATIVE STUDY

ML KWANGE[1*], PL BINDA[1] and K MURONGA[1***]**

[1]CSIR Smart Mobility, Transport Systems and Operations, PO Box 395, Pretoria 0001
*Tel: 012 841 2237; Email: lkwange@csir.co.za
**Tel: 012 841 3355; Email: pbinda@csir.co.za
***Tel: 012 841 2337; Email: kmuronga@csir.co.za

ABSTRACT

The 4th Industrial Revolution triggers the concept of '*The Internet of Things*' (IoT). IoT refers to the interconnectedness, making the connectiveness of all of these myriads of devices possible. In the transport domain, this inclusive connectivity refers to a range of infrastructure, vehicle to vehicle (V2V) communication and so forth. In urban areas, the physical transport infrastructure can now be connected to digital technology, giving rise to the term '*Smart Transport Infrastructure*'. However, this excitement is about data sharing, how fast it can be shared, along with a low latency network, which is what industry is looking for. The fifth generation of networks (5G) seems to be the answer.

Fatal crashes are still a problem in South Africa, as more than 10 000 of these occurred in 2018 and more than 12 000 people died due to these crashes. From the fatal crashes that occurred in 2018, about 89 % were due to human factors. Human factors have contributed more than 75 % of fatal crashes since 2014, with the highest being 91 % in 2017. Humans make mistakes and as such it is time to trust technology and take advantage of the 5G innovations. This paper compares different cases and reports the findings of the first phase (qualitative research) of a three-year project, investigating the use of 5G technologies to address road safety in South Africa.

Keywords: 5G for road safety; road safety technology, vehicle to vehicle communication; smart transport infrastructure; Vehicle to everything (V2X); 5G for Smart Cities.

1. INTRODUCTION

The United Nations (UN), through the World Health Organisation (WHO), reports that road traffic injuries have taken the lead as the cause of death for people under the age of 29 years and it is also the 8th leading cause of death to all people, making it more dangerous than HIV/AIDS and tuberculosis (WHO, 2018).The latest United Nations Decade of Action for Road Safety (UNDoA) 2021- 2030, is a call to action for governments and citizens to urgently address the high number of road traffic deaths. The Global Plan for the UNDoA sets out five pillars according to which countries can align their safety interventions. These pillars are *Road Safety Management, Safer Roads and Mobility, Safer Vehicles, Safer Road Users and Post-Crash Response*. The status of safety performances associated with these pillars is, however, still considered inadequate in developing countries such as South Africa (Small, 2014). These inadequacies need to be resolved systematically within the Safe System approach along with building institutional and human capacity of the implementing agencies (Small, 2014).

As a signatory to the United Nations Decade of Action for Road Safety 2011-2020 (UNDoA), South Africa has pledged to half road traffic crashes by 2020 from the 2010 baseline. In 2010 the country recorded 10 837 fatal crashes in which 13 967 people lost their lives. The Minister of Transport in South Africa, on the 23 January 2020, indicated that "a decade ago a commitment was made to reduce road fatalities and injuries by 50%, as part of the United Nations Decade of Action for Road Safety" (Mbalula, 2020). WHO, also indicated that it is important to prevent crashes, and subsequently technology such as advanced braking, vehicle electronic stability control, airbags etc. are some of the vehicle safety standards (Pillar 3 safer vehicles), that have proven to prevent vehicle crashes and/or reduce the severity of the injuries.

A study, analysing data from six countries, namely: *India, Australia, United States of America (USA), New Zealand, Canada and United Kingdom (UK)* found that the use of autonomous vehicles and connected vehicle technologies may reduce the number of crashes by about 47%, as an average of the six countries studied (Wang *et al.*, 2020). If the study by Wang *et al.*, (2020) is to be taken into acount this goal could have been achieved by just implementing the use of technology to reduce human error and subsequently road crashes.

1.1 Definitions

Fifth Generation of Networks (5G), is a low latency network based on the IEEE 802.11ac Wireless Networking Standard in the 802.11 set of protocols, providing high throughput wireless local area networks (WLANs) on the 5 GHz band. 5G will provide better speeds and coverage than the current 4G and 3G networks as it can offer speeds of up to 1 Gb/s for tens of connections or tens of Mb/s for tens of thousands of connections (Banerji and Chowdhury, 2013; Gopal and Kuppusamy, 2015).

The Internet of Things (IoT), are multiple devices that are connected to the Internet via various communications networks, such as Wi-Fi and these can be sensors, home systems, applications etc. (Shapira, 2017).

Smart Transport Infrastructure, can be referred to a cyber-physical transport infrastructure, that allows interconnected devices, such as sensors, cars, traffic lights etc. to share information that can improve the intelligence of the structures to detect such things as their own weakness and strengths, e.g. self-driving cars, by providing real time digital information about the status of the entire connected system (Morimoto, 2010; Stajano *et al.*, 2010).

1.2 Background

The 4th Industrial Revolution (4IR) brings along the concept of '*The Internet of Things*' (IoT), meaning that more people are now interconnected with various devices, making communications between the physical world and the cyber world possible (Jones and Fox, 2009; Muronga *et al.*, 2019). In the transport domain this include connectivity of a range of infrastructure, vehicle to vehicle communication, vehicle to personal mobile devices, vehicle to infrastructure and so forth (Figure 1). In urban areas, the physical transport infrastructure can now be connected to the digital technology, giving rise to the term '*Smart Transport Infrastructure*'.

Figure 1: Example of a smart city infrastructure (SAGE Automation, 2018)

At its core, the use of 5G technologies for '*Smart Cities'* development is a concept about open data exchange and analysis. This means we need responsive, secure, high speed communication networks that can handle substantial amounts of data. All this excitement is about data sharing, and how fast it can be shared, and a low latency network is what the industry is looking for with Fifth Generation of Networks (5G) being the answer to all these.

1.3 Problem Statement

The number of people that are killing on the world roads reached about 1.35 million in 2016 worldwide, which indicates that there is still a global challenge related to road traffic deaths. Despite the promises made a decade ago to reduce road traffic fatalities and injuries by 50% by the year 2020 by the South African government, fatal crashes are still a problem and the goal has not been achieved. In fact, according to the National Road Safety Strategy (SANRSS), the goal post has shifted, and South Africa now aims to half the number of traffic deaths (from the baseline in 2011) by 2030. In 2018, more than 12 000 people died due to road crashes, and of the fatal crashes that occurred in 2018, about 89% were due to human factors. Human factors have contributed more than 75% of fatal crashes since 2014, with the highest being 91 in 2017.

1.4 Objectives of the Paper

This study is a planned project that started in 2019, that aims to investigate smart technologies that could be implemented in South Africa to assist with the reduction of road traffic fatalities and injuries beyond the year 2020. The aim of this paper is to compare different cases where smart innovations and 5G technologies are used to address road safety globally and report on the findings thereof, as part of phase one (qualitative research) of a three-year project.

2. METHODOLOGY

This study is divided into three phases, to be achieved over a period of three years. This paper is only focusing on the first phase, which is a qualitative research process and divided into two stages. Phase 1 focused on making use of a scientific process to identify relevant content. A Systematic Literature Review (SLR) was conducted making use of reputable academically accepted databases. The second stage involved direct content search from government and industry databases, and this was used to find content relevant to 5G innovations and programmes and/or projects that are focusing on using technology for road safety purposes.

2.1 Content Selection

For content analysis for this study SLR and the results thereof are shown in Table 1, three databases (Science Direct; IEEE; Scopus) and one other source (Librarian) were utilised resulting in 849 records found.

Two researchers and one librarian were tasked with finding the content and from the 849 records found, 536 were found to be duplicates (Table 1). A simple keyword was used to search the databases, (5G technologies for road safety), from this keyword a total of 849 records were found and downloaded, though other documents discussed other forms of connectivity for road safety, such as the use of Bluetooth and direct Wi-Fi connection.

Table 1: Content selection using SLR

Number of papers downloaded	Duplicates Found	Number of records screened	Excluded records	Full text analysis
849	536	313	239	74

2.2 Exclusion Criteria

To select the relevant articles to be included in the review an article was considered relevant if it complied with the following:

- It was published in 2015 or later; and
- A peer reviewed article, or industry and/or government document implemented or planned for implementation of 5G for road safety purposes.

To exclude irrelevant articles, a further review was conducted, by reading the abstracts, introduction and conclusion of the studies and articles that discussed software coding for 5G networks, and 5G for smart infrastructure such as energy generation were excluded.

3. RESULTS

During the analysis of the articles, umbrella headings were formulated to group the articles into topic of interests, and this is shown in Table 2. Articles that discussed communication connectivity, making use of 4G and other lower networks, were included but as the focus of this study is on 5G, these papers will only be discussed in brief to motivate why the preference is for 5G networks.

3.1 Systematic Literature Review

The search for content resulted in a selection of about 86 articles, with 12 not directly relevant to the aim of the study as it did not consider 5G technologies. The remaining 74 qualified for full text analysis (Table 2). For a full list of Systematic Literature Review articles, you can contact any of the authors from the contact details above. The results of the search provided the study with 59 papers that discussed 5G technology development and other technical matters, such as the design frameworks; Eight (8) papers discussed the use of 5G technology to assist the road user, including drivers and the last one seven (7) papers discussed security matters in the cyberspace in relation to the use of 5G and connected devices.

Table 2: Selected articles for final review

	Discussion Topic	Selected Articles
1	5G Technology development and technical matters (59)	(Alieiev, Kwoczek and Hehn, 2015; Jamsa and Kaartinen, 2016; Petrov et al., 2016; Scholliers et al., 2016; Zographos, Dimitrakopoulos and Anagnostopoulos, 2016; Campolo et al., 2017; Chen et al., 2017; Choi et al., 2017; Gajewska, 2017; Gharba et al., 2017; Kim, Kim and Choi, 2017; Lianghai et al., 2017; Perfecto et al., 2017; Petrov, Dado and Ambrosch, 2017; Soleimani and Boukerche, 2017; Vlachos et al., 2017; Wang et al., 2017; Abdulla and Wymeersch, 2018; Cecchini et al., 2018; Cinque et al., 2018; Emara, Filippou and Sabella, 2018; Hasan and Jeong, 2018; Kumar and Gupta, 2018; Liu et al., 2018; Liu, Xiang and Punithan, 2018; Luo et al., 2018; Mir and Filali, 2018; Nousiasl et al., 2018; Ojanpera et al., 2018; Schmidhammer et al., 2018; Xiao and Ren, 2018; Zhao et al., 2018; Calabuig et al., 2018; Adegoke et al., 2019; Din, Paul and Rehman, 2019; Geng, Ren and Yan, 2019; Ahmad et al., 2019; He, Guo and Liao, 2019; Hofmann et al., 2019; Kabashkin, 2019; Kutila et al., 2019; Li, Guo and Ge, 2019; Ahmed et al., 2019; Llatser et al., 2019; Mannoni et al., 2019; Masmoudi et al., 2019; Naghsh and Valaee, 2019; Sequeira et al., 2019; Shen, Zhang and Yang, 2019; Shi et al., 2019; Singh, Nandi and Nandi, 2019; Sinha, 2019; Amaxilatis et al., 2019; Wen et al., 2019; Zadobrischi et al., 2019; Anwar, Franchi and Fettweis, 2019; Bey and Tewolde, 2019; Brambilla et al., 2019)
2	Road User Assisting Technology(8)	(Jahn, David and Engel, 2016; Bassoo et al., 2017; Jahn, Morold and David, 2018; Napolitano et al., 2018, 2019; Dasanayaka et al., 2019; Watanabe and Shoji, 2019; Nguyen et al., 2020)
3	Cybersecurity Concerns (7)	(Jaimes, Ullah and Dos Santos Moreira, 2016; Haidar et al., 2018; Azad et al., 2019; Lautenbach et al., 2019; Saglam and Bahtiyar, 2019; Amin et al., 2020; Nkenyereye et al., 2020)

The discussions of the results will start with the lesser articles to the highest articles.

3.1.1 Cyber Security Concerns (7)

It is of concern that only seven out of the full text analysis of 74 articles, discussed security concerns in the cyberspace, whilst making of 5G technologies. 5G technologies rely on the cyberspace and cyber-attacks are a serious security risk to consider before implementing any cyber enabled technologies.

The studies in this group indicated that it is important to look at the integrity of the information being exchanged between the V2X, as intercepted messages might mean a fatal crash, also the authenticity of the sender must be trustable and the last one is about the privacy of the users must be protected.

3.1.2 Road User Assisting Technology (8)

Eight studies discussed how the use of 5G technologies can also be used to enhance the experience of the road user. These technologies are also able to communicate with road users, especially when it comes to assisting the vulnerable road user such as those with physical challenges, cyclists etc. 5G has proven to be able to provide near real time communication that can assist in avoiding collisions.

3.1.3 5G Technology Development and Technical Matters (58)

The bulk of the studies discussed the use of 5G technologies, in terms of the design of the technology, how industry should design the data flows and how the connectivity can be enhanced. These studies indicated that from a well-designed connectivity, an intelligent system can be created (Din, Paul and Rehman, 2019; Kabashkin, 2019). For example, Car A can communicate with Car B and issue warning signals if an expected crash is detected through predictive analysis. The design of the technology can be such that vehicles are able to communicate not just with each other, but other road users; the road infrastructure; the vehicle mechanics such as automated braking system etc. by doing this the drivability is not only in the hands of the driver alone but the infrastructure as well as the driving environment.

In comparison with other connectivity networks like 4G, studies in this group indicated that 5G offers better connectivity, reliable speed, low latency and because of all the benefits, we can now rely on technology to assist with road crash reduction.

3.1.4 Discussions

The studies discussed in the papers analysed can be regarded as indicative that the "*Safe System*" is taken seriously and is being implemented by countries around the world. The system is a simple approach to road safety management, which considers human life and health as very important and should not be compromised by the need to travel.

The component for Safer Roads on the safe system, promotes the ability to identify and segregate different road users. Most of the papers discussed this clearly were technology is developed to identify users, including the vulnerable users by communicate via 5G network with other sensors, such as the handheld devices, that can inform a driver of a vehicle about a vulnerable user approaching an intersection.

Out of all the 74 papers reviewed, about 18 of these papers advised that, to make the communicated messages accurate, a dual system should be used. A dual system simply means a combination of both 5G wireless connection and any other short-range connectivity, like Bluetooth can be used. This will ensure that if the other connectivity mode fails the information will still be communicated correctly to the different road users and/or devices.

3.2 5G Technology for Road Safety in Other Countries

Places in China; Las Vegas; Jerusalem and Barcelona, have already started implanting 5G technologies for road safety and some of the goals of these technologies are as follows:

- Detection of pedestrians at a pedestrian crossing.
- Detection of cyclists when turning right.
- Detection of non-moving car on the road with low visibility.

In July 2019, in Jerusalem, Viziblezone reported that their patent-protected pedestrian detector technology has proven to detect pedestrians even hidden behind objects, such as cyclist at a distance of up to 150 meters (SmartCitiesWorld, 2019). This was in response to the reported statistics by the World Health Organisation that reported that in 2018, more than 1.5 million people were killed, and more than 50 million injured in road crashes and out of this number more than 50 % were recorded as cyclists and pedestrians.

In 2019, Barcelona, Telefonica together with SEAT demonstrated the connected car and 5G assisted driving. The C-V2X technology has been developed to assist with communication between vehicles and other elements of the road environment, such as other cars, traffic lights, pedestrians, cyclists etc. (Frost, 2019).

China, Yancheng City, in January 2019, introduced Human Horizons (H.H) as part of their smart road project they developed H.H pilot (for autonomous driving), H.H Parking (autonomous parking and H.H RSA-C (Road sensing Architecture for V2X coordination), all these developments are aimed at enabling the vehicle to deal with real life traffic (Taas News, 2019).

By January 2020, in Las Vegas, Verizon and HERE Technologies launched two proofs of concepts relating to collision avoidance and visual positioning. The two concepts are the results of trying to create safety and navigational systems based on Verizons 5G Infrastructure and HERES Mapping and AI tools (Ancin, 2020).

4. CONCLUSIONS

It is evident that the Fourth Industrial Revolution is bringing with it a lot of benefits through the IoT. Though in the beginning, connectivity issues, especially high latency networks were a problem, with 5G this concern can be eliminated. In this study we investigated the use of 5G technologies for road safety purposes and the results indicate that researchers and organisation have already started developing technologies to address road safety issues.

The broader feeling is that 5G technologies will provide better connection and real time information transmission, which makes it possible to use where message sharing is required immediately before an accident could occur. The 5G of networks are promising a low latency network and high volumes of data that can be transmitted on this type of connections, maybe it is time to trust in technology and take advantage of the 5G innovations, that are aimed at improving road safety.

5. RECOMMENDATIONS

In this study we did not discuss or investigate the costs related to the implementation of 5G technologies and we recommend that further studies be taken to investigate the viability of these technologies in terms of related costs.

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