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**TIPS REPORT FOR
DEPARTMENT OF TRADE AND INDUSTRY**

TECHNOLOGICAL CHANGE AND SUSTAINABLE MOBILITY: AN OVERVIEW OF GLOBAL TRENDS AND SOUTH AFRICAN DEVELOPMENTS

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ABOUT THIS PUBLICATION

This working paper*, Technological change and sustainable mobility: An overview of global trends and South African developments,* was commissioned by the Future Industrial Production Technologies Chief Directorate of the Department of Trade and Industry (the dti). This unit is focused on preparing South African industry for the fourth industrial revolution.

It is the fourth paper in a series and focuses on technological change and the developments in the sustainable mobility topic in South Africa.

Other papers in the series are *Framing the concepts that underpin discontinuous technological change, technological capability and absorptive capacity; World Economic Forum and the fourth industrial revolution in South Africa;* and *Mapping the meso space that enables technological change, productivity improvement and innovation in the manufacturing sector.*

Saul Levin (TIPS) directed the project, and Bhavna Deonarain was the lead author of this working paper. Dr Shawn Cunningham provided comments and guidance.

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ABBREVIATIONS

APDP	Automotive Production and Development Programme
BRT	Bus Rapid Transit
CSIR	Council for Scientific and Industrial Research
DoT	Department of Transport
DST	Department of Science and Technology
dti (the)	Department of Trade and Industry
EU	European Union
EV	Electric Vehicle
EVIA	Electric Vehicle Industry Association
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HySA	Hydrogen South Africa
IEA	International Energy Agency
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IoT	Internet of Things
IT	Information Technology
IDC	Industrial Development Corporation
IPAP	Industrial Policy Action Plan
MaaS	Mobility as a Service
NATMAP	National Transport Master Plan
OEMs	Original Equipment Manufacturers
OPEC	Organization of the Petroleum Exporting Countries
PRASA	Passenger Rail Agency of South Africa
SAAM	South African Automotive Masterplan
SABOA	South African Bus Operators Association
SANTACO	South African National Taxi Council
SAPS	South African Police Services
R&D	Research and Development
SANAS	South African National Accreditation System
UK	United Kingdom
UPS	United Parcel Service
US	United States

EXECUTIVE SUMMARY

Numerous simultaneous technological changes are occurring globally. Technologies and changing economic, institutional and societal models emanating from Industry 4.0 are emerging across various industrial and social spheres, the transport sector and mobility is no exception, *"Industry 4.0 strategy is all about digitalisation, knowledge intensification, trust building, dialogue and networking. Digitalisation is not only about connecting things to the internet, but also about manufacturers being smart about integrating their suppliers, clients and internal processes,"* (TIPS, 2018). Technological transitions at play are impacting sustainable mobility; transitions in regulatory frameworks, such as emission reduction policies; transitions in key technologies where there has been increased efficiencies of petrol and diesel engines; transitions towards greener technologies such and electric vehicles; and socio-political transitions having implications for jobs. Meaningful transitions of South Africa's mobility systems require an integrated approach to address the various challenges within the sector and possibly a complete overhaul due to disruptive technologies and ideals emanating from Industry 4.0. Hence it is vital to stay abreast of changes to make informed decisions.

Technological innovations that are changing production capabilities of numerous industries across the globe could potentially have devastating impacts on labour-intensive sectors as well as labour absorbing sectors such as the automotive sector and its allied transport services in South Africa. Careful social, economic and environmental consideration must be taken when managing the just transition to technology integration and adoption in the transport sector. To successfully manage the integration of technologies and transition to sustainable mobility across all sectors requires strong governance and sound policy frameworks coupled with investment in research and development (R&D). To reduce risks associated with job displacements, understanding the dynamics between human and machines are vital to ensure that the benefits of digitisation are dispersed. This can be achieved by increased skills development and capacity building. In addition, the quadruple helix of collaboration between government departments, academics and researchers, civil society and the private sector could ensure a sustainable technological transition prevails without undermining economic growth and social development.

This working paper provides an overview of global and South African developments on widespread technological change and sustainable mobility. Section 2 focuses on global technological trends such as increased uptake of electric vehicles; advances in drone, digitised and automated technologies; and changes in commuter and consumer behaviour, impacting passenger, freight and industrial mobility. Section 3 briefly highlights South Africa's technology readiness by comparing developments in the global trends highlighted. This is followed by a case study on the implications of technological disruptions on South Africa's automotive sector, showing that if industry does not adopt, adapt and evolve to global changes in mobility, local production of vehicles and components could be severely affected unless Original Equipment Manufacturers (OEMs) commit to upgrading their South African plants, as technological changes in the automotive sector are occurring at various stages within the value chain. Finally, Section 4 concludes by suggesting possible considerations for managing a just technological transition in South Africa's mobility.

1   INTRODUCTION

In recent years' industries across the globe and across all sectors, have been at a crossroads. Two dynamics, possibly complementary, are at play: sustainability on the one hand and the rapid emergence of digitalisation on the other; both have come with connected technologies, changing business and societal models, and other numerous additional changes. While industrialisation has led to socio-economic development, industrialisation over the decades has subsequently resulted in dire environmental consequences pertaining to issues such as natural resource depletion and large-scale emissions of harmful gases into the Earth's atmosphere. However, rapid innovation and efficient, reliable and accessible technologies have seen a convergence, with the ability to reshape and incorporate sustainability into industrial processes, presenting promising opportunities to address environmental challenges; and to curb emissions while contributing to sustainable economic development. Viewed as disruptive transformations technological change could significantly impact industrial sectors due to changes in business strategies and consumer models as a result of digitalisation, big and open data systems, artificial intelligence, automation and changes in mobility and modes of transport; often referred to as Industry 4.0.

The drastic rise in digitisation has seen cyber-physical production systems being created, systems which integrate physical, mechanical and electrical components, with information technologies and communication networks to form so-called "smart machines". The main aim is to increase productivity and improve service delivery in the most cost-efficient and sustainable manner. Technologies such as 3D printers, drones, sensors, automated vehicles and machinery, app-based transport systems and electrified freight modes are able to link with plant crops, vehicle fleets, humans and warehouse stock for example, potentially disrupting current operating norms across entire value chains. (Deloitte, 2017) Moreover, digitisation has sparked changes in consumer behaviour, permeating most facets of economic spheres. However, with the fast-paced introduction and interjection of new and improved technologies, digitisation also has the ability to drastically abrupt societal and business modes. Since machines do not hold any purchasing power or the ability to consume, ill-prepared economies will not be able to continue growing, thereby worsening social and economic well-being. If not managed correctly the new wave of digitisation could also culminate in dire consequences for employment and the environment in numerous industrial, manufacturing and service sectors across the globe, and the transport sector is no exception.

Technological and societal change underpins the transition towards sustainable transport systems. Embracing technologies can aid in achieving country commitments to lower emission profiles while providing integrated, accessible, affordable and sustainable transport for all.

From a holistic perspective, transport plays a major role in industrialisation, economic growth and social development; it moves goods, services and people on a daily basis. As the South African economy and social aspirations continue to grow, so too does demand for transportation, with reliance on fossil fuels continuing to dominate the fuelling space. Beyond environmental sustainability, the high costs of importing crude oil or producing these fuels through coal, growing congestion and long commuting hours means reforming the passenger transport sector is a priority. In terms of agricultural, freight and industrial mobility, dated technologies and inefficient vehicles and equipment have resulted in sectors not maximising full production potential, while culminating in the inefficient use of energy.

Transitioning to sustainable transport requires changes in technological systems. The concept of technological systems implies that in order for technology to function progressively, it has to be rooted and incorporated or integrated in infrastructure networks, as is the case of electric vehicles (EVs) and

gas-based vehicles where charging and fuelling stations are mandatory requirements for functionality (Markard and Truffer, 2006).

Factors that propel technology adoption include technology-push mechanisms and market-pull mechanisms. Technology-push mechanisms occur when innovation and change is brought about by R&D, while market-pull arises when key factors play prominent roles in technology system adoption, such as crude oil price volatility, consumer behaviour and the drive towards environmentally friendly mobility (Di Stefano et al., 2012; Verbong and Geels, 2007). However, it is also the case whereby existing technology becomes entrenched or locked-in, making it difficult for technology diffusion and absorption to take place, especially if technological systems are at play, depending on and sustained by using infrastructure, as in the case of conventional vehicles where fuelling stations are more prevalent than electric vehicle charging stations (Van der Vooren, 2014).

Technology innovation and convergence is propelled by various stakeholders such as consumers, with changes in behaviour playing a pivotal role in technology adoption, IT companies such as Apple and Google delving in autonomous vehicles, automotive manufacturers developing new vehicle technologies and governments incentivising technology adoption and adaptation.

There are many technological transitions at play impacting sustainable mobility. Transitions in regulatory frameworks, such as emission reduction policies, transitions in key technologies where there has been increased efficiencies of petrol and diesel engines, transitions towards greener technologies such and electric vehicles, and socio-political transitions having implications for jobs. Meaningful transition of South Africa's mobility systems requires an integrated approach to address the various challenges within the sector, and possibly a complete overhaul due to disruptive technologies and ideals emanating from Industry 4.0. Hence it is vital to stay abreast of changes to make informed decisions.

This briefing note provides an overview on global and South African developments regarding widespread technological change and sustainable mobility. The first section focuses on global technological trends such as; the re-emergence of electric vehicles, advances in drone, digitised and automated technologies and changes in commuter and consumer behaviour that are impacting passenger, agricultural, freight and industrial mobility. Section two briefly highlights South Africa's position in terms of technology readiness by comparing developments in the global trends highlighted. Section three provides a case study on the implications of technological disruptions on South Africa's automotive sector, as technological changes in the automotive sector are occurring at various stages within the value chain. Finally, the brief concludes by suggesting possible considerations for managing a just technological transition in South Africa's mobility.

2 GLOBAL TECHNOLOGICAL TRENDS IN MOBILITY

Across the globe, industries, societies and countries are innovating and adopting digitised and connected technologies changing business, production and consumer models in the process. Technological advancements have seen the rise of electric vehicles, drones, additive manufacturing, autonomous vehicles and equipment and sensors operating in real-time through connected information and communication technology (ICT) networks, enabling great efficiencies in cost and time. This section highlights the global and local technological trends and their impacts on passenger, agricultural, freight and industrial mobility.

2.1 The increased uptake of electric mobility technologies

Although EV technologies have been available for over a century, EVs are considered as disruptive due to rapid growing technological advancements and social awareness in recent years, with uptake rates occurring at lightening pace over a short time period. Electric vehicle growth rates have significantly increased, with more than one million vehicles sold in 2017, up by 54% compared to 2016. New EV sales, dominated by China, Europe and the United States (US), have resulted in the global electric passenger car stock surpassing three million vehicles on the road (Figure 1).

Figure 1: Global electric car stock for the period 2013 to 2017
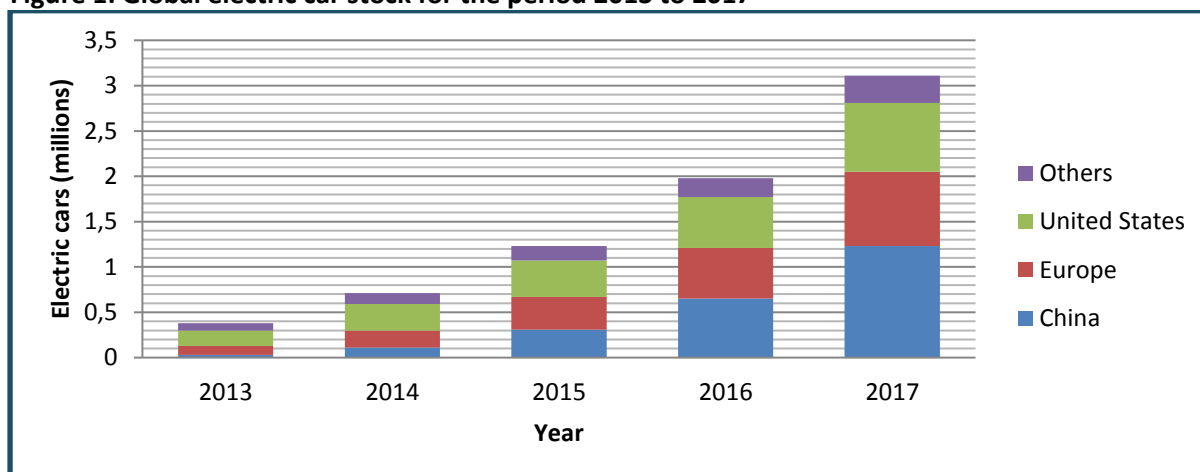
Source: Authors composition based on (IEA, 2018)

Electric buses and two-wheelers have also increased in recent years, with 100 000 new buses and 30 million new electric two-wheelers sold in 2017, reaching a global stock of 370 000 and 250 million respectively. Electric bus manufacturers are looking into light-weight material technologies, such as aluminium and carbon fibre body materials, that will ultimately enable a reduction in the overall energy consumption of buses. Hydrogen fuel cell passenger vehicles, which are an alternative to internal combustion engines and are powered by combining hydrogen and oxygen to produce energy, have seen only 7 500 vehicles operating to date, 3 500 in the US, followed by 2 300 units in Japan (IEA, 2018).

Adoption rates are challenging conventional internal combustion engine (ICE) vehicles manufacturers now more than ever, giving rise to EV model expansions in most of the leading vehicle manufacturing companies. Advancements in battery technologies, along with increased competition across new entrants to the EV market, have resulted in declining battery costs, a factor that previously hindered EV uptake. The International Energy Agency's (IAE's) *Global EV Outlook 2018* predicts that the market

share for EVs will expand significantly in the coming years, and possibly disrupt ICE vehicles by playing a more pivotal role across various transportation modes (IEA, 2018, p15).

Leading original equipment manufacturers (OEMs) across the globe have signalled interest and ambition in EV development, committing to EV technology advancements and electro-mobility in the coming years (IEA, 2018). Aside from the most prominent EV producers; BMW, Nissan and Volvo, manufacturers such as Audi, Daimler, Ford, General Motors, Jaguar, Porsche and Volkswagen (VW) have indicated plans to produce electric models in most of their ranges, with VW committing to spend US$40 billion on EV production by 2030 (Lienert, 2018).

Taking into consideration, country commitments, plans announced by OEMs along with scenarios on EV deployment, high penetration rates have been forecasted for the near future, the Organization of the Petroleum Exporting Countries (OPEC) estimates that EVs will rise to 80 million units sold annually by 2040 (OPEC, 2017), while the IEA predicts that there will be 40 to 70 million by 2025 reaching 200 million by 2030 (International Energy Agency, 2017), indicating fast-paced adoption reminiscent of a technological revolution.

2.2   Innovations in electric freight mobility

Rapid technological innovation and development has resulted in serious considerations for the sustainable movement of goods in terms of freight transportation. Truck, ship and aircraft manufacturers have begun producing and testing battery electric commercial trucks as well as solar powered ships and aircrafts. Tesla's all-electric semi-truck, having the ability to travel 800 kms between charges and integrating autonomous driving technologies, is likely to disrupt the commercial ICE trucking industry with real-world testing already underway in the United States (Mogg, 2018). In the drive to foster sustainable transport in cities, Volvo has announced plans to introduce a 16 tonne fully electric truck for cargo distribution and waste management in urban areas with recent technological change allowing for a one-to-two hour fast charge and providing a range of 300 kms (Venter, 2018a). In the competition to electrify trucking, Daimler has recently revealed two battery-electric models encompassing a range of 400 kms and 370 kms between charges and plans to heavily invest in R&D around EV and autonomous technologies, while vehicle manufacturer Volkswagen aims to invest US1.7 million in autonomous and electric truck and bus development. (Coppola and Kharif, 2018)

In terms of marine freight transportation, Japanese firm Eco Marine Power has announced testing and piloting of the world's first bulk carrier ship that will use technology such as marine computers, turbines, solar panels and energy storage modules, enabling ships to be powered by both solar and wind energy, in attempts to reduce expenditure on fossil fuels while simultaneously combating greenhouse gas (GHG) emissions (Galeon, 2018).

2.3   Introducing drone technologies

Drone technologies are also paving the way for low-carbon transportation of goods, with companies such as Amazon, DHL, Google and United Parcel Service (UPS) embarking on drone deliveries in Germany and the United States, citing that when compared to conventional logistics, drone delivery mechanisms are faster and more cost-efficient, with delivery time in some instances being reduced from three days to three hours (Businesstech, 2018; Desjardins, 2018; Mack, 2018).

In China, the use of drones, autonomous trucks and robots have been emerging in the delivery logistics realm. E-commerce giant, Alibaba, has embarked on drone deliveries of packages and food in Shanghai with plans to expand drone deliveries in numerous cities across the country (Lin and Singer, 2018).

Similarly, in the United States, robots have begun delivering food and coffee across an office park in the Silicon Valley with plans to commercially roll-out the technology in cities and suburbs in the coming months. The technology is owned by Starship, offering a fleet of over 150 robots operating in selected cities across Estonia, Germany, the United Kingdom (UK) and the US through partnerships with Hermes, Postmates and Domino's pizza (Hern, 2018).

In Africa the emergence of drones has been used to transport more complex cargo, delivering medical supplies to remote villages, saving multiple lives. US-based start-up Zipline, an innovative healthcare consultant and logistics provider, has combined technological developments with drone manufacturing to supply goods and medication in Rwanda and Tanzania (Banker, 2018). The government of Tanzania expects more than 2 000 drone deliveries a day, covering more than 1 000 hospitals and clinics that serve close to 10-million residents. The start-up has thus far collected close to US$41 million from investors to enhance humanitarian efforts in regions with low infrastructural capacity and development (Hsu, 2017). By collaborating with the Ministries of Health as well as engaging with medical professionals on the ground and regional and central warehouses, the company was able to cover all links of the supply chain, thereby ensuring ease and pace of delivery. To date, in certain instances, drones have become the first transportation option in cases of emergencies such as blood transfusions, emergency vaccines and the delivery of products that have a short lifespan (Banker, 2018). Similarly, in Australia, drone technologies enabled the world's first sea rescue by deploying a drone transporting inflatable rescue devices. The technology is under piloting phase and will also assist in monitoring for sharks and sounding alarms in cases of emergencies (BBC, 2018).

Drones have also been integrated in law-enforcement and security services sectors, enabling agents and users to patrol and track instances of crime. As such, use of drones for security and monitoring purposes saw sales of drones reach US$145 million globally in 2016. As ease of access and awareness becomes more prominent, it has been indicated that sales of security drones are set to double in 2019 and increase fivefold by 2022 (Slater, 2018).

2.4 Digitised and connected mobility

Information and communication technologies have been interwoven with production technologies culminating in highly intelligent and sophisticated machines and materials. Smart, connected factories are no longer a concept of the future, and automated and sensor technologies are able to streamline complex processes, giving rise to highly organised and efficient industrial production, packaging and dispatching of goods. Furthermore, by tracking each process in the value chain, product information is stored in real-time allowing for the quick resolution of issues such as risk aversion, quality control, maintenance, waste minimisation and environmental stability (Deloitte, 2017).

Connected information and communication technologies combined with artificial intelligence has made it possible to utilize autonomous vehicles in warehouses and automated machinery and equipment in factories, resulting in cost and time savings while increasing productivity outputs. One of the UK's largest food retailers, Ocado, has designed an intricate fully automated robotic system for the packaging of online grocery orders, which are on the rise in the UK (Chambers, 2018). In-house air traffic control systems ensure that hundreds of robots are able to operate efficiently on the warehouse floor to deliver fast paced packaging that was previously undertaken by human labourers (The Economist, 2018).

Recent technological innovation within the agricultural sector has given rise to efficient digitised and automated systems that are able to displace conventional labour and dated transport machinery and equipment required for crop cultivation and harvesting. The term "farming 4.0" has been used to

describe the emergence of technological applications such as agribots, connected tractors and drone farming, combining automated and geographical information systems to enable cost-effective, efficient and environmentally compatible farming (Bonneau et al., 2017; Chigumira, 2018). Collecting, analysing and disseminating data remotely are major benefits of farming 4.0, resulting in increased productivity and sustainability within the sector.

With connected tractors, farmers are able to incorporate GPS and sensor technology to determine shorter routes that allow for lessened crop treatment and harvesting time and increased productivity, thereby reducing fuel consumption in the process while enhancing farming efficiencies (Bonneau et al, 2017). Recent automation of farming equipment, such as automated tractors and agribots, has resulted in changes of business models culminating in reduced human capital (Bonneau et al, 2017; Chigumira, 2018).

2.5   Changes in commuter and consumer behaviour

Passenger mobility patterns across the globe are also changing as commuters are increasingly searching for ease of mobility and mobility as a service driven by the combination of smartphone applications and integrated ticketing systems. In addition, improved vehicle technologies; electric and gas based vehicles are on the rise, as countries in Europe and Asia have committed to phasing out and altogether banning the use of regular internal combustion engines[1] as commuters become increasingly aware of environmental impacts.

Mobility as a Service (MaaS) is a fast-emerging concept. This data-driven and user-centric approach aims to make ease and convenience of mobility more appealing for commuters, ultimately culminating in avoiding the need to own private vehicles for city commuters as integrated travelling options becomes more enticing (Goodall et al, 2017). Figure 2 provides an overview on the characteristics and implications of mobility as a service.

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[1] For example: Norway announced its proposed ban on fossil fuel cars in 2016, planning to prohibit the sale of all petrol and diesel vehicles by 2025. Germany's Bundesrat federal council agreed to ban fossil fuel powered vehicles by 2030 in October 2016. In July 2017, France announced plans to ban all petrol and diesel cars by 2040. The Dutch Government confirmed in October 2017 that it is looking at plans to ban petrol and diesel vehicles by 2030, stating that all new cars in the Netherlands must be emission-free. (https://www.roadtraffic-technology.com/features/european-countries-banning-fossil-fuel-cars/)

Figure 2: Characteristics and implications of mobility as a service (MaaS)

What is MaaS	Characteristics	What does MaaS mean for transport?
Mobility distribution model that delivers transport needs to users through a single interface of a service provider It offers a customer-centric, innovative, pay-per-use transport solution combining different transport modes	-Integration of transport modes -Single platform -Cloud computing -Internet of things (IoT) and technology -Personalisation and customisation -Demand orientation -Tariff options and transparency	*-Autonomous:* Driverless robotic vehicles *-Multimodal transport:* Passenger transport carried out by two or more operators *-Fleet and ride sharing:* Sharing of private vehicles by two or more passengers between destinations *-Personalised journey planning:* Search engine used to find an optimal means of travelling between locations *-Integrated payment systems:* Single fare structures for all city public transport allowing passengers to transfer seamlessly between modes *-Crowd logistics:* Platform-based logistics services provided by geographically dispersed transport operators

MaaS combines ICT systems with cloud computing to provide commuters with easy access to information on the cost, location and scheduling of various transport modes. Advances in technology have made it possible for autonomous trains and trams to operate on designated transport routes managed remotely by an operator. MaaS reduces vehicle ownership and congestion on the country's roads, with commuters shifting to various modes of public transport and shared transport services such as car and bicycle sharing and ride-hailing. While still relatively small around five million commuters engaged in car sharing. In 2014 it was estimated that around five million commuters engaged in car sharing across the globe, while still relatively low, this number is set to increase significantly, reaching 23 million commuters by 2024, which could potentially displace other forms of transport (Goodall et al., 2017).

3   INDUSTRY 4.0 – SOUTH AFRICAN DEVELOPMENTS

Based on the global trends addressed in Section 2, this section focuses on how South Africa compares in terms of adoption of technology in the context of mobility. First, the current state of autonomous mobility and electric vehicles is analysed, followed by the country's transition towards mobility as a service and the emergence of drone technologies. The section then concludes with a case study on the implications of technological change for South Africa's automotive sector driven by trends in the global market.

According to the World Economic Forum's Readiness Diagnostic Model Framework country assessment, South Africa falls under the nascent quadrant, possessing a limited production base while displaying a risk factor for the future (Schulz et al, 2018). A recent study undertaken by Deloitte (Deloitte, 2017) analysed whether Africa is ready for digital transformation, or Industry 4.0. Table 1

provides information on the current use of advanced technologies in South Africa, based on perceptions, interviews with local stakeholders and articles published by news outlets and companies.

Table 1: Overview of current usage of smart technologies in South Africa

Technology	Rate of adoption in South Africa
Advanced Analytics	•Strongest adoption of advanced analytics within automation and automotive sectors; other sectors like process industry are still catching up. •Many manufacturers do not know what kind of data they have, how much it is already connected and what insights and benefits they could derive from it. • Majority of manufacturers have a "reactive approach" when it comes to data usage and analysis and not a "predictive approach". • There are huge opportunities in advanced analytics that are not fully explored yet by South African manufacturers (e.g. to support decision-making, for condition monitoring or predictive maintenance).
Cloud Computing	• Adoption of cloud solutions has increased in recent years with the implementation of better mobile infrastructure/connectivity in South Africa. • Currently, stronger adoption is happening by consumers than by businesses/industry. • However, this is bound to change in the coming years, with higher business adoption expected. • Fear of cyber-crime and privacy concerns are cited as the main concerns hindering cloud adoption.
Drone technologies	• New regulations around the use of drone technologies were issued in 2015/ • Agricultural sector is utilising drone technologies to monitor crop growth and damage as well as for irrigation purposes. • Certain local governments in collaboration with law enforcement agencies are deploying drone technologies for security and surveillance. •State-owned enterprises investigating the use of drones for safety and security. • The rise of online shopping will see an emergence of drone deliveries by 2022, impacting the need for regular delivery vehicles. •Regulations will require amendments to expand the uptake of drones.
Advanced Sensors	• With a few exceptions, advanced sensor technology like machine to machine (M2M) communication is mostly at a foundation stage in South African manufacturing. • Higher traction can be found in the automotive industry, agricultural and industrial mobility and non-manufacturing sectors (e.g. retail, logistics/freight). • However, there is a lot of interest among South African manufacturers to better leverage the potential of sensor technology in their manufacturing processes (e.g. monitoring, controlling, tracking). • Some stakeholders in the agricultural sectors have been implementing sensor technologies to monitor crop health and weather patterns. • In the industrial sector advanced sensors have been used to track and scan goods as well as undertake quality control checks.
Advanced Robotics	• Adoption of advanced robotics remains low across different South African manufacturing sectors. • Use of robotics is mostly at an automated stage and not yet at a smart or advanced stage. • Stronger adoption of advanced automation/robotics technology can be found only in a few industries, e.g. automotive sector with Volvo making use of automated machines for assembly. • Cost factors are a prohibitive adoption factor for many South African manufacturers.

Additive manufacturing (3D printing)	• No widespread adoption of 3D printing yet within the South African manufacturing industry. • Manufacturers are aware of the significance and the potential of this exponential technology. • Examples of actual usage are mostly in rapid prototyping, testing of design options or understanding engineering problems better. • No examples of usage of 3D printing for low-level or mass production due to cost reasons. • Affordability remains an issue in developing markets, compared to developed economies. • Once the cost of printers and material reduces further, more investments by manufacturers and greater usage are expected. •3D printing could reduce the need for freight transportation.

Source: Authors composition and (Deloitte, 2017 p16)

There are varying rates of technology adoption across the different industrial sectors in South Africa, with the automotive industry more adaptive to change to an extent. Automation in the automotive sector is slowly emerging in South Africa. In Uitenhage, VW's manufacturing plant utilises over 600 robots to assemble around 3 000 units. These technologies have enabled the plant to operate at full capacity and during certain months in 2018, it operated 24 hours a day seven days a week, resulting in an addition of 300 more employees (Mtongana, 2018), in contrast to fears that automation and digitisation could render human labour redundant.

Calculating the jobs impact of new technology is a complex process, while jobs are at risk particularly in the automation of routine processes across skill levels; as shown in the above example new possibilities exist in other areas of work. Those with high skill levels like commodity traders can be absorbed elsewhere, while mid-skilled production workers may be at greater risk unless reskilled. Estimations that only look specifically at automation of production lines find that automation could potentially displace 35% of all jobs in South Africa (Phillips et al., 2018). Others have put it at 20 percent and argue "*if South Africa can double the pace at which its workforce acquires skills relevant for human-machine collaboration, it can reduce the number of jobs at risk from 20 percent (3.5 million jobs) in 2025 to just 14 percent (2.5 million jobs)*" (Phillips et al, 2018, p2).

Adopting technologies increases complexities in production in terms of managing technologies, and this will require the skilling and re-skilling of the country's labour force, as well as investigating new manufacturing potential to ensure a successful just transition.

3.1 Transitioning to electric vehicles

The development of EVs displays significant potential for transitioning towards sustainable mobility and enhancing automotive and component manufacturing. EVs produce no tailpipe GHG emissions. In countries such as South Africa, however, where electricity production is coal-based, upstream GHG emissions lead to similar levels of GHG emissions compared to smaller conventional vehicles operating on diesel and petrol (IRENA, 2017), calling for renewable energy-based solutions. However, EVs outdo conventional ICE vehicles in energy efficiency, especially in traffic congestion, due to regenerative braking, a process whereby EV batteries can convert kinetic energy into chemical energy (Suleman et al., 2015).

Electric vehicles are in their infancy in South Africa. As of 2018, there were around 1 000 electric vehicles and over 100 charging stations in the country. A lack of charging infrastructure has been cited as a major deterrent for the uptake of EVs (EVIA, n.d). Nonetheless, plans are underway to support the uptake of EVs, with government departments, in particular the Department of Trade and Industry

(the dti) and Department of Transport (DoT), and the private sector, through the Electric Vehicle Industry Association (EVIA), actively championing the growth of the industry. The draft Government EV Procurement Programme stipulates that 5% of government and state-owned enterprise fleet must be electric. Furthermore, Cape Town jurisdiction has announced a Fossil-Fuel-Free Streets Declaration by 2030 (IEA, 2018), which could spur growth in local EV sales.

Municipal pilot projects have been encouraging in recognising the benefits of using of EV technology. The City of Cape Town, for example, launched the MyCiti Battery Powered Electric Bus pilot project in the latter part of 2016. Ten electric buses and two charging stations were introduced to the city's Bus Rapid Transit (BRT) network in 2017 (Deonarain, 2018), although these initiatives have halted due to concerns regarding the tender process. BMW, Jaguar, Nissan and the Industrial Development Corporation (IDC) are also installing free fast-charging points at selected dealerships and charging stations are proposed for malls and office parks across the country (EVIA, n.d). Furthermore, private sector involvement in the expansion of EV charging infrastructure and development of interactive electro-mobility technologies is gaining traction, due to continued efforts from local-based companies such GridCars, which have locally produced AC charging systems, while importing fast-charging DC systems (Venter, 2017a).

To ensure that local manufacturing of these charging systems is supported as demand for EVs grow, the company is undertaking measures to guarantee that future DC charging systems contain at least 50% of local content. In addition, software systems developed by GridCars provide users with real-time information on location and availability of charging stations as well as user transaction history, allowing consumers to keep track energy consumption and associated costs of charging (Venter, 2017a). In addition, the National Electric Vehicle Technology innovation Programme provides a platform for private sector manufacturers, tertiary institutions and research and development organisations to collaborate on efforts to further develop the EV industry, with particular emphasis on improving energy storage and battery technologies and charging infrastructure (South African Cities Network, 2015); Deonarain and Mashiane, 2018)

The uYilo eMobility Technology Innovation Programme, initiated in 2013 and housed at the Nelson Mandela University in Port Elizabeth, has also been created to support technology development for electric mobility in South Africa through the "electric vehicle systems laboratory". Furthermore, as part of the programme a South African National Accreditation System (SANAS) and ISO17025 approved national battery testing laboratory has been set up to undertake lithium-ion battery testing, among others, along with a live testing environment to conduct real-time and simulated tests on electric vehicles, micro-electric vehicles and electric bikes. Automotive component and energy storage specialist Metair in partnership with the South African Institute for Advanced Materials Chemistry (based at the University of Western Cape) have initiated lithium-ion battery production at its South African operations (Venter, 2017b). To foster entrance into the electric vehicle battery market, Metair has collaborated with OEMs to develop lithium-ion battery projects in South Africa. The company has also partnered with local aluminium supplier Hulamin to produce aluminium foil for batteries. (Venter, 2018b) Hulamin has also entered the lithium-ion battery space by providing Tesla with aluminium required for the electric battery box base plates. The company is also in talks with numerous other electric vehicle manufacturers which are opting for light-weight materials as the drive for sustainability ensues (Hedley, 2018). Further, Hulamin has shown its technical capability in creating a product niche by being the only company in the world that produces a vital component enabling Wi-Fi connections on aircrafts (Wasserman, 2018); it therefore has capacity for involvement in future EV projects and technologies.

Other initiatives underway, championed by the Department of Science and Technology (DST), include exploration of hydrogen fuel cell technologies, To this extent the Hydrogen South Africa (HySA) Infrastructure Centre of Competence was established, by the Council for Scientific and Industrial Research (CSIR) and North-West University, to develop technologies for the production, distribution and storage of hydrogen in the country, and undertake local R&D in platinum-group-metals beneficiation (HySA Infrastructure, 2012). Fuel cell technologies could provide a platform for local technology beneficiation utilising the country's platinum base, and Platinum Group Metals companies have been encouraging research efforts. However, fuel cells have not been prioritised in measures to ensure sustainable public and private transportation in South Africa. Furthermore, future demand for hydrogen fuel cells remains relatively uncertain, with global projections indicating fuel cells will play a small role compared to battery-based EVs.

It has been indicated that procurement schemes for public transport and state-owned vehicles are an important policy tool that could stimulate EV diffusion during the early stages of adoption, enabling local economies of scale around EV manufacturing (IEA, 2018). As part of the Industrial Policy Action Plan (IPAP), the dti, with additional support from the DST, DoT and local government, has encouraged the establishment of a local EV value chain manufacturing industry, including producing the complementary charging infrastructure, testing facilities and public awareness campaigns (the dti, 2017; Suleman et al., 2015)

As part of the Automotive Production and Development Programme (APDP), the Automotive Investment Scheme provides cashback incentives amounting to 35% for manufacturers producing electric vehicles. In addition, the 2013 Electric Vehicle Industry Roadmap proposes tax incentives and rebates for purchases, and support for R&D, in particular the creation of cost-efficient battery technologies and the provision of charging infrastructure across the country, to highlight a few.

Yet, the market for alternate technologies remains nascent in South Africa, despite multiple initiatives by both the public and private sector. Integrated inter-departmental coordination could ensure that plans to develop, enhance and improve sustainable infrastructure and transport systems materialise. This includes policy, project and strategy alignment on achieving and promoting climate-compatible and socio-economic transport planning.

Current regulations and taxation are one of the factors contributing to deterring the transition to low-carbon transport alternatives. In terms of import duties, while all passenger vehicles are subject to a 25% tariff, imports of ICE vehicles from the European Union are subject to 18%, whereas vehicles from the Southern African Development Community are imported duty-free. While non-discriminatory, Ad Valorem Tax remains higher on EVs compared to diesel and petrol vehicles, due to the high cost of EVs. To be eligible for, and benefit from, the APDP incentive framework, local manufacturers need to produce 10 000 EVs a year. In addition, the APDP allows local manufacturers to import vehicles at reduced tariffs; however, it does not allow OEMs to gain EV credits from the export of ICE vehicles. Furthermore, consumer awareness, or lack thereof, has contributed to slow uptake of EVs, as range anxiety and issues around the availability of charging infrastructure continues to form part of the discourse around EV uptake. As such, the South African government should provide the necessary support. One possible measure is to decrease import duties and taxes on EV battery technologies, making electric vehicles more affordable.

A second measure includes tax exemptions or rebates on EV purchases and registration fees, and a third is offering preferential electricity tariffs for EV charging which could promote the uptake of private use. Fourth, in order to reduce demand for high-GHG-emitting and high-fuel consuming vehicles additional taxes could be imposed on such vehicles as well as measures being implemented

to aid eco-mobility, such measures include free parking and exemption from toll fees, as well as access to future car free zones in cities. Fifthly, commitment to implementing the Government EV Procurement Policy, requiring mandatory EV fleet purchases, must be pursed in a proactive manner. The state can utilise charging infrastructure technology advancements and declining prices of battery components to procure its proposed future EV targets for government and state-owned enterprise fleets. Lastly, government and the private sector should collaborate on efforts to develop emissions standards and labelling systems for new vehicles.

Consistent market demand of electric and gas-based vehicles is likely to reduce prices in the medium term. With long-term strategies for infrastructure development, charging infrastructure expansion and attractive incentives, the EV industry could take off in South Africa fostered by government, private-sector and consumer support.

3.2   Aspirations for Mobility as a Service (MaaS)

In South Africa, commuter behaviour is also changing – citizens are adopting technologies at rapid rates and are increasingly seeking convenience, variety and time and cost savings when it comes to travelling (Kgobe, 2018). One of the drivers of this change is congestion. South African cities are experiencing fast growing urbanisation as citizens' move from rural areas seeking employment and educational opportunities. Cities, however, are not well equipped to cope with the vast influx of migrants, placing strain on resources and service provision. The country's transport sector is no exception. After energy generation, the transport sector is the second highest emitter of GHGs in the country. Furthermore, transport provision is plagued by issues related to long commuting hours, particularly for the poor, high transport costs, growing congestion, aging infrastructure and public transport fleets, and heavily pollution public and private vehicles.

A second driver of change is the proliferation of new technologies in the transport sector. In South Africa commuters are increasingly making use of app-based transport service providers such as Uber and Taxify. Digital applications have also made it easier for commuters to plan the most cost-effective and time efficient routes to various destinations. In March 2018 Gauteng MEC for Roads and Transport Dr Ismail Vadi, launched the Gauteng on the Move App, which provides commuters with real-time, point-to-point information when planning travel. Users are provided with locations, timetables and fares for the Gautrain, Metrobus, A re Yeng, Rea Vaya, Metrorail, Gautrain Bus Services, Johannesburg City Sightseeing Bus, Tshwane Bus Services and minibus taxi services.

In response to these drivers of change, to manage the transition to MaaS, and to support the implementation of efficient, affordable and integrated public transport services, Gauteng plans to create a transport authority and a transport management centre which will carry out planning and data management of various public transport networks. Plans are also under way to deploy integrated ticketing systems that automate the issuing, sale and validation of tickets. As such, by 2020, commuters would be able to make use of one card, such as the Gautrain card, across different modes of rail and bus services (Kgobe, 2018; Venter, 2018c). Figure 3 provides a snapshot of what the future of transport could look like in South Africa through the adoption and implementation of sustainable transport and related ICT technologies.

Figure 3: The future of integrated transport management systems in South Africa
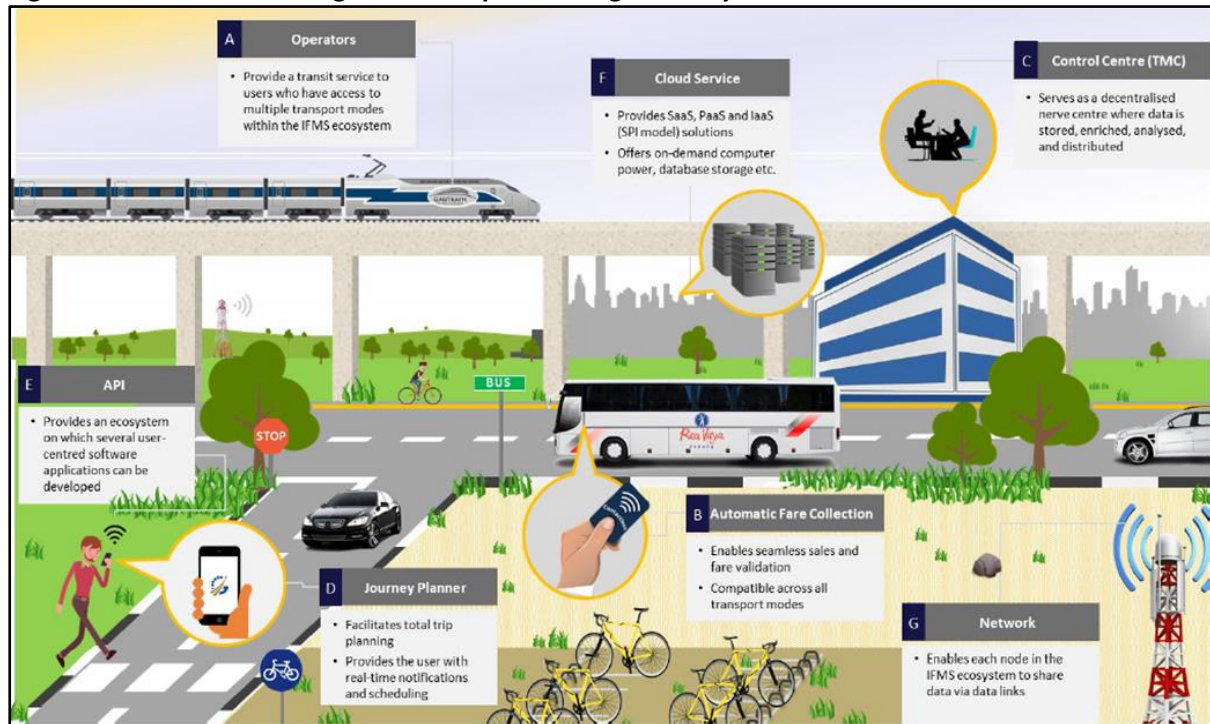
Source: (Kgobe, 2018)

Integrated public transport management systems aim to provide numerous benefits, ranging from improved travel time and costs, efficiencies in scheduling, and increased use of public transport services currently available in South Africa, along with economic benefits such as growth in ICT and intellectual property, skills development, improved access to services and job creation (Kgobe, 2018).

Improving mobility for the majority of South Africans requires efficient and reliable public transport systems and the integration of transport modes. South African policies acknowledge the need for sufficient, reliable and affordable public transport with numerous policy documents and programmes available to support the development of sustainable transport systems, such as the National Transport Master Plan (NATMAP), the Integrated Transport Master Plan, the Transport Flagship Programme and the Green Transport Strategy (Deonarain and Mashiane, 2018).

However, costly infrastructure, coupled with low passenger volumes during off-peak hours has placed financial burdens on municipalities whereby public transport systems are unable to recover their operating costs and need to be subsidised on an ongoing basis.

This is evident in the BRT systems, which have been experiencing higher than anticipated losses, only able to recover around 40% of operating costs in Johannesburg (National Treasury, 2017), while Cape Town's MyCiti has recovered around 49% of operational costs. In 2016, the National Treasury provided subsidies for overhead operating costs amounting to R290 million and R250 million for Johannesburg and Cape Town respectively (Van Rensburg, 2017). Fiscal investments of approximately R15 billion into the development of BRT systems in Gauteng has not matched intended returns, with only 75 000 people using the service in the province, such that South Africa's Minister of Transport has indicated that an urgent transformation of the system is in order (Venter, 2017c). Despite the travel efficiency, safety, reliability and sophistication of South Africa's BRT network, these systems have thus far been implemented with varying degrees of success. The MyCiTi and Rea Vaya BRT systems have experienced numerous challenges to date, particularly the opposition from minibus taxi operators in

the cities, low volumes of ridership during off-peak periods and poor operational cost recovery (Walters, 2013).

The South African government has further pledged a significant amount of economic resources for investing in infrastructure to support integrated sustainable public transport networks. The 2017 Budget Review indicates that R142.6 billion will be allocated to developing affordable and efficient public transport systems over the next three years until 2020 (National Treasury, 2017). National government will provide funding for municipalities to improve and implement integrated public transport systems through the public transport network grant (National Treasury, 2017).

Despite the various modes of public transport on offer, the sector is plagued by numerous challenges, such as inefficiency, unreliability, high costs of travel and unsafe commutes, which have reduced commuter satisfaction (Statistics South Africa, 2014). The transformation from operating unreliable and poorly maintained buses and taxis, to creating formal and efficient transport businesses, that are absorbed and integrated into the new, possibly electric, BRT systems, thus ensuring that there are minimal job losses, is necessary for the transition towards sustainable transport and MaaS in South Africa (Olsen and Fenhann, 2015). Successful integration requires co-operation from governments, cities, ICT and electricity suppliers as well as vehicle manufacturers and the private sector.

The BRT and Gautrain systems are proof that South Africa has the aspirations and capabilities of developing and implementing world class transport networks, however, the success of such systems has been hindered by socio-spatial and economic challenges. The lack of integration between taxis, minibus taxis, buses, BRT and rail services can be tackled using integrated infrastructure such as a multi-use interoperable ticketing system whereby commuters are able to use one ticket for the various modes of transport, using a universal card that can be loaded with credit, as indicated by plans for the transport management authority. Integrated ticketing is slowly making headway in South Africa, with VixTechnology providing technological systems that link the A Re Yeng and Tshwane bus services in Pretoria. Due to ease of mobility between the two service providers, ridership and revenue has since increased (VixTechnology, 2018). The DoT along with various government departments, such as the dti and local government, as well as public-private entities such as the Passenger Rail Agency of South Africa (PRASA), BRT enterprises, South African National Taxi council (SANTACO) and South African Bus Operators Association (SABOA) need to collaborate on this effort to make integrated ticketing systems a reality. Complementary, mobile payments and information services can be developed to aid ease of payment and reduce intermodal transfer times. In addition, scheduling should be timed in a way that aligns the various public transport modes to ensure that there are no unnecessary overlaps on routes. (Deonarain and Mashiane, 2018)

3.3 Integration of drone technologies

The South African Civil Aviation Authority in collaboration with the Department of Transport introduced new drone regulations in 2015, requiring private operators to be over 18 years of age with appropriate licensing to be able to make use of the technology. Furthermore, the regulations stipulate that drones are to be flown below 121.9m from the surface and are not allowed to hover in close proximity to people or above crime scenes, prisons and police stations, courts of law and nuclear power plants, or be used for transporting goods and cargo. Additionally, unless for law-enforcement purposes, drones are prohibited from taking off and landing on the country's public roads. (Wakefield, 2015)

To reduce costs, time and paperwork resulting from the use of manually piloted helicopters, security drones for surveillance are being considered by the South African Police Services (SAPS), metropolitan police and state-owned enterprises such as Eskom. Drone technologies are able to provide real-time footage, enabling responders to react and make decisions in a timely manner. Increased instances of attacks on hikers and tourists in the Table Mountain vicinity has prompted SAPS together with the City of Cape Town, Western Cape Government and South African National Parks, to explore options for the use of drones in surveillance, tracking and identification of suspects. In terms of state-led agencies, the PRASA signed a memorandum of agreement with the Western Cape Department of Transport and Public Works and the City of Cape Town, enabling drone technologies to be used for monitoring railway tracks, thereby improving the safety and security of the system and commuters. Similarly, Eskom, in collaboration with CSIR, are beginning to investigate the use of drone technologies to inspect and monitor power lines. (Slater, 2018) Aerial Monitoring Solutions, a Johannesburg based start-up, uses the Eagle-Owl drone to monitor and provide surveillance and track livestock and game, reducing threats and contributing to anti-poaching campaigns in South Africa. (Timm, 2017)

Drone technologies in South Africa extend beyond safety and security purposes. The use of drones in South Africa's agricultural sector has been increasing in recent years with several firms receiving drone licences via the South African Aviation Authority. Aerobotics, a Cape Town based start-up employing 11 people, uses drones to monitor crop growth, maturity and damage while collecting data on irrigation patterns. After winning the SA National Space Agency and Airbus Defence and Space Innovation challenge, Cape Town based DroneClouds has assisted over 400 South African farmers and agricultural companies, including Bayer and Monsanto, with farming applications resulting in crop yield increases and water savings of up to 30%.

The introduction of drones, satellite imagery and sensors has assisted farmers in gathering updated information and data, in real-time, on weather patterns, soil quality, pest management, levels of irrigation and crop and livestock health monitoring through infrared cameras, enabling remote analysis and reducing the need for conventional vehicles, equipment and human labour, resulting in improved efficiency and productivity. Advances in agricultural technologies could pose significant risks to manual labour as drones and automated machinery and equipment become more popular, however, digitisation could also foster more jobs as increased efficiency and productivity result in better seasonal harvests (Chigumira, 2018).

Emerging innovations have enabled Ran Marine, founded in South Africa, to partner with Transnet and the Port of Durban to sustainably reduce water pollution through the use of solar-powered automated drones, aptly called the WasteShark, that operates through waterways and clearing up waste and chemical substances in ports while collecting data on surrounding environments (Timm, 2017).

Furthermore, locally, Durban-based DroneScan received grant funding from South Africa's Support Programme for Industrial Innovation to develop drone technology that tracks warehouse inventory in cost and time efficient manner "*it allows a drone operator to count as much stock in a warehouse in two days as a team of 80 people with handheld scanners and reach trucks can count in three days*" (Timm, 2017). The company plans to roll out its technology to Nestle international along with five to 10 other sites.

In terms of drone deliveries of goods, in South Africa drone deliveries are expected to operate by 2021 due to the rise of online shopping, which is gaining shares in the clothing markets, with companies such as Spree more than doubling its volume of customer's year-on-year. It has been estimated that more than 55.5% of South Africans own smart-phone devices, lessening the connectivity gap and

enabling the growth of app-based services. Machine-learning has also made it possible to profile users' preferences, thereafter suggesting suitable or similar products, enabling retailers to offer personalised advertising. (Businesstech, 2018) However, if current regulations around drones are not amended, the use of drones for delivery purposes will be prohibited.

3.4 A case study: Industry 4.0 implications for South Africa's automotive sector

According to the World Economic Forum (WEF, 2018), the fourth industrial revolution will culminate in new forms of competition between countries, particularly those with a strong manufacturing base. To avoid lagging behind, countries are now encouraged to adopt, adapt and diffuse technology in attempts to keep up with, or altogether leapfrog, industrial development, with leading manufacturing countries across the global putting forward Industry 4.0 strategies (Cunningham, 2018).

South Africa displays strong capabilities in automotive manufacturing, with the sector deemed an industrialisation success story. This case study provides a brief overview of South Africa's automotive sector contribution to gross domestic product (GDP) and employment. Taking into consideration changes in global vehicle parks along with country commitments to abate GHG emissions, implications for the export market are analysed. Globally automotive sectors are responding to shifts in mobility preferences and changes in technology by advancing manufacturing capabilities, developing light-weight materials and incorporating information technology (IT) into vehicle design.

Figure 4 provides a snapshot of global trends in the automotive sector in response to technological disruptions and changes in mobility.

Figure 4: Global automotive sector response to changing mobility
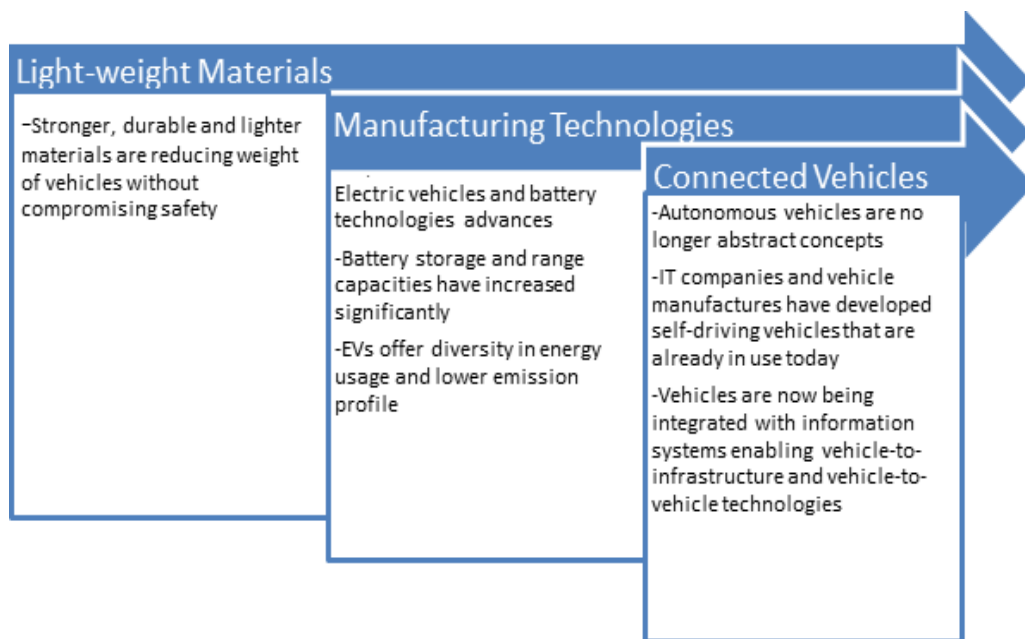
Source: Authors' composition based on Jordaan, 2018.

South Africa boasts a strong automotive sector with multiple leading OEMs locally manufacturing vehicles for domestic and international markets. Table 2 provides an overview of the automotive companies present in South Africa and the respective models manufactured locally.

Table 2: Automotive makes and models manufactured in South Africa, 2018

Segment of Auto	Make	Model
Cars	BMW	4-door 3-Series and X3
	Ford	Everest
	Mercedes-Benz	4-door C-Class
	Nissan	Livina and Tiida
	Toyota	4-door Corolla, new and previous series (Corolla is now known as the Quest) and Fortuner
	Volkswagen	Polo new and previous series (designated Vivo)
Light Commercial Vehicles	Ford	Ranger
	Isuzu Motors	KB and D-Max
	Nissan	NP200, NP300 Hardbody
	Toyota	Hilux and Quantum

Source: Automotive Industry Export Council, 2019

In South Africa, the automotive sector remains the largest exporter of manufactured goods contributing 14.3% of the country's overall exports, amounting to R178.8 billion in 2018. The production of vehicles and related components contributed to 29.9% of the country's manufacturing output in 2018, declining from 30% in 2017. The automotive industry as a whole contributed 6.8% to gross domestic product (GDP), comprising 4.4% of manufacturing and 2.5% of retail (Automotive Industry Export Council, 2019; Mahomedy, 2018). The automotive industry contributes significantly to employment generation in South Africa. Figure 5 shows automotive sector employment and percentage contribution to employment for the period 2013 to 2017, with employment in the formal and informal sectors surpassing 350 000 people in 2017.

Figure 5: Automotive sector employment in South Africa for the period 2013 to 2017
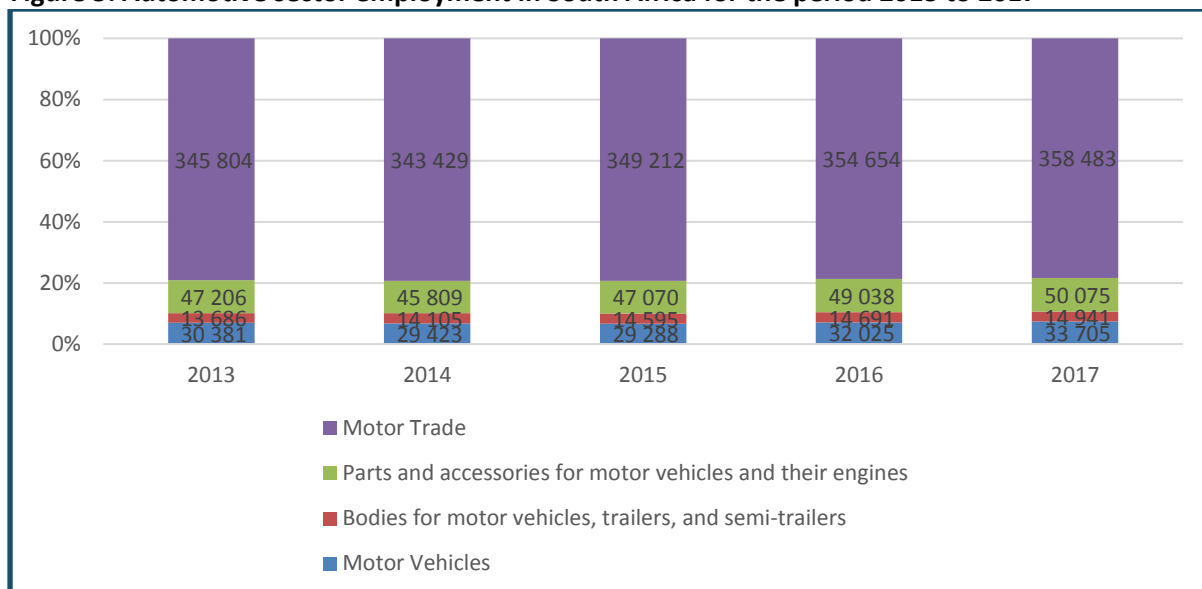
Source: Maseko, 2018

It should be noted, however, that the employment impact of the industry as a whole has a far greater reach, with an estimated four million people directly and indirectly depending on the sector (Maseko, 2018).

In terms of exports, the European Union (EU) is the largest market for South African automotive exports accounting for 58.8% (R105.2 billion) of total exports in 2018 (Automotive Industry Export

Council, 2019). Figure 6 highlights the top 10 countries in the EU importing vehicles from South Africa. Germany accounts for the highest share with 55.9% of exports, followed by Belgium (16.7%), the UK (10.1%), Spain (8.9%) and France (3.8%).

Figure 6: Top 10 EU destinations for South African automotive exports, 2017
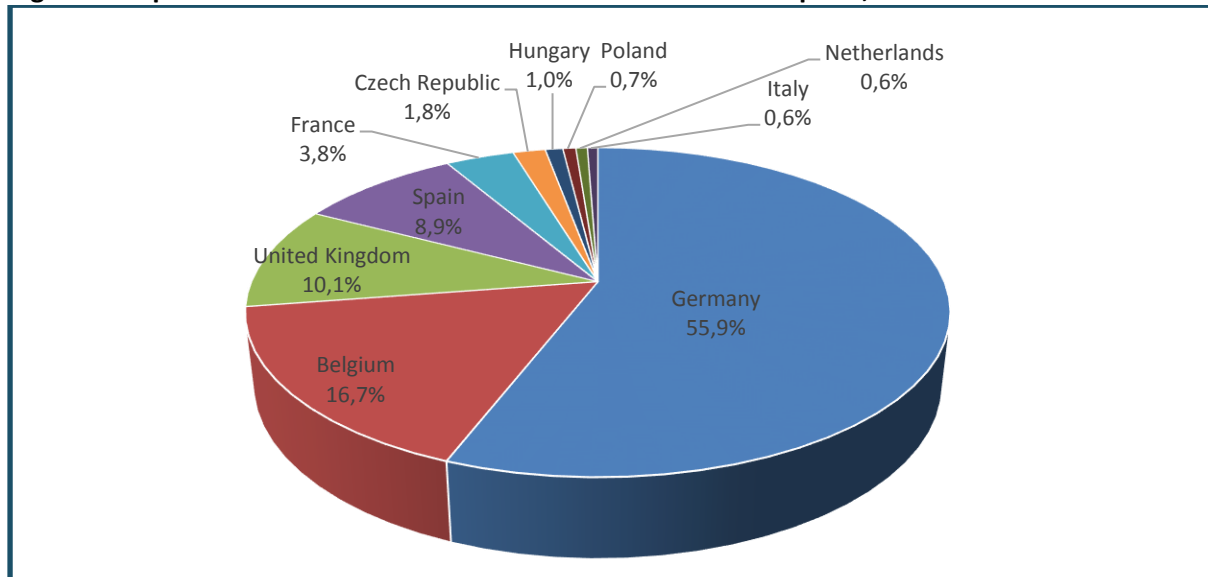
Source: (Maseko, 2018)

Automotive component exports destined for the EU comprises products such as catalytic converters, engine and radiator parts, clutches and exhaust, as depicted in Figure 7.

Figure 7: Top 10 exports by component type, 2013 to 2018 (R million)
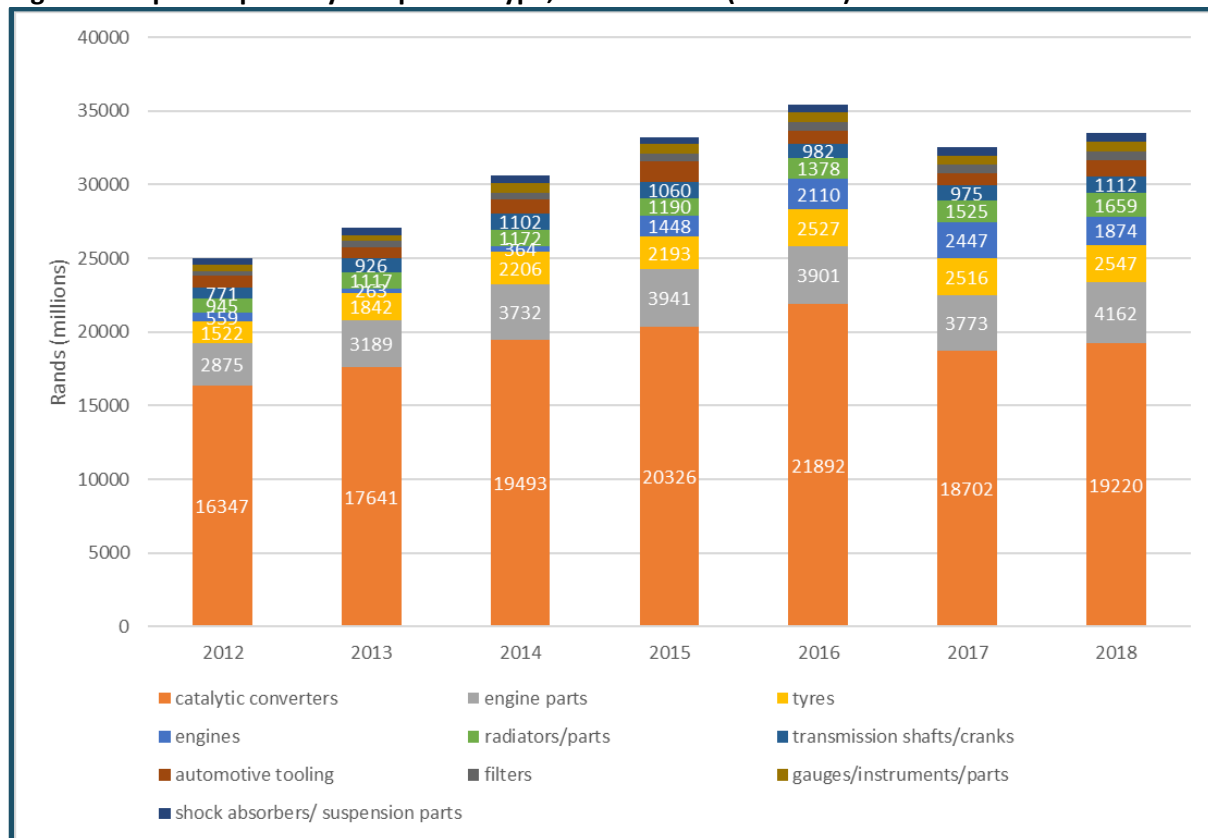
Source: Automotive Industry Export Council, 2017; Automotive Industry Export Council, 2019

Vehicles with internal combustion engines, and related components play a large role in South Africa's export capabilities, with catalytic converter exports contributing to 37.2% of component exports in 2018, amounting to R19.2 billion, followed by engine parts, tyres and engines contributing R4 billion, R2.5 billion and R1.8 billion respectively (Automotive Industry Export Council, 2019).

As the transition to sustainable mobility takes place, several European countries have indicated plans to ban internal combustion engine vehicles: Norway by 2025, Germany by 2030, Scotland by 2032, along with England and France by 2040. Considering the number of EU countries that have committed to phasing out and completely banning new sales of internal combustion engine vehicles. The South African automotive industry would consequently be impacted by these changes and the international companies operating automotive plants would need to make significant investments to update the production lines and processes to continue the functionality of these plants to include electric and gas-based vehicles. Such changes will impact on the structuring of the government incentives to maintain the local production of vehicles for exports, but also the manufacturing of components, as electric vehicles do not require as many components as ICE vehicles. Catalytic converters, the highest component export along with conventional radiators, could see drastic declines once ICEs are no longer in use, as these components do not form part of the composition of EVs. Furthermore, technological change in one sector has the ability to negatively impact another – in the case of South Africa, declines in catalytic converters and related components could pose severe implications for South Africa's platinum industry.

In South Africa, job losses could occur at the architectural and component level, as the automotive industry's main focus is manufacturing ICE vehicles and related components. Since countries have committed to phasing out ICE vehicles, and unless a transition mechanism is put in place the local manufacturing sector could see a decline. As the importation of used vehicles are not permitted in South Africa (Mahomedy, 2018) there is little risk of second hand ICE vehicles coming into the market, however, countries still producing new ICE vehicles would have fewer locations to export too and may target South Africa for their exports. As South Africa is part of the global automotive value chain producing only a few product ranges it is unlikely that the industry could rely on local demand to sustain an ICE industry. And while the rest of Africa is becoming increasingly important market for South Africa's trucks and 'bakkies', it is not a traditional market for South African made cars.

In adapting production to changes in sustainable mobility, a Chinese-owned company was awarded a tender in 2016 to produce electric buses and related equipment for the MyCiTI BRT bus fleet. Although as noted above the process has stalled due to tender considerations, the conditionalities placed on the procurement included local assembly and aspects of the bus body work to be locally manufactured in South Africa, thereby ensuring job creation (Mahomedy, 2018). German manufacturer Mercedes-Benz has also started manufacturing the hybrid-electric C class vehicle in East London, citing that the production of pure electric vehicles will be considered only once the proper infrastructure is in place (Venter, 2018d). Aside from the BYD SA and Mercedes ventures, other locally-based OEMs have not indicated any intention to introduce electric vehicle manufacturing in South Africa. The dti's APDP has been one of the most successful government policies to date, enticing leading manufacturers to set up shop in South Africa, culminating in the expansion of component supply chains and an increase in the number of vehicles produced locally (Venter, 2018d). The IPAP 2018/2019-2020/2021 acknowledges the need for innovation "*in the case of the automotive industry, for example, SA has made enormous progress in establishing a globally competitive, export-rich automotive sector. But the global market requires constant innovation and creativity, and so our efforts in the sector cannot stand still,*" (the dti, 2018b, p5).

A media statement by the dti minister Rob Davies on the South African Automotive Masterplan (SAAM) 2035 and the Extension of the APDP was held on 23 November 2018 when it was announced that by 2035 South Africa's vehicle production should amount to 1% of global vehicle production (140 million units per year), furthermore local content in the automotive sector is expected to increase to 60% up from the current 39% (the dti, 2018a). The dti has recognised the importance of incorporating and adapting to technological change calling for a technology and associated skills roadmap for the automotive sector that aligns with each key element identified in the SAAM stating that "*As product development and production processes within the automotive industry become more environmentally sustainable, there will also be clear requirements for the deployment of new production technologies in South Africa. These may require new types of industrial infrastructure that need to be understood and responded to, to ensure South Africa does not fall too far behind the automotive technology frontier, and that domestic production continues to qualify for supply into developed economy markets with ever-more demanding environmental requirements that are likely to represent new forms of Non-Trade Barriers in future*" (the dti, 2018a).

As the global market gradually shifts to more sustainable modes of transport, incentives and institutional and physical infrastructure for the production of electric vehicles and related components need serious consideration to retain and attract OEMs to the country.

Further analysis of the impacts of Industry 4.0 on South Africa's automotive sector needs to be undertaken to fully comprehend manufacturing, social and economy wide implications; and taking into consideration the magnitude and scale of technological disruptions such as the rise in EVs and mobility as a service. Supporting OEMs localisation of technological innovations, by restructuring incentives in favour of EVs, could ensure that the automotive manufacturing sector remains relevant.

4   CONCLUSIONS

There are numerous simultaneous technological changes occurring globally. Technologies and changing economic, institutional and societal models emanating from Industry 4.0 have been emerging across various industrial and social spheres – the transport sector and mobility is no exception. The rapid rise in digitisation has made it possible to change business and commuter models of behaviour, with cost and time savings being the ultimate goal.

Electric vehicles, drones, digitised and automated technologies along with changes in commuter preferences, has seen technologies been adopted at fast rates in recent years. In the South African context, these technologies are gradually making headway in certain sectors as connectivity has a further reach than ever before. From a consumer and commuter perspective, mobility as a service is emerging as more transport options become available. While the uptake of electric vehicles remains slow, technologies such as drones and sensors as well as automated and connected vehicles are being incorporated into agricultural, industrial and freight mobility, thereby reducing the need for conventional vehicles and mobility equipment.

South Africa's automotive industry is one of the country's most successful manufacturing sectors and largest export of products. The biggest export market for locally produced vehicles and vehicle components is Europe, whose recently policy scenarios and consumer patterns are indicating a shift away from conventional ICE vehicles and towards more sustainable modes of transport such electric vehicles. To remain competitive globally, the South African automotive sector requires policy responses that support OEMs to invest in the local production of electric vehicles and related components.

Careful social, economic and environmental consideration must be taken when managing the just transition to technology integration and adoption in the transport sector. To reduce risks associated with job displacements, collaboration between human and machines is vital to ensure that the benefits of digitisation are dispersed. This can be achieved by increased skills development and capacity building. By adopting and integrating technologies at an early stage as well as enhancing human capabilities, emerging economies such as South Africa, have the potential to compete globally by locally manufacturing and developing goods and services connected to digitisation and new technologies (Deloitte, 2017). Furthermore, mapping of industry and policy changes at a global level needs serious consideration as South Africa's automotive sector is to a large extent dependent on international markets and part of a global value chain.

Technological innovation is changing production capabilities of numerous industries across the globe and could potentially have devastating impacts on sectors such as the automotive industry in South Africa. To successfully manage the integration of technologies and transition to sustainable mobility across all sectors requires strong governance and sound policy frameworks coupled with investment in R&D (World Economic Forum and PwC, 2017).

The quadruple helix of collaboration between government departments, academics and researchers, civil society as well as the private sector could ensure a sustainable technological transition prevails without undermining economic growth and social development.

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