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TRANSPORT DECARBONISATION IN SOUTH AFRICA: A CASE FOR ACTIVE TRANSPORT

Summary. Over two-thirds of greenhouse gases (GHG) emissions that contribute to climate change emanate from transport. This could double by 2050. With per capita emissions nearly twice the global average, South Africa ranks 13th globally on GHG emissions with road transport, directly and indirectly, accounting for 91.2% of total transport GHG emissions. It has been projected that by 2100, up to 100% increase in the country's average temperature above the 20th century average rise. This has far-reaching implications, even for the transport sector. To decarbonise its transport sector, South Africa has committed to reducing its GHG emissions by 34% by 2020 and 42% by 2025, respectively, through pointed strategies and policies. However, efficient implementation of proposed measures and sufficient funding remain daunting challenges. Thus, this paper contends that adequate attention has not been paid to active transport in the country's transport decarbonisation policy implementation despite its inclusion in policy statements. It then asserts that active transport is indispensable to South Africa's achievement of its transport decarbonisation goals, especially when steps taken hitherto seem ineffective. Consequently, the right attitudes, regulatory instruments, and policy initiatives towards the promotion of active transport are recommended.

Keywords: GHG emissions, decarbonisation, active transport, South Africa

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1. INTRODUCTION: THE TRANSPORT AND CLIMATE INTERFACE

Transport accounts for about a quarter of global energy-related carbon emissions, and this contribution is rising faster than for any other energy end-use sector. If the present trend continues, direct transport carbon emissions could double by 2050 [1,9,23]. Transport relies overwhelmingly on oil, with over 53% of global primary oil consumption in 2010 used to meet 94% of transport energy demand. This makes the transport sector a key area for energy security concerns and a major source of air pollutants such as ozone, nitrous oxides and particulates, as well as carbon dioxide [23]. According to the Department of Transport [21], the overwhelming consensus of scientific opinion is that climate change in the form of global warming is real and driven by emissions of greenhouse gases caused by human activity. The single most important greenhouse gas (GHG) is carbon dioxide, which as well is the single most problematic GHG source majorly emitting from the production and consumption of fossil fuels. Meanwhile, more than two-thirds of transport-related GHG emissions are from road transport. Therefore, motorised transport emissions have become a significant contributor to the global problem of GHG emissions that lead to climate change. In 2009, transport was responsible for 23% of global GHG emissions compared with 41% for energy. By 2035, it is expected to become the single largest GHG emitter accounting for as much as 46% of global emissions, and it is set to reach 80% by 2050 [1].

Evidently, climate change is real, and human activities, particularly transport-related emissions, are a major dominant cause [13,23,29,37,47,49]. Today, changes in the climate are observed in all geographical regions of the globe: the atmosphere and oceans are warming, the extent and volume of snow and ice are diminishing, sea levels are rising, and weather patterns are changing. Anthropologic GHG emissions from transport are a key contributor to global climate change, with carbon dioxide representing the largest proportion of the emissions. Over the past three decades, carbon dioxide emissions from transport have risen faster than those from all other sectors and are projected to rise more rapidly. Presently, industrialised countries are the main sources of transport emissions. However, the proportion of emissions being produced in developing countries is rapidly increasing. The majority of transport fuel emissions (76%) are from road transport, including four-wheeled vehicles and personal pickup trucks. Air travel produces around 12% of transport carbon dioxide emissions, and its share is fast growing as well [13].

There are indications that changes in climatic conditions will continue under a range of possible GHG emission scenarios over the 21st century. If the current trends in emissions continue, their impacts by the end of this century are projected to include a global average temperature that is between 2.6 and 4.8°C higher than what it is presently, and sea levels 45-82 cm higher than present as well. Even if emissions are stopped today, temperatures would remain elevated for centuries owing to the effect of the accumulated greenhouse gases from past human emissions present in the atmosphere. Thus, limiting temperature rise would require substantial and sustained reductions of GHG emissions, including those emanating from the transport sector.

Interestingly, the transport sector is both the culprit and the victim of climate change. This is because the far-reaching impacts of climate change are diverse; intense droughts and floods, heat waves, thawing permafrost and sea-level rise, which could damage such transport infrastructure as roads, railways, airports and seaports, requiring extensive adaptation and changes to route planning in some cases. Road assets are particularly vulnerable to climate stressors such as higher temperatures, increased precipitation or flooding [11]. Virtually, all models show that weather extremes will indeed put considerable pressure on the road system, particularly in Africa. The damage and accelerated ageing of roads caused by climate change will require increased maintenance and frequent rehabilitation. Apart from these, climate-related damage to the road infrastructure will cause more frequent disruptions to the movement of people and goods, with direct consequences on economic productivity.

Furthermore, climate change has serious significant adverse effects on not only road transport but also on other major transport systems and modes as well [23]. For instance, rail beds are especially susceptible to the aftermaths of climate change including increased rainfall, flooding and subsidence, sea-level rise, and increased incidence of freeze-thaw cycles. More so, thawing permafrost may lead to ground settlement, which then undermines the stability of railways. Additionally, higher temperatures pose a threat to rails through thermal expansion and buckling. Underground electric rail systems are similarly vulnerable to heat waves and flooding. Even air transport is not immune to the consequences of climate change impacts on the transport sector as more storms in some regions of the world may increase the number of weather-related delays and cancellations. Clear-air turbulence is likely to increase in the Atlantic corridor, leading to longer and bumpier trips. Further, more intense heat and rainfall will have similar impacts on airport runways as on roads. Eventually, higher temperatures at high-altitude and low-latitude airports may reduce the maximum takeoff weight or require investment in longer runways owing to less dense air.

Water transport and coastal infrastructure are vulnerable to the impacts of climate change on transport as well. More frequent droughts and floods may force businesses to use smaller vessels for inland shipping, which will raise shipping costs [23]. Some inland waterways are projected to be useable for fewer days each year because of more intermittent water availability. On the ocean, a projected increase in storms in some regions could raise the cost of shipping by forcing ships to take longer routes that are less storm-prone. Subsequently, more frequent delays and cancellations of ferries could result from extreme weather events. Even with the projection of the Arctic Ocean becoming progressively more accessible to shipping in summer as sea-ice extent decreases, with a virtually ice-free ocean likely by mid-century, the increase in shipping through sensitive ecosystems could lead to an increase in serious local environmental and climate change impacts.

In time, roads, rail and airports near the coast will become more vulnerable to flooding and erosion due to sea-level rise and extreme weather events, as will ports. Extreme events projected to increase include intense rainfall, high winds and storm surges. Globally, the value of all coastal assets exposed to flooding was estimated at 5% of gross domestic product (GDP) in 2005. This has been projected to rise to as high as 9% in 2070 [23]. All these point to the cause and effect relationship between transport and climate. It is such that activities in the transport sector invariably have far-reaching implications for the climate, and changes in climate impact significantly on the transport sector.

2. THE SOUTH AFRICAN TRANSPORT SECTOR AND CLIMATE CHANGE

Transport systems form the backbone of South Africa's socioeconomic activities, enabling the movement of people and products. Therefore, transport and the demand for it has become an integral part of the daily lives of South Africans. The movement of goods and services in time and space defines and influences, and is impacted upon by economic activities. Demands for transport shape the urban landscape and influence the spatial choices that the citizenry makes concerning social and economic services such as place of residence, education and work. Business, in similar ways, makes locational choices based on market proximity and size, as well as considerations for ease of temporal and spatial mobility of labour, goods and services. These choices contribute in a major way to the wellbeing of individuals, households and businesses in the country [21]. Meanwhile, the transport sector in South Africa is confronted with the legacy of apartheid spatial planning, which has resulted in displaced urban development and distorted, fragmented, unequal and inefficient human settlement patterns that result in the movement of people across long distances from home to work. Thus, transport networks are poorly integrated with the majority of the citizens living far from their workplaces. Consequently, many have to commute over long distances. These travel patterns have a substantial impact on air quality, climate change and ozone layer depletion [15,20,21,43].

Research has shown that a steady increase in household incomes directly translates into increased consumption and demand for transport. Accordingly, as South Africans earn more, they tend to end up buying more cars. However, there are externalities associated with this tendency, particularly in environmental terms. Emissions from the transport sector in South Africa account for 13% of the country's total GHG emissions, of which 86% is from the combustion of liquid fossil fuels. In addition to these direct emissions arising from the combustion of fuels, indirect emissions arise from the production, refining and transport of transport fuels. South Africans pay dearly for their auto-dependency predilections largely in form of traffic congestion, especially during peak hours. This brings about an increase in trip times and restrictions in mobility, which has far-reaching psychological, economic and environmental ramifications. Generally, overall productivity is adversely affected [21,25].

Transport is the primary consumer of liquid fuels in South Africa [39]. Demand for energy in this sector is forecast to grow to 24–37% of total energy demand by 2050, possibly representing the largest sectoral demand for energy in South Africa [18,21]. The South African transport sector is estimated to emit 60 Mt CO_2eq and require 800 PJ of energy, similar in scale to the industrial energy demand and emissions [2]. The sector is forecast to potentially eclipse the industry in this regard if conventional vehicle choices and travel modes persist. Greenhouse Inventory for South Africa, covering the period 2000 to 2010, revealed that GHG emissions from transport increased by 32% from 36,016 Gg CO_2eq in 2000 to 47,607 Gg CO_2eq in 2010. Road transport was responsible for 91.2% of GHG emissions from the sector during this period. If these trends continue in the absence of mitigating legislation and policies, the transport sector is projected to emit a total of 136 Gg CO_2eq by the year 2050 [16,43,62]. In addition, it has been stated that South Africa ranks 13th globally on carbon dioxide emissions contributions, and is one of the top 10 carbon-intensive major economies in the world (GDP larger than $200 billion), with a carbon intensity of 0.972 metric tons of CO_2 per $1000 of GDP in 2011 [27]. This competitively compares to leading countries such as Germany at 0.290 t CO_2 per $1000 of GDP, or China at 0.804 t CO_2 per $1000 of GDP [51,54,60].

Noticeably, one underlying factor for the foregoing GHG emission records in South Africa is the high rate of production and sales of motor vehicles in South Africa. Domestic production of motor vehicles in the country surged from 601,178 vehicles produced in 2017 to about 610,000 vehicles in 2018 [59]. Meanwhile, an improvement in industry vehicle production of about 8.0% was projected for 2019 to reach about 657,500 units. Table 1 gives a five-year outlook for vehicle sales in South Africa.

It is on record that South Africa has the highest cars per capita in Africa as one in every five people in the country owns a vehicle [5]. In 2012 alone, more than 250,000 units were sold in South Africa alone. At the end of February 2017, there were 12,027,860 registered vehicles in South Africa [55]. This makes South Africa one of the largest vehicle markets in Africa and a high emitter in per capita terms with 10.3 t CO_2 per person (t cap-1), which is above the global (6.3 t cap-1) and sub-Saharan Africa (3.2 t cap-1) averages [3]. Given this scenario, the scientific consensus is that sub-Saharan Africa, with its geographic location straddling the equator, will experience the greatest negative effects of global warming of all the regions. For South Africa, under the current emissions trajectory, there is projected to be an average increase above the 20th century average of 1.5°C around the coast to 3°C in the interior by 2050, with a doubling of these figures to 3 and 6°C by the end of the century. These changes come with dire consequences [58].

Tab. 1

A Five-Year Sales Outlook for Domestic Vehicle Sales in South Africa (2015-2019)

Sector	2015	2016	2017	2018	2019 Estimates
Cars	412,478	361,264	368,114	365,246	368,000
Light Commercials	174,701	159,283	163,317	159,452	162,000
Medium Commercials	10,394	8,315	7,890	7,913	8,000
Heavy/Extra Heavy/ Commercials/Buses	20,075	18,685	18,382	19,579	20,000
Total Vehicles	617,648	547,547	557,703	552,190	558,000

Source: Wheels24 [59]

3. TRANSPORT DECARBONISATION STRATEGIES IN SOUTH AFRICA: AN OVERVIEW

Many countries and non-state actors have expressed the need for a global leadership platform in support of aggressive actions on transport and climate change. In 2017, for instance, the establishment of a Transport Decarbonization Alliance (TDA), composed of countries, and other entities committed to ambitious action on transport and climate change, was proposed [47]. The alliance brings together more than 150 organisations, networks and initiatives that support ambitious, transformative action on transport and climate change. Along this line, South Africa has some decisive steps towards cutting down carbon emissions. The country has a well-developed base to effect climate change mitigation and adaptation [42]. The country has initiated Climate Change Flagship Programmes to respond to the three key challenges facing it even as global efforts to address climate change intensify. These programmes encompass demonstrating the course of actions needed to respond to climate change, attracting resources at the scale required to enable meaningful transformation, and igniting national-scale action at the speed required to respond to climate change. In addition, Low Carbon, Climate Resilient Transport Systems is duly recognised as one of the major components of the Climate Change Flagship Programmes Goals to 2030.

Specifically, South Africa has committed to reducing its GHG emissions by 34% by 2020 and 42% by 2025, relative to a 'business-as-usual' baseline. This is in the realisation of the country's ranking as one of the world's largest GHG emitting country in absolute terms in 2007, with per capita emissions nearly twice the global average [4,51,60]. According to the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI) [53], South Africa is committed to contributing its fair share to global GHG mitigation efforts to keep the temperature increase well below 2°C. With financial, technology, and capacity-building support, this level of effort will enable South Africa's GHG emissions to peak between 2020 and 2025 in a range with a lower limit of 398 Mt CO_2eq and upper limits of 583 Mt CO_2eq and 614 Mt CO_2eq for 2020 and 2025, respectively. Plateau with a lower limit of 398 Mt CO_2eq and upper limit of 614 Mt CO_2eq for approximately a decade, and decline in absolute terms thereafter to a range with a lower limit of 212 Mt CO_2eq and upper limit of 428 Mt CO_2eq. This is referred to as the Peak Plateau Decline (PPD) benchmark trajectory.

To achieve these goals, South Africa is committed to decarbonisation efforts by taking conscious steps towards achieving a low-carbon economy through a reduction in carbon emissions. So far, the country has taken steps to:

1. continue to put in place transport policies and developments that result in a modal shift in passenger transport to public and low carbon forms of transport including plans to move freight from road to rail over time,
2. encourage the integration of land use and transportation planning in cities in a manner that encourages public transport, non-motorised transport (walking and cycling) and promotes alternative communication methods such as telecommuting to reduce long term transport fuel use patterns,
3. improve the efficiency of the country's vehicle fleet across board through a range of measures including the use of fuel standards,
4. invest in the further development and deployment of cleaner technologies for the transport sector such as electric vehicles and hybrids,
5. build capacity to deal with transport mitigation in the areas of planning, engineering, and relevant technical skills,
6. support the production and use of cleaner fuel technologies and alternative fuels away from current fossil fuels,
7. implement the flat rate specific excise tax based on passenger vehicle carbon emissions, which applies to each gram of carbon dioxide vehicle emissions above a target range, and investigate expanding the emissions tax to include other categories of motor vehicles,
8. consider further incentives in the form of lower fuel taxes to encourage cleaner fuels and integrate climate change information into transport planning to minimise the potential risk to infrastructure from extreme weather events [43].

In addition, to address the environmental and infrastructure implications of unmitigated growth in conventional fuel consumption and travel modes, the Department of Transport published the draft Green Transport Strategy (GTS) [21]. The GTS is guided by the National Climate Change Response White Paper and National Development Plan, which outlines South Africa's commitment to climate change interventions in line with the 2015 United Nations Climate Change Conference (COP 21) and affordable transport systems [14]. The GTS aims to reduce harmful emissions and negative environmental impacts associated with transport systems and has become the primary reference for policy interventions. The interventions identified for implementation in the South African multi-sector energy-economic modelling framework, otherwise known as the South African TIMES Model (SATIM) are:

i. 30% shift in freight transport from road to rail by 2022,
ii. 20% shift in passenger transport from private cars to public transport and non-motorised transport by 2022,
iii. 20% of the public sector fleet and 10% of the national fleet comprising electric or hybrid vehicles by 2022,
iv. All (metro) public and quasi-public (minibus) transport vehicles to move to a natural gas and petrol dual-fuel system within 10 years,
v. 10% of the urban bus fleet to be converted to gas-only vehicles per year,

vi. 10% of the Metrobus fleets to be converted to gas-only vehicles per year,
vii. Fuel levy relief (50% exemption for biodiesel and 100% exemption for bioethanol),
viii. Fiscal policies such as the imposition of a carbon tax.

Moreover, with additional growth expected in road transport demand, emissions are similarly expected to further increase over the next decades [40,41]. Therefore, South Africa faces the need to modernise and expand its transport infrastructure while simultaneously significantly reducing transport-related emissions [9]. Recently, the country implemented several climate strategies and policies in the transport sector, which have been implemented to a variable degree. Table 2 gives an overview of these currently implemented and planned sectoral climate policies.

Tab. 2

Climate Change Policies for the Transport Sector in South Africa

Changing Activity	Energy Efficiency	Renewables	Nuclear/CCS/Fuel Switch
Urban planning and infrastructure investment to minimise transport needs: ▪ Draft Green Transport Strategy (GTS) 2017–2050 (2017) ▪ National Rail Policy Green Paper (2015) ▪ National Transport Master Plan (2010) ▪ Public Transport Strategy (2007)	Minimum energy/ emissions performance standards or support for energy efficient for light duty vehicles: ▪ Vehicle labeling scheme (2008) ▪ Vehicle fuel economy norms and standards (since 2005)	Biofuel target: ▪ Regulations Regarding the Mandatory Blending of Bio-fuels with Petrol and Diesel (2012) ▪ Biofuels Industrial Strategy (2007)	Support for share switch: ▪ Draft Green Transport Strategy 2017–2050 (2017) ▪ National Transport Master Plan (2010) ▪ Bus Rapid Transit Systems (BRT) on city-level (since 2010)
	Minimum energy/ Emissions performance standards or support for energy efficiency for heavy-duty vehicles: None	Support schemes for biofuels: ▪ Regulations on Mandatory Blending of Bio-fuels with Petrol and Diesel (2012) ▪ Biofuels Industrial Strategy (2007)	E-mobility programme: ▪ Electric Vehicle Industry Roadmap (2013)
		Sustainability standards for biomass use: None	
Tax on fuel and/or emissions: ▪ Carbon Emissions Motor Vehicles Tax (2010) ▪ General Fuel Levy (1983)			
Fossil fuel subsidies: None			

Source: CAT [9]

The information provided in Table 2 consists of existing, planned and potential climate change policies for the transport sector in South Africa. However, it should be noted, as indicated in the table, that no policies currently exist on minimum energy/emissions performance standards or support for energy efficiency for heavy-duty vehicles, sustainability standards for biomass use, and fossil fuel subsidies in South Africa. Subsequently, the country would adopt appropriate policies from other countries where such exist. The blank cells indicate that no policies currently exist and a similar policy gap exists in all other countries as well. In addition, the Ministry of Transportation released a Draft Green Transport Strategy (GTS) 2017-2050 in August 2017. Although the prioritised policy interventions aim to address the country's transport needs and directly combat emissions in the transport sector, efficient implementation of the proposed measures and sufficient funding remain critical challenges [21].

Another major initiative towards the decarbonisation of the transport sector in South Africa is a switch in modal share of passenger transport through the launch of the Bus Rapid Transit Systems (BRT) in eight cities and municipalities, to start with. Other model switch policy initiatives mentioned in the Draft GTS 2017-2050 aim to upgrade the mini-bus taxi industry, intelligent urban transport systems integrating public transport and the minibus industry, and non-motorised transport infrastructure [21]. However, no modal shift policies have been implemented for freight transport as of December 2017. The policy objective behind the National Rail Policy Green Paper of 2015 is to proactively facilitate shifting freight and passengers from road to rail and to promote rail as the mode of choice by providing an efficient, reliable and safe setting for passengers and freight [19]. However, no concrete policy action is currently in place [9].

In addition, vehicle fuel-economy norms and standards for newly manufactured vehicles from 2005 onwards were introduced in South Africa [50,57]. In the Draft GTS 2017-2050, the Ministry of Transport states its intention to revise the level of vehicle fuel economy emission standards with unclear implications for transport-related carbon dioxide emissions [21]. However, a gradual tightening of general emission standards will not be sufficient to be in line with the required 1.5°C trajectory even if South Africa introduces higher carbon emissions motor vehicle tax levels [9,10]. Other national policies and regulatory frameworks that form the legislative foundation for the development of the Green Transport Strategy in South Africa include the Constitution of the Republic of South Africa; the White Paper on National Transport, 1996; White Paper on Energy Policy, 1998; National Environmental Management Act 107 of 1998 (NEMA); the National Freight Logistics Strategy, 2005; Public Transport Strategy, 2007; National Land Transport Act, 2009; White Paper on National Climate Change Response Policy, 2011; the Spatial Planning and Land Use Management Act 16 of 2013 (SPLUMA); National Transport Master Plan (NATMAP), 2016, and several other regulations on petroleum products and pipeline.

The abovementioned notwithstanding, in the light of current attains, South African transport sector is not likely to meet the two actionable benchmarks. More so, already implemented policies such as the mandated biofuel blending and fuel-economy norms and standards are projected to have very limited impact on the overall emission levels of the South African vehicle fleet. This is due to a lack of incentives for the promotion of zero-emission vehicles and required infrastructure as South Africa currently makes no progress to phase out fossil fuel car sales between 2035 and 2050 to significantly increase the share of non-emission vehicles. Besides, it has been observed that the majority of existing environmentally-related taxes were introduced with the primary intention of raising revenue [21]. Thus, it is arguable that environmental outcomes are only by products of the imposition of carbon taxes in the country. Even in the field of aviation and shipping where South Africa has initiated some minor activities to reduce emissions, efforts have not been made to develop 1.5°C compatible vision. Table 3 summarises the progress made so far on the most important steps to decarbonise the transport sector in the country.

Tab. 3

South Africa's Transport Sector Progress on Limiting Temperature Increase

1.5 °C-Consistent Benchmark	Projection(s) under Current Policies	Gap Assessment (Qualitative)
Last fossil fuel car sold before 2035	Low projected growth in electric vehicle uptake, similar at best to projections for Rest of World in BNEF 2017 with around 1% EV share in new car sales by 2020 and share of 40–50% by 2040	+ Overarching Green Transport Strategy (GTS) until 2050 defining policy priorities for each area of transport in South Africa + Several policies in place in the transport sector aim to reduce emissions from passenger vehicles, however, have relatively low level of expected impact - No overarching 1.5°C compatible vision for the transport sector in South Africa - Uncertainty about enforcement of biofuel quota programme due to sustainability concerns, but only marginal impact if fully implemented - Insignificant share of electric vehicles sales and no policies in place to promote and incentivise the use of EVs - Freight transport-related emissions expected to increase substantially under current policies with the growing use of road networks for freight transportation
Aviation and shipping: Develop and agree on a 1.5°C compatible vision	• Expected increase of international aviation emissions by 75% until 2030 and 289% until 2050 compared to 2016 under currently implemented policies in South Africa • No projections available for maritime shipping in South Africa	+ Department of Transport actively engages in ICAO's initiatives to reduce emissions, while currently prioritising improved Air Traffic Management (ATM) and infrastructure use for South Africa - No intention announced to participate in ICAO's CORSIA carbon offsetting and reduction scheme - Relatively small emission reductions of currently implemented measures in the aviation sector, whereas other measures for use of alternative fuels and airport improvements are only in early planning stages - There are no strategy or policies on greener or sustainable maritime shipping in South Africa - Inadequate policy initiative to improve rail freight transport to enable a modal shift in the freight transport sector

Source: Adapted from CAT [9]

It is important to note that the two major short-term actionable benchmarks featured in Table 3 are just getting started; as such, it is too early to embark on any objective evaluation. These are: that the last fossil car needs to be sold before 2035 to achieve car fleets consisting of 100% zero-emission cars by 2050 and that a 1.5°C compatible vision for the aviation and shipping needs to be developed and agreed upon. With the findings of the Intergovernmental Panel on Climate Change (IPCC) on achieving net-zero carbon dioxide emissions around 2050 and the rapid update electric vehicles of the last years in mind, this analysis decides to strengthen the benchmark for the vehicle sales to a full 100% zero-emissions car stock by 2050, meaning the last fossil car needs to be sold before 2035 [35].

Research constitutes another important dimension to efforts towards the decarbonisation of the South African transport sector. Thus, several studies with implications for the sector have been conducted. Generally, most of these studies were conducted on the overall energy sector; however, the implications for the transport sector are evident in their findings. For example, Altieri et al. [3] examined the implications of meeting a cumulative carbon constraint between 2015 and 2050 of 14 Gt of carbon dioxide equivalent (CO_2eq), in scenarios considering different economic development pathways for South Africa. According to the study, the emissions constraint was met by a rapid decarbonisation of electricity supply and a move away from emissions-intensive gas-to-liquids and coal-to-liquids. Further, the study found that the rapid and relatively lower cost decarbonisation of the electricity system encourages demand sectors to increase their dependence on electricity. Evidently, this has implications for the transport sector where an opportunity emerges for a large-scale switch to electro-mobility technologies, including battery electric, hydrogen fuel cell, and hybrid vehicles. Such a transition would address one of the main concerns about plug-in vehicles because the carbon emissions simply move from the vehicle's exhaust to the power station [30].

In a follow-up study, Caetano et al. [7] analysed an even more rapid transition to decarbonised energy in South Africa assuming a more stringent constraint of 10 Gt cumulative emissions from 2015 to 2050. To meet this carbon constraint, the electricity sector would undergo a rapid transition leading to higher electricity prices between 2020 and 2040. The electricity price increases owing to the increase in the electricity sector investment requirements, which has a slightly negative impact on the economy. The cumulative impact of the transition is estimated at just over 4% of total GDP in 2040. However, as the cost of renewable energy continues to decline rapidly beyond expectation, these negative impacts of the transition are likely to fall away. Apparently, the focus of these studies was mainly on the rapid transition in the electricity sector as a response mechanism. The potential opportunities that a decarbonised electricity sector could provide for the transport sector have not been explored. Meanwhile, the significance of transport in total final energy demand in South Africa, the country's high reliance on crude oil imports, and increasing global electro-mobility make these opportunities attractive to explore [7]. In addition, an attitudinal problem has been identified towards decarbonisation in South Africa. Specifically, attitudes towards using only energy-efficient vehicles when outsourcing or using own vehicles, the importance of sustainability for the country, and the importance of carbon dioxide emissions for the country are not encouraging [27].

From the foregoing, it is obvious that enough serious attention has not been paid to active transport in the decarbonised transport policy formulation. Although usually, it is casually mentioned with mere lip service paid to it in one policy statement or the other, however, no concrete practical step has been conscientiously taken so far to accord it the pride of place it deserves in the discourses and action plans in the transport sector of the country. As it is, none of the empirical studies has prioritised it, as all forms of active transport have been largely neglected with only public transport mentioned en passant. Meanwhile, the inclusion of active transport in the overarching decarbonised transport policy formulation anywhere cannot afford to limit the inclusion of active transport to mere conceptual-cum-theoretical colouration. Practical steps to prioritise it are indispensable.

4. TRANSPORT DECARBONISATION IN SOUTH AFRICA: THE ROLE OF ACTIVE TRANSPORT

If South Africa would ever achieve her goals and targets of transport decarbonisation, the indispensability of active transport cannot be overemphasised, especially when all the steps taken so far do not seem to promise the much desired effect. Active transport is well captured in the Africa Development Bank's (ADB's) blueprint for mitigating climate change in transport [1]. ADB proposes the Avoid-Shift-Improve Approach, a promising conceptual tool to chart the course of mitigating climate change in transport at country and regional levels. According to the Bank, Avoid means reducing the need to travel, for example, by integrating land use and transport planning to create local clusters of economic activities that require less mobility; by changing how production is organised (for example, doing more online); and by developing multimodal logistic chains to cut wasteful and unnecessary trips. Shift means changing to more energy-efficient modes or routes such as shifting from road to rail or waterways or onto well-defined trucking routes; or shifting passengers from private vehicles to public transport and non-motorised modes. Improve entails using technologies that are more energy efficient including through improving vehicle standards, inspection and enforcement; developing improved vehicle technologies and fuels; and improving transport efficiency using information technology. Evidently, both Avoid and Shift favour active transport. By integrating land use and transport planning to create local clusters of economic activities that require less mobility, active transport would be promoted and carbon dioxide emission significantly reduced. The outcome would be phenomenal when the use of rail and other public transport as well as non-motorised modes is popularised as well.

Active transport includes non-motorised forms of transport involving physical activity, such as walking and cycling, as well as public transport to meet longer distance trip needs as public transport trips generally include walking or cycling components as part of the whole journey [44,56]. There has been a continued increased academic interest in the active transport research, mainly from the perspective of health benefits, safety and ways in which urban design can promote more sustainable travel [22,31,48]. However, these studies mostly emphasise the importance of making active transport an easy choice through good urban design, restrictions on car use and land-use planning that enables services to be accessed without motorised transport [45]. Only a few studies directly relate the promotion of active transport to carbon reduction and climate change [12,28,36].

Walking and cycling constitute the ultimate zero carbon and environment-friendly solution for personal transport. However, both walking and cycling have significantly declined for years, becoming unpopular [12,17,44]. Empirical evidence shows that the decline in walking and cycling is a reflection of the growth and affordability of the motor car and a series of psychological and sociological factors [6,21,44] that range from a generally poor level of fitness as well as safety and security issues to unfavourable weather and physical factors [12,44]. Nevertheless, the South African Department of Transport [21] identified the modal shifts from private car usage to public transport (particularly rail) and non-motorised transport as being essential actions needed to reduce energy consumption and GHG emissions. This necessarily implies that South Africa is very unlikely to achieve the much desired carbon decarbonisation without recourse to active transport.

Research undertaken by research organisations on behalf of the South African government indicates, among other things, the imperativeness of implementing measures that will reduce the need to travel and avoid unnecessary trips through walkable communities, integrated land use planning, transit-oriented development, and improving vehicle occupancy rates [21].

Furthermore, it was found that given that the road transport sub-sector is responsible for 91.2% of direct emissions from transport, shifting of passengers to public transport and freight to rail is a necessity. Besides, several sustainable transport instruments that double as decarbonised transport instruments have also been identified [13]. These instruments clearly emphasise land use planning that prioritises non-motorised modes (walking and cycling) as well as planning for public transport modes, including buses, rail, light rail, metro and underground systems.

It must be acknowledged that as desirable and important as active transport is in achieving the goals of transport decarbonisation, sight should not be lost of the right attitude and behaviour towards it. This is because research has found that people, especially in Africa, generally tend towards auto-dependency for as long as they can afford it [44]. Behavioural change programmes are essential as reducing traffic from short journeys will not only reduce the environmental impacts but also make society healthier as a whole. To make walking and cycling a real alternative for local trips, every local authority, business and school needs to consider 'soft' transport policy measures to promote them [8,24,32,33,34,52]. Towards this end, many relatively simple improvements can be made. Reallocation of space is crucial to increase the safety of zero carbon journeys. This would take the form of cycle lanes and pedestrian areas linked with improved road crossings and safer junctions which are required for a sustainable street for all modes [38]. However, local measures are not complete solutions to make walking and cycling more viable. The main factor behind a decline in zero-carbon trips is that fewer destinations are within walking and cycling distance [12,46].

Underscoring the importance of policy intervention towards engendering active transport, Farrag-Thibault [23] argued that the transition required to dramatically reduce GHG emissions needs system-wide strategies that combine, among other things, modal change, stringent sustainable transport strategies, and profound behaviour change. This was similarly corroborated by Chapman [12], who posited that to achieve a stabilisation of GHG emissions from transport, a behavioural change brought about by policy will be required. Therefore, the key aims to achieve reduced GHG emissions from transport should not be limited to alternative fuels, energy sources or technology as typically emphasised in South Africa, but should also include a change in travel behaviour and modes. Usually, technology improvements are most effective when implemented in conjunction with other instruments within a larger strategy.

Policy interventions towards engendering active transport cannot possibly be effective in the absence of certain regulatory instruments. The following regulatory instruments, largely informed by Dalkmann and Brannigan [13], would go a long way in creating a culture of active transport in South Africa.

i. *Physical restraint measures:* These include such measures as physically restricting the access of certain motorised vehicles in certain pedestrian areas. This reduces traffic volumes and the associated GHG emissions, especially during peak periods.
ii. *Regulation of parking supply*: Parking supply restrictions are known to make car use unattractive, thus, contribute to a shift to active modes.
iii. *Parking pricing*: Parking pricing increases the cost of using a vehicle by raising the cost of parking. Coupled with parking supply regulation, this measure can go a long way in promoting active transport.
iv. *Road pricing*: Generally, road pricing increases the cost of running a vehicle, thus, encouraging the use of alternative/active modes.
v. *Fuel taxation*: Fuel taxes are a way of charging the users of transport infrastructure relative to individual use. Fuel taxation raises the price of travel per kilometre. It is directly proportional to fuel consumption. Both effects can contribute to reducing GHG emissions and promoting active transport.

vi. *Vehicle taxation*: The main principle behind vehicle taxation is to charge vehicle ownership. This can be in two ways: sales taxes charged when the vehicle is purchased (sometimes contributing significantly to the overall cost of the vehicle), and annual vehicle taxes/registration fees (which are a continuous financial burden rather than a one-off tax). Vehicle taxes can also be differentiated according to vehicle type, size or emissions, and noise levels.

vii. *Infrastructure investment for active transport:* While it is true that provision is made for pedestrians along most transport corridors in South Africa, the same cannot be said of cyclists. People would be encouraged to cycle if consideration is made for cycling lanes in road transport facility investments. In addition, dedicated BRT lanes could encourage commuters to shift to the mode, especially in big cities where commuting distance and time are long.

viii. *Public awareness campaigns and mobility management*: These can take many forms. Usually, they are used to inform the public about the travel alternatives available to them or the environmental, economic and social impacts of transport. Awareness campaigns could include providing information on cycling and walking routes and maps. Marketing of sustainable transport solutions is essential when attempting to secure public acceptance of them.

ix. *Financial incentives and motivation*: As done in some European countries such as the Netherlands, United Kingdom, Belgium, Luxembourg, France, Germany and Denmark [61], commuters in South Africa can also be paid to cycle to work.

5. CONCLUSIONS AND RECOMMENDATIONS

The ambitious decarbonisation goals of South Africa's transport sector are attainable. However, if they must be achieved, decision makers have to look beyond the previously seemingly closed list of approaches that do not accord active transport the pride of place it deserves, and acknowledge its proven efficacy. Admittedly, barriers to the overarching integration of active transport are real. They include high facility investment (especially in terms of new cycling lanes and dedicated BRT lanes), and the expense associated with transforming or decommissioning existing infrastructure as well as ingrained social norms and attitudinal idiosyncrasies that characterise Africans where vehicle ownership often symbolically defines socioeconomic status. More so, while alternatives are becoming available, significant policy intervention will be critical to generalising low-carbon technologies and practices for mass transit modes.

Conscious steps that prioritise the aggressive pursuance of measures, which conscientiously target active transport should be adopted and followed through. Also, norms and standards for transport decarbonisation should be developed at the national, provincial and local levels to ensure that there is consistency in the active transport policies that are implemented across different jurisdictions. These should be towards achieving a modal shift in passenger travel in the country. As much as possible, the use of private cars should be discouraged while active travellers should be given all the required support and motivation. Afterwards, the South African rail system should be thoroughly explored to avail the country all the opportunities it has to offer as a veritable mass transit mode of choice. Meanwhile, some facility and infrastructural investments and retrofitting should be made. For instance, BRT systems need to be significantly expanded with their security, reliability and frequency enhanced.

In addition, non-motorised transport infrastructure, specifically the building of cycle lanes along key transport routes as well as improved pavements and sidewalks, measures aimed at enhanced walkability must be included in the maintenance mandates of all relevant agencies. This is imperative if public desire and support for non-motorised transport are to be obtained. Most importantly, South Africans should be educated on the need to embrace active transport irrespective of social class. The great health benefits of active transport can be accentuated to drive home the point that auto-dependency related diseases are no respecters of persons or status. Moreover, all avoidable auto-dependent trips should be eliminated. Finally, public transport should be made more efficient and their drivers more time-conscious and businesslike.

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