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Climate change response measures in South African road transport sector: lessons from BRICS countries

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Climate change can be mainstreamed into road transport sector and its policies by integrating mitigation actions, focusing on Green-House Gas (GHG) emission reduction, and building adaptive capacity for a climate-resilient road transport sector. Although research frequently emphasizes the difficulties of adaptation, this article explores the influence of climate change on the road transport network and examines how road transport contributes to climate change. Factors such as experiencing the costs of climate change, valuing the local ecosystem, resources availability, and political will is key to successful adaptation efforts. This article used desk research to gather information on mitigation and adaptation actions adopted by BRICS countries from various sources like government documents, the internet, books, articles and scientific reviews. It is therefore, deduced that BRICS countries can promote climate-friendly transport by prioritizing green logistics, green innovation and renewable natural resources, while promoting sustainable development and supporting renewable energy. BRICS represents Brazil, Russia, India, China, and South Africa, a group of developing economies working together to strengthen their economic and political influence. This article draws lessons from BRICS countries and conclude that South Africa should decrease fossil fuel use in the road transport sector for climate-friendly options.

KEYWORDS

climate change, roads transport, response measures, BRICS, infrastructure

Introduction

Stern (2016) highlights the worrying cyclical relationship between climate change and road traffic, with global implications jeopardizing sustainability. T Strategies and initiatives for mitigating climate change threats in road transport are also discussed, emphasizing the need for adaptive policy. Extreme weather events resulting from climate change present a significant risk to the road transport infrastructure. Despite this, the deterioration of transport networks hinders the accessibility of socio-economic opportunities such as healthcare, employment, and education. As highlighted in the World Cities Report (2022), there is a noticeable trend of increasing and positive reception towards motor vehicles in urban areas across the globe. Approximately 25% of greenhouse gas emissions worldwide are linked to urban transportation. Projections indicate that this number is expected to rise significantly by 2050. It is crucial at this juncture to reevaluate the requirements and setups of road transport systems to improve resilience to climate change. Globally, local governments have taken the lead in addressing the road transport challenges by implementing laws that support enhanced traffic control, cleaner and less congested urban environments, and the integration of public transport with other non-private transit modes. Shaheen et al. (2020) assert that "Shared mobility" is increasingly

recognized as a more sustainable, socially equitable, and economically viable approach to addressing the rising transport needs in urban areas. Various forms of shared mobility such as carpooling, vehicle pooling, bike and scooter sharing, ridesharing, on-demand services, shuttles, and emerging community transport sectors fall under this umbrella.

Shared mobility encompasses public transport, providing individuals with access to government-owned fleets comprising buses, minibuses, trains, cars, shuttles, and bicycles. The unexplored possibilities and importance of shared mobility options in addressing transport challenges and the broader effects of climate change in Africa's urban context—particularly South Africa—remain to be thoroughly investigated (Liyanage et al., 2019). It is widely believed that South Africa's road transport sector has several obstacles, even if the country's current transport state has not been regularly and accurately assessed. This article critically assesses Brazil, Russia, India, and China's response measures to climate change in the road transport sector and draws lessons that might enhance South Africa's climate change mitigation and adaptation plans.

While there is a lack of comprehensive information regarding the economic impacts of climate change in BRICS countries, several relevant observations can be made about these nations' climate challenges. Brazil is dealing with issues linked to deforestation and extended periods of drought, while Russia is confronting problems such as melting permafrost and a rise in wildfires. India is affected by changes in its monsoon patterns, and China is dealing with the implications of rising sea levels. Additionally, South Africa is experiencing extreme weather events, including heatwaves that may negatively impact road transport infrastructure. To address these issues, BRICS countries should focus on investing in renewable energy sources, enhancing their infrastructure, and implementing sustainable policies. Prompt action is essential to adjust to the evolving climate and mitigate economic impacts, especially emphasizing the connection between climate change and road transport.

Research methodology

In the social sciences, desktop research, also known as secondary research, is essential because it forms the foundation for theoretical frameworks, methodological strategies, and empirical findings (van der Waldt, 2017). To increase the scientific rigor of this field's research, it is helpful to recognise and classify ideas for analysing important social science topics (ibid). Furthermore, desktop research aids in emphasising the fundamentals of integrating digital technology by considering effective strategies and variables impacting the digitisation of procedures in various administrative domains (van Thiel, 2014). By analysing and synthesizing pre-existing data and sources, desktop research collects information and insights without the need for primary data collection methods like surveys or fieldwork. To gather important information and make wise decisions, this entails looking up published reports, papers, studies, and other resources that are accessible to the public.

Nature of road transport systems in South Africa

Transport system encompasses of land, water and air transport. The movement of people, goods and services can take place in either one of the three from one point to another. According to Boyce (n.d.) each transport system operates within economic, social and physical environment. As a result, each mode creates externalities on its environment, such as emissions. The development of land transport sector in South Africa is guided by legislations such as National Land Transport Transition Act, 2000 (Act No 22 of 2000), National Land Transport Act, 2009 (Act No 05 of 2009) and the National Road Traffic Act, (Act No. 93 of 1996) just to mention the few. The focus of this study is on road transport which falls within the land transport together with rail and pipelines. Road transport services are offered throughout the world. Road transport is advantageous to use because of its ability to reach far out to the users and its flexibility. Road transport in this study refers to both public and private usage.

In South Africa public transport is predominantly private owned. As a result, the quality is often not satisfactory especially the road public transport (i.e., taxis and buses). Most of public transport vehicles on South African roads are old some are not even road worthy. The number of vehicles available for public transport is insufficient to accommodate the demand for public transport services. Taxis are commuting most of the commuters compared to the competitors' buses and rails. Pande (2015) asserts that the weaknesses in the road hierarchy play a significant role in enhancing the profitability of road public transport services and their routes. The growing congestion on urban streets can be partly linked to these lucrative routes that lead to downtown areas. In South Africa, delivering efficient road public transport services remains a persistent challenge.

In 2005, the South African government in an attempt to better public transport services and reduce emissions introduced the Taxi Recapitalisation Programme (TRP) (Cokayne, 2006). The programme aimed at scrapping old public transport fleet (taxis) and replaces them with new safe and comfortable taxi vehicles. The TRP failed dismally as the South African roads are still packed with old, unsafe and uncomfortable taxis. Baloyi (2013) concludes that the TRP was a hollow dream because the programme did not realise its set objectives but brought troubles such as job loss and more taxi accidents as taxi drivers drive more recklessly in their efforts to earn enough money to reach the high-profit margins needed to cover their vehicle's monthly payments. South African government is still pursuing the provision of an effective public transport agenda to provide a sustainable public transport system. Understanding the status quo of the road conditions is essential and relevant.

The Department of Transport oversees South Africa's road network, with South African National Roads Agency Limited (SANRAL) managing national highways and provinces supervising local highways. As noted in the Ministry of Transport's annual report (2023), the government is investing in road infrastructure improvements to ease traffic conditions. The Road Traffic Management System (RTMS) is a self-regulatory program enhancing road safety, infrastructure maintenance, and logistics productivity. RTMS aligns with national logistics strategy, setting standards for pricing, driver well-being, vehicle use, and productivity to decrease emissions and promote eco-friendly practices among transport operators.

The road transport system is part of economic development and is key to economic growth. An efficient road transport system ensures access to attractive consumption and production centres, because of which economic growth accelerates (Pande, 2015). The road transport system not only affects economic growth, but also social cohesion. No

economy can be competitive with an inefficient road transport system. According to Vita (2008), flexible working hours in different sectors can affect the demand for mobility. Indeed, the more people move, the greater is the demand for a user-friendly transport system and infrastructure. Vita (2008) further states that infrastructure planning, design and construction have been done the same way throughout the ages. The author suggests considering research on new construction processes and materials to promote the road transport sector. Research should focus significantly on finding construction processes and materials that reduce industrial greenhouse gas emissions.

The road transport system is impacted by climate change, with events like floods and droughts harming infrastructure (Pande, 2015). Mitigation is crucial to avoid higher costs in the long term. In China, efforts have been made to create a climate-proof road transport system through the National Action Program for Adaptation (Xue and Liu, 2022). This program aims to promote sustainable development and adaptation to climate change effects. Howey et al. (2010) suggested strategies to reduce traffic emissions, improve vehicle efficiency, and decrease demand, but economic barriers hinder demand reduction. Strengthening speed limits and improving vehicle efficiency are ways to address emissions and promote sustainability in road transport.

The impacts of climate change on road transport

According to the IPCC (2014) sufficient scientific evidence indicates unequivocal climate warming across continents. All marine and terrestrial eco-systems are affected by the warming and all human and natural environments are affected by regional climate changes. The effects of climate change include droughts, floods, availability of clean water, increased storm activities and change in mortality and infrastructure damages. Scientific evidence shows that global temperatures are the results of observed increase in GHG concentrations resulting from the use of fossil fuel and the changes in land use (Stern, 2006, 2016; IPCC, 2014, 2023). The GHG emissions are responsible for change in the balance of the climatic system. These gases have negative impact and will affect the road transport sector.

Leard and Roth (2015) argue that the climate change events are associated with a significant increase in fatal road accidents. The losses associated with the road accidents on the South African economy are estimated to be 2.5% of the Gross National Product (GNP). Even though the road accidents are caused by numerous factors such as human error and reckless driving, the influence of weather conditions on accidents is also a contributory factor. Effects of meteorology contribute to causing certain road accidents (Edwards, 1999; Leard and Roth, 2015). According to Makinde and Ben-Edigbe (2020) the impact of rain, wind, snow and high temperatures on road transport have been well studied and documented.

Studies on rain (Changnon, 1999; Andrey and Mills, 2003), wind (Baker et al., 1993), high temperature (Chapman et al., 2006; Dobney et al., 2009) show effects on different modes of transport. However, recent developments (IPCC, 2023) indicate that a shift in the severity of meteorology on the impact upon the transport network will be experienced. Furthermore, climate change is likely to result in high temperatures and heavy rainfall frequently. Table 1 indicates the impacts that predicted climate change will have on all modes of transport globally. The impacts include of both the vehicles and the infrastructure. The table further indicates the benefits such as the decreased number of cold days.

Climate change is causing increased natural disasters, which impacts infrastructure and human lives, particularly in BRICS countries. Incidents like floods, hurricanes, and wildfires can significantly harm essential road transport infrastructure, including roads and bridges, leading to interruptions in travel and shipping (Chapungu et al., 2022). These disruptions can affect commuters, business travelers, tourists, and individuals requiring urgent medical transport. To mitigate the effects of climate change on road transport, BRICS nations need to invest in robust road transport infrastructure, systems, and adaptive strategies (Liyanage et al., 2019). This is crucial for maintaining the effective operation of their economies. Studies show that addressing the impacts of climate change on transport networks is essential for developing resilience against future challenges. The BRICS Climate Change and Transport Resilience Report provides insights and methods for adapting to and reducing the impacts of climate change on transport in these nations.

According to Murshed and Dao (2020) climate change refers to significant long-term changes in temperature and rainfall, as well as other elements such as atmospheric pressure and humidity. Furthermore, key global and local impacts of climate change include unpredictable weather patterns, melting ice sheets around the globe, and consequent rise in sea levels. In Africa it is estimated that 183 billion US dollars is needed to maintain and repair roads damaged by climate events through the year 2100 (African Development Bank, 2015). This estimated cost does not include the development of new needed roads but just to maintain the existing road inventory. In an attempt to raise the needed funds, the African Development Bank has requested 40 billion US dollars per annum to provide for African countries to address climate change issues and challenges. The funds are set to enhance adaptation and mitigation of climate change.

As far as road transport is concerned the issues of research and regulatory in regard to climate change have been directed to quantifying, reducing and limiting carbon emissions (Friedrich and Timol, 2011). Consequently, little attention is given to the literature on the impact of climate change on road transport sector. However, internationally climate change is integrated into transport planning process in order to enable effective response at lower levels of government. Frohlich and Knieling (2013) argue that integration of climate change with various sectors and all levels of government in planning process could result in desired outcomes in mitigating the climate change because of their expertise and resources. Indeed, integration is pivotal, since these sectors and government are better positioned to develop mitigation strategies as well as measure and implement them.

The road transport response to climate change

Road transport plays a vital role in the economic progress of BRICS nations. It supports the transfer of goods and individuals but also brings challenges that necessitate effective solutions (World Bank Group, 2021). According to the United Nations Economic Commission for Europe (2020), strategies such as investing in infrastructure and implementing traffic management systems can enhance connectivity and facilitate trade, thereby fostering economic

TABLE 1 The impacts of climate change on transport.

Increased number of hot days	1. Increased thermal loading on road pavements a. Melting tarmac b. Roadway buckling c. Expansion/buckling of bridges d. Increased numbers of tyre blow-outs 2. Increased railway buckling 3. Increased heat exhaustion of maintenance and operations staff 4. Effects of higher density altitudes on aviation Reduced engine combustion efficiency Increased runway lengths required
Decreased number of cold days	1. Reduced winter maintenance costs for road and rail 2. Improved working conditions for personnel in cold environments 3. Permafrost problems: a. Unable to rely on 'frozen roads' b. Infrastructure problems caused due to settlement when permafrost thaws. c. Increased subsidence and landslides on slopes and embankments 4. Positive effects on marine transport: a. Less de-icing required and freezing fog. b. Less icebreaking required. c. Potential opening of new sea passages in polar regions.
Increased heavy precipitation	1. Road submersion and underpass flooding 2. Increased landslides and undercutting 3. Poor visibility 4. Exceedance of existing 100-year flood
Seasonal changes	1. Longer summers/shorter winters will mean changes in timing of: a. Leaf-fall for railways b. Winter maintenance regimes c. Shift in ice/snow belts. 2. Reduction in frozen precipitation–significant improvements in road safety
Drought	1. Navigation problems on inland waterways
Sea level changes	1. Locations of ports may be inappropriate 2. Other infrastructure–many airports are built 10 m > of sea level 3. Localised problems, e.g., storm surges
Extreme events	1. Locations of ports may be inappropriate 2. Other infrastructure–many airports are built 10 m > of sea level 3. Localised problems, e.g., storm surges

Source: Peterson et al. (2008).

growth. Nonetheless, these strategies also have their own disadvantages. The expenses related to infrastructure, technology integration, and safety initiatives can pressure government finances. Moreover, the environmental consequences linked to a rise in vehicle numbers need to be tackled to minimize pollution and emissions (United Nations Economic Commission for Europe, 2020). To address these issues, it is crucial to promote road public transport and environmentally friendly alternatives. With thoughtful planning and investment in sustainable practices, BRICS countries can enhance their road transport systems' efficiency, safety, and connectivity.

In terms of the Stern (2006, 2016) review reports mitigating the effect of climate change is a long-term measure, whilst adaptation to climate change is a short-term measure. This article is more interested in the long-term measure for long term solution; therefore, this article pays more attention to mitigation actions and policies. The IPCC (2023) highlights the anticipated trends in greenhouse gas emissions coming from developing nations. These nations are often recognized as significant contributors to global greenhouse gas emissions due to their rapid industrial growth and rising population numbers. The IPCC (2023) report provides detailed predictions regarding how emissions from these countries are likely to evolve in the coming years. One major forecast emphasized in the report is the continuing rise in greenhouse gas emissions from developing nations. The UNFCCC manages the international dispute of reducing greenhouse gases through the Conference of the Parties (COP). Parties enter agreements to reduce emissions, but no consensus has been reached. Developing countries argue against mandatory targets, demanding wealthier countries take the lead in emissions reduction. Conflict between developing and industrialized countries persists, hindering progress in addressing climate change.

The article discusses climate change mitigation efforts in the CORE emerging economies of Brazil, India, China, and Russia. The BASIC group, formed at COP15, aims to create common negotiating positions in UN climate agreements. BASIC countries made

mitigation pledges in 2009. Hui et al. (2024) show CO2 emissions from fossil fuels are correlated with population and human development. The BASIC group aims to limit temperature increase below 2°C while prioritizing social and economic development and poverty eradication (Kropp, 2014; Cook et al., 2013).

The BRICS nations have exhibited a collective response to the issue of climate change, driven by a process of alignment influenced by their economic robustness, enhanced material capabilities, and mutual responsibilities in global climate governance (Kiprizli and Köstem, 2023). These nations are facing the impacts of climate change, such as floods and extreme weather events, which have required prompt actions to reduce greenhouse gas emissions and protect natural resources (Adebayo et al., 2023). Each BRICS member state presents unique contributions and strategies for addressing climate change, ranging from forest depletion and energy production in Brazil to investments in sustainable energy and electric vehicles in India and China. The depiction of climate change within the BRICS nations is influenced by their collective identity as emerging influential powers, emphasizing accountable global participation and an economic development approach that is sensitive to climate issues. The discussion highlights responses from Brazil, India, China, Russia and lessons for South Africa.

Brazilian government's response to the impact of climate change on road transport

Freire et al. (2023) state that Brazil ranks among the 10 largest economies globally. Furthermore, it is the eighth biggest emitter of greenhouse gases in the world and the third largest among developing nations. The Brazilian population is at risk from climate change due to the presence of its tropical rainforests in the Amazon and the Pantanal wetlands. Studies (Freire et al., 2023; Appiah et al., 2019) show that with rising temperatures, the Amazon rainforest is expected to experience drier conditions, which will result in an increase in uncontrolled fires. These fires will occur more frequently, releasing greenhouse gases and consequently raising their levels in the atmosphere, which will contribute to higher temperatures (Appiah et al., 2019). As noted by Freire et al. (2023), Brazil plays a crucial role in deforestation, overseeing more than 70% of the Amazon rainforest. Therefore, rising temperatures impact the road transport infrastructure by deteriorating asphalt roads and exacerbating the formation of potholes.

Deforestation in Brazil has been a significant concern for several decades, with factors such as infrastructure development, settlement initiatives, governmental support for agriculture, land transport and large-scale projects recognized as primary contributors (Azevedo et al., 2020). These activities have resulted in the clearing of extensive forest areas, especially in the Amazon rainforest, which houses a diverse range of plant and animal species. Nevertheless, there have been advancements in recent years in curbing deforestation rates in Brazil (ibid). The nation has adopted various strategies to address this problem, including stricter enforcement against illegal logging, upholding rigorous environmental regulations, and encouraging sustainable land use practices (de Azevedo et al., 2018). Consequently, deforestation rates have notably diminished in recent years, positioning Brazil as a leader in low-carbon biofuels. This reliance on clean energy sources for electricity generation contributes to a decrease in greenhouse gas emissions.

The first domestic response to climate change was the creation of a government structure called the Inter-ministerial Committee on Sustainable Development. According to Barb et al. (2015), climate change mobilization was achieved through the implementation of the Centre for Weather Forecast and Climate Research under the National Space Research Institute improving Brazil's climate modelling systems. The precise framework of climate change problems was developed already in 1999 within the framework of the interministerial commission on climate change of the Ministry of Science, Technology, and Innovation. That committee, along with several related ministries and departments, was instrumental in summarizing the government's post-climate agreement activities by publishing a CDM-eligible project report.

On the other hand, the transport sector is responsible for more than 40% of energy-related carbon dioxide emissions, reflecting Brazil's high dependence on carbon or low-carbon fuels in other sectors. Non-energy sources such as agriculture and livestock, land use change and forestry, and waste management are responsible for most of Brazil's greenhouse gas emissions. Road traffic is the second largest source of greenhouse gases. The share of the sector in the total volume of the country is about 7–9%. According to Boson (2011) 62% of freight transport is attributed to road modality.

In 1993 the Brazilian government introduced a tax incentive policy for the usage of less powerful cars. The cars were set to be with engines of less than 1 L in size. For qualifying cars, the tax on Industrialized Products was reduced to 10% from 25%. The aim of the policy was to encourage production of more efficient automobiles and make them accessible to lower-income buyers. The success of the tax incentive policy was visible in 2001 when almost three-quarter of domestic sales of new cars were one-litre engine cars, thus the tax reduction did not lead to a net increase in car sales, and that one-litre engine cars replaced more powerful cars. As a result, 2 million tons of carbon was saved.

In 2010, the Brazilian government submitted NAMA to the United Nations Framework Convention on Climate Change and announced a goal to reduce emissions by 36.1–38.9% compared to projected emissions (UNFCCC, 2011). This is 975-1052tCO2e less per year than business as usual (BAU). In addition, NAMA includes:

- Development and implementation of programs to improve road conditions and infrastructure.
- Investment on transport matrix diversification through expansion of railways and waterways.
- Development of mechanisms aimed at stimulating investment in research and development (R&D).
- Scrapping of old fleet and forecast of taxation and incentives structure.

These actions intend to strengthen and formalise national voluntary commitments to the Kyoto Protocol and UNFCCC.

Freire et al. (2023) attest that a large portion of Brazil's energy comes from renewable sources, establishing it as a global frontrunner in this area. Despite these successes, Brazil's emissions are projected to rise sharply soon. While Brazil has achieved notable progress in reducing deforestation and advancing sustainable energy solutions,

considerable work remains ahead. The government, industries, and individuals must continue collaborating to safeguard the nation's invaluable natural resources and address climate change. Through these efforts, Brazil can maintain its status as a leader in low-carbon biofuels while also conserving its remarkable biodiversity for future generations.

Indian government's response to the impact of climate change on road transport

India has been identified as one of the countries vulnerable to climate change. Its population depends on agriculture, which is more vulnerable to climate change effects (INCCA, 2010; Bureau of Work Statistics, India, 2010). India is also vulnerable to sea level rise and extreme weather events. India is a major emitter of CO2 emissions and has grown rapidly since 2009. According to IEA (2016), India's emission in 2009 was only one ton of carbon dioxide. However, India is now the world's third largest emitter, tripling its annual emissions from 600 tons to 1,600 tons between 1990 and 2009. IEA (2016) predicts that India's annual carbon dioxide emissions will increase by nearly 2.5% by 2035, so that India needs to prepare for the negative effects of climate change.

India's stance on climate change is based on three key principles. Firstly, developed nations should take primary responsibility for reducing emissions. Secondly, developing nations like India should not face imposed emission reduction targets due to potential hindrances to poverty reduction and development. Lastly, India calls for technology transfer and financial assistance to help developing countries tackle climate change (Ministry of Environment and Forests, n.d.). India's approach emphasizes equity in global climate action, ensuring diverse capacities and priorities are considered. India, like other developing nations, faces the dual challenge of economic growth and climate change. Environmental concerns are escalating, with cities like New Delhi experiencing worse air quality than their Chinese counterparts (Debbarma and Kaushik, 2022). India is committed to global climate negotiations under the UNFCCC, aiming for a fair and effective global framework. The government has pledged to reduce emissions intensity by 20–25% by 2020, despite having no binding obligations from the COP.

In quest to achieve its pledge, India launched policy measures with the country's constitution being the foundation. The Constitution of India, Article 48-A stipulates that the "State shall endeavour to protect and improve the environment to safeguard the forest and wildlife of the country (Jogesh and Dubash 2015)." Other policies were formulated to implement and enforce this constitutional mandate. Policies such as the National Environment Policy (2006) which lays down the policy framework for environment and climate change, the National Action Plan on Climate Change (NAPCC) which focuses on the required interventions and the Integrated Energy Pricing Policy which seek to align fuel prices with global averages. These policies supplement each other in order to effectively respond to climate change. The Indian government also uses other instruments such as coal cess, increase taxes on petrol and diesel, renewable energy certificates and cut in subsidies to promote actions that addresses issues of climate change. All the policy efforts and actions resulted in decline of emission intensity of India's GDP by 12% between 2005 and 2010. Hence, the Emission Gap Report 2014 of the United Nations Environment Programme (UNEP) recognised India as one of the countries on course to achieve their voluntary goals.

The Indian Road transport sector accounts for 10% of total energy demand, mainly for oil. The country's transport energy use is projected to grow at a rapid rate of 5.1% annually, compared to the global average of 1.1%. To promote a low carbon economy, the Indian government is focusing on developing low carbon infrastructure and public transport systems. India has shifted freight transport and passengers from roads to railways, creating the world's third-largest rail network. This transition aims to reduce the burden on road traffic, which uses less efficient fuel. India is also emphasizing urban transport policies, prioritizing moving people over vehicles. Initiatives like the Mass Rapid Transit System (MRTS) and the National Electric Mobility Plan 2020 (NEMMP), including the FAME India scheme, promote the adoption of hybrid and electric vehicles to reduce emissions while maintaining economic growth (IEA, 2016). India has introduced passenger vehicle fuel standards to reduce CO2 emissions.

According to Vajjarapu et al. (2023), India has implemented a range of sustainable measures and policy interventions to address the issues posed by climate change in the road transport industry. Studies have emphasized how important the transport industry is to the effects of climate change and carbon dioxide emissions (Aggarwal, 2017; Debbarma and Kaushik, 2022). India has implemented policies to regulate road transport demand, encourage modal transitions, encourage electrification, and increase energy efficiency. Furthermore, there's a growing focus on cutting emissions through encouraging the use of alternative vehicle technologies like biofuels and hybrid electric cars, improving the infrastructure for public transport, and discouraging the use of diesel. The Indian government has played its part by formulating policies such as the Clean India Mission and Achieve Energy Efficiency (Sonde, 2007), which are legally binding on their citizens in order to ensure cooperation from their citizens. Moreover, adaption plans are being developed to deal with how climate change affects urban flooding and transport systems, underscoring the importance of resilience and adaptive capacity in light of changing weather patterns (Aggarwal, 2017).

The Indian government works hand in hand with its citizens in responding to climate change. It should be noted that the scientists have found that human activities are the major contributor to the GHG emissions and resulting in adverse climate consequence. Therefore, improved human behaviour is important in mitigating climate change. The Indian citizens play a pivotal role in responding to climate change. Furthermore, the Indian private sector has embarked on actions to mitigate climate change and sustain development. There is a voluntary carbon disclosure programme whereby the Indian industries report on their GHG emissions and carbon management and strategies.

Chinese government response to the impact of climate change on road transport

Climate change is an escalating worldwide issue that governments are urgently addressing. China has acknowledged the pressing need to confront this challenge and has enacted various measures to lower greenhouse gas emissions, particularly in the road transport sector.

One significant initiative involves the encouragement of electric vehicle usage, with ambitious goals established for their adoption by 2025. China is divided into five climatological regions from South to North (SDPC, 2004). According to Kan (2011) the annual average temperatures of China have increased from 0.5°C to 0.8°C. These changes of temperatures have been mostly felt in winter season. Zhai et al. (2005) indicate that as a result of the increased temperatures rainfall patterns have consequently changed. NDRC (2007) on the other hand states that the rainfall distribution changes are exacerbating the drought trends and flooding. As a result, China experienced more droughts and floods. Thus, the country's environmental and ecosystems are highly vulnerable to climate change.

China is the world second largest economy after United States of America (USA). It is dependent on coal and oil for primary energy consumption. China has become one of the world's largest per capita emitters, surpassing the global average but still lower than developed countries (Mallapaty, 2020). Environmental issues in China are linked to its rapidly growing economy, with challenges including changing energy consumption habits and improving efficiency Zhang et al. (2010). According to Harper (2019) air pollution, acid rain, and water pollution are major problems, resulting in an estimated 2.4 million premature deaths per year. Half of China's water supplies are too polluted for human consumption.

Chinese authorities are taking steps to address pollution and climate change, recognizing its social and economic impacts. By 2023, it is projected that water and air pollution could account for 6% of the country's GDP (Managi and Kaneko, 2010; Schruers et al., 2011). Fossil fuels are a major contributor to air pollution and greenhouse gas emissions. Richerzhagen and Scholz (2008) affirm that stricter environmental laws and enforcement measures have been put in place, along with penalties for environmental damage. Energy Conservation and Renewable Energy laws highlight China's commitment to sustainable energy policies.

Capacity is key in responding to climate change, China has developed institutions that are of key importance to its climate adaptation and mitigation strategies. The institutions play different but complementary pivotal roles in responding to climate change. For instance, National Coordination Committee on Climate Change (NCCCC) has formulated and coordinated China's climate change related policies. The other one is China Council of International corporation on the Environment and Development (CCICED) is responsible for addressing scientific issues related to climate change.

China works on a five-year plan in adapting and mitigating climate change. Below is its 12th five-year plan in relation to mitigation within the road transport sector.

- Passenger vehicle fuel economy standards of 7 L/100 km (33.6 miles per gallon).
- Fuel economy improvements of 11% for heavy-duty vehicles and 15% for light-duty commercial vehicles.
- Vehicle pollution supervision centres in 31 provinces.
- Expand bus rapid transit lines from 350 km to 3,000 km, and bus-only lanes from 2,500 km to 10,000 km.
- Increase number of people who use public transport, especially in cities.

China is actively working on addressing climate change in the road transport sector through decarbonization and sustainable transport policies. Studies underline the importance of transitioning to low-carbon road transport systems to achieve carbon neutrality goals (Xue and Liu, 2022). Scholarly research suggests that adopting sustainable transport and electric rail vehicles can help reduce greenhouse gas emissions in China. The country aims to peak carbon emissions by 2030 and reach climate targets by 2060 by promoting transport electrification and phasing out fuel vehicles (Harper, 2019). Integrating road transport with renewable energies is seen as a crucial strategy to achieve carbon peak and neutrality objectives (Xue and Liu, 2022). These efforts highlight China's commitment to addressing climate change in the road transport sector through innovative policies and technological advancements.

The Chinese government is providing subsidies and incentives to motivate consumers to transition to electric vehicles, while also introducing fuel efficiency regulations for manufacturers. In addition, China is dedicating resources to develop infrastructure for alternative fuels and is prioritizing public transport over private automobile use. Through a proactive and all-encompassing strategy, the Chinese government is making notable strides in cutting emissions within the transport sector and fighting climate change.

Russia's response to the impact of climate change on road transport

Russia's strategy towards climate change involves multiple facets, as demonstrated in numerous scholarly research such as Oxford Analytica (2022), Golub and Shenin (2023) and Purushothaman and Philip (2023). The country aims to reduce greenhouse gas emissions and enhance its economic competitiveness by means of structural and technological progress (Porfiriev et al., 2022). The Russian perspective on climate change is essential given the country's substantial greenhouse gas emissions and large fossil fuel reserves. As one of the top global producers of fossil fuels, Russia is ranked third in the world (Russian Federation, n.d.). The Russian economy is largely dependent on fossil fuel exports, with oil and gas revenues constituting a significant share of the federal budget. Poberezhskaya (2015) contends that Russia's reluctance to reduce fossil fuel consumption arises from concerns about the potential impact on its economy. According to Porfiriev et al. (2022) the implementation of climate-related policies by other nations could potentially result in a decrease of approximately half a percent in Russia's GDP growth rate. Russia became a party to the United Nations Framework Convention on Climate Change (UNFCCC) shortly after its inception in 1992, with the aim of showcasing active and constructive participation. Nevertheless, in the subsequent years, Russia has demonstrated diminished enthusiasm towards addressing climate change, despite ratifying all UN agreements pertaining to the issue. Similar to numerous non-European countries, tackling climate change is currently not a primary focus for Russia.

Historically, Russia's position on climate change has been characterized as dissident or sceptical, influenced by economic downturns and a scientific community that remained unconvinced about the anthropogenic effects on climate. Russian scientists contended that global endeavours to regulate climate phenomena would be ineffective, the costs of mitigation measures would be prohibitive, and that Russia's extensive forests would naturally absorb a majority of its carbon emissions (Poberezhskaya, 2015).

Additionally, Russia perceived climate change as a Western plot designed to economically weaken developing nations, including Russia.

Golub and Shenin (2023) argue that the response to climate change is complex, with various political factions in the United States expressing different opinions on Russia's climate strategies, highlighting the importance of global cooperation in tackling climate change. Moreover, the analysis of changes in river flow within Russian watersheds underscores the impact of climate warming on hydrological patterns, with variations in streamflow changes across different basins, underscoring the need for customized adaptation approaches (Wang and Shpakova, 2022). Essentially, Russia's reaction to climate change involves a combination of policy actions, economic considerations, and environmental challenges that call for collaborative efforts at national and international levels.

According to Vakulenko (2019) Russia is actively addressing climate change within the transport sector through a focus on decarbonization and management of climate-related risks. Initiatives involve the expansion of energy sources for motor vehicles, such as natural gas, electric vehicles, and hydrogen fuel cells. Russia is examining climate vulnerabilities within transport systems to shape strategic adaptation decisions, highlighting the significance of a precautionary stance towards extreme weather events and the necessity of organizational, technical, and economic interventions. Moreover, the nation is appraising the susceptibility of its transport sector to climate change, taking into account adaptive capacities and mitigation tactics to mitigate adverse effects (Trofimenko, 2023). These combined endeavours demonstrate a holistic approach to confronting climate challenges within the transport sector across diverse geographical areas.

Russia is tackling climate change in its road transport sector by promoting alternative fuels like biofuels and supporting electric vehicles. The government offers tax benefits and assistance to encourage the shift towards EVs and lessen reliance on traditional gasoline-powered vehicles. Furthermore, Russia is improving its public transport system to lower emissions and ease traffic congestion (Russian Federation, 2021). While the nation's efforts have shown encouraging results, there is still considerable opportunity for further carbon emission reductions. Russia could enhance the availability of electric vehicle charging infrastructure and provide additional financial incentives to bolster its initiatives. Investing in renewable energy sources to support public transport could also aid in decreasing emissions.

Lessons for South Africa in responding to climate change

Climate change is anticipated to have widespread ramifications on various facets of society and the environment. The frequency and severity of natural calamities, such as hurricanes, floods, and droughts, are forecasted to rise due to climate change, heightening the peril to human lives, infrastructure, and ecosystems (Purushothaman and Philip, 2023). These consequences could also spur internal migration, the relocation of communities, and the emergence of climate migrants. Consequently, these elements contribute to the potential for famines, social unrest, and instability.

South Africa can learn a lot from Brazil, Russia, China and India such as political will. The three countries have demonstrated a level of political will in responding to climate change. In all three countries there is a committee headed by the president on climate change. This illustrates a "buy-in" from higher level and will encourage lower levels to effectively engage in the efforts of combating climate change. In South Africa the National Committee on Climate Change is dominated by the officials from Department of Environmental Affairs and it is very much isolated from other departments hence it is not as effective as it could be if the key politicians and other departments were involved in the committee.

South Africa faces the task of balancing infrastructure enhancement with road safety initiatives amidst financial constraints. The construction and upkeep of infrastructure, the adoption of technology, and the execution of road safety campaigns demand substantial funding, which puts pressure on government finances. To alleviate costs, South Africa should seek collaborations with private enterprises for extra financial support and expert insights. Exploring alternative funding options such as public-private partnerships or crowdfunding can also distribute financial obligations among various stakeholders. Emphasizing preventive strategies, like education initiatives and public awareness efforts, can decrease the necessity for expensive infrastructure improvements over time.

Tackling environmental issues, such as traffic congestion and vehicle pollutants, is essential for the nation's sustainable growth. Investing in eco-friendly transport methods, such as public transit networks and cycling facilities, can enhance road safety, boost transport efficiency, and produce positive environmental results. By adopting these approaches, South Africa can successfully improve road safety, upgrade transport systems, and foster sustainable development for its population. Key steps for the nation to achieve enduring progress in road safety and infrastructure advancement include collaboration between public and private sectors, investigating alternative funding avenues, focusing on preventive measures, and addressing environmental challenges.

In responding to climate change South African government should adopt a hybrid approach. All spheres of government should independently but interrelatedly address climate change. Each province should have mitigation strategy, particularly each provincial department of transport. This will allow even municipalities at local level to be effective as the mandate will be closer to them. In India each and every state has its own State Action Plan on Climate Change. While in China the national government is providing guidelines to local governments on addressing the effects and impacts of climate change. In Brazil each city is developing an inventory of GHG and setting its own targets. City of Johannesburg in South Africa has taken similar approach to Brazil by developing its own climate change strategy and setting its targets.

Legislation is key in all the three countries; South Africa has developed number of policies and strategies but has not yet developed a coherent legislation on climate change. Legislation is crucial in regulating the actions. Furthermore, legislation will encourage people to change behaviour knowing that there are sanctions failure to abide and that will assist curbing the CO2 emissions. South Africa should also invest in public awareness campaigns. Literature on public perceptions has revealed that most South Africans are not aware of climate change let alone how their activities influence climate change.

Therefore, the government should educate and inform its citizens about climate change and its impacts and effects.

In Brazil the private sector, NGOs and civil society at large are very active in the fight against climate change. These sectors are crucial in Brazilian policy development forums. South African government should engage and encourage the private sector and civil society to join in addressing climate change. The private sector can also assist with financing climate change.

South Africa can draw valuable lessons from other BRICS countries in responding to climate change. Brazil's focus on deforestation and energy production, coupled with South Africa's status as the largest carbon dioxide emitter in Africa, highlights the importance of robust mitigation strategies (Sibanda and Manik, 2022). India's emphasis on investing in cities, solar energy, and electric vehicles can guide South Africa in transitioning towards sustainable practices. China's policies on carbon pricing and renewable energy showcase the significance of strong regulatory frameworks. Russia's efforts to reduce carbon emissions domestically underscore the need for comprehensive national strategies. Furthermore, the importance of knowledge management for climate change in South Africa emphasizes the necessity of a structured approach to information dissemination and action. Integrating these lessons can enhance South Africa's climate change response and contribute to global sustainability efforts.

Conclusion

The intersection of climate change and road transport creates significant policy challenges. Policymakers are under increasing pressure to weave climate resilience into transport planning and development. This entails securing funds for adaptive measures, such as building climate-resilient roadways and incorporating green technology into road transport infrastructure. Furthermore, initiatives aimed at reducing carbon emissions from road transport, like promoting electric vehicle adoption and improving public transit alternatives, are crucial for lessening the effects of climate change. South Africa could strive to reduce emissions and achieve its decarbonization goals by exploring shared mobility alternatives and promoting active road transport. Additionally, as highlighted in the examination of adapting road transport in South Africa, understanding the impacts of climate change on road transport could facilitate the effective integration of climate change aspects into transport projects. By implementing these concepts, South Africa can enhance the resilience of its road transport sector and contribute to the global endeavours aimed at addressing climate change.

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