## REVIEWING CLIMATE CHANGE RESEARCH FOR SOUTH AFRICAN PORTS, TRANSPORT AND LOGISTICS SUPPLY CHAINS IN SOUTH AFRICA -JACK DYER, JULY 2018

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## INTRODUCTION

With 2,758 kilometres of ocean coastline and an Exclusive Economic Zone exceeding 1,500,000 square kilometres of ocean, the South African coastline is second only to the Somalian coast in terms of African geographical significance. Geopolitically, the Cape of Good Hope ranks along with Cape Horn, the Suez and Panama Canals as among the most significant maritime trade routes in the world. Durban Harbour ranks in terms of actual and potential containerised cargo throughput as the most significant harbour not only in Africa but the Southern Hemisphere. In 2017 South Africa’s ports exported 22,785,761.9 tons of cargo, 4,634,829 TEU’s and received 9,821 vessels. The South African government under the ANC leadership in 2014 came up with an indigenous African initiative: Operation Phakisa, which considers that South Africa’s future lies in its development of a maritime economy. The African Union echoed this vision 8 months earlier with the 2050 AIM (Africa Integrated Maritime) Strategy, seeking to independently establish a future African maritime economy. The maritime centred city of Durban and province of KwaZulu-Natal’s Planning Commission in 2013 introduced the development of an Integrated Maritime Industrial Strategy. Conversely, the Department of Environmental Affairs are working towards a green economy based on environmentally sustainable development.

Over 90% of the world’s trade is seaborne; based on global, macroeconomic contributions and connections of seaports, vessels, maritime economic hinterlands and their interconnecting supply chains. Globalisation relies on continuing and facilitated trade. However, its participants seldom consider what happens when those connections fail and logistics chains no longer facilitate trade, swiftly, safely, securely and efficiently. Profits and physical survival risk the prosperity of all stakeholders. Inter-port competitiveness is multiplying from African port expansions; logistics supply chains face higher threats from automated technology, scarcity of qualified labour, increasing regulation over emissions, globalisation, US-EU trade deals; piracy and China’s One Belt One Road Initiative. Other transport network, survival prospects are increasingly threatened by encroaching sea levels, higher temperatures, wind velocity and precipitation. Increased frequencies and intensities of hurricanes, tsunamis, droughts and other climate-related influences (IPCC 2015), adversely disrupt port, shipping and overall supply chain performance. Currently, these risks impose significant yet understated, under-investigated costs, risks, concerns and consequences for dependent stakeholders. A survey of over 200 global ports, indicated how few African or Southern Hemisphere ports were contemplating climate change (Asariotis, Benamara, and Mohos-Naray 2017).

2011 floods in Durban South Africa cost an estimated $100 million in damage alone! Evacuating 1,500,000 people from Cape Town, approaching Drought Day Zero visualised climate change as a reality for the first city globally threatened to run out of water! A vessel blockading Durban Harbour could paralyse sub-Saharan Africa’s economy. From a Madagascar cyclone off Durban, species extinction and collapsing Sardine Run; what will global climate change really mean for a world increasingly dependent upon maritime resources, ports and supply chains? What can Africa and South Africa faced with unprecedented climate change events and uncertainty, learn from other nations? How do we maintain business as usual, ensure prosperity and survival, whilst avoiding ecosystem collapse? How much will it cost? Do we retreat; adapt or surrender? Can we afford –can we continue to ignore the problem –to just be reactive to environmental circumstances? To what extent are we prepared as humans? Do we know what to do? We in Africa are utterly just as dependent upon the maritime sector for our economic growth and potential development, as the hinterland to which so many only ever preoccupy themselves with. As the threat of global climate change emerges as the prime challenge for the twenty first century; the maritime sector is destined to become increasingly more vital to the future of humanity. We can no longer afford to ignore this. The South African government via the Department of Environmental Affairs, South African National Biodiversity Institute, National Research Foundation and other core policy stakeholders are prioritising the greatest uncertainty to a global “business as usual” future.

# RESEARCH GAP AND PROPOSAL:

Despite increasing evidence (agreed to by 97% of global scientists and the Intergovernmental Panel on Climate Change (IPCC); our planet and humanity face an increasingly uncertain future from climate change. However, whilst Department of Environmental Affairs, Long Term Adaptation Scenarios have been developed in Agriculture, Forestry, Health, Water, Biodiversity, Marine Fisheries and certain other areas, this review identifies a significant research gap for climate change impacts on South African ports, logistics supply chains and transport directly; along with the ecosystems, infrastructure, economies and communities which support them. This literature review will provide a brief overview of related scholarship into the projected risks, impact costs, constraints and solutions for this sector. Providing insight aims to recommend to the South African Department of Environmental Affairs (DEA) and other core affected stakeholders to prioritise research, funding and allocating resources to transport supply chains. Ensuring greater climate resilience, futureproofing against risks and developing opportunities will not only minimise disruption but aid in ensuring an ecologically sustainable, profitable and survivable, ‘business as usual’ future.

## GLOBAL CLIMATE CHANGE RISKS

Research from Pernetta and Hughes (1992) to Dyer (2018) has traditionally focussed on modelling projected risks and associated impact costs with underlying assumptions. These sources aim to provide supply chain stakeholders with specific guidance over which adaptation actions to prioritise, during pre and post-disruption events. These sources target where to efficaciously allocate resources and determine the quantity and quality of resources necessary to recover. Sufficient empirical, scientific evidence exists from sources including the United Nations (2010), IAPH (2013), Pacific Island Forum (2013), SPC (2014), SPREP (2014), IPCC (2015) and the Australian Academy of Science (2015); to presume climate change actually exists. To establish research credibility, the definitions above and the physical, climate change process are not based on personal opinion but over 1200 peer reviewed, internationally accepted scientific sources consulted. These findings were agreed by over 170 nations for the Intergovernmental Panel on Climate Change (IPCC). These and myriad, research sources consulted for this review officially affirm the existence of climate change as primarily anthropogenic rather than natural (IAPH 2011; World Bank; 2012; IPCC 2013).

Whilst understanding the nature of climate change uncertainty and controversy; to be scientifically credible and justifiable, this review accepts climate change as the prime risk for global supply chains, especially for African land and small island, developing states. This is based on the criteria of an increasing number of peer-reviewed scientific literature as climate change impact studies, physical evidence and the response of nations, organisations, corporations, supply chains and individuals. They consider climate change to be a significant threat; enough to prioritise significant efforts in mitigation and adaptation. According to the IPCC and other core sources, the following represent direct climate change risks globally, to Africa and South Africa

* An increase in global average land surface, atmosphere and sea level temperature levels, of 1.5-2º Celsius for the B1 scenario. This occurs even if emissions were to cease, based on historic inventory levels.
* 2.5-4º increase for the IPCC (2015) A1B scenario, if emissions are stabilised at the current, medium growth rate by 2100.
* 4-7 º increases for the IPCC (2015) A2 scenario if emissions are not reduced.
* A 0.5 metre global, average SLR is projected for a low risk, current growth, scenario where emissions are highly reduced, 0.8 metre rise. This presents a medium risk if emissions are stabilised. Up to 1.1 metres high is expected for a high risk, continued emissions increase scenario by 2100, in pursuing current, global GDP growth rates of 3-5% annually.
* Other global, African regional and individual increases in sea level, temperature, humidity, precipitation and wind speed are anticipated. Potential variations in wind direction, current, ocean swell, wave energy and sedimentation, are expected as long-term risks.
* Greenhouse CO2 emissions would have to stabilise around 450 parts per million (ppm) (430–480) at present; no higher than 550 ppm (530–580) by 2100, to ensure survival.
* A projected increase in the frequency, duration and intensity of short term, climate- related, natural disaster risks. These include storms/superstorms, flooding, tsunamis, hurricanes with higher precipitation and wind speeds, heatwaves, droughts and landslides.

## AFRICAN CLIMATE CHANGE

Whilst fewer global climate change sources have specifically focused on the African continent; the IPCC specifically includes a chapter on projected regional risks. Niang et al. (2014) identify existing climate trends and data projections indicate existing minimum temperature increases of 0.5º over the past 50 years and 2-4º by 2055. Africa will experience reduced precipitation, increased frequencies of droughts/El Nino and more heatwaves (I.e. the Sahara experienced 40-50 from 1989-2009). The report specifically focuses on ecosystems highlighting delayed South African bird species migration, increased Sahel desertification, higher malaria and invasive species risks and reduced aquifers. It lacks country specific identification of risk events and downscaled, localised climate projections. It primarily details socio-economic factors of vulnerability with projected implications for agriculture, crops, livestock, pests, fisheries and food security, health, nutrition and disease. These are projected to present emergent threats to regional economic and social stability with security, increasing migration. Table I highlights the core research priorities between 1989-2018 in existing IPCC African studies. This reflects a continuing lack of institutional capacity, resources, research and data available to understand specific implications to communities, individuals and systems. Its most significant research gap however, ignores physical infrastructure, transport, systems and other core foundations enabling trade, livelihoods and access to essentials.

Table I: Major Conclusions From Previous IPCC Assessment Reports.

|  |  |
| --- | --- |
| **Special Report on the Regional Impacts of Climate Change** | * Sensitivity of water resources and coastal zones to climatic parameters * Identification of climate change as an additional burden on an already stressful situation * Major challenges for Africa: lack of data on energy sources, uncertainties linked to climate change (mainly for precipitation), need for integrated studies, and the necessary links between science and decision makers |
| **Third Assessment Report** | * Impact of climate change and vulnerability of 6 sectors: water resources, food security, natural disasters, natural resources and biodiversity management, heath, human settlements and infrastructure, desertification * Adaptation strategies for each sector * Threats of desertification and droughts to the economy of the continent * Suggestion of adaptation options mainly linked with better resource management * Identification of research gaps and needs, capacity building, data needs, development of integrated analysis, consideration of literature in other languages |
| **Fourth Assessment Report** | * Vulnerability of Africa mainly due to low adaptive capacity * Source of vulnerability mainly socioeconomic causes (demographic growth, governance, conflicts) * Impacts of climate change on various sectors, energy, tourism and coastal zones * Potential impacts of extreme weather events i.e. droughts, floods, cyclones * Adaptation costs. * Need for mainstreaming climate change adaptation into national development policies * 2 case studies: Food security -Climate change could affect the three main components of food security. Traditional knowledge: African communities have prior experience with climate extremes, although this knowledge will not be sufficient to face climate change impacts. * Research needs: better knowledge of climate variability, more studies on the impact of climate change on water resources, energy, biodiversity, tourism and health, the link between different sectors (e.g. between agriculture, land availability and biofuels), developing links with the disaster reduction community, increasing interdisciplinary action of climate change and developing institutional capacity. |
| **Fifth Assessment Report** |  |

Source: IPCC 2015.

Access to credit and finance represents a significant challenge to reducing disruption risks across Africa. Since the ratifying of the non-binding Kyoto Protocol to stabilise greenhouse gas emissions; Africa’s climate-related aid has increased from $850,000,000 to $5,100,000,000 over 2004-2010 (Halvorson-Quevedo, 2014). 52% is mitigation orientated, 32 is adaptation directed and 16% both. The transport sector received only 22% of all budget expenditure. As the second largest African economy (largest from 1900-2016), South Africa received only 12% of total related aid. Understanding specific climate change consequences for African ports and the logistics sector is hindered by limited information available including accessing and linking climate services (HR Wallingford 2014). This subsequently challenges operations, general planning, risk management, performance and commercial activities in the short, medium and long-term time horizons. Accessing information and experience influence stakeholder’s risk perceptions and actions, related policies, behaviour and design changes. For example, HR Wallingford (2014) detail how storms and sea level rise can influence Walvis Bay in Namibia’s port accessibility via a sand spit. It advises reconfiguring port projects to factor in IPCC global and regional Africa climate projections including wind, waves and rainfall. This prompts greater risk concern, awareness and more capable, decision-making processes. It can prompt taking responsibility and action.

The source highlights a lack of awareness and access to climate change data for African ports. However, it emphasised how Durban port’s expansion had its Environmental Impact Assessment revised to specifically incorporate climate change into its design standards and operating plans. Specific risks include preparation for 580 mm sea level rise, 5% wind velocity over 50 years, 10% increase in storm surge height and extreme intensity of precipitation. This followed a legal challenge by the DEA. Yet this preparation has not been specifically extended to other South African and African ports, which remain highly vulnerable. Existing ports have yet to receive information access, funding or be climateproofed. The source emphasises the need for new research into the economics of adapting African ports to climate change and dissemination of existing information.

To resolve climate uncertainty for stakeholders, an independent evaluation of African risk warning systems and institutional capacity was initiated (Scott et al. 2017). A proposed pooled insurance scheme to which all African countries would contribute, aimed to minimise exposure to climate risk events. This parallels a similar PCARI scheme successfully implemented in the South Pacific. The review was meant to test the cost-effectiveness of mutual risk pooling and transfer, however it received significant delays, funding issues and wasted time on producing superfluous reports/consultations. This continued inability to access timely relevant data for past, present and future events, stalls or hinders effective decision-making whilst maximizing disruption costs. The report cites the need to enhance government and public understanding of “the nature, intensity and likely impact of the climate and weather affecting their countries” along with need for insurance and contingency plans. Specific hazard, vulnerability, loss and damage information is also crucial. Few countries provided research examples relating to climate change and transport, business, supply chains or the private sector as conspicuous scholarship gaps.

Other specific impacts for Africa include higher subtropical regional temperatures (Serdeczny et al. 2015), aridity and evapotranspiration plus increased precipitation in the Gulf of Guinea. Extreme 1 in a 100 year storm or cyclone events are more likely to occur every 1 in 20 years. African climate change will affect over 1 billion people, its ecosystems, people, cultural heritage and infrastructure. Climate change threatens over $45 billion of forthcoming road project investments. Over $40 billion per year until past 2030 or 3% of the continent’s 2012 GDP, is estimated as necessary to prepare (African Development Bank or ADB 2012). This needs distribution in access to climate services, climateproofing processes; sustainable transport, land use, resource management and renewable energy, for mitigation and adaptation. It excludes indirect cost consequences including to trade, migration, taxation, production and consumption. It ignores current issues in attaining existing UN sustainable development and poverty eradication goals meant to be achieved by 2015-2030. ADB cite several examples of how transport can become more sustainable to reduce emissions and other pollution sources including a Tangier-Marrakech Railway Capacity Increase Project in Morocco for public transport. Nigeria is constructing a Lagos Cable Transit system. Transport and logistics are indispensable to Africa’s economy and society. Whilst few sources critically evaluate regional or sector specific examples of African transport infrastructure, Cervigni et al. (2016) focused on roads and bridges for the World Bank. However, it provided only generic impacts and need for a road inventory of 2,800,000 kilometres, lacking a specific case study or sectional implications. It utilised disruption, breakeven and bridge analysis methods in response to developing climate change projections to prepare in long term adaptation planning.

The ADB especially highlighted how climateproofing needs to be incorporated into adequate maintenance and periodic rehabilitation as risks continuously change. It estimates costs up to 10 times higher if this is marginalised from increased pressures of more intense and frequent precipitation plus more extreme temperatures and heatwaves. It concludes humanity cannot afford to ignore climate change. It needs specific data on road assets lifetime cost; value of freight and passenger traffic expected to use these assets; the criticality of the road segment; the level of network redundancy plus how climate stressors such as precipitation, flooding and extreme temperatures will create impact cost consequences. Yet it ignores the implications of sea level rise, wind speed, cyclones, tsunamis, landslides and other climate related risks, severely underestimating vulnerability. It recommends evaluating the optimal timing and benefits for infrastructure adaptation. Resilience solutions highlighted included more capable sector and spatial planning; non-engineering solutions such as traffic control and truck restrictions along with a more conducive regulatory enabling environment with regular maintenance and inspections. It counsels being proactive rather than reactive to risk event management. Disruption time (envisioned as 100,000,000 days by 2050) and resources will be reduced.

By 2020, regional agricultural and fisheries yields are projected to decrease by 50%. The Nile delta has experienced 0.2-0.3 degrees per decade. Higher temperatures and more frequent droughts threaten 75-250,000,000 people (Viljoen 2014), threatening food security and the agrarian bases of many rural economies, thus reducing access to resources for logistics supply chains. Over 30% of coastal infrastructure remains exposed to ocean risks. Saltwater intrusion and drought affect the great African Lakes from Chad to Victoria to Malawi and rivers from the Nile to the Congo to the Zambezi, Okavango and Orange. Transport remains primarily orientated towards mitigation of greenhouse gas emissions. It aims to minimise climate change drivers rather than proactive adaptation other than partial climateproofing of infrastructure (Viljoen 2014). However regional trade agreements such as the COMESA/SADC/EAC Treaty focus only on general obligations towards cooperation in responsible environmental conservation and natural resource management rather than specifically binding obligations to climate change. However, COMESA’s proclaimed 2011 Climate Initiative mentions striving for regional cooperation in technology, information sharing, capacity building and other support, especially to implement a bio-carbon facility and other mitigation projects. Whilst several examples of individual nations’ climate change priorities were highlighted, none included examples for transport and related infrastructure. SADCC did draft a Protocol on Transport, Communications and Meteorology, seeking members to enhance climate services and consider climate change but after 7 years has yet to be fully implemented, ratified and enforced.

Implications extend beyond transport to the urban infrastructure, systems, settlements, communities and infrastructure. Middleton (2016) focused on how poverty, limited resources and other existing challenges of local governmentswill be amplified by the dependency and vulnerability of informal settlements. African cities require climate compatible development, given migration and future pressures. It recognises how few African cities have climate change adapation strategies for an entire city, let alone detailed ones for transport. The source limits transport adaptation focussing only on emissions rather than subsequent proactive risk minimisation. Future EU research echoes the preoccupation with seeking to reduce the pace of climate change, rather than recognising its existing and even more probable future disturbance costs (UNEP 2012). The EU’s Research Framework Programme dedicated 146,000,000 euros to 1241 participants of African research projects. Examples include drought and water scarcity, food security, health, flooding, and ecosystems based adaptation such as desertification, deforestation, coastal erosion, coral bleaching and freshwater scarcity. Mitigation and carbon sequestration receives significant funding attention as has the need to establish institutional capacity to support existing researchers. The report mentions AFRICAN CLIMATE as a web-based knowledge exchange platform; the need for accurate identification of equipment required, more training, localised case studies and students/researchers under CLUVA.

## CLIMATE CHANGE RISKS AND IMPLIED OBLIGATIONS FOR SOUTH AFRICA

International climate change action could assist South African priorities under the IPCC 1.5 degree Celsius and other objectives of the 2016 Paris Agreement (1 November), the implementation of the UNFCCC and UN Sustainable Development Goals. Aside from AIMS, the National Development Plan and SIPS projects, the proposed review for South African ports, logistics supply chains and coastal communities/resources could aid the DEA under its recently implemented Climate Change Bill and various Department Strategic Plans. It would support the National Climate Change Response White Paper and SA’s Second/Third National Climate Change Reports under the UNFCCC framework. Specific legal obligations include the requirement for an updated greenhouse gas inventory for emissions, reduction of emissions through carbon sinks and reservoirs; promote and cooperate in education, training and public awareness. The report could establish these for road, rail, air and maritime transportation with effective policy recommendations and designs to minimise externality costs. Promoting sustainable transport aligns to the 2018 National Climate Change Bill, towards a low carbon economy, climateproofed against uncertainty according to the Precautionary Principle. The bill aims to minimise and stablise emissions in all sectorrs including transport. However, it currently lacks sufficient related risk/impact information. The Minister is mandated to determine seectoral emissions reduction targets every 5 years. Carbon budgets are also expected. The current existing absence of specific adaptation strategies inhibits the capacity of the bill to minimise risks and benefit from green economy opportunities, envisioned. A detailed sector assessment will further aid the obligations of country wide mayors and municipalities to produce and enact climate change risks, vulnerabilities, impacta, needs and response strategies.

South Africa’s national climate change response strategy (UNFCCC 2004) requires integrating and prioritising climate change in all affairs. This involves stakeholder information sharing, communication and cooperation, facilitating public awareness, education, research and training. It aims to augment institutional capacity building by determining direct and indirect costs of risk events, mitigation, adaptation, inaction and maladaptation. Under the Initial National Communication to the UNFCCC in 2000, South Africa detailed its efforts at stabilising emissions, producing a national inventory of gasses, impacts, mitigation and adaptation solutions. Emissions increased from 347,346 Gg CO2 equivalents to 379,842 Gg CO2 in 1994. Although not specifically highlighted in the inventory methodology and statistics, transport formed part of the 8.9% emissions allocated to industry in 1990 and 8% in 1994.Road transportation contributed to more than half of the transport sector emissions, which increased by about 36% between 1990 and 1994. Transport emissions increased from 30,941.18 to 42,716.69 CO2 (1990-1994). CH4 increased from 8.63 to 10.58. N2O increased from 1.36 to 1.88. Vehicle emissions are increasing from increasing power and size of vehicles, fleet size, mileage per capita, decreasing car occupancy, higher traffic congestion and poor law enforcement. This reflected a government change in priority from formerly favouring state-owned railways (Former SA Harbours and Railways Corporation now Transnet), to supporting truck logistics companies. Aviation emissions expanded with globalisation and ending of apartheid. International shipping emissions expanded whilst localised companies declined. Former domestically flagged vessels registered abroad as South Africa uniquely didn’t pursue cabotage among the top 50 global trading economies.

The White Paper on National Transport Policy similarly targeted the need for sustainable transport, principally through public transit and mitigation of emissions. It considered implementing a fuel tax would attain multiple benefits. Imposition of a fuel tax would achieve a total reduction of 45,498 Gg. Improved fuel efficiencies are estimated to reduce emissions by 143,426 Gg. Fuel switching could reduce emissions by 148,225 Gg; travel demand management could reduce emissions by 33 854 Gg. Mode switching to public transport could reduce emissions by 42,856 Gg. No subsequent assessment of the tax has been conducted to determine if these targets have been achieved or surpassed. Transport usage increased from 5,200,153 to 5 850,565 in 1998. Cars are less technologically efficient with average age increasing from 7.4 years in 1982 to 12.5 years by 2000 according to the reports. In 1999, SA ports handled over 139,262 tonnes of cargo. However, as with the 1998 Moving SA forward project; this ignored detailed national, regional and local implications of climate change for the South African logistics sector and how to respond.

Earthlife Africa and Oxfam International (2009) re-emphasise the current focus on climate change, energy and mitigation of emissions primarily via the Clean Development Mechanism and Carbon Disclosure Projects. These are emphasised as essential to ensure pro-active risk management -that pre-empts impact consequences by slowing the rate at which climate change is forecast to occur. It projects higher rainfall in eastern South Africa and drier in the west, reduced frost and mosquito migration to the Highveld. It re-iterates public transport investments. The Second DEA National Communication under the UNFCCC’s Article 12, produced a national gas inventory for the year 2000. Overall C02 emissions increased to 461,000,000 tonnes. Emissions from industrial processes (including transport) decreased to 7% and the waste sector 43%, reflecting South African deindustrialisation policies. However, transport specifically increased by 25%. *C02* produced 79% of emissions, CH4 16% and N20 5% with others >1%. Electric vehicles, rail substitution and enhanced technological efficiency were solutions. The report provided more detailed risk projections including coastal regional temperature increases of 1-2 degrees by 2030 but interior temperature increases of 2-3 degrees reaching up to 3-4 degrees in coastal areas and 6-7 degrees by 2100. Winter rainfall will decrease whilst summer rainfall may possibly increase. West coast sea level rise was increasing by 1.87 mm per year, south coast by 1.47 mm and east by 2.74 mm. Other Southern Africa climate trends include up to 0.4° temperature increase per year and 0.013 mm per year average rainfall decrease. Subtropical anticyclones are experiencing a poleward drift (Jury 2013). Rossouw et al. 2012, Ocean highlighted during 1985-2007, the Agulhas Current warmed 1.5 degrees. The report emphasised the need for effective localised information, poor planning, market access barriers and few climate change related social platforms for public awareness and interaction. Enhanced communication, monitoring networks to provide early warning and techniques are considered imperative. Funding and skilled human resources limit technology-based solutions to climate change, although South Africa possess greater capacity than other African nations. 125 Clean Development Mechanism projects were submitted. The report over-emphasises renewable energy and energy efficiency rather than fully acknowledging the extent of transport emissions and need for sectoral actions for adaptation. Examples include carbon capture, transport and storage technology.

The Department of Science and Technology illuminates the challenges of preparing for climate change uncertainty and how to change for divergent processes and challenges emerging. Yet more attention needs to simplistically convey how local communities and municipalities with scarce resources can pragmatically implement mitigation, adaptation and ecological rehabilitation. Whilst the current Climate Change Bill calls for each municipality to draft its own adaptation strategy and agenda/carbon budget this realistically is beyond their institutional capacity. Only 6% of municipalities received clear, sound financial audits. This would impose significant burdens in having to recruit additional staff or otherwise employ consultants. This does not value add as many policy recommendations, risks and impact costs are likely to be similar. Municipalities with limited resources (i.e. Ermelo and Nkandla,) would benefit least as they would waste money deploying consultants, many of whom frequently engage in desktop studies. No monitoring and evaluation, post-feasibility studies exist for current climate financed projects either. Furthermore, local municipalities are not empowered to specifically prioritise climate change, enact or adapt related policies. Under the current Constitution, environmental affairs relate to national and province. To specifically address climate change affairs would require a constitutional amendment, specifying the rights and obligations of each sector of government, private sector, parastatals, traditional leaders, communities and individuals. In response, this review mentions many municipalities would be better served by general targets to reduce emissions, climateproof risks into local designs, restore ecosystems etc, nationally, provincially and the 8-9 major metropolitan areas. They could then have more training, resources and funding to help them to be aware of and respond to climate change risks. This extends to climateproofing the transport sector. A specific set of case studies established by this review’s suggestion of a full study into climate change research for ports, logistics supply chains, coastal resources, communities and ecosystems; would provide many generic/specific suggestions, which do not need to be replicated for each individual community. This applies to each LTMS strategy and report. The business sector also needs to focus on their own research and collaborate in information, financing and preparation.

The 2005 Midrand Plan of Action details many specific intentions to implement climate change research and other priorities under its National Adaptation Plan but no monitoring and evaluation assessment was conducted as with many published plans. It ignores specific sectorial impact consequences to determine the extent of vulnerability and possible capacity to adapt or constraints to adaptation. The DEA 2000 Second National Communication also focuses on significant risks to species migration (72% reducing range, 25% expanding) and biodiversity (vegetation changes/extinctions) especially Fynbos. 97% of Kruger Park bird species would face habitat threats. Between 2000-2009, floods caused 140 deaths and R4,700,000,000 damage. Wildfires killed 34 and R1,750,000,000 in damage. Storms killed 6 and created R395,000,000 of damage. Droughts caused R1,150,000,000 and with other risk events are projected to increase in frequency, duration and intensity. CSIR indicated climate change adaptation funding increased from $47,452.5 million in 2010 to $274,175.3 million in 2015. USAID (2016) estimated various IPCC scenarios for South Africa, reaching 0.37-1.66° Celsius by 2030 under a medium scenario. Under 2050, this increases between 0.86-2.4°. 43% lower rainfall by 2050 is projected under a business as usual, high emissions growth scenario. High drought risks exist, particularly around the southwest/Cape. It estimates up to 0.4 metres sea level rise by 2030. Britz et al. (2011) mentions further loss in the Southern Ocean’s carbon sink ability to mitigate emissions through absorption. Geo-engineering through iron filing and other technological methods are too uncertain and unpredictable in experiments to rely upon.

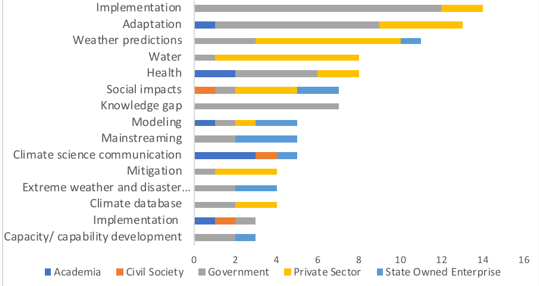
South Africa’s Third National Communication in 2011 revealed emissions increasing to 539,112 Gg’s. Industry decreased to 6.9% of the total. Energy contributed 79.6% and waste 4.1%. C02 expanded to 454,921 or 83.7% of emissions. CH4 emissions increased to 2,399. N20 decreased 86.6 Gg’s (5.5% frrom 2000). 10.7% of total emissions were from transport. The succession of reports continue to ignore the implications of climate change for infrastructure, transport services and suppply chain stakeholders. It emphasises other areas, many of which have subsequently formed LTAS Scenarios and DEA reports. However, research is increasingly focussing on the potential of climate change and the green economy to assist in radical economic and social transformation, poverty eradication and sustainable development goals. Each province has produced its own climate change response strategy or green economy plan. Examples include the Gauteng Climate Change Response Strategy, KZN Progress Report on Climate Change Activitie/Developing a Strategy for a Green Economy in KwaZulu Natal, Limpopo Green Economy Plan and Western Climate Change Response Strategy. Green Strategic Programme for Gauteng, 2011. It includes: The 2012 Eastern Cape Sustainable Energy Strategy, Renewable Energy Strategy for the North-West Province, – Western Cape, 2012, “Green is Smart”, Free State Green Economy Strategy, 2014 and 2016 Mpumalanga Draft Green Economy Sector Plan.

This aims to develop the knowledge economy plus activities in renewable energy, waste reduction, water and ecological conservation, tourism and sustainable transport. However, only the Limpopo specifically indicates sustainable transport and infrastructure as a regional priority. The majority of the nation’s 8 metropolitans, 44 district municipalities and 226 local municipalities have yet to implement their obligations under their provincial green economy plans or the 2018 Climate Change Bill. The same report emphasised the vulnerability of South African coastal city assets and population from only 1.26% within a 20 metre contour line in East London to 27.59% in Cape Town and 43.25% of the population in Saldanha. It summarised a few protective flood adaptation measures but not specific cost estimates. Essential ecosystem services such as mangroves and estuaries woluld be severely affected from disturbed sediment, mouth closures and fisheries loss, influencing ports and dependent transport.

Related research is primarily mitigation orientated focusing on transport emissions (Cohen 2011). In growing concern to emissions and climate change several South African corporations are voluntarily disclosing their carbon footprints and environmental sustainability efforts, joining the global CDP initiative. The 2017 report evaluates company transparency and changes in performance as indications of how sincere firms are in their commitments to the Paris Agreement. However, these reports are brief and lack specific indicators as to how these targets are reached i.e. not providing individual mitigation strategies such as transport. These completely ignore the need for adaptation, sustainable funding, training, access to climate information and other hurdles. Transport measures recommended in the source are limited to enhanced fuel efficient, electric or hybrid vehicles, intermodal transport shifts, zoning and planning and biofuels. The report especially emphasises the major risks to climate change as risks to resources, to infrastructure and physical assets; to health and safety of people and to operations. Several company individual examples are provided such as Oceana and Woolworths. The report mentions converting climate change into long term, commercially viable opportunities in the green and blue economies. Stakeholder communication, cooperation and information sharing is extending towards carbon disclosure and generic risks for business, influencing future preparation for events. Under infrastructure, the source confines itself merely to improved energy devices, lighting, recycling and green building design standards. There remains a need for both autonomous and planned adaptation. The report recommends the vital need to motivate commercial reasons for businesses to respond to climate change; for sector coordination plus availability of locally relevant climate change data and tools.

The future of South Africa’s climate change research agenda is currently being evaluated by the Department of Environmental Affairs (Hunter 2018). This includes motivating the next stages of the Long Term Adaptation Scenarios. This review further elucidates the significant contributions made by logistics to the South African, African and global economies and increasing interdependence of people on commercial activities, the resources, networks and infrastructure which support them. For example, the report indicates insufficient adaptation funding in the Western Cape could shrink employment by 10% and provincial GDP by 17% by 2040, if not climateproofed. Local GDP could increase by over 15%, employment by 12% and trade 6.4%. Despite its pivotal significance, transport and infrastructure did not form one of the top 15 indicative climate adaptation knowledge needs by an online survey of stakeholders. The source highlighted current source locations of climate data and sector models but nothing relating to this review’s core focus, as Table 2 illuminates. A fundamental research gap is that stakeholders lack awareness of personalised impact costs, adaptation or opportunity costs or how investments and decisions might be personally affected. This review will further contribute towards understanding the direct and indirect implications of climate change beyond just transport/logistics but across the economy in an integrated risk-vulnerability, impact cost analysis and adaptation strategy approach. This could potentially extend across a supply chain from producer or point of origin to final point of consumption/reuse. The report further indicated the pressing urgency and need for South African and private sector, specific adaptation options. This includes translating existing research into a commercial perspective to encourage proactive behaviour as a paradigm shift towards ensuring a business as usual, IPCC scenario future. Conventional academia is critiqued in not performing to business timeframes and constrained resources.

Figure I: Top Fifteen Climate Change Adaptation Research Priorities in South Africa.



Source: Hunter 2018:

Table II: Climate Change Data Strengths and Research Gaps

|  |  |  |
| --- | --- | --- |
| **Infrastructure** | * Knowledge about general climate risks available * Some national entities such as ESKOM have undertaken specific studies | * Location specific risks not known * Vulnerability of major forthcoming investments (e.g. SIPS) generally not known. |
| **Integration/ Interactions** | * General awareness of importance of interactions, such as Food, Energy, Water | * Very few detailed studies |
| **Social and economic impacts** | * National scale study on economic impacts using general equilibrium model * Western Cape Government * SA Vulnerability Atlas * Disaster management vulnerability data | * Impacts on labour, inequality, etc… |

Source: Hunter 2018:

## CLIMATE CHANGE IMPACTS ON THE SOUTH AFRICAN ECONOMY

Concentrating on South African logistics supply chains will assist the Department of Environmental Affairs, researchers, individuals, businesses, communities and other stakeholders to obtain a far more accurate perspective of climate change for the South African economy. Globally, research is focussing more on sustainable development, environmental sustainability and the green economy. Climate change mitigation and adaptation remains synonymous with minimising adverse environmental consequences. This it correlates to facilitating green economy opportunities. In 2017, South Africa produced a green economy inventory (DEA 2017). It primarily identifies bus rapid transit, rail and non-motorised transport opportunities with support to small and medium enterprises, improved energy efficiency plus green building design. Of 64 planned initiatives, 23 were in planning, 12 in non-motorised transport, 10 fuel efficiency and emissions, 8 alternative fuels, 3 in roads, 3 taxis, 3 car share and 2 in freight. The report mentions few only 16% indicated specific job benefits, all of which were casual rather than proven on a longer term basis. 13 were in Gauteng, Western Cape 6 and other provinces 0-3. Examples include the Iyeza Bicycle Courier Service for Western Cape medical deliveries. The Department of Transport funded only 8 whilst the private sector undertook few sectoral initiatives. Financing ranged from R100,000 to R17 billion. Common market failures preventing financing of green or climateproofed logistics solutions include the following constraints to adaptation summarised in Table III. The report’s main concern emphasised how few overall transport projects were funded, given the potential demand and proclaimed green economy opportunities. Additionally, many potential projects were not specifically linked and motivated for inclusion into the South African green economy. This literature review also critically notes that none of these green economy projects have proven themselves to be sustainable when factoring in climate risk projections and impact costs.

Table III: Constraints to Climate Change Adaptation for South African Logistics Supply Chains

|  |  |
| --- | --- |
| * **Land/Geophysical** | * **Environmental** |
| * **Information** | * **Political** |
| * **Communication** | * **Administrative** |
| * **Labour** | * **Technical/Technological** |
| * **Capital** | * **Lack of Coordination** |
| * **Financial/Funding** | * **Lack of Cooperation** |
| * **Commercial: Profits** | * **Education/Training** |
| * + **Fixed costs** | * **Planning/zoning** |
| * + **Variable costs** | * **Transport** |
| * **Demand/Supply** | * **Uncertainty of Climate Change** |
| * **Enforcement Capacity, Legal and Policy** | * **Other** |
| * **High risk perceptions from technological/other uncertainty** | * **Policy risks -lacking clear, long term obligations and commitments** |
| * **Enforcement** | * **Equity -ensuring risk exposed pays** |

Numerous methods exist to evaluate climate change risks, impact costs and adaptation strategies. A subsequent review of the South African logistics economy could ascertain the advantages and disadvantages of various qualitative, simulation and quantitative methodologies. None have previously been recommended individually for South Africa or Africa. Other methods would need to be modified i.e. robust decision-making for climate change implications for coastal infrastructure (Daron 2016). The method requires determining objectives and strategy then management options, coping capacities and vulnerabilities against scientific risk projections. Strategy performance is ascertained under uncertainty, considering alternative strategies and payoffs or opportunity costs of decisions before acting. However, the source remains biased towards coastal engineering solutions such as rock revetments, groynes, beach nourishment and sea walls. In contrast one climate change study on urban road transport (Friedrich and Timol 2011), performed a simulated model of network analysis for traffic volume changes, travel time plus volume to capacity ratio. It provides an Ethekwini Municipality case study in response to sea level rise modelled as 0.5-0.9 metres initially up to 2.8 metres. Multiple criteria decision analysis identified 5 km2 in Isipingo, 4 in the Bayhead Area and 20 kilometres inland of the Umgeni River Mouth. Climate change was illustrated as presenting major congestion, inefficiency and opportunity costs for certain flooded transport routes. Recommendations include allowing more case studies to compare consistency and statistical validity, ensuring the model remains dynamic rather than static as risks change and factoring more risk types such as extreme temperature or precipitation.

Monitoring and evaluation of projects determining their potential successes and failures, with the intention of learning from experience to eliminate forthcoming vulnerabilities, is seldom mentioned. This would enable the South African economy to become more climateproofed against disruption. The implications of climate change’s capability to dramatically alter local cities’ transport sectors is starting to be recognised (South African Cities Network 2014). Implications for risk and vulnerability along with municipal capacity to conduct service delivery, were analysed with the intention of striving towards more resilient cities. Ekurhuleni and Bloemfontein are not considered climate resilient or prepared. Johannesburg has isolated climate change policies but lacks a consolidated, systematic approach. This review recommends existing climate change research agendas remain subordinate to existing Integrated Development Plans. It advises power/responsibility for implementation devolves to technocrat experts in other fields i.e. health, engineering, transport, town planning, environment, disaster risk management etc, at levels below national, province and metropolitans, (which lack specific climate change capacity or the ability to afford expensive consultants). South African Cities Network (2014) concludes to ensure more climate resilient local economies. This includes forecasting abilities and systems to identify risks; assessing implications for service delivery; devising contingency plans; staff capacity; a register of extreme events, impacts and responses and strategic partnerships with other various stakeholders. The South African Department of Environmental Affairs (2017) concludes sustainable transport operating on short, punctual, efficient transport minimises emissions and is climate-resilient, lessening impact costs. It proposes developing more intermodal transport substitutions and contingency plans. This extends to hydrogen fuel cells and renewable energy, particularly for public transport. This aims to condense delays, diversions, disruption and failures of ecosystems, transport, economies and humans.

Converting existing research into verified examples that can be implemented, remains a priority of future climate change scholarship, as the agenda affirmed. This especially applies to logistics supply chains, requiring business orientated approaches, especially in understanding practical implications for business plans, decisions, finance and risk management. As previously indicated, companies need more than merely the current academic focus on producing transport sector, emissions inventories. Cohen (2011) focuses only on emissions. For example, a 2009 inventory (Tongwane 2009) calculated it for civil aviation, fuel, bunkerage, road and rail. Road emissions increased from 54% in 1994 to over 90% by 2000. The source cites South Africa in the top ten for tons of carbon emitted per unit of GDP annually. In 1995 its emissions intensity ranked 240 times above the world average. It ranked 189 times the global average of emissions per capita of 1.07 tons. From 2000-2009, truck emissions increased by 53.85%, (25.09% for light duty vehicles), 59.18 from buses, 12.44% minibuses and 12.69% for cars. South Africa has therefore failed in its frequent obligations to reduce the rate of climate change growth, both locally and internationally. This further echoes the need to concentrate on adaptation not just mitigation. Rutherford et al. (1999) focus only on climate change vulnerability and adaptation for ecosystem biodiversity, threatened to condense to between 38-55% of its current expanse by 2030. Kiker (2000) echoes the research gap by only selecting climate scenario impacts for water resources, aggriculture, forestry, rangelands, human health, terrestrial and marine biodiversity. To avoid the risks of maladaptation and wasting of scarce resources; it particularly cautions the need to assess each adaptation measure for irreversable and catastrophic consequences of climate change, addressing opportunities or averting unfavourable trends. Whether for transport or other sectors, it enquires as to whether it preserves stakeholder requirements, is effective or enhance institutional capacity. Does it address social, cultural, market, legal and institutional barriers?

Letete, Guma and Marquard (2009) propose several mitigation strategies summarised in Table IV. South Africa has yet to calculate equivalent adaptation costs or effectively implement many of the previous sources’ research recommendations. Yet the South African Department of Environmental Affairs, (2015) suggests high economic costs to adaptation. Future attention needs to determine the most critical and vulnerable infrastructure, ecosystems and processes. High variability in projected resilience, exposure and impacts exists across many sectors. Figures II-IV highlights the composition, location and costs of South Africa’s 607,983 kilometres of roads. The report emphasises biophysical impacts on roads, with major costs for maintenance and rehabilitation. Median annual repair costs are estimated at an extra R19 billion a year under a no adaptation scenario by 2100, versus only R6 billion for adaptation. The Eastern Cape will endure the most, due to the highest concentration of roads, Gauteng has the fewest. The report ignores implications for rail, airports, inland ports and seaports, despite over 70% of SADCC trade dependent on the port of Durban. It primarily creates integrated models for agriculture, water supply and hydropower under various temperature, precipitation and evaporation impact scenarios if emissions stabilised or if growth continued as expected. This further ignores sea level rise and other urgent risk sources. The same report evaluates projected economic impacts for GDP, inequality, regions, growth, employment and activity. It concludes a minimum net present value of R930 billion by 2050 (over 35% of 2007 GDP) if emissions are not abated. More detailed regional and sector-specific modelling is urgently advised plus more effective capacity and upscaling localised solutions. The source also counsels the need for updating current design standards or considering additional disruption costs due to possible failure or reduced performance/capacity.

Table IV: Proposed South African Mitigation Strategies

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Mitigation Action** | **Model description and parameters** | **GHG emission reduction 2003-2050** | | **Mitigation cost** | **Rank cost -lowest cost is no 1** |
| **Escalating CO2 tax** | Impose tax on all energy related CO2 emissions including process emissions from Sasol plants | | 12,287 | 42 | 20 |
| **Nuclear and renewable energy extended** | Combines both scenarios. At 50% each = 0 carbon scenario | | 8,297 | 52 | 23 |
| **Electric vehicles/nuclear** | Up to 10% of passenger kilometre demand 2003-2050 | | 6,255 | 102 | 28 |
| **Nuclear/renewables** | No electricity from fossil fuels 2050 | | 5,559 | 64 | 24 |
| **Industrial efficiency** | Improved boiler efficiency, HVAC, refrigeration, water heating, aircon… | | 4,752 | 34 | 8 |
| **Renewables/learning** | As with extended but assuming renewable energy unit costs decline as global installed capacity increases | | 3,990 | 3 | 13 |
| **Subsidy for renewables** | On electricity from power tower/off-grid, | | 3,887, | 125 | 30 |
| **Improved vehicle efficiency** | Improve private cars and light commercial vehicles by 0.9-1.2% per year | | 758 | 269 | 3 |
| **Biofuel subsidy** | R1.06 per litre as incentive | | 573 | 697 | 35 |
| **Passenger modal shift** | From cars to public transport, from air to inter-city rail from 51.8% of passenger km to 75% by 2050 | | 469 | 1,131 | 2 |
| **Hybrids** | 20% of cars by 2030 -0 in 2001 | | 381 | 1,987 | 36 |
| **Biofuels** | Biofuel blends increased to 8%, ethanol with petrol and 2% biodiesel with diesel 2013 -to 20% and 5% 2030 | |  |  |  |
| **Land use, fire control** | 50% reduction in savannah fires from 2004. Discourage smoking | | 455 | 15 | 10 |

Source: DEA 2015.

Figure II: South Africa’s Road Network in Kilometres by Road Type.

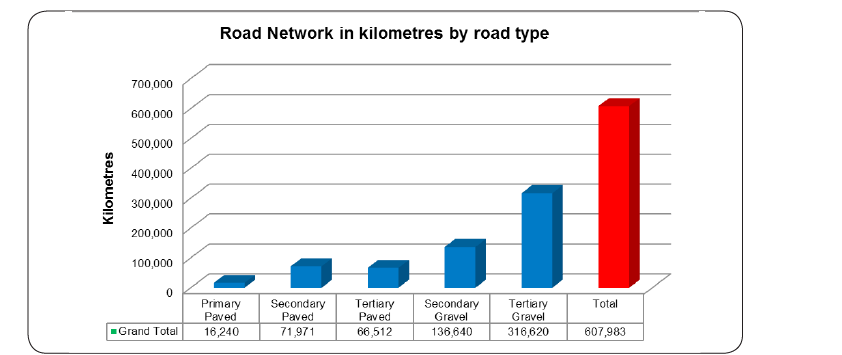
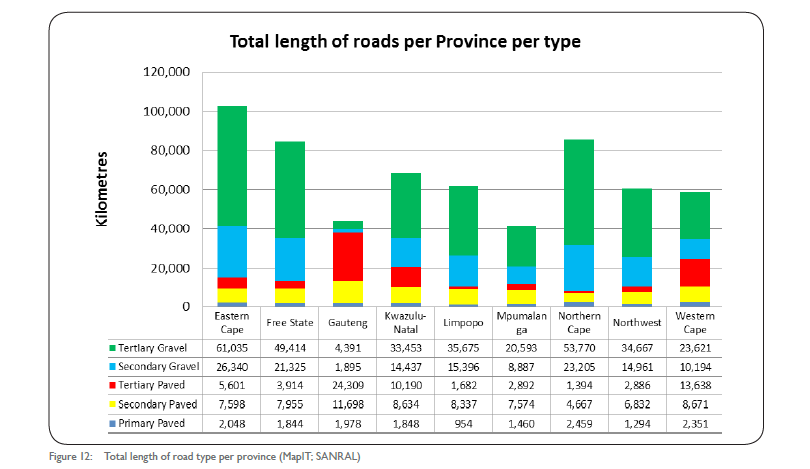
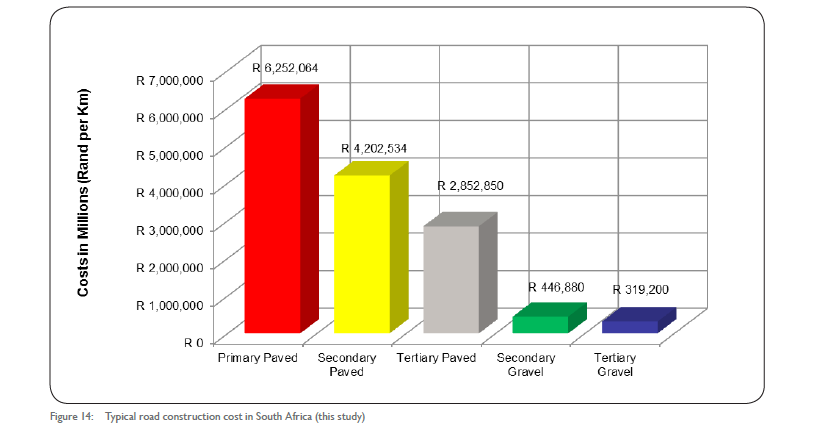


Figure III: Total Length of Roads Per Province Per Type



Source: DEA 2015

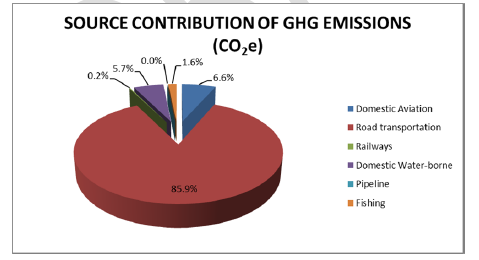


Source: DEA 2015.

Other sources provide similar variations on climate mitigation policies. WWF (2016) focus on passenger transport to convert demand into public transport, lower carbon and more efficient alternatives. It provides examples of planning, regulatory, information, economic and technological instruments. This includes discouraging suburbs with land use densification, bus rapid transit, reduction in vehicle weight, flexible work hours, combustion engine efficiency, providing biofuels, electric, solar, hydrogen and hybrid vehicles. It includes reversable lanes and road reallocation. Planning measures include benchmarking, green procurement and traffic impact assessments. Regulatory instruments include parking restrictions, providing high occupancy lanes, speed restrictions and traffic diversions. Economic measures include congestion charging, fuel taxes and fuel-efficient vehicle incentives. Information measures include increased public and driver awareness, training and vehicle labelling initiatives.

South Africa’s currently drafted Road Policy (South Africa Department of Transport 2017), refers to environmental sustainability as a core pillar. However, it and the National Disaster Management Act fails to explicitly mention or formally incorporate climate change and related climateproofing against future projected risk as mandatory. Yet this would assist the stated mandate to protect public investment, promote traffic safety and support sustainable socio-economic objectives for all transport forms. Nor are emissions reporting and controls mandatory, despite a significant contribution to global and local climate change. Conversely however, the Department of Transport has developed a Green Transport Strategy 2016-2021. The role of transport is explicitly stated as crucial in assisting South Africa to achieve its Paris Agreement objectives of 34% emissions reduction by 2020 and 42% by 2025. From 2000 to 2010, road transport created 85.9% of sector emissions (Figure V). Resolving the existing research gap for transport, business, logistics supply chains and coastal resources/communities will facilitate its prime responsibility of a more climate resilient and low carbon economy. It can create specific interventions and case studies, to channel scarce resources more optimally. This strengthens capacity building. Environmentally sustainable logistics further upholds South Africa’s constitutional obligations to preserving the environment for individuals (Section 24) and the 2011 National Development Plan. This further supported in the 2011 White Paper on National Climate Change Response Strategy.

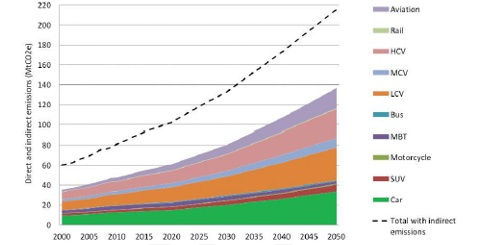
Figure IV: South Africa Transport Sector Emission Sources 2000-2010



Source: Department of Transport 2016

Several core policies focus only on environmental sustainability/sustainable development, specifically needing revision to incorporate climate change as the most fundamental and uncertain, emerging risk. Examples include the 1996 White Paper on National Transport, the 2015 National Rail Policy Green Paper, 2013 Non-Motorised Transport Policy, 2011-2014, National Strategy for Sustainable Development and Action Plan and others relating to Cabotage, Shipping, Ports, Pipelines and Civil Aviation. Others include the SIP 2 Projects, Operation Phakisa, 2005 National Freight Logistics Strategy and 1998 National Environment Management Act. The 2015 EIA Regulations, Industrial Policy Action Plans, MPFMA/PFMA and 2013 SPLUMA Acts, further ignore climate change. Future transport sector emission trends forecast in Figure VI, targeting 8% reduction in transport emissions by 2050 yet not clearly demarcating how systematic change will be accelerated. An additional 7.7% of emissions is attributable to fuel refineries and SASOL. Yet many of the recommendations remain confined to mitigation and not enforced including solar powered locomotives, electric vehicles and state access to natural gas/biogas. Solutions primarily focus on public transport, supporting minibus taxis, recycling, switching fuels/fuel standards, integrated urban transport planning, behavioural change and economic incentives. The report also highlighted the vulnerability of road infrastructure with 78% of national networks exceeding its 30 year average design life but was conspicuously silent on ports, bridges, rail and core infrastructure/systems. No risk/cost estimates are provided to assess the validity of this option versus alternatives. Nor does the rail strategy allude to training, maintenance, operational risk, change of business, access to resources or other factors potentially influenced by climate change. George Airport remains the only airport to be partially powered by solar energy, whilst shipping is completely ignored.

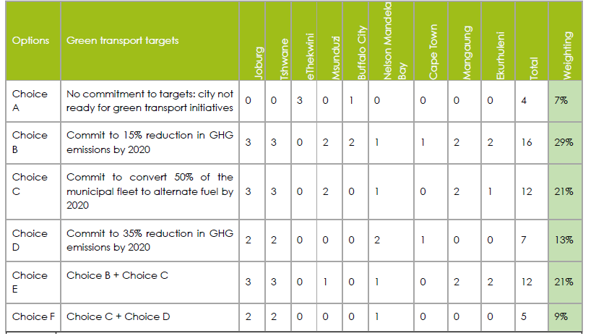
Figure V: Future Transport Sector Greenhouse Gas Forecast Growth.



Source: Department of Transport 2016.

The South African Institute of International Affairs further confirms the need to understand localised economic impacts and distributional effects for climate change (SAIIA 2009). Global inaction could exceed $5 trillion by 2050 based on the Stern Review. Suleman et. al. (2015) further advocate solutions via a South African Cities Green Transport Programmes. Municipalities are conducting 64 projects summarised under Table V Its ‘Well to Wheels’ concept proposes measuring all emissions associated with the production, distribution and consumption of transport fuels and electricity. ‘Pump to Wheels’ focuses only on emissions deriving from vehicle operations. This endorses driver training, electric/hybrid vehicle and biogas technologies, biofuels and vehicle maintenance. Prime challenges include technological/political uncertainty, high fixed costs in existing infrastructure, lack of public awareness and regulations. It however confines its business proposals to benefitting only municipal bus fleets and minibus taxis. These have yet to be endorsed by the private sector. Johannesburg Municipality estimated sufficient biomethane existed to supply 700,000 litres of diesel every year. The report was concerned about vehicle tests only one at a time whether for a solar zoo golf cart or biogas-diesel truck, complicating the need for consistent comparisons over an extended time period. A National Electric Vehicle Technology Innovation Programme was formed by the Department of Trade and Industry, Technology Innovative Agency in 2013. Assessing the costs of various vehicle options in Table V suggests that, whilst Diesel may have the lowest nominal local vehicle price to retailers and consumers (R2,3,72,000 average), biogas is the lowest eco-efficient choice in total cost R3,968,000, compared to alternatives. The source advises a Working Group to be established with sufficient technical and financial support to implement technologies.

Table V: South African Cities Green Transport Targets



Source: Department of Transport 2016.

Table VI Cost of Eco-Fuel Technologies Versus Diesel in South Africa

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rands (100’s) including VAT** | **Diesel Baseline** | **Ethanol** | **Compressed Natural Gas** | **Compressed Biogas** | **Electric Battery** |
| **Lifecycle Financed Vehicle Cost** | 2,372 | 2,609 | 2,965 | 2,965 | 4,744 |
| **Lifecycle Fuel Cost** | 2,970 | 3,267 | 4,010 | 4,010 | 5,941 |
| **Fuel Price (R/DLE)** | 1,612 | 13,10 | 1,149 | 1,011 | 345 |
| **Unit Price (R/litre/ms/kwh** | 12.59 | 8 | 7.52 | 6.62 | N/A |
| **Lifecycle Maintenance Cost** | 296 | 403 | 7.76 | 6.83 | 0.79 |
| **Total (Nominal lifecycle cost)** | 4,878 | 6,272 | 507 | 507 | 202 |
| **Total Discounted Cash Flow** | 3,489 | 4,481 | 5,666 | 3,968 | 6,488 |

Source: South African Department of Transport 2016

Transnet mention adherence to a Climate Change Framework of the Department of Public Enterprises. However, they failed to provide specific operational, maintenance, training, capital reserves or other preparations affirming their infrastructure and own capacity to resist climate related risks (Transnet 2014). The framework lacks specific policies, procedures or case studies. It focuses primarily on emissions reduction and mitigation. Its aim proclaims “*To optimise the impact of state owned companies on reducing greenhouse gas emissions and develop the green economy without compromising financial viability”.* This includes exploiting climate incentives, innovation and specific connections to planning, operating and procuring. Transnet’s proclaimed Port Development Plans are favouring intermodal transport shift to rail and electric locomotives. Rail produces an average of only 3,038.4 emissions, saving 9,147.58 tons (75.04%) of gas emissions, despite travelling for 720 kilometres not 566 by road. Transnet also produced trial experiments with biofuels, natural gas and fuel cells for locomotives and wagon covers

Whilst climate change implications for South African transport remain concentrated overwhelmingly on emissions and mitigation; an increasing number of municipalities are integrating this sector into generic climate change response strategies. Taylor, Cartwright and Sutherland (2014) investigate Durban, Cape Town and Theewaterskloof. Leadership, knowledge and practical exchange experience are regarded as pivotal for all policies to succeed. Cape Town and Durban have energy efficiency, clean development mechanism, greenhouse gas inventories and other climate change programmes since 2003. These include localised climate change projections for coastal ecosystems, assets and people under various sea level rise/storm surge scenarios. Adaptation options are also proposed including Climate Smart Communities for public awareness and ecosystem-based adaptation. The ports, airports and logistics hubs and their stakeholders remain conspicuously absent. Durban has created a Climate Protection Branch, Summit and Partnership to encourage mutual awareness and support from communities and investors. Its Climate Change Strategy (eThekwini Municipality, 2014) precisely observes increasing shoreline erosion, sea level rise, storm events, wave heights and subtropical wind speeds. Higher bushfire risks exist as do heatwaves, accelerating road and ecosystem pressures. Existing natural capital is highly affected needing conservation. Dune restoration is advised. It details adapting infrastructure on a risk averse approach, integrated coastal management and engineering, retrofitting structures, relocating informal settlements and municipal facilities where highly exposed or damaged. Climate change also needs integrating into existing Environmental Impact Assessment regulations.

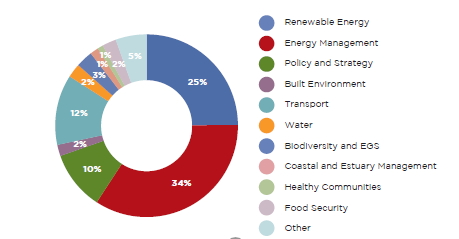
However, other municipalities and coastal areas incur a significant research gap without their equivalent climate change preparation and impact cost assessment. Aurecom have similarly undertaken a resilience policy framework for the West Coast District Municipality (Aurecom 2014) with the intentions of securing funding, preventing barriers and mainstreaming into planning, with information and cooperation. Individuals require climate change resilience. The Western Cape Province further alludes to the need for research that can be simply communicated and disseminated in Sustainable Transport and the Built Environment. This extended to updated climatic risk data and geographical information systems for hazard mapping. These especially pinpoint heatwaves, higher maximum temperatures, more extreme droughts, sea levels, floods and storm surge. Its recommendations echo others in calling for localised climate change risk assessments. This is endorsed in the recent Climate Change Bill under review. Whilst costs may differ, many share similar characteristics, distinguished primarily by degree of exposure and intensity. Aurecom (2014) fail to provide a detailed, localised model to enforce their recommendations. Potential impacts to roads are concisely noted including, changes in deterioration and maintenance, coastal erosion, possible damage, interrupted traffic and flooded roads. It also mentions general uncertainty for development planning, climateproofing or retrofitting infrastructure, potential damage plus increased insurance costs. Further recommendations included reviewing design standards and ecosystem-based adaptation, effects for infrastructure and regional economies.

Public climate change risk awareness has been the focus both of the recent Cape Town Adaptation Futures Conference and emerging popularist guides (i.e. Earthlife Africa and Oxfam International 2009; Bornors and Zipplies 2011). Those involved in the logistics and other sectors would benefit from a more incisive awareness of highly probable futures and the need to act. This would enable them to climateproof livelihoods, consumption, production and behaviour. Design standards also require revision as risks do not remain static but are fundamentally dynamic. This need for public awareness extends to not only individuals, businesses, investors, communities, urban planners, educators, parents and civil society organisations but usage of transport. This includes persuading people to change fuels, embrace vehicle technologies and face a carbon tax for the reluctant. Psychologically, many factors explain why people remain reluctant to prioritise climate change. The report specifically mentions prompting DTI incentives for low carbon economy alternatives and for getting business to favour greener public transport. The report specifically mentions:

* Finding an alternative to company car schemes and allowances;
* Maximizing persons per vehicle by purchasing a dedicated staff bus,
* Provide a space where employees can publicise travel times and routes for car sharing;
* Provide bicycle lock-ups, changing rooms and showers at work,
* Subsidise employees who use public transport instead of providing on-site parking;
* Enable certain employees to work from home occasionally;
* Prioritise video conferencing so business meetings can be held without employees flying long distances;
* Lobby for better public transport;
* Lobby for better freight rail transport.
* Stop offering air tickets as awards to high achievers
* Implementing a zoned road freight tax in urban areas/suburbs
* Retest all vehicles annually to ensure compliance to emissions standards
* Adding catalytic converters to all vehicles as mandatory.
* Providing hub and spoke rail/bus systems than line haul projects.
* Discourage urban sprawl.

Multiple benefits exist beyond climate change risk reduction for promoting green transport and a low carbon economy. Western Cape Government (2016) incorporates sustainable transport, biodiversity and ecosystem goods to aid knowledge management. Other strategic goals it serves including creating opportunities for sustainable growth and jobs; education outcomes and youth development; a resilient, sustainable, quality and inclusive living environment; increasing wellness, health safety and tackling social ills such as traffic congestions or accidents. Despite these benefits, transport only received 12% of total climate related aid in the Western Cape. (2011-2015) as in Figure VI. Specific identification of these funds available nationally, across provinces and municipalities against projected demand could be determined for future resources, prior to determining the most optimal allocation of expenditure. One recurrent theme across these sources reflects the challenges of securing funding and general support for mitigation and adaptation. Often the urgency and necessity of emergent risk minimisation are not emphasised. 29% of emissions across the province originate from transport (84% in the Karoo). Yet 6% of emissions could be abated via public transport, 3% from more efficient engines, 2% from fuel. The aim is 80% for more efficient diesel engines, 10% gas and 10% diesel hybrid by 2040 and 15% for rail. The prime focus of effective resilience remains ecosystem-based adaptation through integrated coastal management. However, this has yet to be specifically associated to ports, logistics infrastructure and transport systems, whether in the Western Cape or in South Africa. As Dyer (2018) identifies the global focus remains hard engineering, abstention, technology and technical design standards rather than retreat/surrender, accommodation, migration or ecological rehabilitation. Examples include seawalls, revetments, groynes, breakwaters, gabions and geotextile arrangements.

Figure VI: Western Cape Climate Change Funding 2011-2015:



Source: Western Cape Government 2016.

Operation Phakisa focuses on developing a local maritime or “blue” economy aiming for 1000,000 jobs by 2033. Although South Africa is investing over R250 billion in the SIP2 Gauteng-Durban logistics corridor, related port expansions plus R300 billion in rail; the implications of climateproofing or potential damage have not been factored into design estimates. Few case studies exist across Africa and locally. A fundamental research gap exists in determining projected risks, impact costs, constraints to adaptation or adaptation strategies for any of South Africa’s’ seaports, dry ports, inland ports, roads and railways. Transnet have indicated an initial willingness to engage in a climate change response dialogue for transport sector emissions. However, specific targets have yet to be established along with methods, policies and resources to reduce externality costs (Transnet 2014). Although freight rail modernization has received attention (Mathabatha 2015) as an overarching barricade to the future of logistics and the South African economy; it has yet to identify, let alone prioritise climate change as the most uncertain risk. Over 21,000 kilometres, (many of which pre-date 1910 Union) are exposed. Over 593,000 kilometres of road remain equally vulnerable. If risks are not incorporated, this threatens Transnet’s, PRASA’s, SANRAL and provincial transport investment. Van Rensburg (2015) argues the need for ‘green logistics”, favouring environmental sustainability, which could incorporate climate change with ecological economics.

Over 1500 bridges are threatened by flooding under climate change (30% of the South African total). Mathabatha’s thesis notes poor maintenance and transport environmental impacts of emissions and pollution but doesn’t affirm how climate change will progressively worsen existing issues costing over R200 billion per year in economy inefficiency costs. The green economy and climate change remain notably absent from its core recommendations. It estimated poor roads can add 9.97% increase in average company logistics costs plus 120.94% increase and repair costs when contrasted to a good (i.e. climateproofed road). Increased frequencies, durations and intensities of storms, landslides, cyclones, precipitation, heatwaves and other effects present increased maintenance and other expenses. If South Africa is to substantially reduce emissions, more attention and support needs to be devoted to substituting road for rail. Prioritising this research gap for South Africa’s national climate change agenda would assist Transnet’s Logistics Performance Index rating, cost efficiency and service provision effectiveness in reliability. Existing policies including the 1996 White Paper on National Transport Policy, the Constitution, 2007 Public Transport Strategy and 1996 SADC Protocol on Transport need updating to embody climate change as part of existing policies. This especially applies to the National Development Plan, 2009 National Land Transport Act, 2014 Infrastructure Development Act; 2015 National Land Transport Strategic Framework and local Integrated Development Plans. Stakeholders are more likely to comply with extensions of existing plans rather than seek to reconcile entirely new adaptation strategies given finite resources and possible conflicts of policies.

Existing South African climate change impact and adaptation research has primarily focused on the ecological and human rather than infrastructure, economy and physical systems. For example, Dallas and Rivers-Moore (2013) identify consequences for freshwater ecosystems including species, water quality and habitat. Dyer (2018) found current risk management, logistics supply chain and economic theory overwhelmingly ignore climate change risks to the ecosystem resources they depend upon, for supply chains to survive. Climate change was briefly mentioned as a risk in a UKZN Master’s thesis questioning whether Durban’s proposed port expansion was really necessary. (Dyer 2015. Various functions are collated in Table VII to reinforce this economically significant relationship. This review considers an integrated review linking ecosystems and logistics processes in South Africa then Africa, is essential; in order to measure true vulnerability and economic intersectoral interdependence to climate change disruption risks. This further solidifies the basis for an ecosystem-based adaptation approach towards these risks. Rossouw and Theron (2009) remain the sole and brief source to investigate climate change impacts on maritime operations in South Africa. It proposed the implications for 1:100 year design models with physical model tests of waves and structural stability. For example However, this ignores local climate change policies, IPCC scenarios and is obsolete. It also focuses predominately on waves and sea level rise It advised including up to 40-100% sediment transport rise, 26% wave height, 10% wind modelling for a breakwater. Specific risks highlighted include to navigation, mooring and port service processes along with additional idle capacity/downtime delays to supply chain processes. Local coastlines will also be adversely altered. Richard’s Bay is currently experiencing an erosion shortfall of 300,000-350,000 m3 a year. It gives the example of a breaching of natural sand spit breakwater Walvis Bay plus potential dredging impacts.

Table VII: Ecosystem Functions for South African Supply Chain/Economy Stakeholders

|  |  |
| --- | --- |
| **Ecological** | **Economic** |
| Biomass/Biodiversity Life Formation and Habitat | Life, Food, Material |
| Conservation | Supply of Natural Resources, Reduced Imports |
| Biological/Physical/Chemical | Redundancy against Uncertainty |
| Growth, Reproduction, | Trade, Production, Consumption, Income/Profit |
| Respiration/Oxygen/Photosynthesis | Greenhouse gas mitigation funding/ source sink |
| Water supply/purification. Food security/Nutrition | |
| Protection | Protection –Vulnerability and Resilience |
| Ocean Chemistry, currents, salinity | Risk Identification, Monitoring, Prioritisation, Adaptation |
| Coral atolls –geographical physical formation, continued growth and survival | Risk Enhancement if Ignored –Legal, Reputational, Insurance, Security, Operational, Impact Costs |
| Sand formation, nourishment and sediment | Opportunity |
| Evaporation, Condensation and Absorption | Insurance against Maladaptation, |
| Climate Regulation –calcification, stratification | Future Sustainability and Survival |
| Counter eutrophication | Knowledge –Existing and Potential/Spiritual |
| Detoxification | Stability/Security/ Increased Adaptive Capacity |
| Population equilibrium | Aesthetic/Cultural/Social |
|  | Tourism |

Source: Dyer 2018

The source further emphasises the need for long-term, time series data monitoring risk events, to determine trends and whether climate change presents an increasing risk. The entire coastline needs to be surveyed to encompass the extent of all hazards and status of resilience. The core challenge to resolve is to consider whether existing impacts of risk events are worsening due to climate change. Southern African states have limited adaptive capacity and ability to minimise impacts with sustainable solutions that are durable, low cost and minimise risk. It cautioned to develop setback lines for safety and provide coastal protection for properties. Rossouw and Theron also cited several UNCTAD adaptation measures summarised in Table VIII, which they recommended could be applied to the Southern African maritime transport sector. However, they have not provided particular locations where these measures have been ratified nor provided objective criteria with which to monitor and assess performance under business as usual, low carbon economy or other climate scenarios. Mojafi (2014) constitutes the sole climate change thesis related to South African ports. It prefers the cobweb model in which climate change directly impacts on the natural, operational, financial, economic and infrastructure processes of port environments. It proposes first establishing the port context and risk/vulnerability identification; then conducting risk analysis then analysing and evaluating risk consequences prior to determining solutions. Rather than developing specific, localised projections for South Africa’s eight ports, it succinctly notes generalised impacts of storms, ocean currents, heatwaves and rainfall can influence navigation and berthing, materials and handling, vehicles and movements, goods storage, transport and supply chains. Reputation and communication risks remain from any disruption occurring. Transnet’s own Sustainability Framework has only included climate change mitigation and adaptation specifically within the last 4 years as an environmental dividend (Transnet 2014).

Table VIII: Potential Impacts and Possible Adaptation Measures for Maritime Transport

|  |  |  |
| --- | --- | --- |
| **Climate Change Factor** | **Potential Implications** | **Adaptation Measure** |
| * Rising/high temperatures * Melting ice * Large variations (spatial and temporal * Frequent freeze-thaw cycles | * Shorter distance for Asia-Europe trade/less fuel consumption * Competition, lower passage tolls, reduced transport costs * Damage to infrastructure, equipment, cargo * Increased construction and maintenance costs, new ship design and strengthened hulls * Higher energy consumption in ports * Variation in demand for and supply of shipping/port services * Challenges to service reliability | * Heat resistant construction and materials * Continuous inspection, repair and maintenance * Monitoring of infrastructure temperatures * Reduced cargo loads, speeds and service frequency * Insulation and refrigeration * Modal shift * Transit management scheme/navigation * Ship design, skilled labour and training requirements |
| * Rising sea levels * Flooding and inundation * Erosion of coastal areas | * Damage to infrastructure, equipment, cargo * Increased erosion, sedimentation, construction and maintenance costs * Relocation and migration, labour shortage, shipyard closure * Variation in Demand/Supply ship services * Structure and direction of trade * Challenge to service reliability, increased dredging * Changes in water levies in harbours | * Relocation, redesign and construction of coastal protection schemes * Migration * Insurance |
| * Extreme weather conditions * Tropical cyclones * Storms * Floods * Precipitation * Wind | * Damage to infrastructure, cargo, equipment * Increased damage to ships as a result of storm-wave-current interaction | * Integrate emergency evacuation procedures into operations * Set up barriers and protection measures * Relocate infrastructure, Alternative routes, Redesigned ports * Amended beach nourishment programs |

Ports may also be indirectly affected by climate implications for tourism (i.e. cruises and seafarers as a port of call).as a future research direction. Fitchet, Grant and Hoogendoorn (2016) indicate climate change risk perceptions for tourists to Cape St Francis. Reputational risks and climate/environmental exposure from sea level rise, storm surge and others affect reputation and visitation rates. Direct risk experience (i.e. for 14 interviewed) can modify behavioural change to invest in adaptation and value action for vulnerable, coastal property owners. Ziervogel et al. (2014) further supports the need to develop integrated, holistic and interdisciplinary models assessing climate change, given its severe macroeconomic implications. This extends not just to trade and tourism but this research proposal’s core objective aiming to understand entire supply chain and economy impacts; from ecosystem resources and point of production to point of final destination/consumption. Climate adaptation strategies for logistics and other sectors (South African Department of Environmental Affairs) are advised to be robust, with sufficient capacity and resources, education and training that they minimise adverse externality costs and risks. Sound early warning, monitoring and evaluation sharing, information, cooperation and coordination are pivotal for systems to avoid maladaptation and extreme opportunity costs, given many stakeholders face scarce resources. Ensuring the future of climate change research in South Africa focuses on ports, transport, logistics supply chains and coastal communities, further strengthens existing policy frameworks from the 1996 Constitution and 2005+ Long Term Mitigation Scenarios to the 2018 Climate Change Bill and Research Agenda. This overcomes the most vulnerable remaining area, upon which international and local economies depend on so crucially.

Turpie et al. (2002) gave a basic overview of general climate change, economic impacts locally. The report gave basic probable case studies in Woodbridge Island, Muizenberg, Durban and Walvis Bay for property damage. Risks include increased coastal erosion, saline water intrusion, increased storms, floods, wind and coastal groundwater rise. Woodbridge Island was valued at R263 million potential damage from sea level rise, Muizenberg R20 million but no estimates are provided for Durban and Walvis Bay. Yet a systematic survey has yet to be undertaken of vulnerable coastal property, ecosystems and assets across South Africa as a future area of research. South Africa’s business responses to climate change, concentrate primarily by underestimating risk. In 2000, coastal ecosystems were directly valued at R143 billion directly and R34 billion indirectly. 38-55% of biome ecosystems and biodiversity will radically transform the ecosystem’s carrying capacity to withstand human extraction of resources and resilience against extreme risk events. Several river mouths will close affecting recreation, sedimentation, fishery yields and bunkerage. The source’s estimation of fishery losses under climate change could provide initial estimates for interdependent supply chains -R441.37 million. Wheat loss is projected as 10-20% by 2050. Real estate for developments will face increasing invasive species, bush fires, coastal erosion, storm surge and sea level rise. No existing source exists for assessing African climate change on transport, ports, infrastructure or supply chains that assimilates ecological economics principles i.e. valuing the ecosystem.

However, more businesses are participating due to climatic trends presenting increased risk, easier information accessibility, finance capacity and equity (Institute of Directors Southern Africa 2010). Our transport is notably energy intensive in our coal industry and trade exposed to sea level rise and storm surges. A review is essential to overcome existing gaps and exploit opportunities but primarily to direct stakeholders towards future survival, given projected uncertainty. Climate change threatens South Africa’s trade systems and economy (Jooste et al. 2009), yet minimal localised research has been conducted. Yet, the commercial sector is preparing to adapt to emergent risks, collaborate in partnership, undertake informed decision making and link it to corporate strategy, to maintain performance and competitiveness in theory (NBI 2017). Future research could investigate their assertions and receive insight as to how capable supply chains would be to withstand climate related pressures. The report illuminates concerns of droughts, floods, water shortages, public heath, damage to infrastructure and ecosystems. This possesses unquantified implications for resource security, physical asset resilience/vulnerability, disruptions to operations and employee productivity/welfare and safety. It argues the need for future research, more fiscal incentives, greater policy certainty and cooperation among various stakeholders including tiers of government. This needs to quantify and define total costs to logistics and commercial activity, communicate effectively and link climate change experts to businesses.

Locally focussed case studies are needed as well as psychologically conditioning people to value the need to act. Indirect implications for logistics included SA Breweries losing grain security, Woolworths experiencing 2010 Pakistan floods affecting cotton supplies and 90% fruit losses from 2012 Western Cape storm damage. Telkom face higher maintenance costs from temperature increases. Transnet are concerned about storm surge and sea level rise yet have not added these risks as explicit considerations in various Port and other development plans. Royal Bafokeng Platinum worried about 2015 flash floods. Specific adaptation strategies have not been assessed as effective with cost-benefits against alternatives. Examples cited include relocation, physical engineered barriers such as sea walls, ecosystem barriers, wetland buffer zones, land use and transport planning, design standards, public transport, higher efficiency aircraft and fuel-efficient vehicles. To adjust to increasing climate uncertainty, current climate change research is repositioning itself to invest in early warning systems. These aspire to pre-empt or predict climate related risks via a National Framework for Climate Services, a Climate Services Portal and National Climate Centre by the DEA and South African Weather Service. Harmann et al. identify the current status of South African climate science and emphasise research gaps remaining that amalgamate biophysical with socioeconomic impacts for climate change. Information has been provided through national programs such as South African Environmental Observation Network (SAEON) and Applied Centre for Climate and Earth Systems Science (ACCESS). Implications from area case studies need scaling up for lessons at national level, whilst national projections need downscaling locally if they are to be of assistance to stakeholders calculating specific impact cost consequences.

# FROM CLIMATE CHANGE UNCERTAINTY TO FUTURE OPPORTUNITIES:

The transition to a low-carbon, climate resilient, “green economy” is based on sustainable development. An emerging research focus presents climate change as therefore transforming risks into socioeconomic opportunities. For example, 390,000 sustainable transport jobs are estimated as possible, by the Alternative Information and Development Centre, (2016) aiming for 1000,000 Climate Jobs. They primarily consider promoting public transport (250,000 in buses, 30,0000 in trains and 70,000 in taxis) and electric vehicles. It proposes generating consumer demand. This includes enforcing a law: In 5 years all new vehicles sold must be electric. These combination of measures and initiatives is estimated to reduce carbon emissions from 81,000,000 tons to 8,000,0000. Inter-city flights could be reduced by improved high speed rail connections. Infrastructure climateproofing could reduce energy consumption another 5% of national emissions. Further opportunities exist in construction and manufacturing, retraining and research. The source proposes the transition from an extractive resource economy to this green economy could partially be financed by subsidies to new industries and entrepreneurs, from enforcing the polluter pays principle. An alternative is the surplus of Unemployment Insurance Fund not more coal power stations or nuclear reactors or state enterprise bailouts. The source estimates the total upfront costs of a green economy and 1000,000 jobs as R346 billion but net costs to government of R112 billion. It proposed increased company taxation, high incomes, tax bond sales and close tax haven loopholes. A minimum of 10% of pension fund assets could also be devoted to climate change. Nelson Mandela Bay Municipality’s Climate Change and Green Action Plan includes water conservation, renewable energy, ecosystems, green buildings and public transport (R5 million per year), as sectors to invest in. Since 2011, it has promoted a Green Procurement Strategy. It motivates a green economy reduces against volatility and long-term uncertainty; avers irreversible environmental and economic damage and narrows the poverty and quality of life gaps. It aims to preserve natural, financial, manufactured and social capital.

## GLOBAL EQUIVALENT AND DIRECTIONS FOR THE FUTURE

Future research could develop upon the 2018 Maritime Transport Policy White Paper and local IDP’s. National Business Initiative and Business Unity South Africa. The proposal could also link to ecosystem-based adaptation, the development of a South African green economy and blue economy opportunities under Operation Phakisa for radical economic transformation. If structured as not only a research but green/blue economy and sustainable development employment opportunity involving communities and radical economic transformation/National Youth Service, it could apply to Global Climate Funds, African Development Bank, Global Environment Facility, Climate Resilient Infrastructure Facility, BRICS Bank, World Bank, UNEP, UNDP and others. It could extend to the Development Bank of South Africa, the Public Investment Corporation, the Green Fund and GIZ/aid agencies. Options include the NEPAD Climate Change Fund and World Adaptation Fund. YPARD, SANCOR, CLIVAR and Terra-Viva Grants along with the Climate Resilient Infrastructure Facility present futureproofing financing options for climate change and the South African logistics sector. In consulting various stakeholders for this pre-feasibility review; they have advocated not only answering KRQA-KRQE but the following enquiries. This review strongly recommends conducting a field research survey of qualified, experienced, concerned and vulnerable stakeholders to ascertain their awareness of climate change, their experience and insights to lessen potential disruption risk and impact costs.

**How aware are you/your organisation of potential climate change information; funding, legislation, risks, impact costs, solutions…?**

**How is climate change and risk management for the South African logistics sector addressed or planned to be addressed?**

**Please indicate why and how the above risks are of concern to your organisation…**

**Which assets/resources/systems/infrastructure/products/equipment were affected specifically for each risk event?**

**If affected by a risk above, for each risk event; which of the following impact costs did your organisation experience and if possible, what was the estimated size of impact in $ for each asset lost, damaged, delayed or replaced?**

**For the adaptation strategies indicated above please indicate why you/your company/organisation would prioritise these solutions over others. Please provide any estimated adaptation costs or resources necessary to successfully adapt if possible**

**Which long and short term, climate change risks from the list above/questions 2/3, are you/is your business least prepared for?**

**Have you, your business/organisation interacted or considered interacting with other supply chain stakeholders to coordinate a projected response to climate change; to minimise disruption costs**

**If yes, how has your business/organisation specifically cooperated with other stakeholders?**

**If not, why not?**

**What funding/resources were available for recovery to your company/organisation/ association both internally and externally?**

**Which specific risks/impact costs should be prioritised with limited funding resources and why?**

**By which stakeholders should these risks and impacts be prioritised and why?**

**As a stakeholder; is existing climate change related, risk, impact cost and adaptation information for supply chains sufficient?**

**What further information would benefit you and your organisation/business/association to adapt with minimal disruption risk?**

Climateproofing South African and African communities, their economies and livelihoods through these climate change opportunities presents numerous co-benefits. Benefits include business continuity, resource security and sustainable development. It lowers vulnerability, enhancing resilience through greater experience and awareness. Other opportunities include increases in aid from more numerous risk events and foreign direct investment; attracted by adaptation efforts. These states could provide research, experience, training and education to less prepared nations. They could market indigenous knowledge about surviving climate change plus crafts, resources, products and techniques. By investing in ecological capital via the ‘green’ and ‘blue’ economies, they could ensure sustainable reserves, market rare species that recover and gain access to carbon credits, venture capital, funding grants and other emissions reduction incentives. Adapting to increased risk events minimises future disruption costs, increases recovery time and enhances reputation/publicity. These opportunities create long term cost savings, new markets, products and services from trade diversion and creation. It enhances competitiveness and ultimately a greater probability of survival.

## RESEARCH GAP SPECIFIC FOR MITIGATION, RISKS, IMPACT COSTS, CONSTRAINTS, ADAPTATION AND OPPORTUNITIES

In conclusion a research gap clearly exists for assessing future climate change implications for African and South African physical infrastructure. Given high forecast disruption costs to the future of global and local trade, ecosystem resources and community survival; identifying risks, impacts and solutions for South African ports, transport and logistics supply chains/coastal communities is paramount. This review recommends future research under the Long-Term Adaptation Scenarios and other climate change research initiatives including the Department of Environmental Affairs, focus on rectifying this literature gap. In determining South Africa’s next climate change research agenda (currently being drafted); priority is vital to ensure an ecosystems-based adaptation approach focuses on ecological resource security but also core logistics infrastructure and systems. This is imperative to assist core stakeholders; given the significant adverse costs of potential uncertainty and projected increased frequencies, durations and intensities of climate related events. The research could prioritise emissions mitigation and climate adaptation. The research could investigate local and international existing, related research prior to downscaling global and local climate change scenarios and projected implications for coastal communities/logistics stakeholders within South Africa/SADCC. It could prioritise climate change risk identification both via scenarios and developing data of time series related data. It would then target projected impact costs, constraints to adaptation and adaptation strategies related to impacts on South African ports, logistics, supply chains and coastal communities. This aims at minimizing potential disruption risk, via climate resilience/climateproofing, whilst preserving core stakeholder requirements. Whilst other core and ancillary objectives could be added, this research proposal would target the following core questions:

**KRQA: What are the risks of climate change to South African ports, transport logistics supply chains, coastal communities and resources?**

**KRQB: What are the projected impact costs of climate change to South African ports, transport logistics supply chains, coastal communities and resources?**

**KRQC: What are the constraints to climateproofing South African ports, transport logistics supply chains, coastal communities and resources?**

**KRQD: What are the projected adaptation strategy solutions to climate change for South African ports, transport logistics supply chains, coastal communities and resources?**

**KRQE: What are projected climate change opportunities for South African ports, transport logistics supply chains, coastal communities and resources?**

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