

WEATHERING THE STORM: ADDRESSING FLOOD-INDUCED MOBILITY CHALLENGES IN SOUTH AFRICA'S TRANSPORTATION INFRASTRUCTURE

L KOTE

Tshwane University of Technology; Pretoria West Campus; Staatsartillerie Rd,
Pretoria West, Tel: 063 044 8527; Email: lebogangkote35@gmail.com

ABSTRACT

Mobility mainly refers to the movement of people, goods or services across different places. This includes using different transport modes, such as walking, cycling, driving and using public transport, like busses, trains and mini-bus taxis. These transportation systems have their own issues, and limitations which form barriers for those who depend on them.

Climate change is becoming a big issue in transportation systems globally, with the rise of temperatures worldwide that are triggering catastrophic weather events that end up changing the area landscape. These changes affect and ruin transportation infrastructure compromising overall mobility. This essay explores the impacts of floods on transportation systems and the challenges they pose to mobility in urban and rural areas, as well as solutions to the problems.

Flooding in South Africa causes major mobility challenges by interfering with transportation systems such as roadways, airports, railways and public transit. Airports close during floods which disrupts the national and regional trade and flooded dirt roads can isolate rural communities. These issues are made worse through urban inequality, with infrastructure differences between rural and urban areas and with informal settlements being built in flood-prone areas, overwhelming the existing drainage and stormwater systems. To combat this new technology and road pavements are designed to be able to coexist with the current problems. This essay covers the impact of floods in South Africa on transportation systems affecting mobility and how flood modelling and resilience assessment will be required to adopt and incorporate the newly designed floodway channel roads into the existing roadway systems.

Keywords: Floods, Transportation systems, Mobility, South Africa, Climate change, Infrastructure, Resilience, Urban areas, Rural areas, Public transport, Roadways, Airports, Railways, Informal settlements, Flood modelling, Adaptation, Disaster risk, Drainage, Stormwater, Vulnerability, Floodway channels.

1. FLOODS IN SOUTH AFRICA

Southern Africa's diverse climate, topography, and urban development patterns contribute to regular flooding. We have witnessed multiple severe floods in recent decades, which are frequently linked to extreme weather conditions and climate change. Floods occurring in urban or rural settlements has a major impact on road transportation systems and on overall mobility as roads become damaged and unusable, floodwaters change the landscape as well as creating problems for the economic and social community.

2. IMPACT OF FLOODS ON TRANSPORTATION SYSTEMS

Floods are recurring weather events with its own sets of challenges which are intensified through climate change. Floods are mainly caused by heavy rainfall, tropical cyclones and rapid urbanisation which can lead to environmental and infrastructure damage including loss of life. It is a global problem to transportation networks, interrupting key infrastructure, affecting economic activity, and worsening social inequality between rural and urban areas. Causing physical damage and exposing poor infrastructure and drainage systems. The existing transportation facilities are becoming old and outdated, meaning they are not strong enough to withstand the current climate conditions, leading to flooded roads and damaged bridges, as well as paralyzed ports and airports.

Floodwaters erode road surfaces and collapse bridges, washing away gravel roads and mudslides that can isolate local communities that are affected, they submerge railway tracks which erode the embankments damaging the signalling systems. In 2022, the Durban floods disrupted Transnet Freight Rail, as wagons and vehicles were destroyed which affected the railway lines, this led to the closing of the railway operations and delaying with the exportation of goods and services. (Gordhan, 2022)

The 2022 KwaZulu-Natal floods destroyed over 800 roads, including highways like the N2 and N3, which needed millions for repair costs. Temporary closure for roadways, train stations and port harbours alike were needed as a response to the floods, this affected businesses and economic activity (Cele & Njini 2022). The KZN floods forced the Port of Durban, one of Africa's busiest ports to close operations after flood water wreaked havoc on the port leaving shipping containers and goods damaged. (Bruno, 2022)

2.1 Mobility and Access

The need for better infrastructure in South Africa's transportation systems was clearly shown with the recent floods in Kwa-Zulu Natal, which affected different people across the province. The floods created physical barriers like the collapse of infrastructure which includes highways, railways bridges which left rural communities isolated. These barriers negatively affect vulnerable populations, especially those from lower-income communities that rely on public transportation such as minibus taxis, busses or walking. When floods disrupt these facilities, these communities face higher risks, they often have limited alternatives, leaving them stranded and unable to reach workplaces, they have limited access to food and supplies as well as delayed medical assistance.

2.2 Economic Mobility

The floods have made roadways and transport services unsafe and unusable. Delays in freight and supply chains caused by floods and hinder business operations and job access. Damaged roads are closed off, which can leave a lot of people stranded and incapable of going to work and school, as most bus services and taxis were not operating, this has a greater impact on those relying on daily income. Rail lines and ports are forced to operate at limited capacity, and freight transport was at a halt. (Pillay & Magubane, 2022). Critical infrastructure, such as the Durban Port, which handles 65% of South Africa's container traffic, was forced to close for five days due to soil erosion and equipment damage, delaying R1.2 billion in daily exports (Siyakatshana, Ndayi & Mokoena, 2024)

3. FUTURE RISKS AND CLIMATE CHANGE

Floods in South Africa happen mostly in coastal and low-level areas and flood frequency depend on factors such as climate variations, land topography, human activities like urbanisation and agricultural land use. Coastal regions experience frequent floods due to heavy rainfall in the summer and tropical cyclones while inland regions are more prone to face flash floods which are caused by heavy rainfall over a short duration or dam failure.

The average annual precipitation should be considered in every region, as it plays an important role in terms of floods along with river routes, especially now with climate change intensifying extreme weather events, such as increased rainfall activity and rising sea levels, this creates a change in the weather patterns that should be monitored. The average precipitation is calculated using either rain gauges, satellite observations or numerical methods.

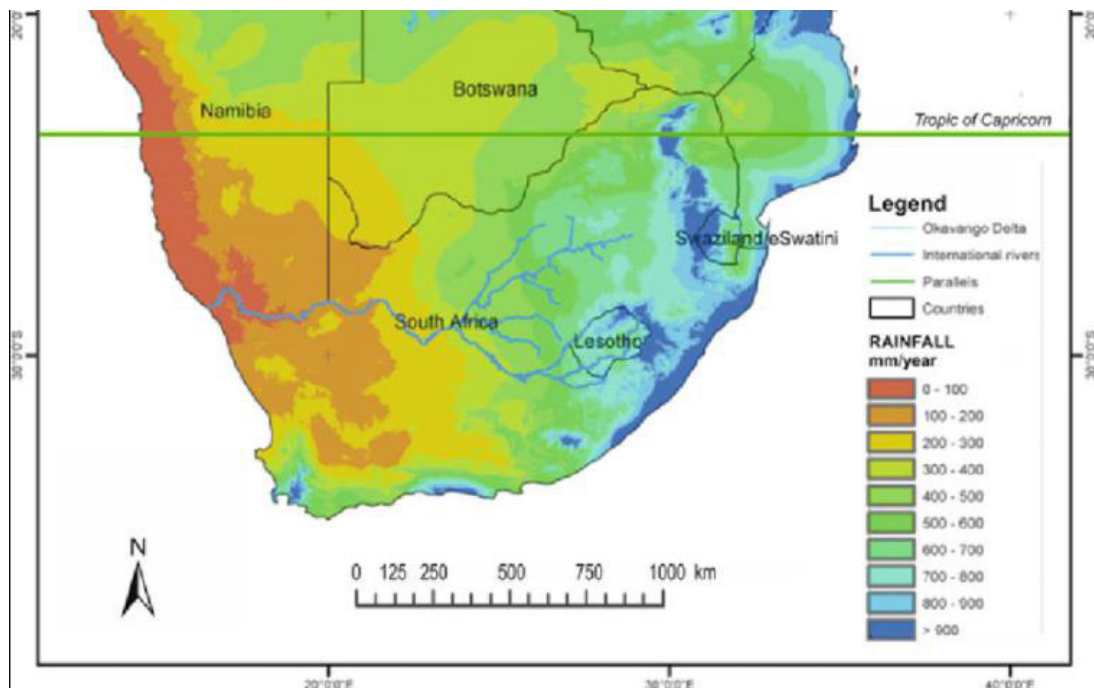


Figure 1: Image showing the mean annual precipitation in South Africa (Dintwe et al., 2014)

With KZN being the most prone place for floods to occur, the rainfall data for that region is closely monitored to research exactly how existing transportation systems react to floods and climate change.

South Africa is no stranger to floods, but climate change is making them more frequent and intense, causing greater damage than before. Warmer oceans are fuelling stronger storms, like Tropical Storm Eloise that happened in 2021 and the 2022 floods in KwaZulu-Natal and the Eastern Cape, they were linked to climate change, with studies indicating that such extreme rainfall events are now twice as likely to occur (Tandon, 2022).

Urbanisation, which is the rapid growth of cities and urban areas can lead to the loss of natural flood absorbing landscapes like wetlands and floodplains. When these places are replaced by impervious material like concrete and roads, water tends to run off, often straining the existing drainage systems, which can result in flash floods if they are not maintained properly.

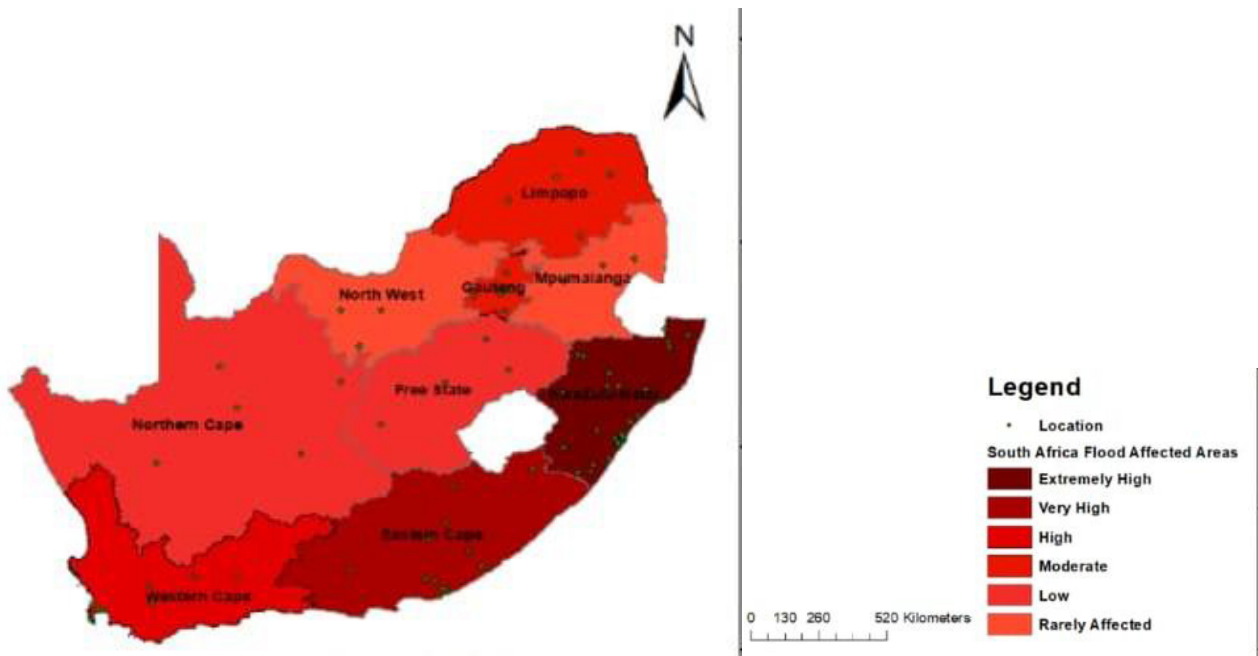


Figure 2: Image showing the severity of flood disasters in South Africa from 1959 to 2019 (Busayo et al., 2022)

Rainfall data is used to determine the probability of floods across the country. This information is important, as funding will need to be allocated properly in event of natural disasters across the country. The pie chart below shows the estimated flood probabilities based on real events from the 1987 to 2024 in South Africa.

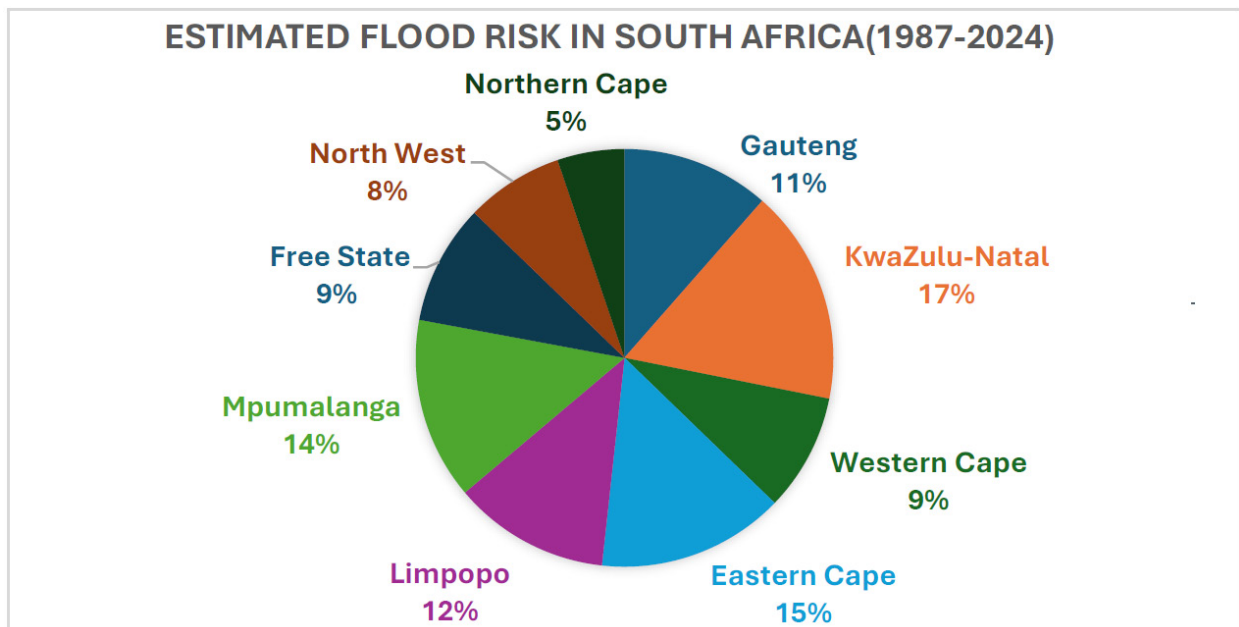


Figure 3: Pie chart showing the estimated risks of floods occurring in provinces from 1987-2024

The table below shows the major flood events that occurred in South Africa, showing the damage caused by flooding on transportation systems.

Table 1: Damage caused by floods in South African provinces by floodwaters and effects of floods

Year	Event	Affected Regions	Road Damage	Rail Damage	Port Damage
1987	Eastern Cape Floods	Port Elizabeth, East London	Collapse of major bridges; highways submerged for days	Partial collapse of Port Elizabeth-East London line	-
2000	Mozambique-SA Floods	Mpumalanga, Limpopo	N4 highway to Mozambique washed away; rural roads ruined	Damaged tracks and infrastructure	-
2012	Gauteng Flash Floods	Johannesburg, Pretoria	N1 highway closures and flooded roads	Metrorail services were delayed	-
2019	KZN Coastal Floods	Durban, Pietermaritzburg	Washed away roads and rural bridges destroyed	tracks were damaged	Durban port operations slowed
2022	KZN Floods	eThekweni	N2/N3 severed and 800 damaged roads	Cato Ridge-Durban line ruined	Durban port shut for 2 weeks, container terminal flooded
2023	Western Cape Floods	Cape Town, Overstrand	Road networks were damaged and closed	Submerged tracks and infrastructure damage	Cape Town port delays
2024	Eastern Cape Flash floods	Kariega, Blue Horizon Bay	N2 closed, 1 week, Mthatha airport access roads washed out	Gqeberha-East London line blocked	Nggura port congestion

4. MITIGATION STRATEGIES

4.1 Flood Resistant Infrastructure

Communities can have emergency water retention and redirection modular barriers in flood prone areas and hotspots, which can help direct flood waters onto road pavements that are built to resist extensive flood water damage, only these special built roads will be closed off leading flood waters away to natural water basins. This means that extensive planning is needed for alternative routes for evacuations for isolated communities if the adjacent roads absorb floodwater. This ensures minimum road damage in the area and only to the floodable road, the main idea focuses on using roads as sacrificial floods ways, through using barriers and such, this will lessen the effect of flood damage on main roads, that are used daily.

Early warning systems for extreme weather events should be implemented and used. The roads on which floodwaters will be routed to will be built will require using innovative infrastructure, like building flood resistant foundations, which can be modified chemically or through geotextiles. The roads will be designed to function as temporary flood channels like Rotterdam's water squares in the Netherlands known as a waterplane, these are spaces that are integrated into the surrounding landscape and designed to store excess

rainwater, preventing floods from happening in nearby residential and commercial areas, (De Urbanisten, 2013). The design of these structures will require extensive planning and research on building road surfaces that are more resilient to water damage, considering the drainage design, the slopes in the area and use of modified road pavement layers. The use of hydrophobic roads could be a practical good starting point of designing the roads surfaces. The roads can clear water within 8-12 seconds for rainfall over 75mm/hr, reducing hydroplaning risk and extend the road lifespan (theconstructor.org, 2025).

This design idea can be implemented across all transport infrastructure, using selected roads as water channels that redirect floodwater to free spaces acting as man-made water basins to temporarily store rainwater and reduce damage on main transport infrastructure facilities that influence overall mobility of the people. A study can be done on Modular Barrier Systems, they can be improved or redesigned totally as they are not intentionally designed to reroute floodwaters. The barriers will act as a physical buffer which steers water towards roads built to withstand flooding, redirecting floodwaters towards the temporary catchment areas. This will reduce damage caused by floods on transportation facilities and other structures. Existing flood maps created using the existing and new traffic models, as well as GIS mapping, can be used to determine which roads and areas that will require the specialised roads.

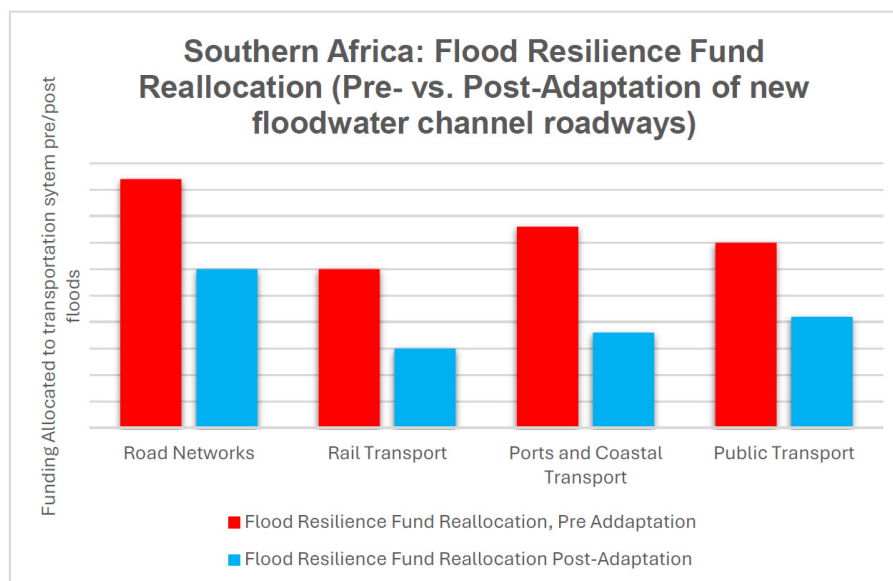


Figure 4: Graph showing estimates flood resilience & fund reallocation (Pre- vs. post-adaptation of new roadway channel design)

This includes a flood impact assessment on transportation networks in areas mostly affected by floods. This will depend on real time data of Flood Impact and Damage Reports, and how floods influence transportation systems, whether directly or indirectly, this includes physical damage and cases whereby alternative routes become congested as main roads are closed off as they can't handle the increased traffic volumes. Flood risk assessments will be done in selected regions, assessing the impact and risk of a flood in that region based on environmental, economic and social factors. The roadways will be strategically placed and closely monitored on how it reacts to wet and dry conditions, with its main function is to act as a channel for floodwaters.

Achieving sustainable flood resilience in Southern Africa requires a diverse approach that integrates technological advancements with community-driven mobility solutions like, integrating adaptive infrastructure with emergency mobility networks and local partnerships, the effects of the recurring floods can be mitigated efficiently. By centring

vulnerable communities and aligning with SANS codes and AU Climate Resilience Frameworks, Southern Africa can turn flood recovery into long-term adaptive strength.

Through recent flood events, it can be stated that mobility doesn't necessarily focus on daily movement of people, but also about survival.

5. REFERENCES

Bruno, M. 2022. Article title. Port of Durban faces backlog after flood devastation. Port Technology International. Available at:

<https://www.porttechnology.org/news/port-of-durban-faces-backlog-after-flood-devastation/>.

Busayo, ET, Kalumba, AM, Afuye, GA, Olusola, AO, Ololade, OO & Orimoloye, IR. 2022. Rediscovering South Africa: Flood disaster risk management through ecosystem-based adaptation. *Environmental and Sustainability Indicators*, 14:100175. Doi: 10.1016/j.indic.2022.100175.

Cele, S. & Njini, F. 2022. Floods Wash Away Bridges, Close Routes to Key South African Port. Moneyweb. Available at: <https://www.moneyweb.co.za/news/south-africa/floods-wash-away-bridges-close-routes-to-key-sa-port/>.

De Urbanisten. 2013. *Watersquare Benthemplein, Rotterdam*. [online] De Urbanisten. Available at: <https://www.urbanisten.nl/work/benthemplein>.

Dintwe, K, Okin, G, Odorico, P, Hrast, T, Mladenov, N, Handorean, A, Bhattachan, A & Caylor, K, 2014. Soil organic C and total N pools in the Kalahari: Potential impacts of climate change on C sequestration in savannas. Doi: 10.1007/s11104-014-2292-5.

Gordhan, P, 2022. Recovery of Transnet infrastructure from KZN floods: Progress report. Presentation to Ad Hoc Joint Committee on Flood Disaster Relief and Recovery. Available at: https://static.pmg.org.za/220811DPE_Presentation.pdf.

Pillay, Y & Magubane, T. 2022. *Port operations affected as major damage caused to Durban Road networks*. [online] IOL. Available at: <https://iol.co.za/mercury/news/2022-04-13-port-operations-affected-as-major-damage-caused-to-durban-road-networks/>.

Siyakatshana, N, Ndayi, V & Mokoena, R. 2024. Council of Scientific & Industrial Research (CSIR). Paper title. Climate impacts on South African transport infrastructure. CESA Infrastructure Indaba: Session 3 - Infrastructure Upgrade, Investment and Development in an Era of Climate Change, CTICC. Available at: https://www.cesa.co.za/wp-content/uploads/2024/03/Session-3_Dr-Njabulo-Siyakatshana_-Vuyo-Ndayi_Refiloe-Mokoena_CESA-Indaba-2024_CSIR_Final_18032024.pdf.

theconstructor.org. 2025. Article title. Hydrophobic Roads: The Self-Draining Future of Infrastructure. Available at: <https://theconstructor.org/concrete/hydrophobic-roads-the-self-draining-future-of-infrastructure/577580/>.

Tandon, A, 2022. Climate change made extreme rains in 2022 South Africa floods 'twice as likely'. *Carbon Brief*. Available at: <https://www.carbonbrief.org/climate-change-made-extreme-rains-in-2022-south-africa-floods-twice-as-likely/>.