EASTERN AND
SOUTHERN AFRICA

KENYA

Transport Sector Background Note

World Bank Group

COUNTRY CLIMATE AND DEVELOPMENT REPORT

November 17, 2023

Editor: Chandrahas Choudhury

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November 2023

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Abbreviations and Acronyms

ADB	Asian Development Bank
AfCFTA	African Continental Free Trade Agreement
APU/GPU	Accelerated Processing Unit/Graphics Processing Unit
BAU	Business As Usual
BEB	Battery Electric Buses
BEV	Battery Electric Vehicles
BioSNG	Biomethane/Bio-Synthetic Natural Gas
BRT	Bus Rapid Transit
BtL	Biomass to Liquid
CBD	Central Business District
CCD	Climate Change Directorate
CCDR	Country Climate and Development Report
CET	Common External Tariff
CO_2e	Carbon Dioxide Equivalent
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPS	Cyber-Physical Systems
CVRS	Computerized Vehicle Routing and Scheduling
DPL	Development Policy Loan
EAC	East Africa Community
EAD	Expected Annual Damage
EAEL	Expected Annual Economic Losses
EM-DAT	Emergency Event Database
EMS	Environmental Management System
ERC	Energy Regulatory Commission
EU	European Union
EV	Electric Vehicles
FDI	Foreign Direct Investment
FTA	Free Trade Agreement
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
GoK	Government of Kenya
HGV	Heavy Goods Vehicle
HoAGDP	Horn of Africa Gateway Development Project
HVO	Hydro-Treated Vegetable Oil
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engines
INDC	Intended Nationally Determined Contributions
INTP	Integrated National Transport Policy

IPCC	Intergovernmental Panel on Climate Change
KAA	Kenya Airports Authority
KCAA	Kenya Civil Aviation Authority
KCERT	Kenya Carbon Emission Reduction Tool
KEBS	Kenya Bureau of Standards
KENGEN	Kenya Electricity Generating Company
KeNHA	Kenya National Highways Authority
KEPSA	Kenya Private Sector Alliance
KERRA	Kenya Rural Roads Authority
KETRACO	Kenya Electricity Transmission Company
KMA	Kenya Maritime Authority
KNBS	Kenya National Bureau of Statistics
KPA	Kenya Ports Authority
KQ	Kenya Airways
KRC	Kenya Railways Corporation
KURA	Kenya Urban Roads Authority
LCFS	Low Carbon Fuel Standards
LCV	Light Commercial Vehicle
ICD	Inland Container Depot
IoT	Internet of Things
MC	Motorcycle
MGR	Meter Gauge
MOA	Matatu Owners Association
MOE	Ministry of Education
MoRT	Ministry of Roads and Transport
MoTIHUD	Ministry of Transport, Infrastructure, Housing and Urban Development
MRTS	Mass Rapid Transit System
MSW	Municipal Solid Waste
MtCO$_2$e	Million Tonnes of Carbon Dioxide Equivalent
NaMATA	Nairobi Metropolitan Area Transport Authority
NAP	National Action Plan
NCA	National Construction Authority
NCCAP	National Climate Change Action Plan
NDC	Nationally Determined Contribution
NEECS	National Energy Efficiency and Conservation Strategy
NIUPLAN	Nairobi Integrated Urban Development Plan
NMA	Nairobi Metropolitan Area
NMT	Non-Motorized Transport
NPV	Net Present Value
NTFIPF	National Green Fiscal Incentives Policy Framework
NTSA	National Transport and Safety Authority
NUTP	National Urban Transport Policy
NZE	Net Zero Emission
OSM	OpenStreetMap

PC	Passenger Car
PEFCR	Product Environmental Footprint Category Rules
PSV	Public Service Vehicles
PtX	Power-To-X
RCP	Representative Concentration Pathways
RICS	Road Inventory and Condition Survey
RMF	Road Maintenance Fund
SBTi	Science Based Targets Initiative
SCEA	Shippers Council of Eastern Africa
SDoR	State Department of Roads
SDoT	State Department of Transport
SGR	Standard Gauge Railway
SOE	State-Owned Enterprises
SRAT	Systemic Risk Assessment Tool
tCO_2e	Tonnes of Carbon Dioxide Equivalent
TFP	Total Factor Productivity
TOD	Transit Oriented Development
UN COMTRADE	United Nations Commodity Trade Statistics Database
VKT	Vehicle Kilometers Traveled
VoT	Value of Time
WEF	World Economic Forum
WHO	World Health Organization
WTW	Well-To-Wheel

CHAPTER 1.   Kenya's Climate Commitments and Delivery

1.1   A greener and climate-smart growth pathway in transport and logistics

Advancing on a low-carbon, efficient, and climate-resilient development pathway in the transport and logistics sector is key to boosting Kenya's economic competitiveness. While the agricultural sector is the backbone of the Kenyan economy, accounting for about 18 percent of GDP, the transport and storage industry added about 13 percent to GDP in 2020 and grew by 8.1 percent in the first quarter of 2022. Air transport, for example, has increasingly become an important component of the Kenyan economy in the form of direct industry employment, high-value trade flows, and tourism receipts generated by air travelers. According to the International Air Transport Association (IATA), the air transport sector contributes more than 4 percent to Kenya's GDP, with a gross value-added contribution equivalent to approximately US$3.2 billion. The aviation industry alone enabled direct employment amounting to 18,000 jobs, supported another 130,000 jobs through local services and suppliers, and an additional 410,000 tourism-related jobs.[1]

Further, the development of a green and sustainable transport and logistics system is critical to achieving the government's commitments towards low-carbon growth in line with the country's development priorities. These include the National Climate Change Action Plan 2018–2022 (NCCAP) and the country's long-term development blueprint Kenya Vision 2030. A clean and sustainable energy and transport system is also essential to the implementation of the government's Big Four agenda for 2018–2022, which focuses on ensuring food and nutrition security, affordable and decent housing, increased manufacturing, and affordable healthcare. The country's blueprint until 2030 calls for US$2.1 billion to be spent annually to connect the nation's roads, railways, ports, airports, water and sanitation facilities and telecommunications networks.

Kenya's Climate Change Act (2016) requires public and private sector actors to develop and report greenhouse gas (GHG) profiles. A Climate Change Coordination Unit at the State Department for Transport (SDoT) is responsible for consolidating transport data relevant to the GHG inventory. In 2019, the transport sector was the first sector to comply with the act's requirement of publishing an annual climate change report that describes the transport sector's emissions and mitigation actions. In addition, Kenya publishes emission projections for different sectors at the Kenya Carbon Emission Reduction Tool (KCERT) 2050 Calculator website, helping policy makers and the public understand the emission-related choices that the country faces.[2]

To fully harness its advantageous geographical location, the Kenyan government could further accelerate its low-carbon pathway and leverage green growth policies to enhance its competitiveness and strengthen its position as a regional transshipment hub. As noted in the NCCAP, Kenya is a commercial, transportation, and communications hub for eastern Africa.[3] The government of Kenya is not only a signatory to the Paris Agreement on Climate Change but has also committed to a 32 percent reduction in greenhouse gas emissions by 2030, compared to a business-as-usual scenario. The transport sector, which is a significant source of GHG emissions, is expected to contribute to this objective by cutting emissions by at least 8

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[1] IATA Economics. 2017. "The Importance of Air Transport to Kenya."

[2] https://kcert.ilabafrica.ac.ke/.

[3] Republic of Kenya. 2018a. NCCAP, 2018, p.9.

percent (minimum target). In 2015, the sector accounted for about 13 percent of Kenya's total GHG emissions in 2015,[4] slightly higher than the world average of around 11–12 percent.[5]

Adaptation actions and mitigation measures are equally important to address the impact from climate change as well as to counter the trend of rising energy-related CO_2 emissions in the sector. Emissions related to the movement of passengers and freight in Kenya are projected to increase at a faster rate than in other sectors, and are estimated to rise to 17 percent of the country's total national emissions in 2030.[6] To achieve Kenya's Intended Nationally Determined Contributions (INDC),[7] GHG emissions reductions in the sector are expected to be between 1.9 and 4.7 MtCO$_2$e by 2022 and 2030, respectively (Table 1). At the same time, climate change impacts over the past 10 years have resulted in socioeconomic losses estimated at 3 to 5 percent of Kenya's GDP annually, despite the country being a very low emitter of GHG emissions (<0.1 percent of global emissions in 2018). Consequently, climate-proofing transport infrastructure and adopting proactive adaptation for supply chains to minimize climate-related risks are essential.

Table 1. Emission reduction potential (MtCO$_2$e), 2020–2030 projections for NDC target

	2022	2025	2030	NDC Target
Energy	2.4	33.0	48.1	15.41
Transport	1.9	3	4.7	3.46
Forestry	10.4	14.3	20.8	20.10
Agriculture	2.7	5.3	9.7	2.77
IPPU	0.8	1.4	2.4	0.78
Waste	0.7	0.7	0.8	0.39
Total	39.7	57.7	86.5	42.90
Source: Institute for Global Environmental Strategies 2021				

The trend of rising energy-related CO_2 emissions in the sector is compounded by the unbalanced modal split. Following the deterioration in the performance of railway transport, road transport has emerged as the main mode of transport in Kenya for both passengers and freight, due to its advantage in terms of speed, flexibility, and accessibility. This distorted modal split, whereby the road network carries more than its fair share of traffic, in particular in freight transportation, compared to railways, has resulted in high road maintenance costs due to a higher rate of road deterioration. This could limit chances for further road development in areas that have had no roads. There is a critical need therefore to ensure a more balanced modal split between road transport and railway traffic. For freight transport, the capacity of rail freight was expected to reach 10 million tonnes (22 percent of total capacity) in 2020 and 22 million tonnes (35 percent of capacity) in 2025, according to estimates in 2018 (GIZ 2018). While these projections have not yet been met, rail freight traffic has increased on the Standard Gauge Railway (SGR), which carried about 6 million tonnes in 2022, substantially contributing to the revenue of SGR.

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[4] Republic of Kenya. 2018a. NCCAP, p.61.

[5] McKinnon 2018.

[6] Republic of Kenya. 2018a. NCCAP, p.61.

[7] Kenya's INDC target (2020) is to abate GHG emissions by 32 percent by 2030 relative to the BAU scenario of 143 MtCO$_2$e; while the total emission reduction potential is 86 MtCO$_2$e by 2030.

Figure 1. Standard Gauge Railway (SGR): passenger and freight traffic (2017–2022)

Source: Kenya Railways 2023

Figure 2. SGR sources of revenue, KES billion (2017–2022)
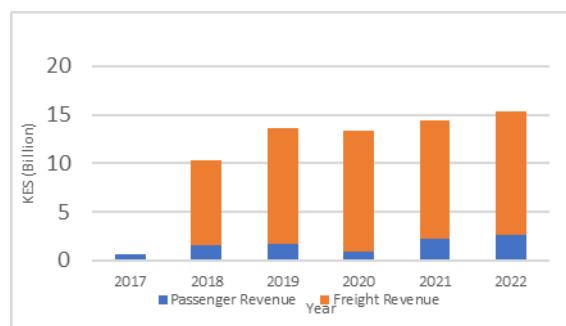
Source: Kenya Railways 2023

In 2019, total domestic transport sector emissions in Kenya amounted to 12.343 MtCO$_2$e (not including emissions from waterborne navigation), an increase of about 4.6 million tonnes from 2010.[8] The transport sector of Kenya comprises the road, rail, aviation and maritime sub-sectors under the leadership of Ministry of Roads and Transport (MoRT), which consists of the State Department of Roads (SDoR) and SDoT. The road subsector was responsible for 12.09 MtCO$_2$e, which accounts for 97.95 percent of sector emissions, while emissions from rail and aviation subsector are 0.062 MtCO$_2$e (0.50 percent) and 0.188 MtCO$_2$e (1.52 percent) respectively. According to projections,[9] total road transport emissions are expected to increase by 380 percent over the period of 2015–2050, with the emissions share of heavy goods vehicles growing from 41 percent to 55 percent (Figure 3). While passenger cars dominate total mileage driven, heavy goods vehicles (trucks) cause the greatest emissions (Figure 4).

Figure 3. Total CO$_2$ emissions in baseline (national perspective) [tCO2e]

Figure 4. Mileages and CO$_2$e emissions of road transport in Kenya (2015)
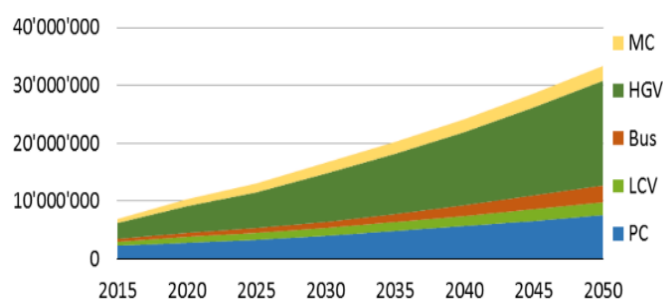
Source: GIZ 2018
Note: MC = motorcycle, HGV = heavy goods vehicle, LCV = Light commercial vehicle, PC = passenger car

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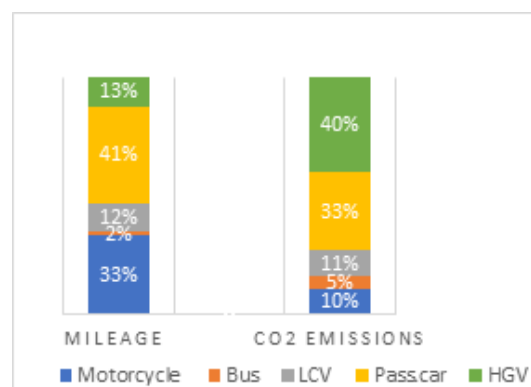
[8] Republic of Kenya. 2021. Transport sector climate change annual report 2018/2019, 2021.
[9] GIZ 2018.

1.2 Transport and logistics sectoral commitments and targets

Kenya's Nationally Determined Contribution commits to lowering GHG emissions by 32 percent (45.8 MtCO₂e) by 2030 relative to the business as usual (BAU) scenario of 143 MtCO₂e. The sectoral emissions reduction target is 3.46 MtCO₂e (million tonnes of carbon dioxide equivalent) by 2030 against a 21 MtCO₂e baseline, amounting to 7.6 percent of the total target reduction of 45.8 MtCO₂e. With this target, annual sectoral emissions in 2030 should not exceed 17.54 MtCO₂e.

Figure 5. Tank-to-wheel emission factors (weighted average per vehicle category [grams of CO₂e/km], 2015

g CO₂e/km | 2015

- 70.1 — Motorcycles (MC)
- 189.6 — Passenger car (PC)
- 220.2 — Light commercial vehicles (LCV)*
- 167.9 — Matatus petrol (LCV)
- 150.7 — Matatus diesel (LCV)
- 772.3 — Heavy goods vehicles (HGV)
- 860.1 — Buses

Light commercial vehicles include matatus/minibuses, vans, pickups etc. 220.2 gCO₂e/km refers to the average across these vehicle types.
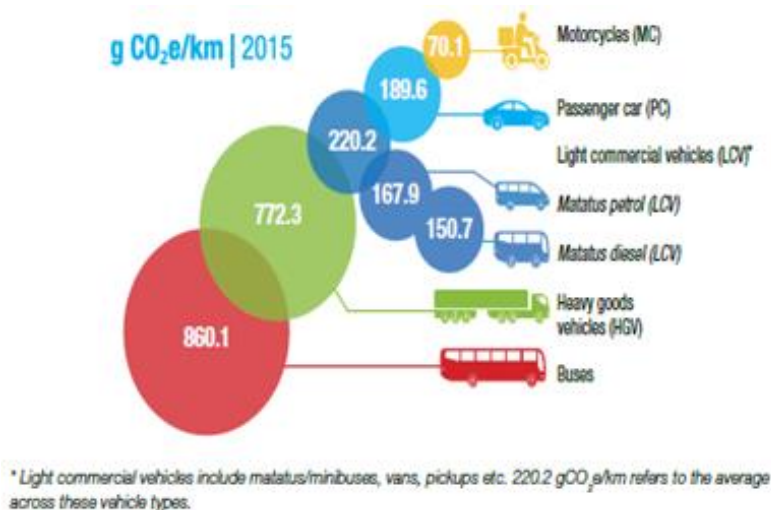
Source: Transport Sector climate change annual report 2018/2019

The government is taking several measures to tackle climate change through transportation- and logistics-related initiatives. In the government's NCCAP, several low-carbon initiatives and actions (Table 2) are proposed such as improved heavy-duty vehicle stock efficiency, a shift of containerized freight from road to rail, the completion of the Mombasa-Nairobi SGR and its electrification, the construction of the Bus Rapid Transit (BRT) system in the Nairobi Metropolitan Area, low-carbon technologies in the aviation and maritime sectors, and pilot projects for electric vehicles. In partnership with GIZ (Advancing Transport and Climate Strategies Project), Kenya is one of the first countries in East and Central Africa to develop country-specific road transport emission factors (Figure 5).[10]

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[10] https://changing-transport.org/new-and-improved-data-on-road-transport-in-kenya/.

Table 2. NCCAP Strategic Objective 7b: Establish efficient, sustainable, world-class transport systems and logistics services that withstand the projected impacts of climate change

Action	Expected Results by 30th June 2023	Adaptation/Mitigation
Develop an affordable, safe and efficient public transport system	• 70 km of Bus Rapid Transit (BRT) for Nairobi Metropolitan Area designed, constructed, and implemented in 5 routes • Use of electric hybrid vehicles (buses) piloted and appropriate incentives provided for their use • Standard Gauge Railway (SGR) extended from Nairobi to Naivasha • Feeder public transport to BRT, commuter rail, and SGR developed and provided for the public • 150 km of non-motorized transport facilities constructed, including pedestrian and bicycle access within, and to, town centers and transit stations	Mitigation with target GHG emission reductions of 2.3 $MtCO_2e$
Reduce fuel consumption and fuel overhead costs	• SGR from Nairobi to Mombasa electrified • 30% of freight from Mombasa to Nairobi shifted from road to rail • Roadmap for the improvement of heavy-duty truck efficiency developed, including increased use of low-rolling resistance tires, super structure fittings, etc. and development of vehicle standards • Light-duty vehicle fuel economy improved through labelling, promotion of fuel-efficient driving, and improved traffic management	Mitigation with target GHG emission reductions of 2.39 $MtCO_2e$
Encourage low-carbon technologies in the aviation and maritime sectors	• Shore power infrastructure for four berths installed to provide power to ships while at berth instead of using their engines • 2 new aircraft (B787) which have fuel-efficient engines purchased • Service Charter on Sustainable Aviation Fuels (certification and use of biodiesel production for captive use at airports) implemented by 2020 • 0.5 MW solar power plant installed at Moi International Airport and commissioned by 2018	Mitigation
Climate-proof transportation infrastructure	• Climate information used in infrastructure planning, and transport resilience plans developed • Feasibility study on constructing roads that systematically harvest water and mitigate floods undertaken • 4,500 km of roads climate-proofed	Adaptation
Enabling (technology)	• Domestic technology development for electric modes of transport encouraged • Research on the use of renewable energy for powering different modes of transport undertaken	Enabling
Enabling (capacity development)	• Awareness built on the fuel economy and electric mobility options, including exploring infrastructure needs for electric mobility	Enabling
Enabling (policy and regulation)	• The Integrated National Transport Policy (2021) reviewed and implemented • The international standards on aviation (ICAO Annex 16 Vol 4), and maritime (MARPOL Annex VI) transport domesticated and implemented by 2021 and 2020, respectively • Standards for electric cars and two-wheelers developed and implemented by 2019 • Standards for climate proofing of transport infrastructure developed • Planning and building control regulations to encourage compact development, mixed use, and reduced provision of parking near MRT stations updated and implemented	Enabling

RELEVANT INSTITUTIONS: Ministry of Roads and Transport (MoRT),, Ministry of Energy (MOE), Climate Change Directorate (CCD), County Governments, Nairobi Metropolitan Area Transport Authority (NAMATA), Kenya Railways Corporation (KRC), National Transport and Safety Authority (NTSA), Kenya Civil Aviation Authority (KCAA), Kenya Airports Authority (KAA), Kenya Civil Aviation Authority (KCAA) , Kenya Airports Authority (KAA), ERC, KETRACO, KENGEN, KEBS, Kenya Urban Roads Authority (KURA), Kenya National Highways Authority (KENHA), Kenya Rural Roads Authority (KERRA), National Construction Authority (NCA), Kenya Ports Authority (KPA),Kenya Maritime Authority (KMA), Kenya Airways (KQ), the private sector, the academia, research institutions, civil society. All sectors identify actions to realize the strategic objective.

Source: NCCAP, 2018, p. 91–93

In the climate action plan of the capital Nairobi,[11] a low-carbon climate resilient pathway in the transport sector is expected to have significant impacts on black carbon emissions, a key stressor for air quality in the city. This will be driven by (i) a shift to increased Non-Motorized Transport (NMT), (ii) an improved public transport system (commuter railway modernization/expansion project and BRT), and (iii) improved efficiency in vehicles (more fuel-efficient vehicles, emission controls, introduction of electric vehicles).

In Kenya's most recent NDC, adaptation actions appear to feature more prominently than mitigation measures.[12] Whereas the section on mitigation refers to the "promotion and implementation of low-carbon and efficient transport systems," the adaptation section covers the enhancement of capacity to climate-proof road infrastructure through vulnerability assessments and the creation of at least 4,500 km of all-weather roads. These include (i) upscaling the construction of roads to systematically harvest water and reduce flooding, (ii) enhancing institutional capacities on climate-proofing vulnerable road infrastructure through vulnerability assessments, and (iii) promoting the use of appropriate designs and building materials to enhance the resilience of at least 4,500 km of roads to climate risk.

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[11] https://nairobi.go.ke/climate-action-plan-2020-2050/.
[12] Republic of Kenya, 2022b. Ministry of Environment and Forestry.

2 Boosting Competitiveness through Greener Growth

This chapter focuses on how a low-carbon pathway and green growth policies in the transport and logistics sector can further enhance Kenya's economic competitiveness and strengthen its position as a regional transshipment hub. It identifies critical transport links that merit strategic "resilience interventions" to counter impacts from climate events. It also reviews low-carbon and efficient mitigation measures, and potential investment needs and outlines a pathway to improve transport and logistics services towards a reduction of GHG emissions, relative to the BAU scenario. The chapter will also examine the policy and investment options needed to enable Kenya to generate low-carbon growth in the transport and logistics sector while boosting the country's competitiveness.

2.1. Background

Despite being one of the fastest-growing economies in Africa, Kenya continues to face significant challenges in terms of growth, basic connectivity, and equity, since nearly two-thirds of the population still live in poverty. The country has relied on the domestic market for economic growth, as the export-to-GDP ratio halved over the last decade and is below the global average for its economic size and income level. Trade will become an increasingly important driver of growth as international markets provide significant opportunities for Kenyan producers over the domestic market, while increased trade integration can raise productivity and technology adoption, which will lead to a boost in growth and job creation.

Kenya has an extensive road network, estimated to total 246,757 km, of which 162,055 km consists of the classified network (into 7 classes of class A to G). According to the Road Inventory and Condition Survey (RICS)[13] data of 2018, about 100,000 km of the network is maintainable. The National Trunk Road network currently stands at 44,021 km and the rest are county roads. Over the last ten years, the government has invested heavily in road development and maintenance. This has resulted in an overall improvement of road conditions: the poor road network has declined from 59 percent to 37 percent between 2009 and 2018 (Figure 6 and Figure 7).

Figure 6. Road condition in 2009 and 2018
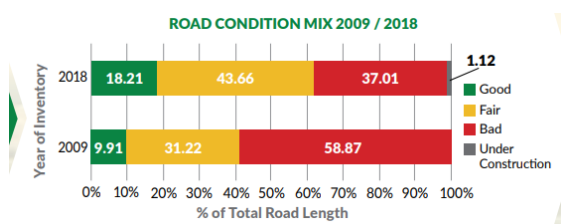
Source: Kenya Roads Board

Figure 7. Rural Access Index (2018)
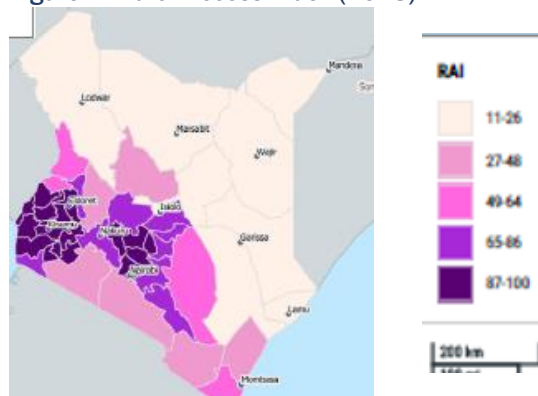
Source: Kenya Roads Board

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[13] Every five years, the Board normally undertakes a countrywide Road Inventory and Condition Survey (RICS), The next RICS (2022) is under way.

While the proportion of roads in poor condition has declined over the decade, regional disparities in road maintenance are still significant, which requires a big investment to bring the network to maintainable standards. Transport movements in Kenya have been concentrated along the Northern Corridor, which connects Mombasa, Nairobi, and the Uganda border. The Rural Accessibility Index also indicates poor access conditions in the north and northeastern parts of the country. Conversely, high accessibility is observed along the Northern Corridor and in highly populated areas.

Kenya is engaged in several trade integration initiatives with significant opportunities for driving inclusive and climate-smart growth through enhanced regional and international supply chain linkages. Kenya is in the middle of negotiations for a Free Trade Agreement (FTA) with the United States, is renegotiating the East Africa Community (EAC) Common External Tariff (CET) and has recently signed the African Continental Free Trade Agreement (AfCFTA). These trade integration initiatives present significant opportunities to tap into large regional and global markets, foster regional value chains, and modernize the regulations and institutions that govern international trade in the country.

Further integration in supply chains is an opportunity to reduce trade costs and improve the competitiveness of the Kenyan economy, and at the same time accelerate the low-carbon transition. By reducing tariffs, eliminating domestic trade costs, and promoting trade and transport facilitation measures, these initiatives can promote increased foreign competition in the domestic market and create a competitive business environment that can boost productivity, investment, and innovation. Effective implementation of these trade integration initiatives could help Kenya become a globally competitive regional hub that provides producers with access to inputs at world prices, attracts foreign direct investment (FDI), and is integrated into global and regional value chains.

A determined effort to accelerate the low-carbon transition and the reduction of trade and transport costs will have significant benefits. For instance, in the case of the US FTA, the largest gains in GDP and income (0.7 percent and 2.8 percent, respectively) would come from reducing domestic trade and transport costs. These measures will make it easier for firms to export and to gain access to cheaper imported inputs that will boost competitiveness in many export-oriented industries, resulting in a significant increase in exports.[14]

Recent inter- and intra-regional supply chain patterns

Kenya's share of exports as a percentage of GDP has declined steadily in the last two decades and remains below countries of similar economic size. Exports of goods and services as a percentage of GDP declined from 28.5 percent in 2005 to 10.6 percent in 2021 (Figure 8). The ratio of exports to GDP declined partly because of strong domestic growth, but also due to sluggish export performance that underachieved compared to global and regional comparator countries. Based on a comparison with other countries of similar economic size, the gap in the export to GDP ratio is large and increasing, with Kenya's ratio about a third of the average ratio for a country of similar size (Figure 8). Thus, significant export opportunities are available to Kenya as exports still have ample room to grow.

Figure 8. A declining share of exports in GDP that is well below its income level

Exports of goods and services (% GDP)

Exports as share of GDP and economic sizes
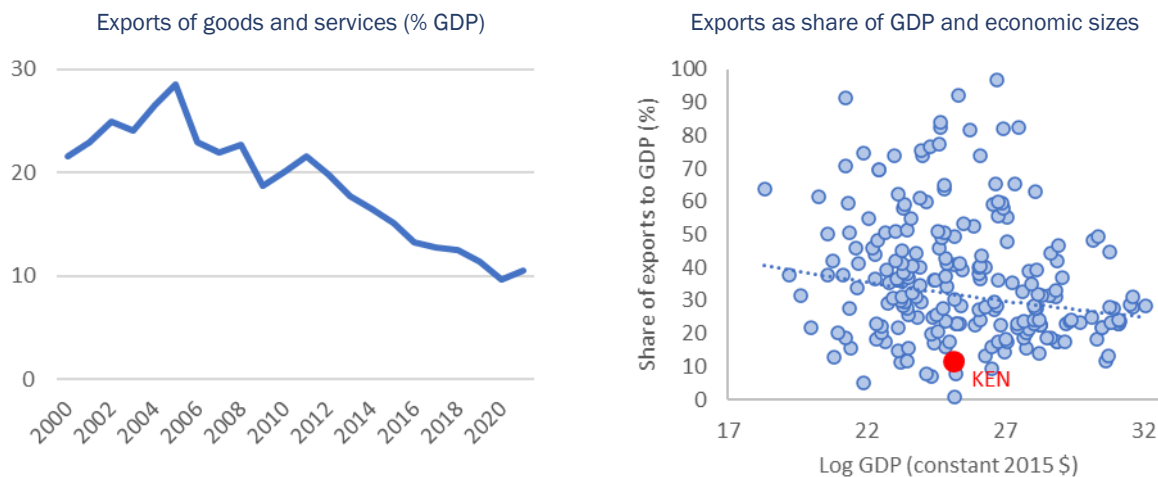
Source: WDI

Source: WDI

The decline in the share of exports to GDP is consistent with an economy experiencing low productivity growth and high trade costs like Kenya. From 2004 to 2017, the contribution of total factor productivity (TFP) to GDP growth in Kenya (0.9 percentage points) significantly lagged that of comparators like Rwanda (2.4 percentage points) and Tanzania (1.8 percentage points). Kenya faces many constraints that are preventing productivity growth. There is a need to improve the business regulatory environment, reduce the large presence of legacy state-owned enterprises (SOEs), enhance access to finance, improve the adequacy of physical capital (transport infrastructure, electricity), and increase investments in human capital.[15] In a context in which high trade costs protect domestic industries from competition, and low productivity prevents most firms from competing abroad, firms would typically devote their resources to serve the domestic market.

Agriculture remains the largest contributor to Kenya's exports followed by manufacturing and minerals (Figure 9). Kenya's total exports fluctuated around US$6 billion over the last decade. Tea, the top export commodity, accounted for 24.8 percent of total exports. Other major agricultural exports are cut flowers (9.4 percent) and coffee (3.9 percent). Exports of manufactured products declined from 36.9 percent in 2012 to 31 percent in 2021. Exports of chemicals, cement, steel products and other consumer goods also continued to decline in relative terms. At the same time, exports of fuels, ores, and other minerals increased from 5.1 percent in 2012 to 8 percent in 2021, as the country started exporting new ores in 2014.

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[15] World Bank. 2022a.

Figure 9. Kenya's exports and imports, product group and country (2020 and 2021)

Breakdown in economy's total exports
By main commodity group, % (2020)

- Agricultural products: 59.9
- Fuels and mining products: 11.9
- Manufactures: 27.9
- Other: 0.3

By main destination, % (2021)

- European Union: 15.7
- Uganda: 12.3
- United States of America: 8
- Pakistan: 7.2
- United Kingdom: 6.7
- Other: 50.1

Breakdown in economy's total imports
By main commodity group, % (2020)

- Agricultural products: 18.7
- Fuels and mining products: 15.5
- Manufactures: 65.3
- Other: 0.5

By main origin, % (2021)

- China: 20.5
- India: 10.8
- European Union: 10.6
- United Arab Emirates: 8.3
- Saudi Arabia, Kingdom of: 5.3
- Other: 44.4

Source: COMTRADE

The sluggish performance of agricultural exports is partly due to the failure to introduce new export products and access new markets for existing products. Kenya has steadily lost market share in the EU, its main market for agricultural exports (Figure 10) which points to a loss of competitiveness in international markets. Exports to the EU rely on the same products (flowers, coffee, tea, avocados, green beans) as two decades ago, as Kenya has struggled to introduce and consolidate new export products. This is because a poor business environment, lack of access to finance, and poor transport and logistics have acted like barriers to entry for new firms into exporting. Kenya only managed to introduce four new products with exports above US$10 million in the EU since 2002, which is the lowest among comparators (Figure 10). As a comparison, Peru tripled the number of export products above US$10 million in the EU from 11 to 37 during the same period, while Morocco almost doubled them from 25 to 48. For instance, exports of fresh avocados, Kenya's main horticultural export, are not allowed in the two largest world markets for this fruit (US and China) and the largest regional market (South Africa) due to the inability to comply with sanitary and phytosanitary (SPS) requirements.

Figure 10. Lack of new agricultural export products and a declining market share in the EU

Share of EU agricultural imports

Number of agricultural products over US$ 10 million exported to the EU
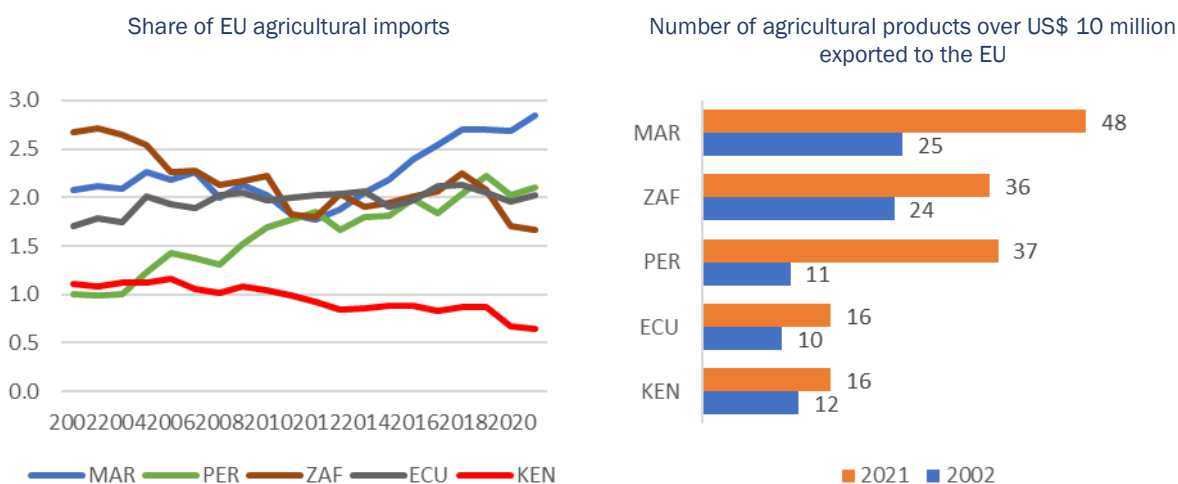
MAR: Morocco, PER: Peru, ZAF: South Africa, ECU: Ecuador, KEN: Kenya
Source: COMTRADE

Source: COMTRADE

To remain competitive in EU markets for its exports and potentially increase its share, Kenya must further integrate environmental requirements from national and European regulations on sustainability. In today's world, rising global awareness about environmental problems is being translated into a commercial reality for Kenyan agribusinesses (Box 1). Both private companies and governments are tightening their environmental demands, as major buyers and retailers increasingly set carbon emission reduction targets, demand good water management, and expect to work with their Kenyan suppliers to achieve such environmental goals. Simultaneously, governments in Western markets are looking to improve their environmental policies, including setting regulatory demands for the products they import.

Box 1. Carbon Footprint of Horticulture Production: Measuring Environmental Performance (examples)

The Product Environmental Footprint Category Rules (PEFCRs)

There is a European project aimed at developing a reliable method of calculating the CO_2 footprint of a product: Product Environmental Footprint Category Rules (PEFCR). The EU is working on a set of approved rules to be made mandatory later. To prepare the industry for this, the floriculture sector has harmonized rules for calculating the environmental footprint of pot plants and cut flowers. This is expected to yield an officially approved PEFCR for "cut flowers and potted plants" (FloriPEFCR).

Source: https://green-business.ec.europa.eu/environmental-footprint-methods_en

The HortiFootprint Calculator

Horticulture growers worldwide will soon be able to get valuable insights into their environmental footprint thanks to the HortiFootprint calculator, a new software developed by MPS and Letsgrow.com. The tool measures the carbon footprint of horticulture production based on inputs including energy use, fertilizers, and packaging. A scenario analysis function makes it quick and easy to calculate the impact of changes made to these inputs in the future.

Source: https://www.hortifootprintcalculator.com/

Major buyers of Kenyan exports have committed to reduce their carbon footprints, including in their supply chains. The UK supermarket Tesco, for instance, participates in the Science Based Targets initiative (SBTi), a major private carbon emissions program encompassing many large brands. Tesco has committed to cut supply chain emissions by 17 percent by 2030. Similarly, the US retailer Walmart has announced "Project Gigaton," committing to cutting down emission from its global value chain by one gigaton by 2030. Many other major supermarkets and brands buying fresh produce and agricultural commodities like coffee and tea (like Nestle and Hershey's) have set similar targets. Major international fresh-produce buyers define best practices and set goals for environmental performance. The Westfalia Fruit Group, for instance, has set a goal of carbon neutrality by 2030 and of ultimately recovering lifetime carbon emissions by 2049.[16]

Legislation may speed up demands for environmental management. In 2019, the EU launched an ambitious green growth strategy—the European Green Deal—that aims to transform how the EU produces and trades many of the products it consumes. While many elements are as yet only expressed as political statements and not translated into legislation, exporters to the EU are expected to be affected. The European Commission is also working to develop sustainability criteria—potentially including criteria for

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[16] https://www.freshfruitportal.com/news/202/06/15/westfalia-fruit-group-illustrates-its-commitment-to-sustainability-with-science-based-targets-initiative/.

carbon emissions and water use—for a range of food and agricultural products.[17] The European Commission has also announced draft regulations covering mainly heavy industrial products but also fertilizer.

Furthermore, manufacturing exports in Kenya have struggled to expand beyond neighboring countries in which they enjoy significant tariff preferences. More than three quarters of Kenya's manufacturing exports are destined for EAC members or landlocked neighboring countries for which Kenya serves as a transit point. As such, the regional transport corridors are key to support the export industry. Manufacturing exports to the EAC consist mainly of final products (steel, pharmaceuticals, processed food) that attract the highest CET rate of 25 percent but for which Kenya is exempted, resulting in significant preference margins that make these exports profitable. With the AfCFTA progressively reducing tariffs in the continent over the next decade, Kenya should boost the competitiveness of its producers and rely less on the protection afforded by the CET.

The lack of export dynamism at the aggregate level is mirrored by trends at the firm level. Although the number of exporters increased from 4,451 in 2012 to 6,824 in 2020, the average number of products and destinations reached by exporters has consistently declined over time. The average number of products exported per firm has declined from seven in 2012 to just under five in 2020. This indicates firms becoming less diverse over time. Similarly, the number of countries reached by the average exporter has declined from 2.8 in 2012 to 2.2 in 2020. This is fewer than the same statistic for Malawi, Senegal, and Tanzania, where firms all export to an average of at least four countries. Each exporter earns an average of about US$ 0.9 million, which is slightly below the average earnings per exporter in Uganda and Tanzania.

2.2. Regional and international supply chains: the role of transport links and logistics nodes

The Northern Corridor, one of the busiest and most important multi-modal trade routes in East and Central Africa, is the principal transportation link for domestic, regional, and international supply chains. Its main gateway is the port of Mombasa, and it then links the landlocked countries of Uganda, Rwanda, and Burundi, as well as servicing the eastern part of the Democratic Republic of Congo, South Sudan, and Northern Tanzania. The Northern Corridor is composed of road[18] and railway networks and inland waterways along which Kenya exports about US$2.2 billion worth of goods (equivalent to about 37 percent of total exports) to its neighbors. The port of Mombasa, the principal maritime node, recorded a throughput of about 35 million tonnes in 2021, a slight increase over 2020 (34.12 million tonnes), representing a growth of 1.2 percent, with transshipment contributing to about 25 percent of the total growth.

In Kenya, most exporters are located within the vicinity of the Northern Corridor, especially around Nairobi, Mombasa, Eldoret, Kisumu, Nakuru, and Thika. The highlands for tea production are spread across 19 counties,[19] mostly surrounding the Rift Valley. Kericho, Bomet, and Nandi counties are the origin points of about 46 percent of total tea production in Kenya. The main production areas of the floriculture industry are around Lake Naivasha, Mt. Kenya, Nairobi, Thika, Kiambu, Athi River, Kitale, Nakuru, Kericho, Nyandarua, Trans Nzoia, Uasin Gishu and Eastern Kenya. About 30 percent of flower farms in Kenya are located near Lake Naivasha. The remote regions of western Kenya near Lake Victoria are rich in gold

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[17] European Commission. 2020, 2022.

[18] See Box 2.

[19] https://www.statista.com/topics/8363/tea-industry-in-kenya/#topicOverview.

ore. Coffee is grown in 33 counties in Kenya.[20] In the 2018/2019 season, Kiambu was the leading county in coffee production in the country.

Box 2. Transport Networks (Road and Rail), Kenya's Strategic Location

Specifically, the transport link between Mombasa and Nairobi is expected to remain the most important driver for freight flows in the region in the coming years, projected to carry about 66.1 million tonnes in 2040 (Figure 11). Although intra-regional trade has increased substantially, which is reflected in the relative increases of freight flows in the sections Nakuru-Kampala (N4), Kampala-Masaka (N5), and Masaka-Kigali (N6), inter-regional traffic remains the most important driver for freight flows in the region, as demonstrated

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[20] Including Nairobi, Kiambu, Muranga, Nyeri, Kirinyaga, Embu, Meru, Machakos, Makueni, Taita Taveta, Kajiado, Nakuru Kericho, Nandi, Uasin Gishu, Elgeyo Marakwet, Baringo, Trans Nzoia, West Pokot, Narok, Bomet, Kisii, Nyamira, Migori, Homa Bay, Kisumu, Siaya, Busia, and Bungoma.

by its existing magnitude. According to recent studies, the Northern Corridor is the preferred route, as its cost is about 37 percent lower than the Central Corridor (culminating in Dar es Salaam port), mainly due to a lower average distance. While the share of exports to GDP has declined, export trade to Uganda has recorded a near doubling of volumes over the last three years, from just over 2 million tonnes in 2019 to about 4 million tonnes in 2021. Within this context, Lake Victoria, the primary inland waterway servicing both the Central and Northern corridors, plays an important role by means of an integrated rail/ferry system through the port of Kisumu connecting Mwanza (Tanzania) and Port Bell/Jinja (Uganda).[21]

Figure 11. Northern and Central Corridor: freight volumes transported (MT), by section (2020–2040)

Northern Corridor		2020	2040
N1	Mombasa – Nairobi	25.8	66.1
N2	Nairobi – Nakuru	20.2	53.1
N3	Nakuru – Kisumu	3.1	7.2
N4	Nakuru – Kampala	12.8	36.5
N5	Kampala – Masaka	3.9	12.5
N6	Masaka – Kigali	2.3	7.8
Central Corridor		**2020**	**2040**
C1	Dar es Salaam – Dodoma	9.7	26.8
C2	Dodoma – Nzega	6.4	18.3
C3	Nzega – Mwanza	1.0	2.6
C4	Nzega – Nyakanazi	4.0	12.2
C5	Nyakanazi – Kigali	2.0	6.4
C6	Nyakanazi – Kampala	1.1	3.3
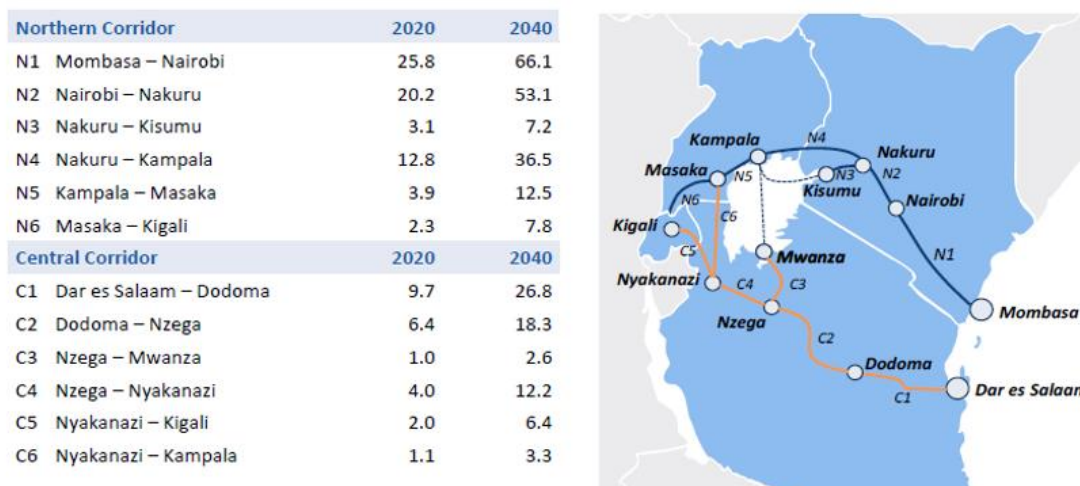
Source: MTBS

Figure 12. Kenya's Inter-Regional Traffic Forecast 2020–2040

000' Tons	2020	2025	2030	2035	2040
Container	6,855	9,378	13,073	17,019	20,184
General Cargo	1,584	2,505	3,446	4,410	5,147
Dry Bulk	6,556	7,188	9,045	10,705	11,816
Liquid Bulk	5,814	7,100	8,597	9,976	10,958
Total	**20,809**	**26,171**	**34,161**	**42,111**	**48,105**

Source: MTBS

2.3. Mitigation: decarbonizing supply chains and logistics

As discussed in Section 1, Kenya has acknowledged the importance of addressing climate change, including the development of low-carbon and efficient transport and logistics systems. The development of a sustainable transport and logistics system is critical to achieving the government's commitments towards low-carbon growth in line with the country's development priorities. At the same time, a transport and logistics system that has a low-carbon footprint and low trade costs is expected to boost trade and

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[21] In February 2021, the newly built Standard Gauge Railway and refurbished Metered Gauge Railway became operational between Kisumu and Malaba. In addition, the Kisumu Port was refurbished at a cost of $30 million in 2021.

commerce as it responds to the growing demand from destination markets to comply with environmental policies (including regulatory settings) for the products they import.

With over 80 percent of traffic and 76 percent of freight depending on trucks and motor vehicles,[22] the heavy reliance on road transport and fossil fuel–powered vehicles comes at an environmental cost (especially in terms of air pollutants and GHG emissions). As presented in Section 1.1, the total domestic transport sector emissions in Kenya amounted to 12.343 $MtCO_2e$ (not including emissions from waterborne navigation) in 2019, an increase of about 4.6 million tonnes from 2010. The road subsector was responsible for 12.09 $MtCO_2e$, which accounts for 98 percent of sector emissions, while emissions from the rail and aviation subsectors are 0.062 $MtCO_2e$ (1 percent) and 0.188 $MtCO_2e$ (2 percent) respectively. According to projections) total road transport emissions are expected to increase by 380 percent over the period of 2015–2050 (Figure 3). While passenger cars dominate total mileage driven, heavy goods vehicles (trucks) generate the greatest amount of emissions (Figure 4).

According to previous studies,[23] climate mitigation measures to reduce the GHG footprint of freight transportation and logistics lie in (i) reducing the energy intensity of vehicles and operations, and (ii) developing smart logistics and a modal shift from road to rail (Figure 13). While the estimates of mitigation potentials are highly probable, mostly focus on HGV efficiency, and do not consider the construction and extension of the SGR and the additional modal shift, these estimates provide evidence that mitigation measures are of great importance, as presented in the NCCAP. The NCCAP has set the target that mitigation measures in transport and logistics will reduce GHG emissions by 2.39 $MtCO_2e$ by 2030, more than twice the estimates of the earlier study. These estimates will be complemented in this chapter with some back-of-the envelope estimates, based on typical emissions per tkm.[24] More detailed assessments should be undertaken, including on the role of smart logistics and the modal shift from road to rail (including electrification of the SGR) to support further decarbonization of supply chain and logistics in Kenya.

Figure 13. Scenario of mitigation potentials (tCO_2e): 2018 study
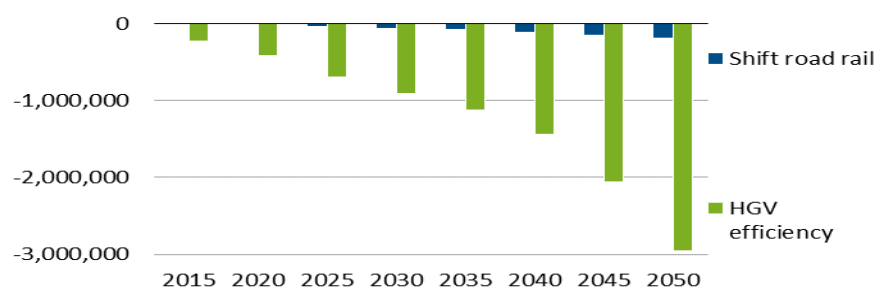
Source: GIZ 2018

2.3.1. Reducing the energy intensity of vehicles and operations

Energy demand and the use of fossil fuels

Inevitably, there is a direct link between GDP per capita increase and the share of transport-related energy demand, in particular for fossil fuels and consequently on total GHG emissions. While the country's development has resulted in rapid emissions growth in transport (albeit from a relatively low base), freight and passenger movement (retail pump outlets and road transport[25]) consumes the largest share of petroleum fuels in Kenya (about 76 percent in 2021) and hence is a major contributor to GHG emissions. The transport sector consumes about 72 percent of all petroleum products imported into Kenya (Figure 15). Petroleum fuel consumption in the transport sector has increased significantly over 2014–2018 and without intervention, fuel consumption over the years 2018–2025 is projected to grow at an accelerated rate (Figure 14). The share of road transport in the consumption of petroleum fuel stands at about 85 percent, while the aviation sector accounts for about 15 percent (Figure 16). With the introduction of freight rail services along the standard gauge railway (SGR), the rail sector's consumption of fuel more than tripled from 1,147 tonnes in 2017 to 3,544 tonnes in 2018 and almost doubled over the period of 2020–2021 (11,500 tonnes to 19,400 tonnes).

Figure 15. Petroleum fuel consumption by sector, 2019
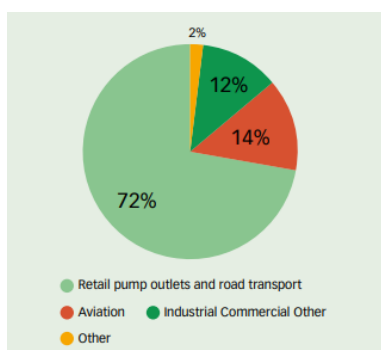
Source: NEECS, 2020

Figure 16. Petroleum fuel consumption in transport by category, 2018
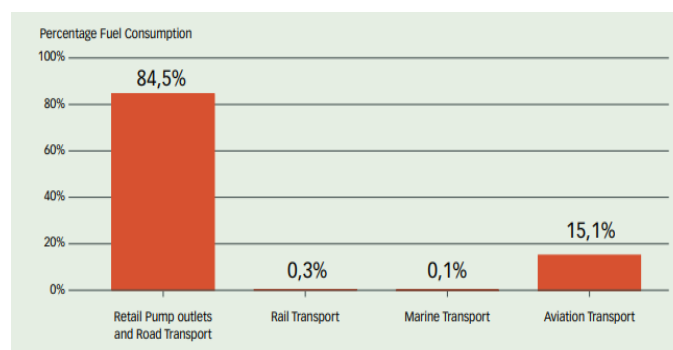
Source: KNBS, Economic Survey 2019

Figure 14. Projection for fuel consumption (2018–2025)
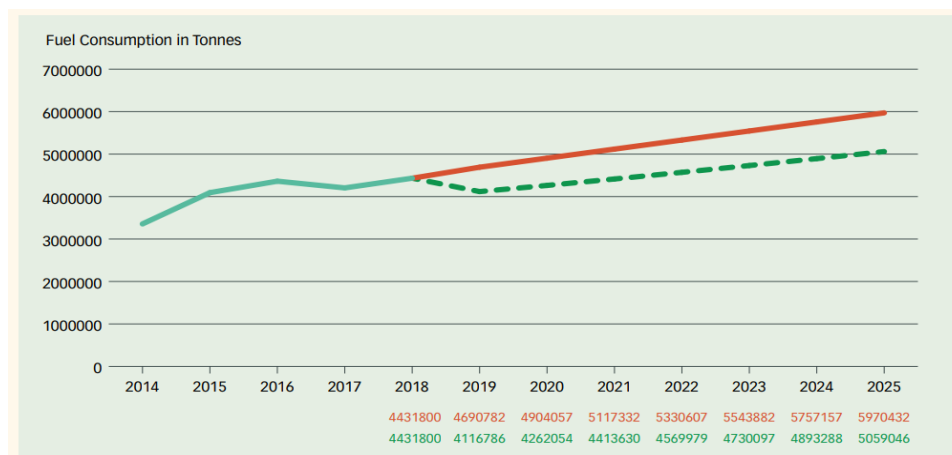
Source: KNBS, Economic Survey Report, 2019

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[25] Republic of Kenya. 2022a. Economic Survey. https://www.knbs.or.ke/wp-content/uploads/2022/05/2022-Economic-Survey1.pdf.

As petroleum products make up a significant portion of Kenya's annual imports (Table 3), reducing the energy demand and consumption of fossil fuels could also contribute to addressing the significant trade deficit. Petroleum products are one of the major imports in Kenya, used mainly for transportation and for industrial and residential energy needs. In 2021, petroleum fuels imported by Kenya increased by 12 percent to 6.4 million tonnes, costing the country US$3 billion. Numerous studies have demonstrated that the transport sector, and in particular road transport, offers opportunities for savings on imported fuels through energy efficiency and fuel substitution as internal combustion engines (ICE) consume the largest share of energy in the road transport sector (Figure 17).

Table 3. Kenya's trade deficit, 2017–2021 (Trillion KSh and USD billion)

Kenya's Trade Deficit Over The Past 5 Years

Year	2017	2018	2019	2020	2021
Deficit (Trillion, Ksh)	1.14	1.15	1.2	1.0	1.41
USD (Billion)	9.5	9.6	10	8.4	11.8

Source: KNBS 2022 Economic Survey

Kenya's Petroleum Fuel Imports Over The Past 5 Years

Year	2017	2018	2019	2020	2021
Ksh (billion)	263	325	313	206	345
USD (billion)	2.2	2.7	2.6	1.7	2.9

Source: KNBS 2022 Economic Survey

Source: KNBS, Economic Survey 2022

Figure 17. Road transport energy consumption by engine type (2015–2050)
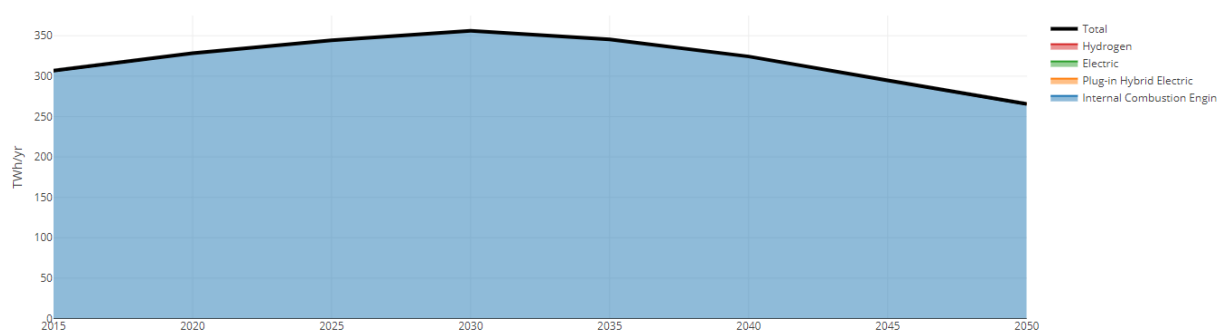
Source: KCERT 2050 carbon calculator, Ministry of Energy, Kenya

Replacing fossil fuels with alternative, sustainable energy sources

Fully eliminating GHG emissions from the transportation and movement of freight and passengers in Kenya, as elsewhere, would require large-scale conversions to green fuels. At present, the Kenyan government is developing a comprehensive renewable fuels strategy focused on road transportation as well as the aviation sector with five key elements: i) A regulation to establish minimum biofuels content for ethanol and diesel; ii) Programs to support farmer participation in the industry; iii) A production incentive to stimulate domestic production; iv) Support for the use of ethanol from the sugar industries; and v) Initiatives to support next-generation technologies. While biofuels have the advantage that they can be distributed in exactly the same way as fossil fuels, making use of existing transport refueling infrastructure, their development, however, is also linked to a major challenge. This is the limit to which the amount of sustainably sourced biomass can be used for biofuel production without entering into conflict with food security or direct and indirect land-use change.

Box 3. World Energy Outlook: An Updated Roadmap to Net Zero Emissions by 2050

According to the World Energy Outlook 2022 and under the Net Zero Emission (NZE) scenario, the global road transport sector can be almost entirely decarbonized by 2050 (see Figure B2.1). Electricity is expected to be the main fuel for road transport, accounting for over two-thirds of total energy consumption and nearly 90 percent of total road activity by 2050. Hydrogen also plays an important part and is responsible for almost one-quarter of energy consumption in the sector. Despite the high costs of these energy carriers and the considerable energy losses incurred in their production, hydrogen and low-emissions synthetic fuels play a key role in reducing carbon emissions from long-distance modes thanks to their high energy density.

Figure B2.1. Projected path for decarbonization of the transport sector

Direct electricity use is key to decarbonising road transport and rail; hydrogen and hydrogen-based fuels play a major role in aviation and shipping

Note: Light-duty vehicles include passenger light-duty vehicles and light commercial vehicles. Other includes two/three-wheelers, buses, rail, pipeline and non-specified. STEPS = Stated Policies Scenario.

Source: https://www.iea.org/reports/world-energy-outlook-2022/an-updated-roadmap-to-net-zero-emissions-by-2050

While biofuels have been blended with standard petroleum for many years (Box 4), the viability and development of other alternative fuels (e.g., natural gas, hydrogen) and technologies (e.g., batteries, fuel cells) could be further studied in the context of Kenya. The following four main characteristics should be carefully studied within the context of Kenya in order to determine further development: (i) technical readiness (including power and energy density, durability, overall energy efficiency, storage options, and maintainability, as well as fuel availability), (ii) infrastructure readiness (availability of storage, distribution, and fueling infrastructure), (iii) economic viability (delivered fuel cost, capital cost of introducing fuel and its supporting infrastructure), and (iv) environmental impacts (life-cycle resource and energy impacts).[26]

Among others, fiscal and economic measures are contemplated in the transport sector to steer Kenya's economy towards a low-carbon climate-resilient green development pathway. This is the objective of the recently published draft National Green Fiscal Incentives Policy Framework[27] with measures that are anticipated to help stimulate a shift in production, consumption and investment in low-carbon climate resilience and environmentally sustainable practices. Among others,[28] the government is proposing a change in the transport fuel tax rate, particularly in combination with carbon tax, which is expected to enable a comparison of fuel-use changes compared to growth in vehicle miles travelled.

The phasing out of subsidies for fossil fuels is generally coupled with programs to offset their impact in a gradual manner to avoid a "shock" to the economy. This is particularly pertinent for low-income households who may have a disproportionally higher dependence on fossil fuels. Carbon pricing mechanisms can provide additional incentives to reduce GHG emissions. And Kenya voluntarily participates in the carbon offsetting and reduction scheme for international aviation (CORSIA) in its pilot phase (2021–2023) and given the importance of aviation for freight and passenger movement, the Kenya Civil Aviation Authority has developed an Action Plan for CO_2 emissions reduction in the sector (2022–2028).[29]

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[26] World Bank. 2023b. Decarbonizing International and Intercity Freight and Logistics in Developing Countries. Forthcoming.

[27] Republic of Kenya. 2022c. https://www.treasury.go.ke/wp-content/uploads/2023/01/Draft-Green-Fiscal-Incentives-Policy-Framework.pdf.

[28] In the transport sector, the government intends to shift public expenditure towards electric mass transit. The draft policy proposes providing incentives for the import, manufacture, and assembly of electric and hybrid motor vehicles, motorcycles, and their spare parts. To boost support for charging infrastructure, the government will offer incentives for electric vehicle and e-mobility infrastructure. The draft policy proposes a congestion charge in major cities targeted at changing the traffic flow.

[29] Republic of Kenya. 2022d.

Box 4. Experience with Biofuels

Biofuels have high energy densities and are typically compatible with existing vehicle fleets and fuel distribution infrastructure. There are three main fuels that are currently commercially available with technically mature production processes:

- **Biodiesel** can be produced from oil crop feedstocks, used cooking oil, and animal fat wastes. Consumption is most commonly in blended forms from B5 to B20 (the number indicates the percentage share of biodiesel to ordinary diesel) while higher blends, such as B50 or pure biodiesel (B100), can also be used but require modifications to freight vehicles.
- **Hydro-treated vegetable oil (HVO)** can be produced from a similar range of feedstocks to biodiesel. It is technically a "drop-in" fuel and can be used unblended (HVO100) without any modifications to diesel engines or fueling infrastructure. However, blends with fossil diesel (e.g., 30–50 percent HVO by volume), are currently more commonly used.
- **Biomethane** is similar in its physical and chemical quantities to natural gas, and it can be used in natural gas–fueled vehicles. Biomethane is produced by anaerobic digestion of high moisture content organic wastes.

Other fuels currently being researched include:

- **ED95 ethanol**, from either conventional crop-based and cellulosic feedstock
- **Biofuels from thermochemical production processes, such as gasification and pyrolysis**, can produce fuels suitable for use in heavy-duty transport from a range of biomass feedstocks, including forestry and agricultural residues, and municipal solid waste (MSW). Syngas produced from gasification can be upgraded to biomethane (BioSNG) (as produced via anaerobic digestion) and a range of other fuels collectively known as biomass-to-liquid (BtL) fuels
- **Power-to-X (PtX)** synthetic fuels combine hydrogen (e.g., produced via electrolysis) with carbon or nitrogen to produce gaseous or liquid fuels, including ammonia (from hydrogen and nitrogen)

GHG emissions from biofuels vary considerably depending on the feedstock and precise process used to produce them and the extent to which they are calculated on a net or gross basis. Several biofuels (e.g., biodiesel) emit GHG just as conventional diesel does but the argument is made that if they were not converted to biofuel, they would emit GHG naturally or, if grown specifically for conversion to biodiesel, that they have absorbed CO_2 from the atmosphere. California has a set of emission standards[a] which for 2021 estimated the GHG from various biofuels on a WTW[b] basis at between 25 percent to 50 percent of that of diesel. But as electricity is a significant contributor to the GHG emissions from biofuel production, this ratio will vary from country to country. Some biofuels also generate reduced local air pollution impacts compared to diesel. The cost of the crop-based biofuels is a function of feedstock prices, such as soybeans in the US and sugar in Brazil. The cost of the waste-based biofuels such as HVO is principally related to collection costs. The cost of PtX synthetic fuels is driven by energy costs and these require large-scale green electricity for them to be a realistic option.

Source: World Bank 2023b, forthcoming.

Notes:

a) The LCFS (Low Carbon Fuel Standards) which publish annual estimated emissions of various fuels. The EU has a similar set of numbers (the Fuel Quality Directive) which, although not identical, show the same general pattern.

b) Well-to-wheel i.e., including the net emissions created during the production of the fuel as well as its end-use. Californian electricity averages about 300 gCO2e/kwh.

Since emissions from freight transport account for a large share of Kenya's road transport emissions, measures that go beyond the efficiency of the engine itself, such as the optimization of superstructures of tires, reduced road roughness, eco-driving, etc. can also have a major impact. Logistics service providers naturally support efforts to improve the energy efficiency of vehicles and facilities, as they represent a large share of their own operating costs. Most fuel efficiency improvements, however, are incremental and will be introduced over 20years or more in line with fleet renewal. This has been in evidence across all freight modes over the past decades. A wide range of technology improvements have either been proposed or under development, with the most promising being: vehicle lightweighting, aerodynamic fittings to tractors or trailers to reduce drag, improved tires, improved drivetrain and auxiliary equipment, and engine controls.[30]

Kenya's National Energy Efficiency and Conservation Strategy also foresees measures to improve the fuel economy. Measures include the initiation of fuel economy standards and labelling for vehicles, including the average fuel consumption per mile and CO_2 emissions (Table 4). These targets, however, apply to light commercial vehicles, representing only 11 percent of total CO_2 emissions in the sector.

Table 4. Kenya: expected improvements in fuel economy performances (target by 2025)

Objectives	Indicators	Status (2019)	Target by 2025
Improve fuel economy performance and reduce CO_2 emissions in Kenya	• Average fuel consumption (light duty vehicles) per 100 km travelled • Average CO_2 emission per km travelled	Average fuel economy = 7.5 L/100km[a] Average CO_2 emission = 181.9 g/km[b]	6.5 L/100km 160 g/km

Source: Kenya's National Energy Efficiency and Conservation Strategy, 2020
https://repository.kippra.or.ke/bitstream/handle/123456789/3074/ENERGY%20STRATEGY.pdf?sequence=1&isAllowed=y

Many middle- and high-income countries have set national standards limiting fuel consumption of new, heavy-duty vehicles with diesel and gasoline engines.[31] Similar standards could be set in Kenya given its reliance on the import of used vehicles. Furthermore, fuel efficiency standards could also be set when licensing trucks, together with a voluntary scrapping and replacement program for the least fuel-efficient vehicles. However, average fuel consumption per distance travelled, as targeted in Kenya, has to consider the direct relationship with the quality of the road infrastructure. For a paved road, for example, there can be a 2 to 5 percent difference in fuel consumption between a good quality road and a road in poor condition; comparing a gravel road to a good quality, sealed road, the difference could be as much as 10 to 20 percent of fuel consumption.[32]

Along the Northern Corridor and under the auspices of the Northern Corridor Transit and Transport Coordination Authority, which developed the first green freight strategy in Africa,[33] an eco-driver training program has been launched, among other initiatives. Those programs have been shown to reduce truck fuel consumption by up to 5 to 10 percent, especially when combined with driver rewards and bonus

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[30] Teter et al. 2017; World Bank, 2023

[31] International Council on Clean Transportation, 2023; ICCT, 2022a; ICCT, 2022b.

[32] In practice, some of these gains may be eroded because of the higher speeds often driven on road with better quality pavements.

[33] Climate and Clean Air Coalition. 2017.

schemes to reinforced learned behaviors beyond the training period.[34] Many of these programs focus on reducing idling and techniques for more gentle acceleration and deceleration. They have demonstrated significant GHG emissions savings (at very low cost) in China, Thailand, Lao People's Democratic Republic, and Vietnam.[35] The GHG emissions reduction potential of eco-driving training is potentially greater in low- and middle-income countries than in high-income countries because of more difficult traffic conditions and the older truck fleets not being equipped with onboard driver assistance devices. Incentives are particularly well-aligned in countries where drivers are responsible for their own fuel costs. Driver training can also improve road safety, an important co-benefit in low- and middle-income countries with high traffic fatalities and injuries.

Several initiatives are also under implementation in Kenya to increase the energy efficiency in terminals and logistics facilities, such as for example in the aviation sector.[36] The Kenya Airports Authority (KAA)[37] is (i) installing a 0.5 MW solar plant at Moi International Airport under the ICAO/EU assistance project, (ii) using solar-powered auxiliary power units (APU)/ground power units (GPU) at Moi International Airport under the ICAO/EU assistance project, (iii) installing 9 APUs that are electrically powered at Jomo Kenyatta International Airport, and (iv) has developed sustainable concessionaire policies that encourage ground handlers to improve their ground handling equipment and promote use of low/zero-emission vehicles and other equipment. In 2021, KAA's Jomo Kenyatta, Moi, Kisumu and Eldoret International Airports joined the Airports Council International (ACI) Airport Carbon Accreditation (ACA) Program, achieving Level 1 "Mapping" accreditation.[38]

2.3.2. Climate benefits of smart logistics and modal shift: reorganization of supply chains

Logistics optimization through digital platforms

A key step towards cleaner transport and logistics systems is technological improvements as well as better planning of multi-modal operations. Digital technologies and their establishment play a key role in the development of the trade-supporting logistics and supply chain connectivity in Kenya on its path to climate neutrality. Smart Logistics concepts can be used to optimize the overall resource consumption and thus exploit new efficiency potentials, as well as make important contributions to sustainability and climate protection. It can therefore be assumed that government support for the development, piloting, and integration of key technologies, such as CPS, IoT, artificial intelligence, 5G networks and distributed ledger technology, will continue to be an ongoing trend in Kenya in the future.

The adoption of just-in-time principles, the rise of e-commerce, and growing environmental awareness are trends that put customer pressure on supply chain flexibility, efficiency, transparency, sustainability, and now more than ever, as demonstrated by the recent COVID-19 pandemic, resilience. The fragmented logistics market suffers from chronic inefficiencies in terms of low load factors, empty runs and low market power of small and medium sized enterprises.[39] Digital logistics platforms (DLPs) are a manifestation of logistics digitalization with a capacity to address contemporary issues within the logistics domain.[40]

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[34] Wang and Boggio-Marzet, 2018; AECOM 2016.

[35] ADB 2016; Grütter and Dang 2016.

[36] Republic of Kenya. 2022d.

[37] KAA launched its Going Green Initiative in 2019 with a goal of becoming the greenest airport operator in Africa by 2022, in line with the authorities' 2018-2022 strategic plan, which highlights environmental stewardship as one of the main strategic areas with a goal of obtaining ISO14001-2015: Environmental Management System (EMS) Standard.

[38] https://www.airportcarbonaccreditation.org/participants/africa.html.

[39] Lafkihi et al. 2019.

[40] WEF 2016.

The potential of DLPs has been widely recognized, especially in road transport and freight forwarding.[41] As a signal of this, it is not only venture capital–funded start-ups that have set up their own platforms, but also major logistics services providers (e.g., DHL and UPS), competitors (e.g., Maersk) and customers (Amazon and AliBaba), each having their individual entry strategy and business logic.[42] They include platforms for the buying and selling of vehicle capacity, to capacity sharing (co-loading), often combined with computerized vehicle routing and scheduling (CVRS) digital tools. Advanced CVRS can set to minimize fuel consumption and CO_2 emissions even if this does not necessarily minimize vehicle- or ton-kms.

In Kenya, several logistics companies have recently been established working based on similar service delivery models as in public transport, only that they deal with large cargo in an environment that is ridden with complex logistical issues and a fragmentation of the market. These include online platforms to match transporters and distributors with cargo owners and shippers for the selling and buying of vehicle capacities. Such platforms are widespread in middle-income countries, such as China, Indonesia, and Nigeria. They give details about available loads to any operator as well as access to a range of other freight management services, including route planning, track-and-trace, proof of delivery, and invoicing.

Companies offering such service in Kenya include the likes of Lori Systems, Leta, Senga Technologies, Sendy, Amitruck, and Tai+ among others. The use of DPLs has substantial climate-relevant co-benefits, as they improve capacity utilization, avoid wasteful transport and reduce GHG emissions. Leta, for example, claims to have optimized over 500,000 deliveries, in the magnitude of over 20,000 tonnes of goods and 2,000 vehicles.[43] Amitruck, another Kenyan DPL, has expansion plans to become the regional go-to platform for shippers and transporters doing in-country and cross-border business.[44]

2.3.3. Shifting supply chains to lower-carbon transport modes

Kenya's freight logistics transition and the ambition to expand as a transshipment hub for the region goes hand in hand with its decarbonization pathway because low-carbon logistics are, on the whole, more efficient and competitive. As part of delivering Kenya's Vision 2030, the country completed the construction of the SGR from Mombasa to Naivasha (592 km in total).[45] The revitalization of the Thika–Nanyuki line was successfully completed as of 31st December 2020. The revamping of Longonot–Malaba route with a total length of 465 kilometers has been completed, while the Naivasha ICD to Longonot link, which is 23.4 kilometers long, has also been completed. This is an important part of the East African Railway Master Plan. The 472 kms of railway service in passenger and freight from Mombasa to Nairobi began operating in May 2017. The 120 km extension from Nairobi to Naivasha opened in October 2019. Plans for a 369 km extension from Naivasha to Malaba (near the border with Uganda) have been shelved. A working paper by the China–Africa Research Initiative notes that China Exim Bank has declined to finance that section of construction until the Kenyan government provides an improved feasibility study. In the meantime, the two countries have agreed to refurbish the older-era meter gauge line to connect with the SGR.[46]

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[41] Riedl et al. 2018a; Riedl et al. 2018b.

[42] Witkowski 2018; Manners-Bell & Lyon 2019.

[43] https://techcrunch.com/2022/11/22/leta-a-kenyan-supply-chain-and-logistics-saas-provider-raises-3m-to-scale-in-africa/.

[44] https://techcrunch.com/2022/02/01/kenyan-tech-enabled-logistics-platform-amitruck-raises-4-million-embarks-on-uganda-tanzania-expansion/.

[45] A state-of-the-art internal container depot at Naivasha SEZ ensures seamless last mile connectivity to Kisumu via a meter gauge railway. The new line has an axle load of 25 tonnes/km and a design speed of 120 kph (passenger) and 80 kph (freight). Traction power is diesel. The maximum capacity for each freight train is 216 double stacked TEUs, or 4,000 tonnes. Current passenger train capacity is 960 passengers.

[46] Brautigam et al. 2022.

Figure 18. Kenya railway map
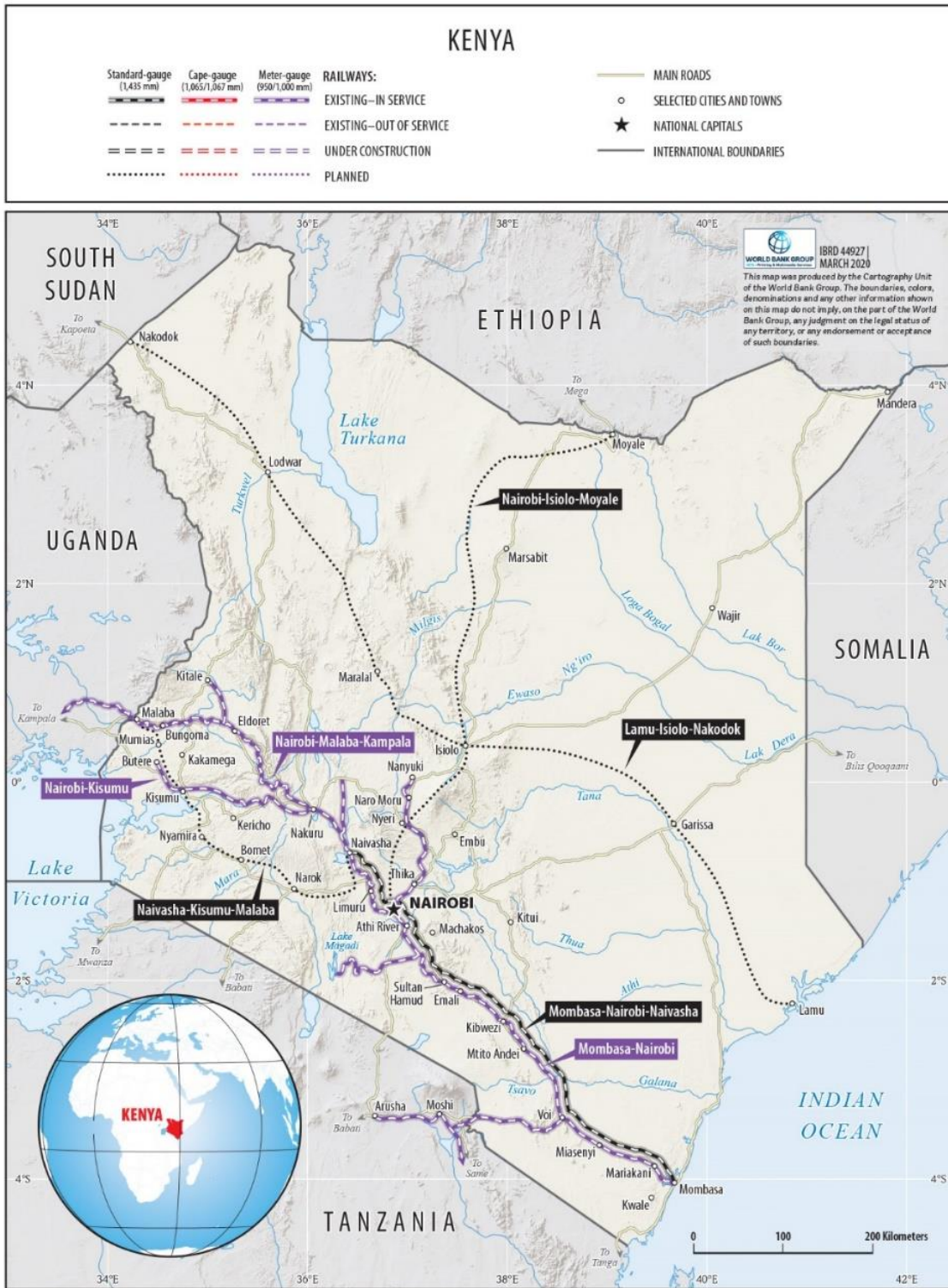
The SGR railway connects directly with the port of Mombasa and has Inland Container Depots (ICDs) in Embakasi, near Nairobi, and at Mai Mahiu between Nairobi and Naivasha, and has moved about 5.4 million tonnes of freight in 2021 (Figure 1). The Embakasi ICDs function as a dry port and has direct links to both the MGR and SGR. Containerized cargo terminating in the Rift Valley or Uganda transfers from the SGR to the MGR at Embakasi. The facility has the capacity to handle 450,000 TEUs[47] per annum. The SGR lacks feeder lines into the export and industrial zones in Kenya, hence most users must use trucks for last-mile delivery.

To counter the rising trend of energy-related CO_2 emissions in the sector, a further modal shift in favor of railways is estimated to save emissions of more than 20,200 metric tonnes of CO_2 (tCO_2) for each million tonnes of freight.[48] With expected traffic growth in railways, it becomes increasingly important to assess the potential reduction in CO_2 emissions when shifting freight from road to rail. Based on the average CO_2 emissions of the different modes of transport, estimations of saved emissions for the transport of an additional 1 million tonnes of freight were calculated. Transporting the additional freight on the SGR would result in emissions of around 15,000 tCO_2e, which is over 20,200 tCO_2e less than transporting the same amount of freight by road (Figure 20). If the SGR were electrified, emissions could be further reduced by approximately half compared to using diesel trains.

Figure 19. SGR: CO2 emissions savings, 1 million freight tonnes (tCO2e and %)
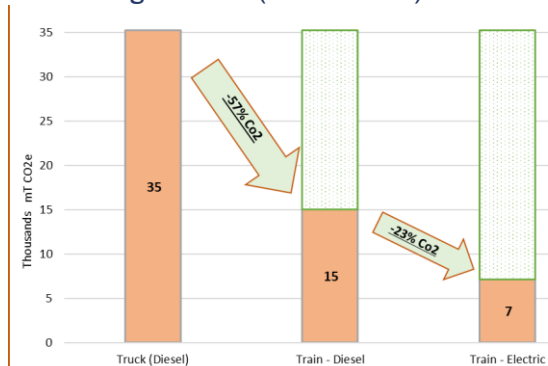
Source: World Bank analysis; where necessary, estimations were made

Figure 20. SGR: emissions savings, 1 million freight tonnes (comparison: truck, diesel train, electric train)

	Truck (Diesel)	Freight Train (Diesel)	Freight Train (Electric)
CO_2 emissions of 1 metric tonne additional freight (tCO_2e)	35,200	15,000	7,100
CO_2 savings on 1 metric tonne of freight on SGR (tCO_2e)	-	20,200	28,100

In metric tonnes of CO_2e

Source: World Bank analysis; where necessary, estimations were made

Electrifying the SGR in Kenya, which is currently powered by diesel, could potentially offer a solution to further reduce emissions in the transport sector. The complete electrification of the SGR is estimated to result in emissions savings of over 53,000 tCO_2e annually, with the majority of the savings coming from the freight rail sector (Table 5). It should be considered that this estimation does not take into account any emissions related to the necessary infrastructure for electrification (such as overhead lines and poles) or emissions generated during the construction process. However, the extent of these emissions is likely to be considerably lower than the long-term emissions savings. The figures provided are estimates and not specific to the Kenyan SGR; as such, they can only offer an approximate idea of the potential savings.

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[47] A TEU is a twenty-foot equivalent unit, a measure of volume in units of twenty-foot long containers.
[48] It is important to note that these numbers are only estimates and do not account for all relevant factors, such as variations in the length of the travelled distance by truck due to changes in freight routings and connections.

Table 5. SGR electrification: estimated emissions savings (tCO₂e)

CO₂ Emissions SGR 2021	Freight Rail SGR	Passenger Rail SGR	Total
Current Diesel emissions in tCO₂e	81,300	22,100	103,400
Electrified Rail emissions in tCO₂e	38,700	11,100	49,700
Emission Savings in tCO₂e	42,600	11,000	53,700

In metric tonnes of CO₂e

Source: World Bank analysis; where necessary, estimations were made

With nearly 6 million tonnes of traffic in 2021, the SGR is approaching economic and financial viability for an investment in its electrification, alongside considerations for the further development of the railway sector. The electrification of the SGR, as outlined in the NCCAP, should be further studied, including opportunities to expand current traffic. These would also include developing private sector led ICDs/dry ports along the link, connecting industries with bulk transport needs and specialized terminals (e.g., grain, petroleum products). Furthermore, the Government of Kenya is also considering whether to allow open access on the rail infrastructure, including the SGR and MGR. This could encourage private sector investment and operations, but pricing and terms of access would need to be developed and de-risked to realize the potential. A study commissioned by the Kenya Private Sector Alliance (KEPSA) in collaboration with Shippers Council of Eastern Africa (SCEA) cited, among others, three key factors explaining the dominance of trucking relative to rail transport: the high cost involved in double handling, unpredictable service levels, and inadequate infrastructure linkages (November 2020).

Even if rail freight gained significant modal share in the coming years, trucking is likely to remain the dominant mode of freight transport (and the sole mode of transport for first- and last-mile delivery), as is the case in most upper-middle-income and high-income countries. This is particularly true for Kenya, which has a relatively low rail accessibility and maritime frequency, which puts the country at a major disadvantage. So, measures to decarbonize and increase the efficiency of trucking operations deserve policy priority, as presented above. At current levels of battery technology, electrifying trucking—particularly heavy-duty trucks used for long-haul shipments—is challenging, while other promising technologies, such as hydrogen, are still under development. Complementary measures, such as wider cargo consolidation, equipment sharing, and standardization; digitalizing corridors through technologies like intelligent highways; and more seamless intermodal truck-rail transitions for containerized freight, will therefore be needed to increase the efficiency of trucking and logistics.

Optimization of supply chains and other measures at borders and gateways

There are significant opportunities to minimize GHG emissions (reduce the kilometers travelled) by optimizing the flow of goods in the supply chain, along routes as well as at gateways. These measures relate to the optimization of locations of production sites, special economic zones, and warehouses/terminals. At the regional and national level, the trend over the past few decades has been to concentrate inventory and related materials-handling activities in more centralized facilities which allow companies to serve wider areas more quickly, reliably, and cheaply and exploit the so-called square root law of inventory.[49] While the concentration of activities in centralized facilities reduces the carbon intensity of warehousing operations

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[49] McKinnon 2018.

by reducing energy consumption per unit of throughput,[50] these gains are often more than offset by the additional GHG emissions generated from transport and delivery of goods over longer distances to and from fewer locations.[51] Thus, the economically optimal supply chain arrangement may not always be the one with the minimum GHG emissions.

The aggregation, distribution, transport and storage and trade-related processes of key export products should be carefully studied to ensure optimal supply chain arrangements, both from an economic and environmental point of view. Kenya's economic geography and its relatively concentrated export/import basket as well as highly concentrated freight flow (mostly along the Northern Corridor) is well-suited to undertake such assessment. As a significant share of exports is carried by air, it appears that the logistics infrastructure and services offered by railways and ports are geared towards imports rather than exports. Several studies note that Mombasa Port and the SGR pose a challenge to the efficient, timely, and cost-effective export of goods by sea, as an estimated 90 percent of goods moving through Mombasa Port are imports, while exports account for only 10 percent (Graph 1). Reportedly, container ships frequently wait for 5 to 6 days to enter the port due to lack of berths, and perishable goods are treated the same way as any other ambient product passing through the port.[52]

Graph 1. Challenges in aggregation, storage, and transport (2020)
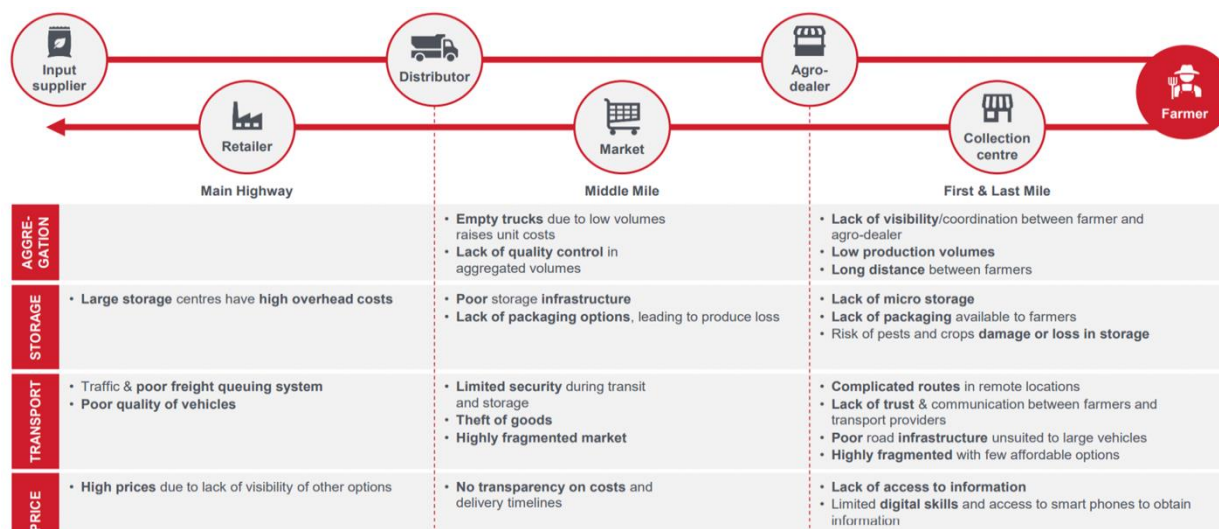
Source: Mercy Corps 2020

This should create incentives and synergies to accelerate a transition towards a greener and sustainable transport and logistics sector over the medium and long term, including through greater intermodal growth. In 2022, about 40 percent of domestic imports but only 11 percent of exports from the region were transported by rail, signaling significant room for intermodal growth as well as greater adoption of rail freight operations. Access to rail (and waterborne) services has become increasingly dependent on road feeder movements, making door-to-door freight movements "intermodal". The effectiveness of a freight modal shift as a decarbonization option will depend on wider industry adoption of inter-modality for appropriate classes of commodity. Furthermore, the majority of horticulture products bound for export require

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[50] Baker and Marchant 2015.
[51] McKinnon 2018.
[52] Kingdom of Netherlands 2021.

temperature management. While there is a general shortage of cold chain logistics providers operating on the road, the problem is worse when it comes to railways. Both the MGR and SGR line lack the facilities to handle refrigerated containers, and shipping lines are not offering through bills of lading export services via rail for this very reason. The block nature of trains also poses a challenge, as delays in the handling of a single wagon means delay for all consignments.

Other aspects of trade supply chains also offer significant opportunities for reducing carbon emissions and for increasing the use of measurement and monitoring to guide interventions. For example, delays at borders and ports can be a major source of emissions. Delays at the California–Baja California land border crossings reportedly result in an average of 457 tonnes of CO_2 equivalent emissions each day, equivalent to the consumption of more than 51,400 gallons of gasoline.[53] Delays at borders and ports are prevalent in low- and middle-income countries and offer the opportunity for interventions that not only reduce carbon emissions but also increase economic efficiency. Investments in port equipment, the streamlining and automation of customs clearance and immigration procedures, and policy reforms that increase the transparency and predictability of policies applied at the border are central to curbing delays. These measures could be complemented by reforms that support the modernization of trucking fleets and investments in green logistics.

2.4. Adaptation: climate change impact on transport infrastructure

2.4.1. Climate exposure and resilience of transport infrastructure

As previously presented, climate change impacts the resilience of domestic and international supply chains. Kenya is highly exposed to many natural disasters according to the World Bank's Climate Country Risk Profile (2021), the most common being floods and droughts. It is estimated that over 70 percent of natural disasters in Kenya are attributable to extreme climatic events. Increasing urbanization, particularly into flood plains and/or low-lying areas, has also increased flood risk, as water drainage systems fail. Figure 21 shows different levels of risk to Kenya from river flooding. Transport infrastructure is particularly vulnerable to flooding, as critical tourism assets and settlements are situated close to the coast and other low-lying areas.

Fluvial and coastal floods are the major causes of natural disaster in Kenya. According to data from the Emergency Events Database EM-DAT (Figure 22), in the time period from 1900–2020, flash floods occurred eight times causing US$500,000 of total damage, and riverine flood occurred 37 times causing damages worth over US$136 million while also causing the greatest losses in terms of human lives and infrastructure.[54] In particular, areas such as the county of Baringo, West Pokot, Kisumu and Laikipia are some of the country's most disaster-prone areas and have required significant adaptation measures.[55]

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[53] https://dot.ca.gov/programs/public-affairs/mile-marker/issue1-2022/project-spotlight.
[54] EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir, Brussels, Belgium. URL: http://emdat.be/emdat_db/.
[55] Development Initiatives Kenya. 2019.

Figure 21. Risk of river flood   **Figure 22. Natural disasters in Kenya, 1990–2020**

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Drought	Drought	16	196	52,911,500	1,500
Earthquake	Ground Movement	1	0	0	0
	Tsunami	1	1	0	100,000
Epidemic	Bacterial Disease	20	1,576	59,801	0
	Parasitic Disease	5	1,595	6,807,533	0
	Viral Disease	7	514	3,850	0
Flood	Flash Flood	8	245	193,500	500
	Riverine Flood	37	1,150	2,232,222	136,038
Landslide	Landslide	4	133	140	0
	Mudslide	1	20	6	0
Storm	Convective Storm	1	50	0	0

Source: World Bank Climate Country Risk Profile 2021

Source: EM-DAT: The Emergency Events Database. URL: http://emdat.be/emdat_db/

The susceptibility of infrastructure to climate risks is typically influenced by the extent to which transport assets are exposed to and resilient to extreme events. While inadequate maintenance of networks can result in a gradual deterioration of conditions over time due to precipitation, the more immediate impacts are experienced in the form of compromised vehicle stability and disrupted traffic. The disruptions are typically more pronounced when precipitation levels exceed a flood height of 250 mm. Consequently, climate-proofing transport infrastructure and implementing proactive adaptation for supply chains to minimize climate-related risks are essential, as highlighted by Kenya's NCCAP, NAP, and NDC.

The transport sector has started incorporating climate and natural disaster considerations, particularly in the road sub-sector. Selective vulnerability assessments have been carried out and inform the investment. For example, the World Bank–funded Horn of Africa Gateway Development project carried out climate vulnerability assessment for the entire Isiolo–Mandera road corridor (a 740-kilometer corridor) and its recommendations informed the engineering design of the road and associated structures from the perspective of network climate resilience enhancement. The road authorities plan to mainstream such assessments to cover their respective road networks.

2.4.2. Risk analysis for the multimodal national transport network

Acknowledging flooding as the most damaging natural disaster throughout Kenya, this deep dive focuses on the river (fluvial) and costal flood maps of the country to estimate climate risks to transport assets, by generating flood return period extents and flood depths for flooding across the different parts of Kenya.

Assessing transport value
The analysis under this sector background note relies on the Systemic Risk Assessment Tool (SRAT)[56] and support from its developers[57] to characterize the impacts of flooding damage to the country's road and rail network.

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[56] Pant et al. 2023. https://east-africa.infrastructureresilience.org
[57] In particular, we thank Raghav Pant, Ph.D., who generously provided detailed results and patiently answered all our questions.

The analysis is conducted in major four steps: (i) assessing the importance of a transport link based on its disruptive impact on the rest of the transport network and estimated flows; (ii) identifying the elements and locations in the transport network that are exposed to climate hazards under baseline and various climate scenarios; (iii) computing associated direct/indirect risks associated with the various climate scenarios; (iv) aggregating these results to county-level for a better understanding of geographic results and trends.

The model incorporates:

- Flood maps data;[58]
- Road network information, including geospatial network structure, as well as physical network condition attributes such as link width, length, and condition from OpenStreetMaps (OSM). Freight costs[59] are estimated and used to estimate the cost of traversing any particular route;[60]
- Rail network data is provided by OSM but enhanced with road network data of Kenya Roads Board. Port and airport information are then sourced from national port authority documents and country-specific reports such National Airport Masterplans;
- Global OD matrix of country-country import/export trade flows classified by commodities/industries and by mode of transport (maritime/air/land) in tonnes and dollars;
- In conjunction with population estimates and locations of economic activities, trade network flows are disaggregated to lower administrative levels and split among different modes (road, rail, port, air);
- In terms of trade flows, 2019 was chosen for the baseline and assumed future flows grow at 4 percent annually. While the Global OD matrix did not change, the study added new rail links in the future flow allocations by accounting for new railway lines being built in the region due to growing demand.

Climate scenarios considered and assumptions

Two future climate conditions are considered for the river and coastal flooding modeling based on the Representative Concentration Pathways (RCP) that provide a range of possible future for atmospheric conditions, as defined by the IPCC. The outputs are given for the years 2030 and 2050. For each scenario and projection year, we rely on the Aqueduct[61] modeling effort to assess riverine and coastal sea rise flood risk.

1. **Baseline** – the baseline for this assessment was estimated by modeling the current damage likelihood for each link in 2019, using historical data on floods, damages, and network usage from 2000–2018.
2. **RCP 4.5** – represents a stabilizing scenario for the global climate, in which greenhouse gas emissions would reach their peak by the 2040s, before declining for the remainder of the century. This would result in the earth's radiative forcing, which refers to the difference between the amount of sunlight absorbed by the earth and the energy radiated back into space, stabilizing at 4.5 Watts/m^2 by the year 2100. The temperature of the planet would consequently increase by 1.7–3.2 degrees Celsius from pre-industrial levels.
3. **RCP 8.5** – Widely considered to be a pessimistic climate scenario. This projection assumes that global greenhouse gas emissions would continue to rise until the year 2100, resulting in an earth's radiative forcing of 8.5 Watts/m^2 and a corresponding increase in global temperature of 3.2–5.4 degrees Celsius from pre-industrial levels.

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[58] https://www.wri.org/data/aqueduct-global-flood-risk-maps.

[59] Osborne et al. 2014; Teravaninthorn, Supee and G. Raballand 2009; ITF.2016; CCTTFA 2017; Pant et al. 2018.

[60] Freight and rehabilitation costs, in particular, are estimated in academic literature based on historical datasets. For rehabilitation costs, the relevant reference is: Koks et al. 2019.

[61] Aqueduct tools : https://www.wri.org/aqueduct.

Evaluating economic risk to infrastructure

Within this framework, the next step in the SRAT is to intersect baseline/scenario flood maps with road/rail transport assets. The model thereby estimates the probability of different transport links being damaged (by links, we mean piecewise segments of road/rail). In particular, the model utilizes the length of the overlap between the link and the hazard layer and applies vulnerability curves (developed in prior literature) to estimate road damage given flood inundation depth and road/rail typology. The result is an estimate of (a) the extent of each link's physical damages and (b) estimated freight tonnage along that link that has to be rerouted or is unpassable due to no alternative route options.

Network risk estimations in economic terms are then divided into (a) direct (losses of transport assets that are incurred due to the physical damage to network nodes and links when exposed to flooding, and rehabilitation costs) and (b) indirect (losses that are incurred due to disruptions to network flows following direct damage to network nodes and links). For indirect risk (which is related to economic criticality), the economic loss is estimated in terms of increased cost of rerouting plus value of freight lost if there is no rerouting. Specifically, based on the several assumptions,[62] SRAT computes risks for each transport link as:

1. Expected Annual Damage (EAD) – estimated as the area under the damage versus hazard annual exceedance probability curve. For each projection year/RCP scenario, the tool computes the expected damages to transport assets taking into account different return year floodplain inundation depths (i.e., the probabilities of different flood levels). The EAD is then computed by multiplying damage probabilities by expected rehabilitation costs using transport asset-specific characteristics and cost matrices using historical data. SRAT computes EAD in minimum, medium, and maximum values based on severity estimates. In this assessment, the medium value was adopted to understand the direct damage.
2. Expected Annual Economic Losses (EAEL) – estimated as the area under the economic loss versus hazard annual exceedance probability curve. For each projection year/RCP scenario, the tool uses historical trade data as well as transport allocation assumptions and network data to estimate the value of goods passing through each transport link on a daily basis. The costs of flow disruption are then estimated by assuming that damaged links are impassable for a period of 15 days and that goods must be rerouted along the next shortest path (unless no such path exists, in which case the goods are assumed lost). EAEL is then computed for a given transport link by multiplying transport damage probabilities by the costs to reroute the goods that normally flow along the link to the next shortest path, using historical data on freight costs.

Box 5 shows the assessment results for EAD and EAEL based on each climate scenario.

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[62] The original SRAT model's assumption and guidance is as below: All OD tonnages are assumed to grow by 4 percent annually, which means future OD matrices from 2015 values are forecast based on the assumption that: $OD_y = (1+4\%)^{y-2015} OD_{2015}, y > 2015$

- Due to the lack of any data on the population and economic activity changes in the future, no changes to these datasets are considered in the process of disaggregating high-level ODs. Since these datasets are used to assign weights to disaggregate flows, it would not make any difference if some changes based on single growth rate values were assumed.
- The major change in networks in the future is in terms of the rail network, where it is assumed that by 2030 all the new lines under construction, proposed, and rehabilitated are all operational. In the baseline only lines that are currently open are used in the flow allocation.
- Due to upgrades to rail it is assumed that the new lines will be able to accommodate increased flows by having a greater usage as a percentage of their design capacity. By 2030, 2050, and 2080 the usage of each line will be at 30% (based on a study carried out on the Northern Corridor between Kenya and Uganda, the Final Strategic Environmental Assessment conducted by the Environmental Resources Management), 50% (the original model's assumption), and 80% (the original model's assumption) of their design capacity.
- Some increased capacities for roads are also assumed for future flow allocations. By 2030, 2050, and 2080 the capacity of each road link's ability to accommodate more tonnes/day freight will be increased to 110%, 130%, and 150% of their existing capacity. These increases in capacity will be due to improved freight operations along roads, not due to new lanes being added to roads, because of the lack of data on new road developments.

Limitations of the model and research adopted under this risk assessment

Forecasting transport network vulnerability in different climate scenarios is at the forefront of current modeling capabilities and is only possible due to recently developed flood mapping efforts at the global scale and intense interest in understanding the effects of climate change in localities. To forecast transport network vulnerability, this analysis needed to use several sources of uncertainty as are found in general transport network vulnerability. Below are the limitations found in particular in this model and risk assessment study under the sector note.

First, there are uncertainties inherent in global flood mapping models, which include, but are not limited to, poor quality topographic data; poor quality river geomorphology data; uncertainty with regards to how societies interact with and reshape both rivers and coastlines; as well as the difficulty of integrating riverine and coastal flood risk.[63] The uncertainty related to the flood hazard modeling setup and result downscaling to finer resolution is compounded by the use of standard climate scenarios (SSP2–4.5 and SSP5–8.5). These scenarios lack provisions for protective measures, fail to adequately simulate storm surges for tidal data, and ignore compound effects of climate change. While SSP2–4.5 assumes reduced GHG emissions and SSP5–8.5 assumes no reduction, the actual climate change is expected to fall between these two extremes, contingent on governmental adherence to the Paris Agreement. This substantial variability engenders significant ambiguity in rainfall and subsequent flood forecasts. Beyond floods, other climate perils such as high temperatures, wind, drought, and landslides also have the potential to impact transport infrastructure, with their modeling similarly susceptible to notable uncertainties.

Second, there are uncertainties with regard to how direct and especially indirect risk are modeled. In both direct and indirect cases, we only consider current transport network links and so do not consider future links which will be constructed due to growing demand and investment. For direct risk, there is also uncertainty with regard to damage-inundation curves and rehabilitation costs. In both cases, estimations rely on historical data disaggregated by link categories but in reality, there will be local variations and costs may differ in the future with technological development and changing input costs. In particular, climate risk assessment hinges on the available information, with the precision of mapped assets, such as OpenStreetMap (OSM), affecting the accuracy of the direct risk assessment. Moreover, the adaptation of global damage-inundation curves, that build on global research, need to be translated into the local context for more precise evaluation of asset vulnerability and potential damages.

Calculating indirect risk has greater uncertainties. On one hand, there are geographical constraints in modeling current trade flows, so the model may not accurately capture localized trade flows. Additionally, there may be significant changes in these trade flows under future scenarios which the model does not capture. On the other hand, the network-based method also has certain approximations which may be inaccurate. For example, the model requires assuming that damage from flood events closes roads for some period of time. Our choice of 15 days is rather arbitrary, in that rehabilitation may be quicker in many cases while it is more time-intensive in others. In addition, the technique of assuming that goods must be rerouted when routes are closed is the subject of current modeling assumptions. The current method introduces aggregation difficulties, in that indirect risks for nearby roads cannot simply be added.

Also, in the macroeconomic level, the evaluation of indirect impacts is influenced by uncertainties concerning the assessment of goods transported, their value, availability of alternate routes, and the Value of Time (VoT) during delays. Incorporating direct and indirect impacts into economic analyses is subject to

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[63] The specific data used are listed in the Assessing transport value part.

additional assumptions, including the selection of a discount rate to calculate Net Present Value (NPV), which significantly impacts the feasibility of investments. Exploring the consequences of disregarding adaptive capacity could provide valuable insights; for instance, the assumption of transport disruptions during commuting services fails to account for the potential shift to remote work, as witnessed during the COVI-19 pandemic, which substantially alters the perceived value of the transport network. Solving these issues can lead to another topic of research in risk analysis.

Box 5. Maps of Each Scenario
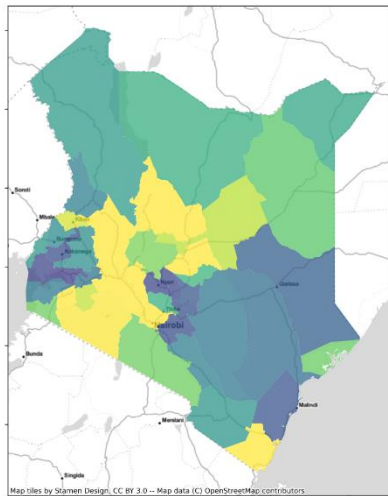
EAD Baseline
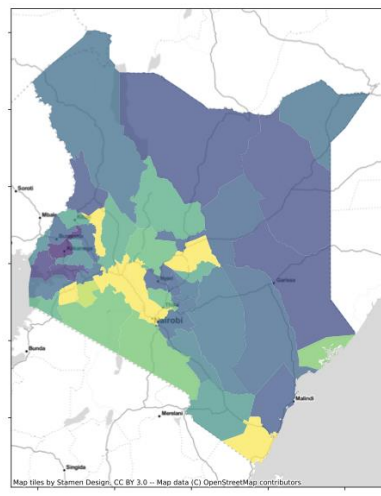
EAD RCP 4.5 2030
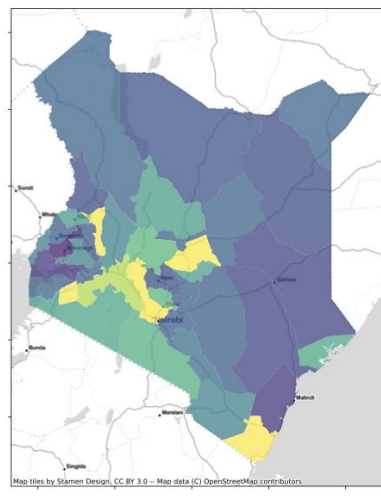
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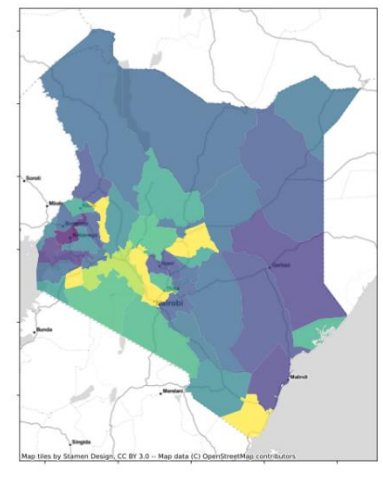
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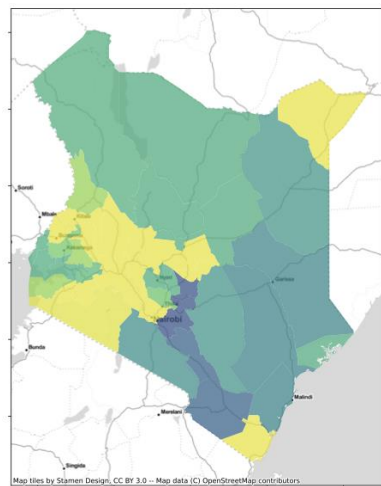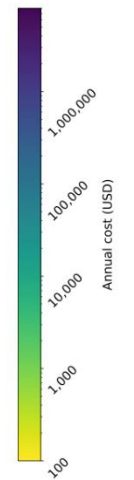
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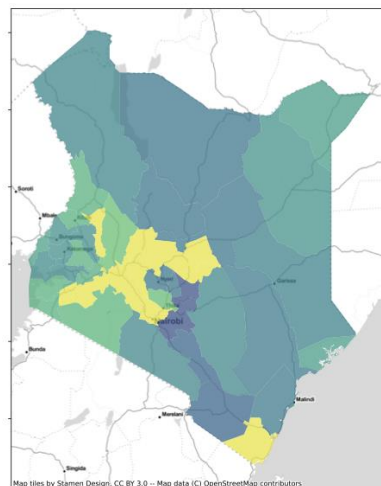
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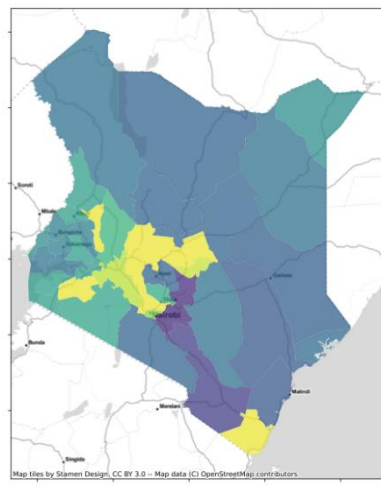
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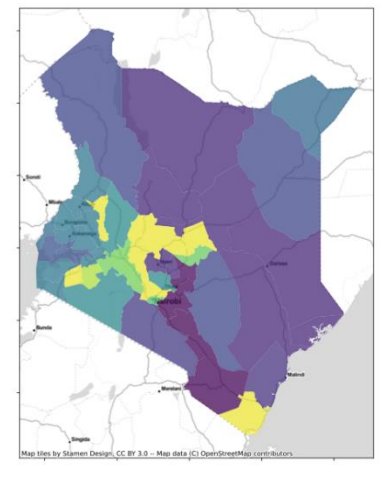
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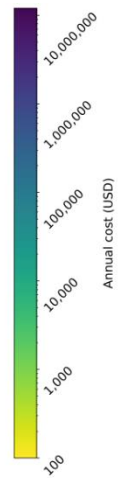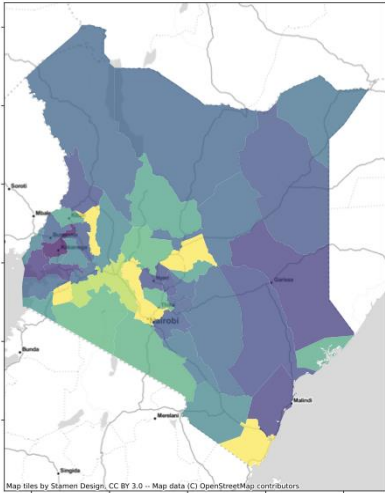
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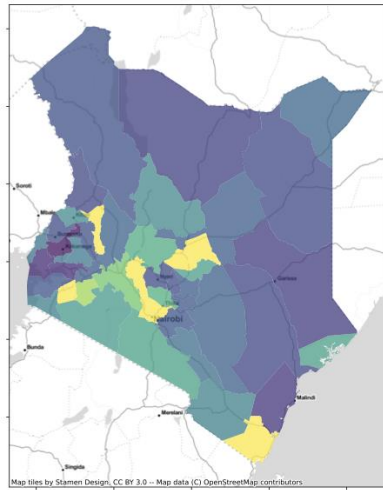
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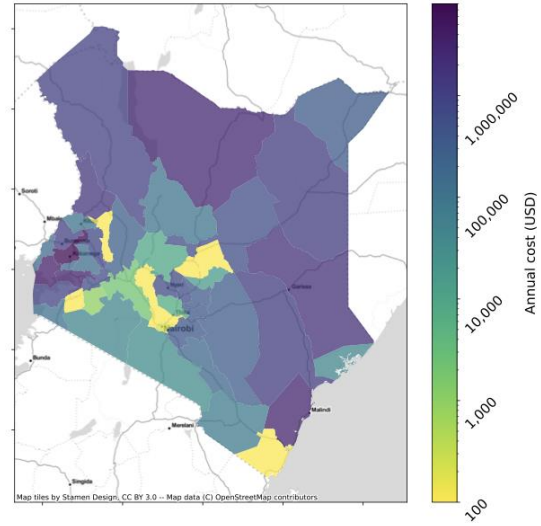
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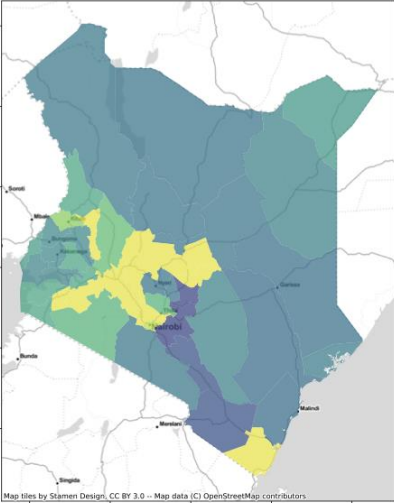
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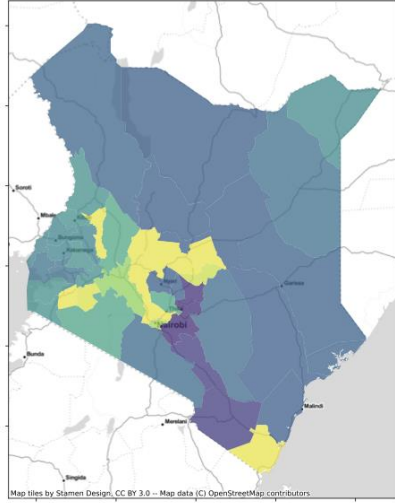
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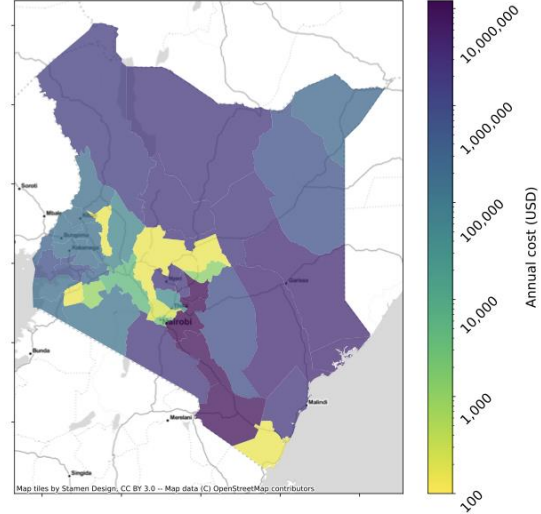
EAEL RCP 8.5 2080

Results

Which areas have the greatest direct damages? For direct damages (Figure 23), which are mostly due to riverine flooding, we see that currently, EAD has three peaks—near Lake Victoria, in the center of the country (NW of Nairobi), and along the coast. However, it seems that future flooding in both the RCP4.5 and 8.5 pathways is most likely to affect the Lake Victoria region, with losses peaking in the RCP4.5 pathway in Kakamega county at US$2.5 million/yr (2030), $3.1 million/yr (2050), and $3.8 million/yr (2080) million/yr; and then $4.4 million/yr (2030), $5.1 million/yr (2050), and $8.6 million/yr (2080) in the RCP8.5 pathway. Future scenarios will also increase damages in the coastal and northern-most regions of the country, with only modest rises in the center. Figure 23 presents county-level trajectories under RCP 4.5 and RCP 8.5 projections over time. While the assessment indicates potential flooding risks in the future in Kakamega county, in the past, flooding in Kakamega was not common. Therefore, further investigations are recommended.

Figure 23. EAD per county, USD/yr under RCP4.5 and RCP 8.5 projections (only top five counties are listed in legend)
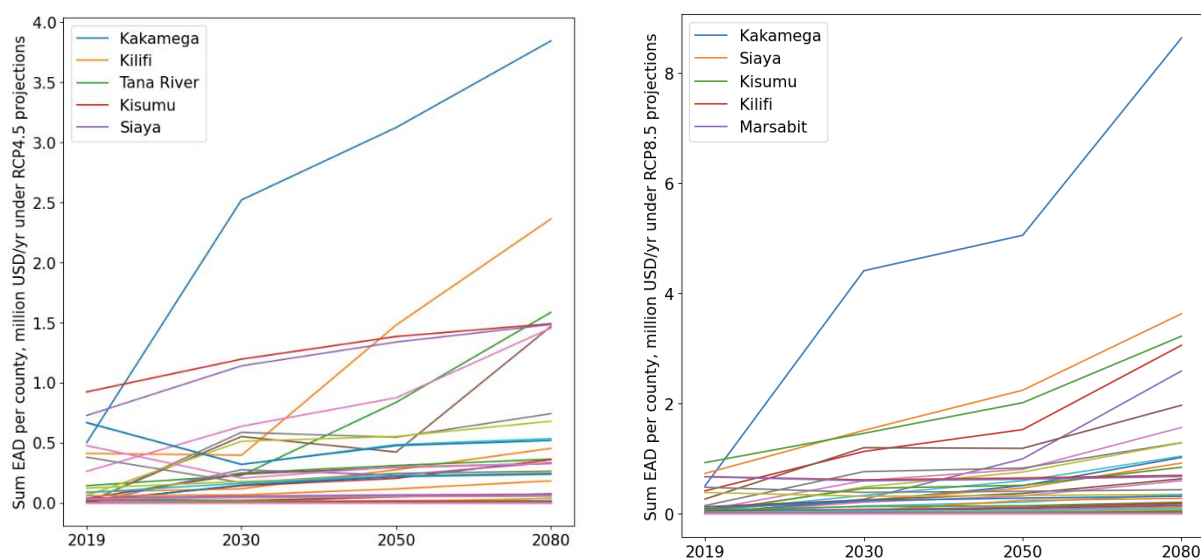
Which areas have the greatest indirect damages? While the Lake Victoria region has the most direct risk, the region also has a very dense transport network. As commuters and freight can take other routes without incurring too much extra cost, the destruction of any single link will not cause excessive indirect risks, resulting in lower risks of indirect damages, although accessing the ports on Lake Victoria could be a challenge if services on the road network are disrupted.

Instead, the region in east of Nairobi has the most critical links. For transport assets in this region, direct risk is not so high. However, due to high freight volumes and (in some cases) relatively moderate network density in this part of the country, damage to any of the few local assets would be likely to cause disastrous effects on the flow between Nairobi and Mombasa as well as between Nairobi and Tanzania.

To highlight these results, we display the county-level max EAEL for baseline and under RCP4.5/8.5 scenarios for 2080 projections below (Figure 24). Instead of displaying rivers as above, we here display the major road/rail network in grey, with thick lines for assets with EAEL>$0/year in Figure 25. In the regions with the highest indirect risk, only a few transport links carry risk. However, due to high freight volume and moderate network density, these risks are high. By contrast, northeastern regions have many risk-carrying links but due to lower freight volumes (in the rural northeastern part of the country), risks of indirect damages may be considered low. Nonetheless, it is worth mentioning the risk of isolating the region in the event of flooding due to the lack of alternative routes.

As in the EAD case, the analysis plots county-level predictions of EAEL under RCP4.5 and RCP8.5 scenarios. Here, the quantity plotted is the link-level max EAEL per county. In some cases, these may be equal between counties if the highest risk link intersects multiple counties or if two links have similar network flows. Such is the case with Taita Taveta and Makueni, which have the same max EAEL over all predictions.

Figure 24. Max EAEL per county, USD/yr under RCP4.5 and RCP 8.5 projections (only top five counties are listed in legend)
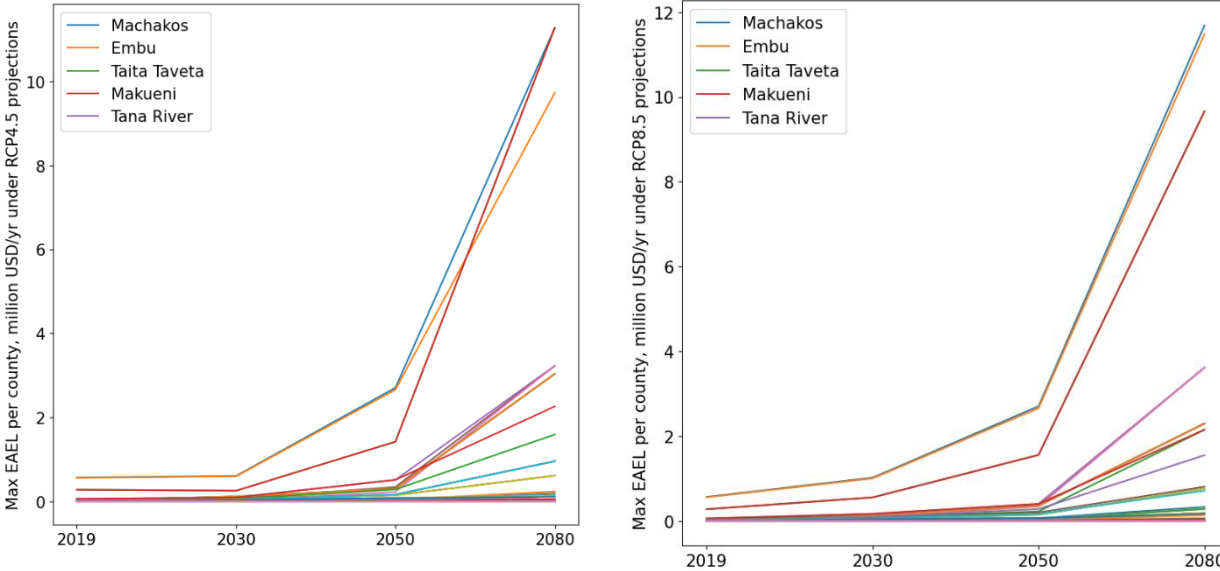
Which areas have the greatest aggregated direct and indirect damages? Because the analysis is computed at the level of transport links, it is useful to aggregate up to roads/railways to gain a better understanding of which transport links are holistically most at risk. To do this, we identify the top 10 damaged transport links based on the historical data and highlight their roads/railways. In order to obtain direct damages at the link-level, we simply sum the EAD of the piecewise segments that compose the respective links. In addition, risks in other key corridors have also been obtained (Table 7). The top 10 transport links with anticipated damage under RCP 4.5 and 8.5 scenarios were also obtained.

For indirect damages, it is problematic to sum up EAEL across links along a particular road because these contained links likely reflect many of the same losses, i.e., they are dependent. For instance, disruption of the highway between Nairobi and Mombasa can occur at many segments, and any of these will have high

EAEL due to the major trade importance. However, summing these would involve double counting. Hence, we take the max EAEL along each road as an alternative.

Secondly, we aggregate transport links to regions to identify the counties with the riskiest assets. Again, for EAD we compute the sum of direct damages across transport links contained in (or intersecting) the counties. For EAEL, summation is again problematic due to dependence along connected links. Hence, we again take the max of indirect damages. Figure 25 and Table 6 show the top 10 most critical links which have the greatest potential aggregated damages shown in USD/year.

Figure 25. Top 10 most critical links and potential aggregated damages (million USD/year), in baseline, RCP 4.5, and RCP 8.5 scenarios (2030, 2050)
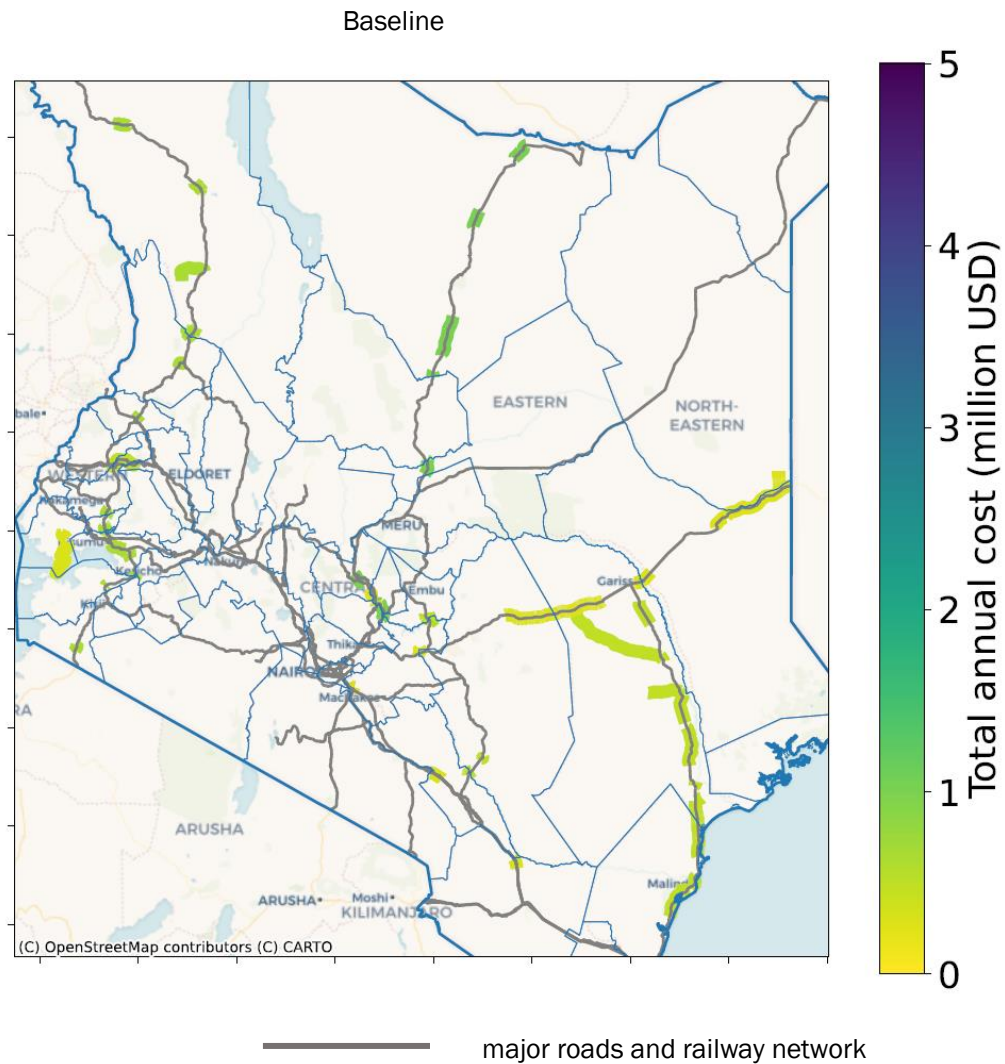
RCP 4.5 2030 and RCP 4.5 2050
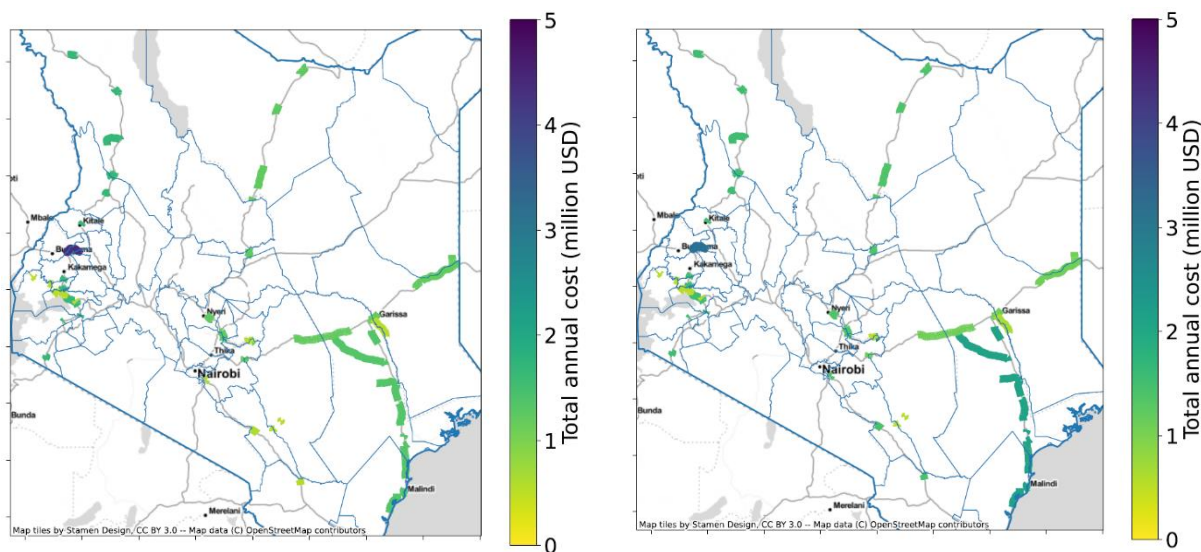
RCP 8.5 2030 and RCP 8.5 2050
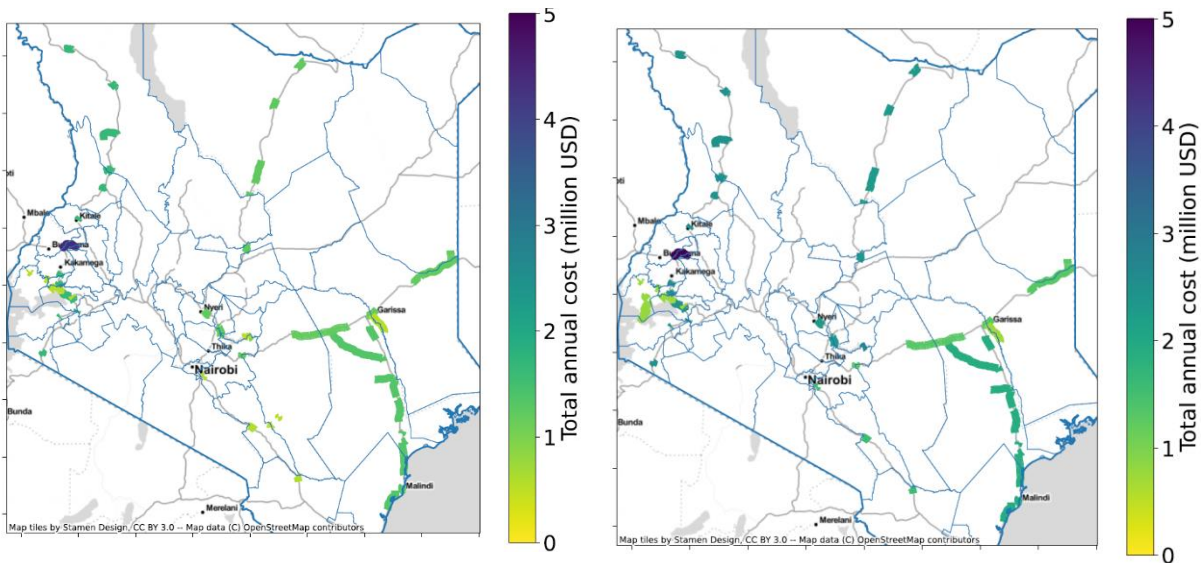
*Note: The strips of road that are shown includes potentially damaged parts and may actually be longer than the road segment, which is likely to be damaged, as the data structures were not able to precisely pinpoint where the damages occur.

The estimated damages were further calculated by road class and rail. In both RCP 4.5 and 8.5 scenarios (Table 6 and Figure 26), higher direct damage is anticipated for the rail network and trunk roads (Class A roads) when adequate adaptation measures were not taken. On the other hand, higher indirect damage is anticipated for secondary (class C) and trunk (class A) roads. These results indicate the criticality of taking adaptation measures for a) the railway and international road network to sustain the economic competitiveness of the country, and b) secondary (class C) roads for rural accessibility enhancement.

Figure 26. EAD and EAEL per road classification and rail, USD/yr under RCP4.5 and RCP 8.5 projections
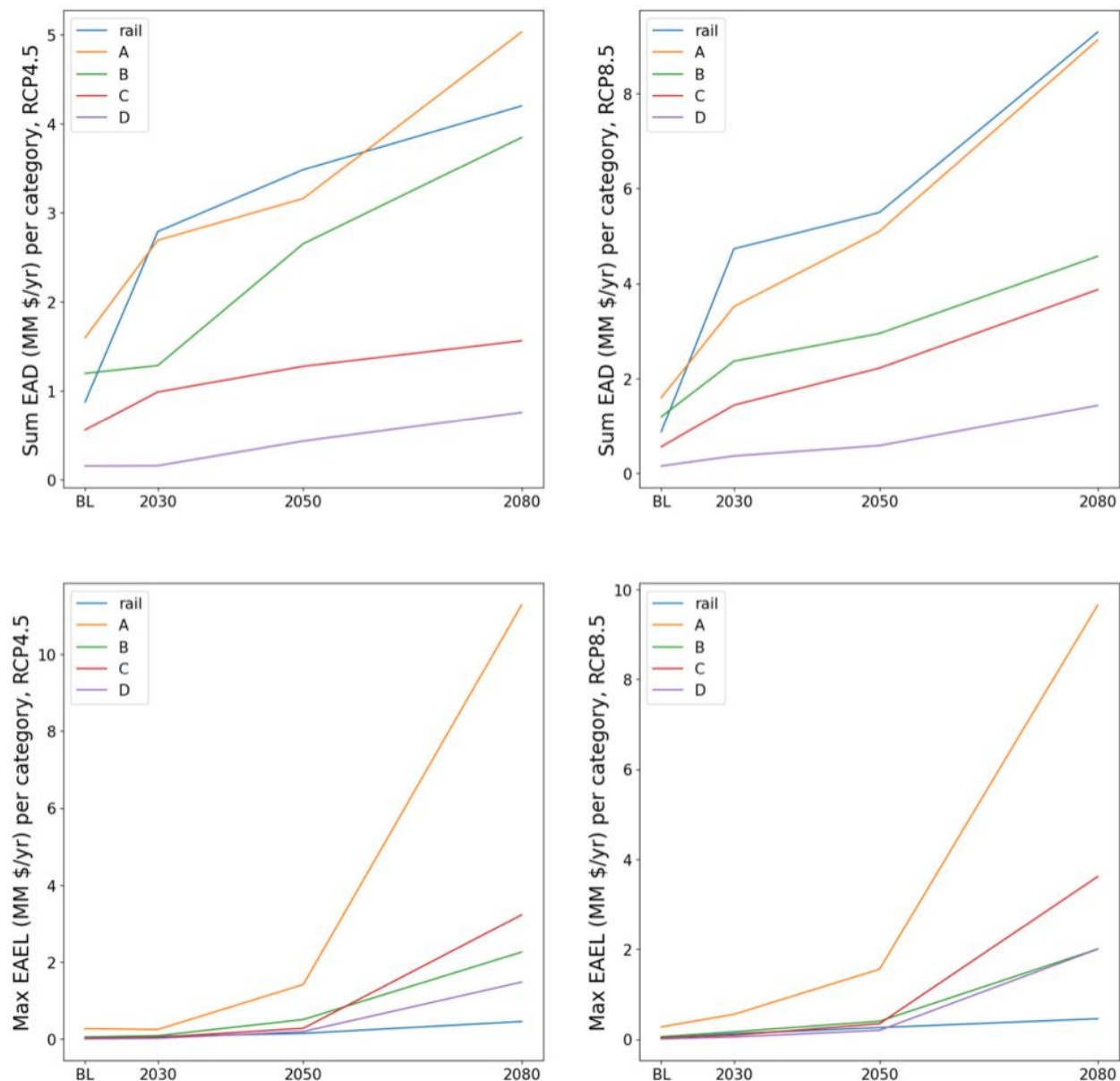
Table 6. Anticipated direct damage to roads (by road classification) and rail in RCP 4.5 and 8.5 (USD/year)

	Baseline	RCP 4.5			RCP 8.5		
		2030	2050	2080	2030	2050	2080
A	1,872,800	3,162,700	6,314,900	36,727,800	4,637,900	8,253,400	40,825,500
B	1,254,000	1,492,300	3,931,500	9,590,700	2,849,500	4,230,400	10,320,700
C	592,500	1,102,800	1,984,600	7,730,900	1,709,700	2,929,000	14,169,700
D	163,800	201,100	998,600	6,504,300	465,100	1,147,700	7,181,100
rail	907,500	2,927,300	3,714,500	5,082,900	4,870,500	5,995,700	11,363,400

In addition to the top 10 most critical links obtained through risk analysis, direct and indirect damages of six other key corridors, Isiolo–Mandera, Lodwar–Nadapal, Nairobi–Namanga–Arusha, Nairobi–Narok–Kisii–Isibania, Mombasa–Malindi–Garissa, and Nairobi–Garissa–Libo, were also calculated, considering their criticality and potential vulnerability to climate change. The roads on the Lodwar–Nadapal corridor have been upgraded during last five years under East Africa Regional Trade Transport Facilitation Development Project, and the Isiolo–Mandera road corridor will be upgraded under the Horn of Africa Gateway Development project. The analysis also indicated the potential high risks of damage on transport assets along Mombasa–Malindi–Garissa and Nairobi–Garissa–Libo links. Adopting climate resilience approach in transport asset management, including maintenance works, and establishing monitoring systems and response capacity will be critical, in addition to integrating climate considerations into design.

Table 7. Top 10 most vulnerable and critical economic corridor links with potential damages under different scenarios identified by the assessment: (USD/year, rounded to nearest hundred)

	COUNTIES	Road/rail names	Baseline
1	Samburu; Isiolo; Nyeri; Marsabit; Machakos; Embu; Kirinyaga	A2 route; Tumutumu Road; Nyeri-Nanyuki Road; Marsabit-Moyale Road; Embu-Nairobi Highway; Laisamis-South Horr Road	1,006,500
2	Machakos; Machakos; Embu	Kivaa-Gitaru Road	568,500
3	Uasin Gishu; Kakamega; Bungoma	Nakuru-Malaba line	482,000
4	Makueni; Kitui; Machakos; Embu	Route B7; Kibwezi-Kitui Road; Embu-Siakago Road	477,000
5	Tana River; Kilifi	Route B8; Malindi Road; Forest Lane; Malindi-Garsen Road; Jamhuri Street; Tana street; B8; Casuarina Road	472,500
6	Kisumu	Route A1; Kisumu-Busia Road; A1; Nairobi Road; Ahero-Masogo Road; Bypass Highway;	425,800
7	Taita Taveta; Makueni; Machakos	Route A109; Mombasa Road; Mutungoni Road	280,900
8	Siaya	Route C28; Ongielo Road; ; D1157; R4 Nyajuok Main	279,100
9	Wajir; Garissa; Tana River; Kitui; Machakos	Route A3; Dadajabulla Road; Garissa-Daadab Road; Garissa Road; ; Habaswein-Dadaab Road; Garissa-Dadaab Road	264,500
10	Kirinyaga	Makadara-Nanyuki line	240,700

	COUNTIES	Road/rail names	2030(RCP 4.5)	2030 (RCP 8.5)
1	Uasin Gishu; Kakamega; Bungoma	None	2,483,100	4,335,600
2	West Pokot; Turkana; Vihiga; Nandi; Kakamega; Kisumu; Kericho; Homa Bay	Kapenguria-Lodwar Road; Turkwel Gorge Dam Road; Morun Bridge; Kisumu-Vihiga Road; Lokapel Lokichar Road; Kisumu-Busia Road; Nairobi Road; Kisii-Kisumu Road; Kisumu -Vihiga Road; Ahero–- Masogo Road; Ondiek Highway; Bypass Highway; Kakamega Road; Rongo-Kisii Road	1,311,900	1,605,100
3	Samburu; Isiolo; Nyeri; Marsabit; Machakos; Embu; Kirinyaga	Tumutumu Road; Nyeri-Nanyuki Road; Marsabit-Moyale Road; Embu-Nairobi Highway	698,300	1,163,800
4	Machakos; Machakos; Embu	Kivaa-Gitaru Road	604,800	1,020,900
5	Wajir; Garissa; Tana River; Kitui; Machakos	Dadajabulla Road; Garissa-Daadab Road; Garissa Road	576,700	1,202,700
6	Tana River; Kilifi	Malindi Road; Forest Lane; Malindi-Garsen Road; Jamhuri Street; Tana street; B8; Casuarina Road	490,600	1,326,600
7	Siaya	Ongielo Road; Nyajuok Main	399,000	511,200
8	Vihiga; Siaya; Kisumu	Kisumu-Busia Road; Kisumu-Busia Road; Kisumu-Busia Highway; Obote Road; Kona Ka Yona-Daraja Mbili Road; Nyerere Road	393,200	518,900
9	Makueni; Kitui; Machako s; Embu	Kibwezi-Kitui Road; Embu-Siakago Road	311,000	511,300
10	Taita Taveta; Makueni; Machakos	Mombasa Road; Mutungoni Road	257,500	570,600

	COUNTIES	Road/rail names	2050 (RCP 4.5)	2050 (RCP 8.5)
1	Uasin Gishu; Kakameg a; Bungoma	Nakuru-Malaba line	3,120,000	4,891,700
2	Machakos; Machakos; Embu	Kivaa-Gitaru Road	2,705,200	2,705,700
3	Tana River; Kilifi	Malindi Road; Forest Lane; Malindi-Garsen Road; Jamhuri Street; Tana street; Casuarina Road	2,041,500	1,877,500
4	West Pokot; Turkana; Vihiga; Nandi; Kakamega; Kisumu; Kericho; Homa Bay	Kapenguria-Lodwar Road; Turkwel Gorge Dam Road; Morun Bridge; Kisumu-Vihiga Road; Lokapel Lokichar Road; Kisumu-Busia Road; A1; Nairobi Road; Kisii-Kisumu Road; Ahero-Masogo Road; Ondiek Highway; Bypass Highway; Kakamega Road; Rongo-Kisii Road	1,512,800	2,334,000
5	Taita Taveta; Makueni; Machakos	Mombasa Road; Mutungoni Road	1,434,600	1,579,600
6	Samburu; Isiolo; Nyeri; Marsabit; Machakos; Embu; Kirinyaga	Tumutumu Road; Nyeri-Nanyuki Road; Marsabit-Moyale Road; Embu-Nairobi Highway	1,198,600	1,498,900
7	Wajir; Garissa; Tana River; Kitui; Machakos	Dadajabulla Road; Garissa-Daadab Road; Garissa Road	1,072,000	1,271,100
8	Garissa	Gariisa-Lamu Road	620,600	710,100
9	Vihiga; Siay a; Kisumu	Kisumu-Busia Road; Kisumu-Busia Roa d; Kisumu-Busia Highwa y; Obote Roa d; Kona Ka Yona-Daraja Mbili Roa d; Nyerere Road	544,500	758,500
10	Makueni; Kitui; Machakos; Embu	Kibwezi-Kitui Road; Embu-Siakago Road	539,100	673,000

Additional Critical links: Road/rail names[64]	Road/rail	Baseline	RCP4.5 2030	RCP 4.5 2050	RCP 4.5 2080	RCP 8.5 2030	RCP 8.5 2050	RCP 8.5 2080
Route B9; Isiolo-Wajir-Elwak-Mandera	Road	8,700	214,600	274,600	659,200	177,700	287,800	761,500
Route A1; Lodwar-Nadapal	Road	-	10,900	42,500	349,300	22,300	72,000	424,500
Route A104; Nairobi-Namanga-Arusha (Kenya-Tanzania)	Road	-	-	-	1,336,600	-	-	5,346,600
Route B3; Nairobi-Narok-Kisii-Isibania	Road	-	2,700	8,600	6,500	16,700	47,700	89,900
Route B8; Mombasa-Malindi-Garissa	Road	470,100	602,700	2,849,400	8,312,600	1,632,800	2,748,700	8,205,000
Route A3; Nairobi-Garissa-Liboi (Kenya-Somalia)	Road	151,000	462,200	883,500	2,435,400	793,200	1,036,900	2,610,600

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[64] The routes selected are major roads aligned with critical regional/international corridors.

2.4.3. Exploring potential measures to strengthen resilience of transport networks

As a strategic and important gateway to many east African countries, and for Kenya by itself to compete successfully in the global economy, the country should have transport connections to the outside world which are, as far as practicable, equal to its competitors. Different modes of transport gateways to and in Kenya should have the levels of service, safety, and security that are now expected in the world market.

The Government of Kenya is engaged in efforts at both the national and sub-national levels to execute the adaptation measures specified in its Vision 2030 plan.[65] Within the analysis, the assessments should thoroughly evaluate the strength of designs, construction, and maintenance specifications, and take into account how climate risks (including those associated with climate change) have been identified, incorporated into the economic and financial appraisal process, and mitigated through either structural or non-structural measures. Undertaking this process holistically is essential to the adaptation and mitigation agenda, particularly for new, large-scale strategic transport infrastructure investments. This can help to minimize the long-term costs associated with reconstruction or asset recovery.

Within this framework, a coherent integrated transport strategy and analysis should be formulated and followed, especially in areas and transport corridors where the most average damage costs are likely to be incurred, such as in Lake Victoria Basin, which has the densest transport network. For this area, strengthening the road network so that it provides reliable all-weather (or at least all-season) access is critical. For areas like east of Nairobi, which has the most critical links that lead to neighboring countries and regions, a new spatial planning framework that weights network criticality is required. This framework can be developed through several regional transport connectivity and trade facilitation program such as the Garissa-Liboi-Kisimayu corridor development project, which supports trade and economic integration, regional value chains, and improvement in investment climate.

2.5 Recommendations

While Kenya still has a significant need for increased connectivity to reduce poverty and boost shared prosperity, decoupling economic growth and expansion of trade and logistics from climate change impacts can be highly effective. This would involve deploying further policies and building infrastructure, services, and technologies that will continue the path towards low-carbon development. The focus of climate action in the transport and logistics sector is the establishment of efficient, sustainable, world-class supply chain connectivity that withstands the projected impacts of climate change. This is expected to be realized through a number of actions, as described above, including reducing the energy intensity of vehicles and operations, the reorganization of supply chains through logistics optimization, shifting to lower-carbon transport modes and complementary measures, as well as climate-proofing transport infrastructure.

Kenya seeks to transform into an industrialized middle-income country by 2030, offering high quality of life. Transportation and logistics are an important foundation and enabler for national transformation by the facilitation of most other sectors to reach this target. Given the importance of the transport sector in Kenya's socioeconomic development, it is crucial to implement measures that enhance sustainable development within the sector. Kenya's NDC builds on its NCCAP. Within the transport sector, the target of Kenya's first NDC is an emissions reduction of 3.46 $MtCO_2e$ (million tonnes of carbon dioxide equivalent) in transport against projected emissions of 21 $MtCO_2e$ in 2030 in the sector.

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[65] Republic of Kenya (2013). Sector plan for drought risk management and ending drought emergencies, Second medium-term plan: 2013–2017. URL: https://www.ndma.go.ke/index.php/resource-center/send/43-ending-drought-emergencies/4271-ede-mediumterm-plan-2013-2017.

Within this context and based on the above analysis, the following general recommendations could be made:

- **Long-term mobilization of resources in the transport and logistics sector for climate change is vital.** This will expand the capacity of human resources dedicated to transport and climate change as well as translate to real impact as far as developing climate-responsible services as well as building climate-resilient infrastructure is concerned.
- **Coordination with the private sector is essential, especially to optimize supply chain organization (aggregation, distribution, storage, etc.).** Transport mitigation actions depend greatly on the private sector as private sector players manage transportation services for most countries. Linking policy and incentives with the involvement of the private sector will translate into actions on the ground.
- **Carry out smart logistics pilot project**s. Numerous processes and technologies for smart logistics are being developed both in terms of research and application in the industry. However, these are often only available to individual stakeholders or cannot be deployed on a large scale, for example due to a lack of legislation or regulation. In addition, it is difficult to obtain information about the current state of the art in smart logistics. Regardless of whether the results are from practice or from research in the field of smart logistics, there is a lack of transfer of best practices. Therefore, the development and establishment of pilot projects on smart logistics that integrate different approaches and actors from industry, science, and politics is strongly recommended.
- **Implement a strategy to make the global drive towards climate change an opportunity for Kenya's export**s. This would include improving awareness among government and industry on environmental market issues, especially relating to carbon emissions. This also requires building capacity in carbon accounting and the carbon footprint of its exports to understand its carbon competitiveness and identify carbon hotspots. Kenya could also revisit global standards and measurement methodologies, such as international standards exist like ISO 14040 and 14044, the Greenhouse Gas Protocol, and Publicly Available Specification (PAS) 2050, and develop guidance of best practice for development-friendly management of scope 3 (value chain) emissions reductions. Big brands like Nestle, for instance, are today experimenting with how to measure such reductions in cocoa production in West Africa with regard to local supply chains dominated by smallholders and with limited traceability. Being able to document Scope 3 levels initially, and reductions subsequently, is an asset when exporting to buyers with SBTi commitments. This activity aims at including smaller farmers in environmentally conscious supply chains.
- **Explore options for replacing air freight with shipping for selected export product**s. The government jointly with the private sector could explore the technological opportunities and consider financing trial shipment to reveal the potential of such a measure. Kenya should also be ready to communicate better on the use of air freight.
- **Rapid growth in Kenya and the integration into regional and international supply chains will need a resilient transport infrastructure and logistics network.** Reducing the exposure of Kenya's transport links and nodes would require a relatively modest additional investment to achieve transport-related SDGs by 2030. This proactive investment could reduce the repair and maintenance costs of the new assets and over time lower the transport-related disruption in the country.
- **Complementing this, in the medium-term Kenya could lower the carbon footprint of freight transportation by transitioning to a more balanced modal split.** A modal-shift strategy, with investments made in the period of 2023–2035, could begin to reduce emissions from 2030

onwards. It would promote a change in carbon emissions when new infrastructure and services are available for use, promoting a further shift of long-distance transport from trucks to trains.

These recommendations would entail additional investments in transport infrastructure, and underlying services as well as technical assistance support and advisory services, with the objective of:

- **Accelerating climate-proofing strategic road transport infrastructure and critical links**, including through the Regional Transport Connectivity and Trade Facilitation Program (e.g., Nairobi–Garissa–Liboi–Kisimayu development corridor; Mombasa–Malindi–Hola–Garissa corridor; Nairobi–Kitui–Hola–Lamu corridor), and a Rural Roads Connectivity Program. As part of the program, it is advisable to give due consideration to the development of infrastructure inventory and climate adaptation into road planning and design. To facilitate this, the Kenya Roads Boards has developed a GIS-based Map portal, which can be further improved by including inventory details such as locations, design characteristics, costs, current condition, and relevant data on repairs caused by floods, landslides, or other natural hazards, including flood-level recordings. It is recommended that all road agencies and county governments should have access to and make use of this database. Furthermore, it is crucial to conduct vulnerability assessments to evaluate potential climate change risks in road investment plans. Additionally, enhancing road asset management systems to integrate climate change adaptation into the design of road infrastructure is essential.
- **Enhancing transportation connectivity within and around the Lake Victoria Basin while considering the impacts of climate change**. To incorporate adaptive measures in and around the Lake Victoria Basin, it is recommended to conduct a feasibility study and develop an investment program. This program should consider the area from a climate change perspective and provide support through a Transport Development Program. Currently, the existing NCCAP does not encompass the Lake Victoria Basin, so it is important to address this gap during the NCCAP's review. Under the Lake Victoria Basin Transport Development Program, potential investments include the rehabilitation and expansion of existing infrastructure, the establishment of intermodal facilities such as rail terminals and ports, the procurement of wagon and passenger ferries, the mapping of marine transport routes across the entire lake, and the installation of aids to navigation at strategic locations to enhance safety and ensure compliance with environmental regulations.
- **Developing greener freight solutions and logistics practices for domestic and export-oriented supply chains in line with policies and regulations of key export destination countries**. An assessment of current domestic and export-oriented supply chains and logistics is suggested to identify various strategies, such as shifting to lower-emission modes, increasing reliability and efficiency, and developing multi-modal transfer nodes. This assessment should explore the potential benefits and challenges of utilizing rail transport for moving goods inland and maritime shipping for the international movement of goods. Aligned with the NCCAP, it is important to complement the Integrated National Transport Policy (2009, currently under review for revision) with sustainable supply chain management strategies and efficient logistics practices. These strategies should take into account the competitiveness of existing and potential supply chains. By integrating sustainability principles into supply chain management, it is possible to optimize resource utilization, reduce emissions, and improve overall efficiency.
- **Accelerating compliance with international standards on energy efficiency measures at key gateways (airports, ports) and leading initiatives in the wider region and beyond on the decarbonization of road transport (increasing energy efficiency of vehicles and operation through a pilot eco-driver program, fuel tax, review of alternative fuels, etc.).** A roadmap should be developed to improve the efficiency of heavy-duty trucks, including the increased utilization of low-

rolling resistance tires and superstructure fittings. It is also important to establish vehicle standards as part of the NCCAP. To enhance the fuel economy of light-duty vehicles, measures such as labeling, promoting fuel-efficient driving practices, and improving traffic management should be implemented under the NCCAP. In the aviation and maritime sectors, efforts should be made to encourage the adoption of low-carbon technologies, also outlined in the NCCAP. To promote the development of domestic electric modes of transport, it is important to support technology advancements in this area as outlined in the NCCAP. Furthermore, research should be conducted to explore the use of renewable energy sources for powering different modes of transportation. To assist in the implementation of these measures, potential Technical Assistance and Advisory Services should be considered. This may also include support for eco-driving pilot programs, ensuring compliance with international standards, and conducting reviews of alternative fuels.

CHAPTER 3. Enabling Socioeconomic Mobility in a Greener and Climate-Resilient Development

This chapter will focus on how mobility of passengers—particularly in urban settings—can transform itself to be more inclusive, become a vector for improving access to jobs and services, reduce informality, and provide for innovation and increased efficiency by adopting greener transport technologies opportunities. Inter alia, this section will also examine nationwide policies with high potential for emission reduction.

3.1. Urban development and urban mobility

3.1.1. Urbanization trends in Kenya

Kenya is urbanizing rapidly, with the ratio of the urban population against the total population increasing from 19.9 percent in 2000 to 30.8 percent in 2019, at an average 4.3 percent annual urban population growth rate for this period. The 2019 census recorded a total urban population of 13,486,823 in the country. Currently urban population in Kenya is 31 percent and it is projected to be close to 50 percent by 2050. Despite rapid urbanization, Kenya is also recognized as an underperformer on urbanization due to higher GDP per capita for the urban population level compared with other similar countries. This is a unique situation in the African context, where most countries have urbanization rates that far outpace their economic performance, creating consumption cities (Figure 27).

Figure 27. Urban population in Kenya
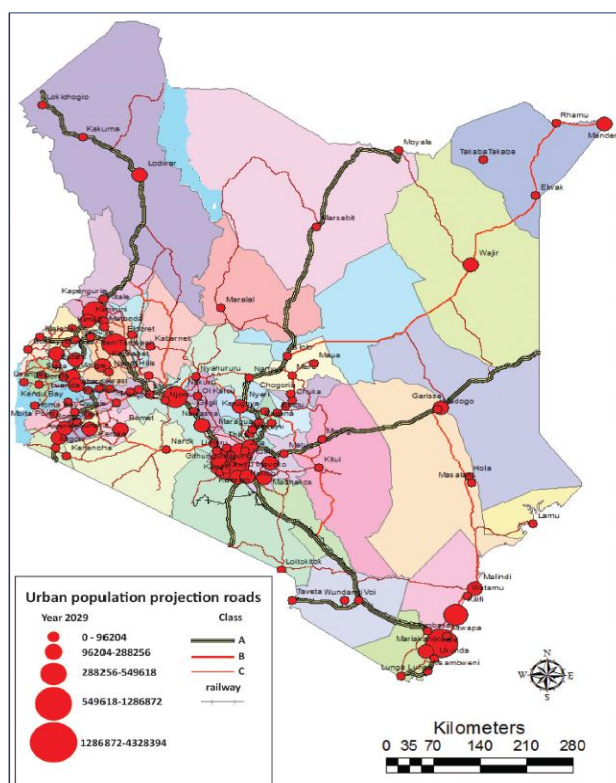
Source: Kenya Urbanization Review, 2016, the World Bank

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[66] Kenya National Bureau of Statistics, 2019 Kenya Population and Housing Census Results.
[67] Ibid.

Kenya's urban population is mostly concentrated in the areas along the Northern Corridor, which connects Mombasa Port through Nairobi to Malaba, with a branch line to Kisumu in the west. In total, 76 percent and 85 percent of urban dwellers live within 15 kilometers and 35 kilometers of this corridor, respectively. The country's five main urban centers—Mombasa, Nairobi, Nakuru, Eldoret, and Kisumu—are also situated along this corridor. In the 2019 census, we observe 14 urban centers[68] surrounding Nairobi County, which define (or compose) a functioning urban Nairobi Metropolitan Area with a total of about 6.6 million people.

Table 8. Urban population, density growth of major cities

Cities	Population* (Urban Core) 2019	Density[69] (persons/sq. km, urban area)	Annual urban population growth rate (%) (2009–2019)	Built-up area (sq. km)
Metropolitan Nairobi	6.6 million***	4,515**	n.a.	2189**
Nairobi	4.4 million*	6,247*	3.4	704*
Mombasa	1.2 million*	5,495*	2.5	220*
Kisumu	567,963*	3,177*	3.5	139
Eldoret	475,716*	1,670	5.1	305
Nakuru	570,674*	1,103	6.4	949

*Source: 2019 Census (Kisumu includes Kisumu East, Kisumu Central and Kisumu West),
** Gulyani and Talukdar 2019
*** Nairobi, Ruiru, Kikuyu, Thika, Karuri, Ongata Rongai, Juja, Kitengela, Kiambu, Mlolongo, Ngong, Limuru, Athi River, Machakos, Kiserian.
Note: data on density and built-up areas for Kisumu, Eldoret, and Nakuru are for the total urban population and areas in each county. Therefore, this information is only for reference purposes. However, the population of Kisumu and Eldoret urban centers composes more than 90 percent of the total urban population in the county; therefore, the information is still useful.

3.1.2. Status of urban mobility

The country's rapid urbanization accompanied by its spatial development pattern has made urban access to advance economic and social development an overwhelming challenge in the large cities of Kenya. The movements of people in urban areas are becoming more frequent and extended. For instance, the population of Nairobi city was 4.4 million people in 2019,[70] and previous studies estimated that the total trip generation in Nairobi is 6.8-million-person trips, with an average of 2.34 trips per person per day.[71] Comparing the data between 2004 and 2013, the increase in the total trip generation is larger than the increase in population. Besides, due to rapid urban growth and expansion of the urban areas, the total number of trips to and from Nairobi County has also increased.[72] In Mombasa, while the current trip rate per person per day is 2.22,[73] (unplanned) urbanization has been taking place in the mainland without proper land use management since 1971, which will result in longer trips. Modal shares in each city are presented in the next section.

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[68] Ruiru, Kikuyu, Thika, Karuri, Ongata Rongai, Juja, Kitengela, Kiambu, Mlolongo, Ngong, Limuru, Athi River, Machakos, and Kiserian (population between 63,800 and 490,000).
[69] Gulyani et al. 2019.
[70] Kenya National Bureau of Statistics, 2019 Kenya Population and Housing Census Results.
[71] Japan International Cooperation Agency, Nairobi: Integrated Urban Development Plan, 2014.
[72] The daytime population of Nairobi city is estimated to grow from 3,280,000 in 2009 to 5,468,000 in 2030 due to the increased net inflow of commuters from outside of the city for work and school (NIUPLAN, 2014).
[73] Japan International Cooperation Agency, Nairobi: Integrated Urban Development Plan.

Damage coefficients (economic loss in traffic congestion)

Inadequate public transport system and poor traffic management have negative impact on travel time and related economic and health costs in Nairobi. The average travel time for men and women in Nairobi in 2013 was 50 and 45 minutes respectively.[74] A study in 2020 revealed that about 40 and 60 percent of men and women in Nairobi travel longer than 60 minutes during peak hours,[75] indicating that people are spending more time traveling in Nairobi. Long travel times are mainly due to an inadequate public transport system and poor traffic management, which lead to severe traffic congestion. It is estimated that Kenya's annual cost of road traffic accidents, in which most victims are pedestrians in urban areas, is equivalent to about US$3 million;[76] traffic congestion in the Nairobi Metropolitan Area alone costs the economy about US$1 billion a year;[77] and approximately 19,000 people die each year in Kenya due to air pollution, of which vehicle emissions are the main source of pollution in urban areas.[78]

Motorization trends

Rapid motorization in the country is also another factor for serious congestion, traffic accidents, and air pollution, particularly in urban areas. In 2021, the total number of vehicles registered in Kenya was about 4.4 million including motorcycles.[79] The country's record shows that between 2012 and 2021, about 2.6 million vehicles have been added to the vehicle stock, indicating an annual growth rate of about 10 percent (Figure 28). As the country does not have a regulation to register or report vehicles when they are no longer in use, the actual number of vehicles on the roads is expected be smaller. Nonetheless, the latest registration statistics reveals the country's high pace of motorization: 93 vehicles per 1,000 inhabitants in 2021, compared with the previous projection of 56 vehicles per 1,000 inhabitants by 2030.[80] It is expected that high pace of motorization will continue with rapid increase in the registration of salon cars and motorcycles (Figure 28).

Figure 28. Vehicle stock
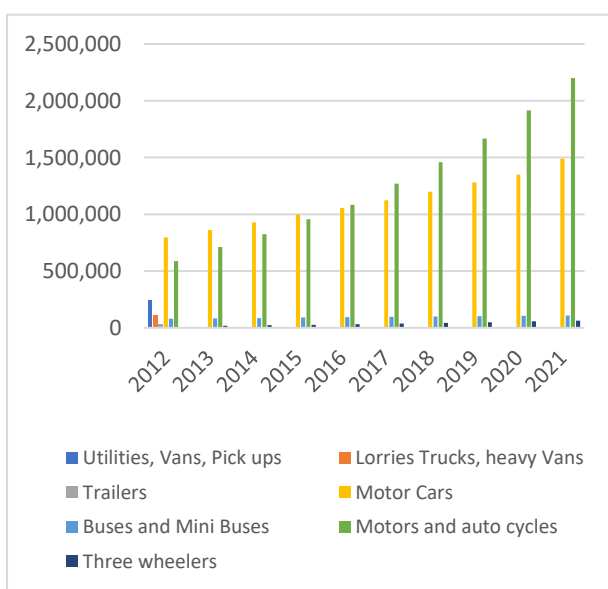
Source: NTSA

Figure 29. Percentage of new registered road motor vehicles in Kenya, 2019

Source: NTSA

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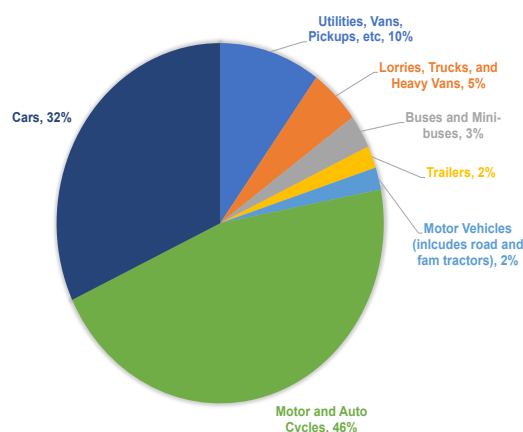
[74] Japan International Cooperation Agency, Nairobi: Integrated Urban Development Plan.

[75] Kishiue et al. 2020.

[76] National Transport and Safety Authority (NTSA) Road Safety Status Report 2015.

[77] https://www.bloomberg.com/news/articles/2019-09-24/traffic-jams-in-kenya-s-capital-bleed-1-billion-from-economy#xj4y7vzkg.

[78] World Health Organization (WHO) estimates.

[79] National Transport and Safety Authority.

[80] Ogot et al. 2018..

Fleet characteristics

The vehicle fleet in Kenya is diverse, but heavily relies on imports and is dominated by petrol vehicles. In 2019, motorcycle and cars made up about 80 percent of total new registrations (327,176, Figure 29).[81] About 90 percent of vehicle engines are petrol (internal combustion engine, ICE) and 9 percent are diesel. Kenya's vehicle fleet relies heavily on imports. In 2019, imports of used vehicles constituted 88 percent of new registrations with the remainder (12 percent) being new vehicle sales.[82] Kenya has imposed more strict age limit for importing vehicles in the East Africa: they must now be less than 8 years old from the year of first registration. Nonetheless, a study estimates that the average ages of passenger cars and matatus in Kenya, based on ages from the year of manufacture, are 12.4 and 15.9 years, respectively, with low fuel efficiencies due to a lack of systematic program for end-of-life vehicles. The emergence of electric vehicles (EV) is observed in the country (in cars, motorcycles, buses, three-wheelers), but they accounted for only 0.1 percent of new registration between May 2021 and February 2023. The government of Kenya has set a target that 5 percent of newly imported vehicles will be electric by 2025 and as part of this aim, EVs receive tax benefits of a reduced import duty: 10 percent for EVs as compared to 25 percent for other types of vehicles (ICE).

Motorization management

While the government of Kenya has established a set of standards to manage the increasing vehicle fleet in the country, the implementation of and compliance with standards remain challenging. Kenya has established a standard for road vehicle inspection, called the code of practice for inspection of road vehicles (KS1515: 2000). The inspection of road vehicles covers an emission test that examines the vehicle's carbon monoxide and hydrocarbon levels and its overall condition (primarily safety elements). However, it is not clear if the vehicles that fail the test make the required repairs before obtaining the certificate. In addition, the government is exploring realistic options to enforce the emission test, which is not currently undertaken, as part of vehicle inspection. As of January 2023, "Standards for smart transportation for fuel efficiency and pollution emission reduction in bus transportation services" is under preparation with a preliminary draft, awaiting technical committee discussions.[83]

In Kenya, the advent of digital (online) platforms in the transport sector has led to a rise of a new and partially unregulated industry, especially in the passenger segment.[84] This service market mainly offers ride-hailing as well as a combination of passenger transportation and delivery services (products). Just recently, the government of Kenya withdrew the operating licenses of a digitally facilitated "point to point" operator, SWVL Kenya, citing non-compliance with public transport regulations. The main area of contention, based on reports from the media, was that the operators had not acquired the appropriate public service vehicle license, which meant they were not operating within the set public service vehicle regulations in the country. As this example shows, the transport sector in Kenya, particularly the public transport sector, faces several challenges.

Governance

Institutional arrangement in urban mobility requires streamlining. While reforms have been implemented, institutional arrangements in the urban transport sector in Kenya are still complex. There are as many as 15 organizations involved in urban transport, with overlapping and contradictory mandates and responsibilities. The ineffective institutional structures and weak legal and regulatory framework diminishes the quality, reliability, and safety of public transport, particularly in urban areas. Finalization of the ongoing revision of the Integrated National Transport Policy as well as development

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[81] National Transport and Safety Authority.
[82] Kenya Association of Manufacturers (KAM). 2020. Automotive Sector Profile – 2020.
[83] KEBS Standards Work Programme Bulletin, January 2023.
[84] GIZ 2020.

of National Urban Transport Policy are urgent tasks for GoK to achieve streamlined and enhanced institutional arrangements.

It is crucial for the government to show more commitment towards achieving low/zero-carbon development targets. The SDoT has taken the lead in the establishment of a task force team with relevant institutions to address climate change in the transport sector. Improving public transport through the development of mass rapid transit, enhancing non-motorized transport options like walking and cycling, integrating land use and transport planning, and establishing emission monitoring and control are key actions that should be further enhanced with concrete actions. This will not only promote sustainable development but also ensure a safer and cleaner environment for everyone.

The development of policy and strategy for e-mobility, together with capacity enhancement in both public and private sectors, are urgent tasks. Electrification of the transport sector, particularly the introduction of electric vehicles (EVs), is a relatively new concept for Kenya. The recent emergence of electric vehicles, especially for passenger electric vehicles, is welcome and makes EVs a viable option for Kenya together with country's greener energy production. While the SDoT is currently developing standards for charging facilities, e-mobility policy and strategy are not yet in place. In addition, policy decisions from many developed countries that ban the sale of new gas and diesel cars from 2035 will further accelerate Kenya's shift to e-mobility.

3.2. Inclusive and greener public transit

3.2.1. Connecting land use planning and transport planning

The need for a shift towards integrated land use planning and transport planning to improve urban mobility and create livable and competitive cities is becoming increasingly urgent. The National Spatial Plan was prepared in 2015, and since 2017 county governments have started formulating integrated development plans that include land use plans and urban infrastructure investment plans.[85] However, most cities do not have a transport plan, and linkage between land use plans and planned activities in the transport sector in the counties' integrated development plans is limited. Housing and land-use decisions are often taken on the basis of the location of available land, with almost no assessment of transport impacts, while road transport investment decisions are made on the basis of criteria often unrelated to land-use patterns. For example, affordable housing projects are under way in major cities, with no coordination with transport services, rendering them largely inaccessible not only to employment opportunities but also to social services and interaction. Urban mobility planning should adopt a holistic approach, with cross-sector, harmonized mobility and land use planning, as well as priority for public transport and non-motorized transport to create more environmentally, economically, and socially sustainable cities.

3.2.2. Public transport in Kenya

Available public transit modes are most likely similar among Kenyan cities. Table 9 shows the modal share in each city, which indicates that urban dwellers in Kenyan cities rely primarily on walking and public transport/paratransit modes. For Nairobi and Mombasa, the modal share of paratransit (matatus/bus) is already high, which should be maintained by introducing mass rapid transit system and improving feeder services, discouraging private vehicle use, managing boda bodas (motorcycle taxis), while encouraging active mode of walking and cycling with adequate non-motorized transport

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[85] Through the Kenya Urban Support Program, 59 municipalities have been supported in the preparation of Integrated Development Plans (IDePS), with some counties utilizing the urban institutional grants in developing county and urban land use plans. Further, under the Nairobi Metropolitan Service Improvement project, over 20 integrated strategic urban plans were developed for selected urban areas within the Nairobi Metropolitan area and are at different stages of approval and implementation.

(NMT) facilities. For other cities, provision of improved bus services and NMT facilities are urgent tasks to avoid further expansion of the boda boda system.

Transport costs are relatively high in Kenya. The bottom 20 percent of households in Nairobi need to spend 40 percent of their budget on transport if they want to use motorized transport. This is one of the explanations for the high dependency on walking. Affordability of public transport should be taken into consideration in urban mobility policy and plans.

Generally speaking, most public transport modes available in Kenyan cities are informal even though they register as public service vehicles (PSVs) and public service drivers. None of the road-based public transport modes has predetermined schedules: they leave only when the vehicle is full, and most PSVs stop anywhere in order to pick up and drop off customers as close as possible to their origin/destination. In addition to emission concerns discussed above, their chaotic and dangerous operational manner needs to be addressed.

Table 9. Modal share of transport in urban areas

Modal share (%)	Nairobi (2013)	Mombasa (2015)	Nakuru (2018)	Kisumu
Walking	37.8	45.5	63.8	52.7
Matatus (bus)	41.5 (10.5)	36.9 (includes ferry and rail)	15.4	13.0
Boda-boda	4.0	Included in others	13.2	19.3 (moto cycle and moto boda)
Tuk-tuk	Included in others	Included in others	Included in others	3.4
Private vehicle	12.6	2.5	6.2	5.6
Others	4.16	15.1	1.4	6.0

Source: Nairobi: Integrated Urban Development Plan; Mombasa: Comprehensive Development Master Plan in the Mombasa Gate City; Nakuru: County Integrated Development Plan (2018–2022), Kisumu: Kisumu Sustainable Mobility Plan (2020)

Access to jobs and services are serious challenges in Kenya. In the case of Nairobi, due to concentration of employment opportunities[86] in the Central Business District (CBD) and its immediate surrounding areas (a red dot in the figure, with the surrounding areas as orange dots), inadequate public transport system and traffic management, a resident in Nairobi can reach 4 percent, 11 percent, and 24 percent of the jobs within 30 minutes, 45 minutes, and 60 minutes of travel, respectively, using the minibus (Table 10).[87] Compared with other cities in Africa and other regions, the job accessibility in Nairobi by public transport is lower. However, with the implementation of the commuter rail investment plan as per the master plan, about 50 percent of population will be within 3 km from a commuter rail station, allowing the public transport system to reach an additional 170,000 jobs on average in 60 minutes.

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[86] We have used the number for projected employment at the census zone level prepared under the commuter rail master plan study for Nairobi.
[87] Nakamura and Avner 2018.

Figure 30. Employment opportunities in Nairobi
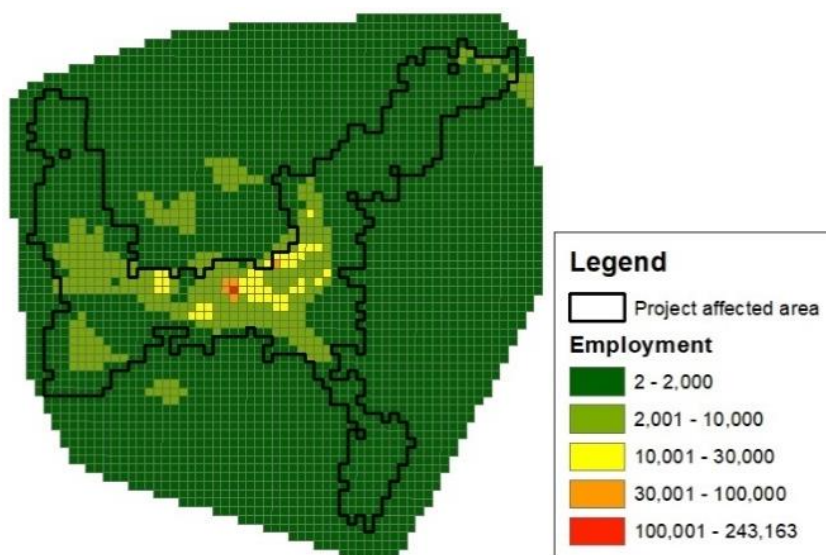
Table 10. Average share of accessible jobs in Nairobi

	Nairobi Walking (1)	Nairobi Transit (Minibus) (2)	Nairobi Cars (3)	Dakar Transit	Buenos Aires Transit	Lusaka Transit	Dar Es Salaam Transit	Douala Transit
Within 30 minutes	1.8%	3.9%	43.7%		7%			
Within 45 minutes	4.0%	10.8%	71.8%		18%			
Within 60 minutes	7.3%	23.9%	88.7%	52.0%	34%	34.1%	12.2%	39%

Note: Numbers are the average share of jobs in the city that Nairobi residents can reach by foot (column 1), minibus (column 2), and car (column 3) within 30, 45, and 60 minutes. Figures for Nairobi are based on Nakamura and Avner (2019). Figures for Dakar and Buenos Aires are borrowed from Stokenberga (2017) and Peralta-Quirós (2015) respectively. Figures for Lusaka, Dar Es Salaam, and Douala come from Peralta-Quirós, Kerzhner, and Avner (2019).

The gender gap in urban accessibility needs to be addressed to achieve inclusive mobility. In addition, another study also revealed that travel differences by gender are influenced by gender norms and violence, demonstrating that women rely more on walking, and have limited access to cars and other motorized transport compared to men. As such, to achieve inclusive mobility, the gender gap in urban accessibility needs to be addressed, together with accessibility for persons with disabilities, which are not well studied yet.

3.2.3. Towards lower/zero emission urban transit in Kenya

The GoK aims to establish a world-class integrated transport system that supports lower/zero emission urban transit. The Integrated National Transport Policy (INTP) 2009 set a vision to establish "a world-class integrated transport system responsive to the needs of people and industry." While the policy is currently under revision, INTP 2009 has already identified the following as the elements of its framework and priorities for urban transport which would support lower/zero emission urban transit: a) transport sector reforms; b) development of an urban transport policy; c) development of an integrated, balanced, and environmentally sound urban transport system that is shifting to high-occupancy vehicles and emphasizing non-motorized transport; and d) enhancement of the private sector's involvement in passenger transport.

This section summarizes the results of two analyses (Table 11) in emission reductions: a) modal shift in Nairobi Metropolitan Area, and b) introduction of e-mobility at national level. In Nairobi, planning for the development of mass rapid transit system (MRTS) is advanced with numerous studies. The proposed MRTS network in Nairobi Metropolitan Area consists of six commuter rail lines (total 295km in length) and five BRT corridors (total 94 km in length) as in Figure 31.

The objective of the analyses was to demonstrate the relative impact of a range of policies under different scenarios. These included:

- Policies designed to encourage an increased share of public transport by discouraging the use of other modes, particularly private vehicles. e.g., limiting increases in road space, restrictions on parking
- Policies designed to encourage the take-up of electric vehicles or, in the case of public transport, to mandate it
- Policies to significantly improve the service quality of public transport by investment in mass transit, e.g., commuter rail, BRT

Figure 31. Planned MRTS network in the Nairobi Metropolitan Area
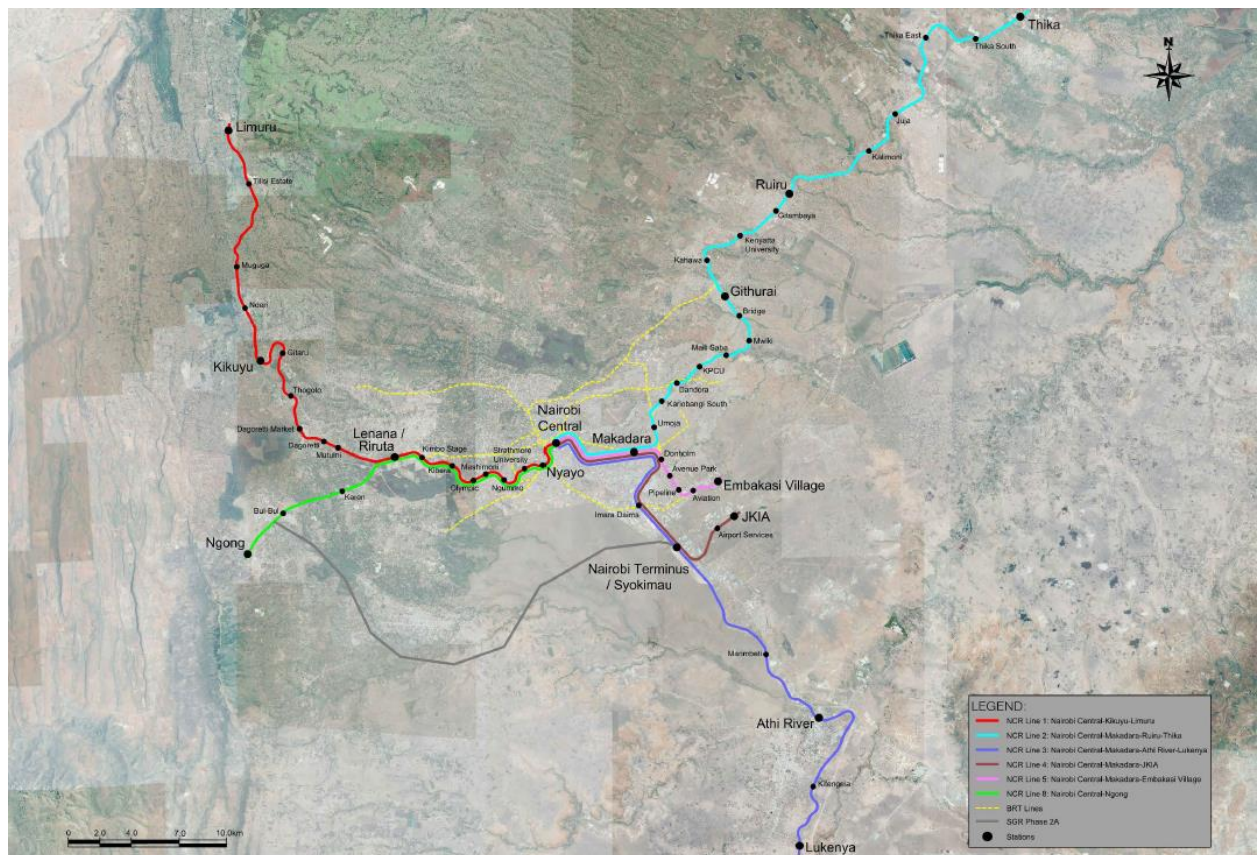
Table 11. Summary of Case Studies

	Case study 1: Modal shift in Nairobi Metropolitan Area	Case study 2: Introduction of e-mobility at the national level
Geographic coverage	Functional urban area, consisting of Nairobi county and census zones of Ruiru, Kikuyu, Thika, Karuri, Ongata Rongai, Juja, Kitengela, Kiambu, Mlolongo, Ngong, Limuru, Athi River, Machakos, and Kiserian	National
Scope	Emission reduction through modal shift from private vehicles to public transport, and from minibus/buses to higher capacity and greener modes such as commuter rail and BRT	Emission reduction through the introduction of e-mobility
Scenario	**BAU** (assumes the current PT mode share)	**BAU** (nominal share of EV)

	2030 Scenario (increased mode share of BRT and commuter rail by 2030, reflecting ongoing projects/initiatives) 2040 Scenario (aspirational scenario with the increased mode share of BRT and Commuter rail by 2040 as reflecting key and ambitious proposed projects and initiatives)	2030 Scenario (30 percent of private and passenger vehicles in new registration and 70 percent of two-wheelers and three-wheelers in new registration will be electric vehicles)
Data source:	Nairobi Integrated Urban Development Plan Commuter Rail Master Plan Feasibility studies of BRT line 3 & 4 and Project Note of BRT line 3 Transport GP's calculation	E-mobility scoping tool (transport GP)
Potential emission reductions	**2030 scenario** Commuter rail: 54,615 tonnes of CO_2/year BRT (line 3) average 23,482 tonnes of CO_2/year **2040 scenario** Commuter rail:186,995 tonnes of CO_2/year BRT (line 3 and line 4): average 37,127 tonnes of CO_2/year	5,132,178 tonnes of saving in CO_2 emission; 27,074 tonnes of saving in local pollutants emission (NOx, SOx, PM_{10}) (with 161 million liters of gas and 37 million liters of diesel in saving at year 2030
Energy demand	N/A	538 GWh of additional power needs at year 2030

Case study 1. Assessment of emission reductions in Nairobi Metropolitan Area
Assumptions and Scenarios

The total number of trips and modal share by mode in 2030 and 2040 were based on the transition scenario developed under the Nairobi Integrated Urban Development Plan (NIUPLAN) 2014 (Table 12).

Table 12. Total number of trips and modal share by mode in 2030 and 2040

Case/Scenario	Modal Share (%)					Total Trips
	Walk	Private	Public			
Year			Bus/matatus	BRT	Rail	
2013 (reference)	3,090,103 (46)	916,624 (14)	2,754,489 (41)	0	14,006 (0.2)	6,775,222
2018 (BAU)	3,246,051 (41)	1,289,796 (16)	3,281,825 (42)	0	14,416 (0.2)	7,832,087
2030 Scenario	3,951,771 (39)	1,763,111(18)	3,333,295 (33)	300,000 (3)	669,500 (7)	10,017,678
2040 Scenario	4,558,655 (36)	2,593,821 (21)	3,576,361 (28)	480,000 (4)	1,400,000 (11)	12,608,837

The modal share of public transport is already high in the NMA. Based on the past trends (2004–2013), it is reasonable to consider that the modal share of public transport will remain around 41–43 percent. With the increase of average per capita income in NMA through economic development during this period, further increase of motorization and the shifting of travel mode from public transport to private vehicles for certain part of the population is expected. At the same time, more people who are currently relying only on walking will be able to afford to shift to public transport. As such, a slightly increased shared of private vehicles and a slightly decreased shared of walking are observed in the 2030 scenario and again in the 2040 scenario.

In addition to business-as-usual scenario, the following two scenarios with improved public transport system have been prepared. While the 2030 scenario assumes increased mode share of BRT and commuter rail by 2030, reflecting ongoing projects/initiatives and being realistic, the 2040 scenario is the aspirational scenario with an increased mode share of BRT and commuter rail, reflecting key and ambitious proposed projects and initiatives (Table 13).

Table 13. Scenario 2030 and 2040

Scenario 2: 2030 scenario	Scenario 3: 2040 Scenario
• Modal share of public transport remains high at 43% • Policies to shift to higher capacity and greener public transport mode: 9% shift from Matatus to BRT and commuter rail by 2030. • Planned BRT line 3 (stage 1 Dandora to Kenyatta Hospital, 12.4km) and commuter rail improvement (Central Station to Ruiru 32 km and Central Station to Embakasi 13km)) were incorporated into the transition scenario of 2030 of NIUPLAN: estimated ridership 300,000 per day for BRT line 3. • The Thika–Nairobi Central line accounts for around 45 percent of the total estimated demand of 1.4 million. The proposed Kenya Urban Mobility Improvement Project (P176725) will finance the upgrading of the Ruiru–Nairobi Central station line, which is part of the Thika–Nairobi Central line, covering 74 percent of total demand of this line. The Embakasi line entails about 13 percent of total estimated demand of 1.4 million. Upgrading of Embakasi line is under discussion to be financed by other development partners. As such, an estimated 467,000 per day[88] (1.4 million*45%*74%) and 182,000 (1.4 million *13%) are used for the total trips for commuter rail. • BRT line 3 will deploy 110 buses (articulated 18 m) by 2030. While these buses are assumed to be fully electrified, in this assessment, we adopt the diesel Euro 4 as per the feasibility studies, which will indicate the impact of modal shift on GHG reduction.	• Modal share of public transport remains high at 43.3% • Policies to shift to higher capacity and greener public transport mode: 14% shift from Matatus to BRT and commuter rail by 2040. • Based on 2013 data and 2030 scenario (assumption) in NIUPLAN, annual growth factor of -0.00856 and 0.01572 are obtained and used for the split of trips by mode of walking and public transport (walking, private and public) in 2040. • For commuter rail, the total estimated demand for the investment proposed under the commuter rail master plan, 1.4 million, was adopted. For this aspirational scenario, operationalization of BRT lines 3 (including extension under stage 2) and 4 are assumed with daily passengers of 480,000 (360,000/line 3, and 120,000/line 4) based on the feasibility studies of BRT line 3 and 4.[89] • BRT line 3 will expand fleet size to 170 by 2040. Line 4 requires 58 buses. Adopting the same approach as in Scenario 2030, this scenario will use articulated 18 m buses with diesel Euro.

Emissions

Commuter rail

Based on the 2030 and 2040 scenarios, we have calculated annual emissions reduction, comparing them with the BAU scenario using the following formula (Figure 32). Annual emission reduction through modal shifts from matatus/buses and private vehicles to commuter rail is expected. The results demonstrate an annual emissions reduction of 54,615 tonnes of carbon dioxide equivalent (tCO_2e) for the 2030 scenario and 186,995 tonnes of carbon dioxide equivalent (tCO_2e) for the 2040 scenario.

Figure 32. Annual emissions model

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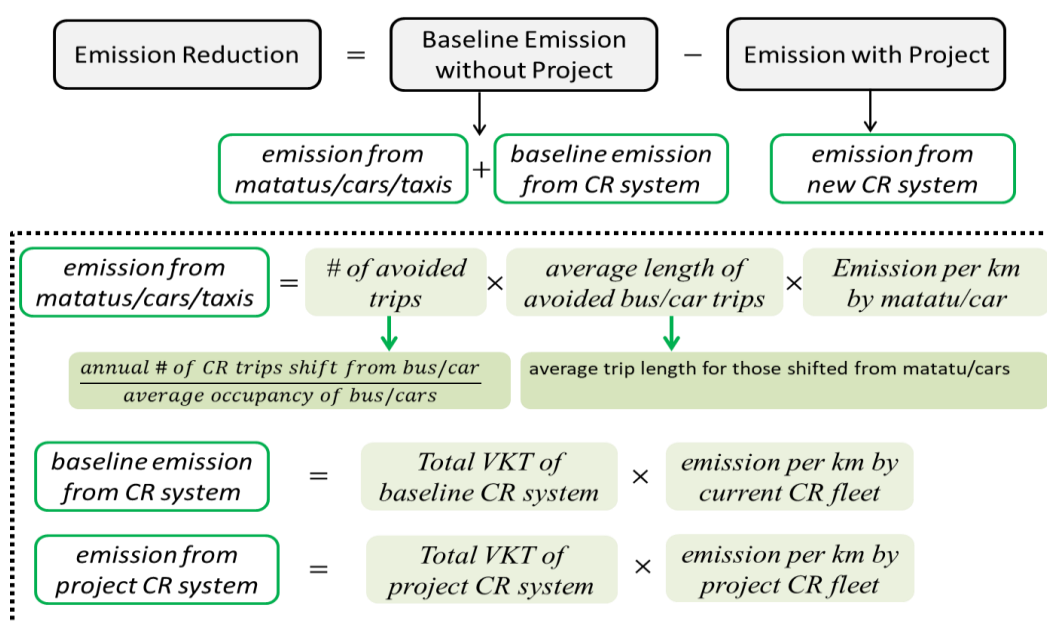
[88] Nairobi-Thika section accounts for 45 percent of the entire demand, Nairobi - Ruiru section accounts for 74 percent of demand between Nairobi-Thika
[89] As the feasibility studies were as of 2019 and considered 2023 to be the commencement year of BRT operation, the projected data for 2023 and 2035 are adopted for 2030 and 2040 scenario in the CCDR assessment.

BRT

The total reduction of 117,416 tonnes of CO_2 emission is expected by 2030 (equivalent to average 23,483 tonnes/year) and 379,919 tonnes by 2040 (equivalent to average 25,327 tonnes/year) resulting from the development of BRT line 3 (operation starts in 2025/26). While information on annual emission saving on BRT line 4W is not available, the feasibility study of BRT line 4W estimated that the total reduction in CO_2 emissions will be 353,000 tonnes over 30 years of BRT operation with an average annual reduction of CO_2 emissions of approximately 11,800 tonnes overall, inclusive of private vehicles and public service vehicles.

Table 14. Estimated emission reduction per year (unit: tonnes)

	2030 Scenario	2040 Scenario (Aspirational)
Commuter rail	54,615	186,995
BRT line 3	23,483	25,327
BRT Line 4W	Not yet operational	11,800
Total	78,098	224,122

In total, then, based on the existing studies on BRT line 3 and 4 as well as the estimations for commuter rail, potential annual reductions of 78,098 and 224,112 tonnes of carbon dioxide equivalent (tCO_2e) are estimated for 2030 and 2040 scenarios through modal shift to mass rapid transit (Table 14).

Case study 2. Assessment of emission reductions through the introduction of electric vehicles (EVs)

The benefits of electric mobility transition in Kenya include improved air quality, reduction of greenhouse gas emissions, and positive economic impacts of the technology through the creation of new local value chains. This is especially favorable given that more than 90 percent of Kenya's energy is generated via renewable sources. Kenya has a significant reserve capacity for electricity generation to accommodate growth in EV mobility.

Green mobility innovation and start-ups

While there is no electric vehicle manufacture in Kenya, there are six assemblers in operation.[90] There are about 50 pilot activities to introduce e-mobility in the country. Most of the current attention and initiatives are on electric two-wheelers and buses. Taking the bus industry as an example, over 10 different companies are developing/deploying electrical mobility products in Kenya. E-bus producers who have deployed or plan to deploy in Kenya include: BYD, Volvo, Golden Dragon, Ashok Leyland, and Yutong. While several plans at national and local level have emphasized the introduction of e-mobility, no policy and strategy to guide its development are yet in place, leaving ongoing initiatives remain largely fragmented.

E-buses

BasiGo, in partnership with the Chinese electric vehicle giant BYD, started by importing two 26-seat electric buses and began a pilot scheme in March 2022, operated by the local matatu operator CityHoppa.[91] Basigo adopts Pay-As-You-Drive (PAYD) financing model and as of November 3, 2023, 19 electric buses are running in Nairobi Metropolitan Area. Roam, a Swedish–Kenyan technology company has developed two different types of fully electric buses adapted to the African use-case: the mass transit bus and the feeder bus. The Kenguru electric minibus is another example of mini-electric buses available in Kenya. The Matatu Owners Association (MOA) in Kenya has announced plans to introduce 11-seater electric minibuses to operate in Nairobi's CBD to reduce air pollution and congestion.

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[90] AHK Services Eastern Africa Limited 2021, Roadmap to e-mobility in Kenya.

[91] Towards developing an E-bus Roadmap for Nairobi, December 2022.

Two-wheelers and three-wheelers

Most of the EVs in the country are currently motorcycles. The existing business model of e-motorcycles includes direct sale, leasing, and battery swapping.

E-mobility assessment

E-mobility assessment was carried out to understand the economic and financial viability of e-mobility in Kenya.

Two scenarios were prepared:
- **Business as usual (BAU)** with nominal share of EV
- **2030 Scenario:** 30 percent of private and passenger vehicles in new registration and 70 percent of two-wheelers and three-wheelers in new registration will be electric vehicles.

In the 2030 scenario, about 1.4 million EVs are anticipated in the country with 147,000 (10 percent) and 11,000 (1 percent) being passenger cars and buses, respectively (Figure 33). Results indicate a favorable economic case for EV uptake in Kenya, leading to cost advantage in both economic and financial analysis. However, cost advantage by mode has mixed results: two-wheelers are making an economic case, while cars and buses do not show cost advantage in economic analysis. This is due to the high capital cost for vehicles and charging facilities. For financial analysis, all modes show cost advantages (Figure 34).

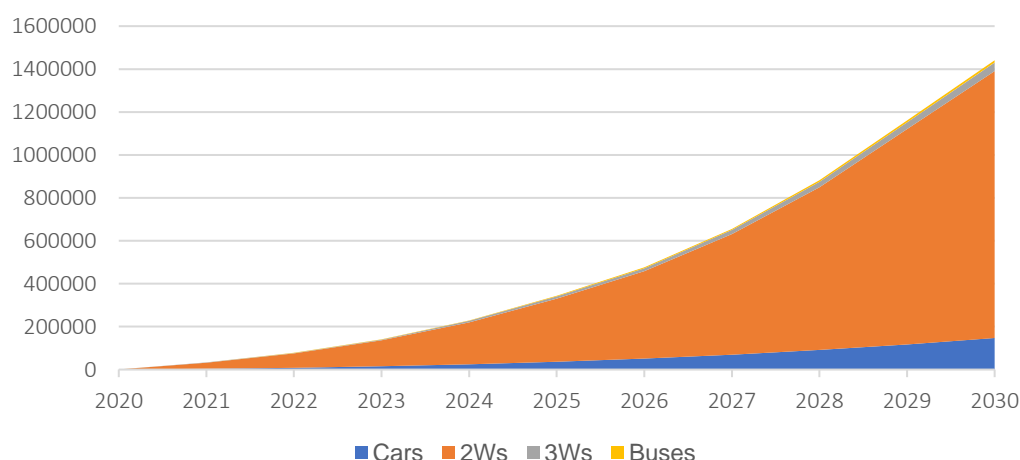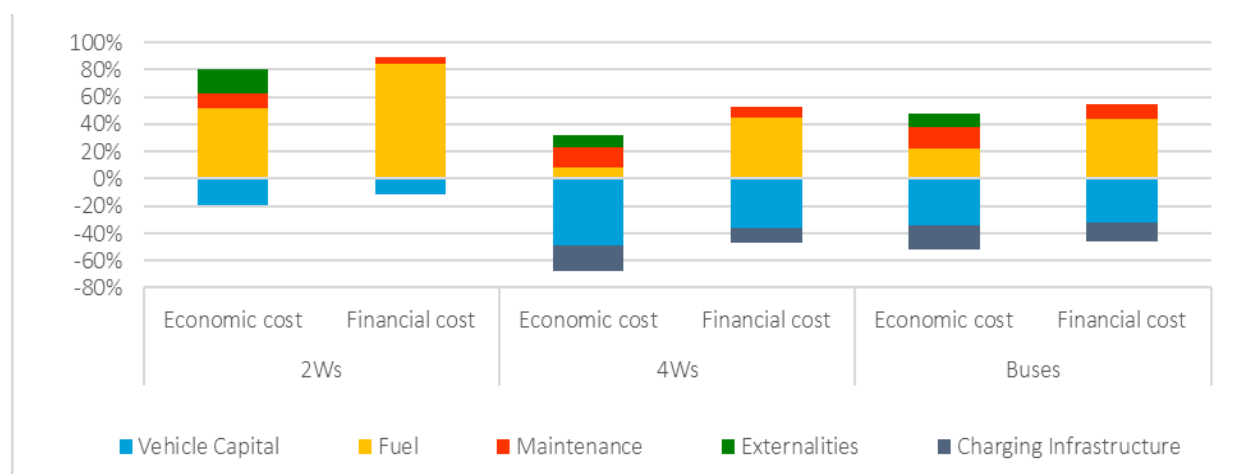### Figure 33. 2030 Scenario BEV stock

Figure 34. Drivers of cost advantage at 2030 (% of total)

We examined the economic viability of e-buses further with increased vehicle kilometer traveled (VKT) from 43,000 km/year to 62,000km/year based on the BRT feasibility studies. With higher VKT, the bus segment also becomes economically viable.

In total, the assessment estimates 5,132,178 tonnes of saving in CO_2 emission, 27,074 tonnes of saving in local pollutants emission (NOx, SOx, PM_{10}) (with 161 million liters of gas and 37 million liters of diesel in saving) at year 2030. When we adopt the higher VKT (62,000km) for buses based on the several BRT studies in Nairobi, there will be an additional 362,219 tonnes of saving in CO_2 emissions (total 5,494,397 tonnes, Figure 35), and 3,812 tonnes of saving in local pollutants emission (NOx, SOx, PM_{10}) at year 2030. While the buses have only 1 percent share in EV stock in 2030, adopting EV in public transport can generate 1,218,626 tonnes of savings in CO_2 emissions (22 percent). About half of the emission savings is from two-wheelers.

Figure 35. CO_2 emission saving through e-mobility (total 5.5 MtCO2e)
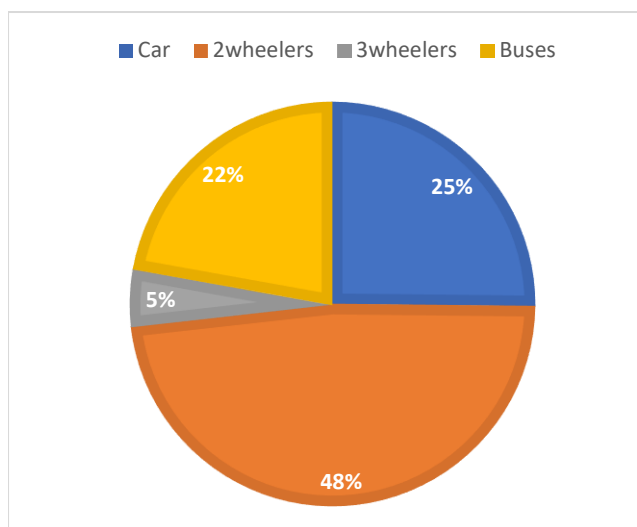
Figure 36. Breakdown of investment need at year 2030 (%) (total US$480 million or 0.13% of GDP)
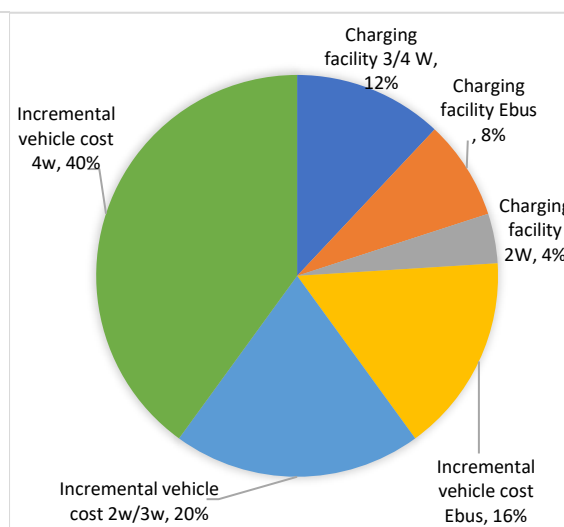
While not included in this assessment, GoK is also considering greener solutions for commuter rail operation and railway cars with diesel engines with electric battery are under consideration. As such, further emission reductions are anticipated.

To materialize the 2030 scenario, a total investment cost of US$480million is needed and 24 percent of the investment cost (US$115million) will be for charging facilities (Figure 36). A study indicates that subsidizing public charging stations is 6 times more cost-effective than subsidy in consumer purchase.[92]

In addition, this scenario requires 538 GWh of additional power at year 2030, which may require additional investment in the power sector.

As the Road Maintenance Fund (RMF) in the country is supported by a fuel levy, adopting e-mobility will have an adverse impact on the available budget for road maintenance. The assessment estimates that 198 million liters of petrol and diesel will be saved through adopting e-mobility in this scenario. This

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[92] Briceno-Garmendia et al. 2022. The Economics of Electric Vehicles for Passenger Transportation, World Bank

implies that the RMF will lose KSh 3,564,000,000 (fuel levy at KSh 18 per liter), which is 4.6 percent of the RMF expenditure in FY 2021/22 (KSh 77.3 billion).[93]

3.4. Policy recommendations

Adopting of the "Avoid-Shift-Improve+Resilience" approach is highly recommended to identify suitable GHG emissions mitigation and climate resilience measures and improve urban mobility in Kenya. "Avoid" refers to reduced amount of travel or shorter travels by adopting transit-oriented development and compact city concept into the land use. "Shift" refers to modal choice change of people and goods from more GHG-intensive modes to less GHG-intensive. In the case of Kenyan cities, this means shifting from matatus to higher-capacity public transport such as commuter rail and BRT, from boda bodas to buses, and from private vehicles to buses/commuter rail/BRT. "Improve" focuses on the adoption of a more efficient transport system and fuel through improved operations, better management practices, enhanced emission inspection, and cleaner vehicle or fuel technologies. "Resilience" aims to enhance the ability/capability of the transport system to provide uninterrupted service in the face of one or more major obstacles to normal function and recover from the disruptions in a timely manner.

Within the "Avoid-Shift-Improve+Resilience" framework, the following key recommendations are prepared for this chapter.

Develop a comprehensive enabling National Urban Transport Policy framework

The need for a National Urban Transport Policy in Kenya is crucial to define a clear and sustainable vision for urban mobility, guide public transport management, and establish a financing framework for urban mobility. The absence of the National Urban Transport Policy and downstream planning at the local level have been hindering the government of Kenya from defining a long-term vision for sustainable and resilient mobility and a clear implementation plan for most urban areas in the country. During the identification mission of the Kenya Urban Mobility Improvement Project (P176725), stakeholders reconfirmed the overlapping and fragmented institutional arrangement for urban mobility in the country and requested the development of National Urban Transport Policy. The National Urban Transport Policy can define the government's role in public transport management, specify a clear direction to manage urban mobility in the country, and guide the financing framework for urban mobility. National Urban Transport Policy will guide counties in preparing their own urban mobility strategies and plans. The Urban Mobility Plan for the Nairobi Metropolitan Area is also an urgent task to achieve the goal of an integrated public transport network. As MoRT is currently reviewing the Integrated National Transport Policy (INTP), a low-carbon development path should be well articulated in the updated INTP and a strong linkage between INTP and National Urban Transport Policy should be established. Both policies can scale up mainstreaming gender and green mobility to the next level.

Develop a green and reliable public transport system and NMT facilities in urban areas

A shift in priorities in urban transport to enhance public transport and non-motorized transport facilities in the main urban areas is imperative. The majority of urban dwellers in Kenya rely on walking and public transport. The modal share of private vehicles is about 12 percent or less. In light of this evidence, the priorities in urban transport have to shift from traffic/car-centric to people-centric, and to the enhancement of public transport and NMT facilities as a matter of urgency in the main urban areas in Kenya. The availability of a green and reliable public transport system and a safe and secure walking environment in urban areas will have a strong impact on GHG reductions through a modal shift to less GHG-intensive modes as well as improved accessibility to jobs and services. However, it is important to establish the funding mechanism for mass rapid transit and improved bus services. While public transport investments have good socioeconomic benefits, revenues from users rarely offset all capital and operating costs when considering social inclusion objectives such as the affordability of fares. As

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[93] https://www.krb.go.ke/img/download-20220830-630dafaf7cf79.pdf.

part of the development of a green and reliable public transport system, strategies to manage/control boda bodas to avoid their unnecessary expansion in urban areas, fleet renewal programs, and emission monitoring and control of all types of vehicles should be developed.

Accelerate the introduction and expansion of e-mobility

Adopting e-mobility in conjunction with the development of a mass rapid transit system will be a game changer for Kenya. Coupled with bus route rationalization and as part of sector reform, e-mobility would enable the achievement of higher VKT, which would result in additional fuel saving, reducing traffic congestion and air pollution. While the share of buses is anticipated to be about one percent in the total EV stock in 2030, adopting EV in public transport could reduce 1.22 million tCO_2e (22 percent) of emissions. Meanwhile the Ministry of Roads and Transport is working on the standards of charging facilities. There is also the need to establish the demand profile, the charging tariff design, and the battery end-of-life management regulations applicable for battery electric buses (BEBs) and other battery electric vehicles (BEV) types to advance the transition to e-mobility.

Development of e-mobility policy to set the enabling framework for introduction and expansion of e-mobility is an urgent task. Over the last 10 years, Kenya has successfully developed substantial power generation capacity and has overcome the shortfalls that had plagued the energy sector for decades. The country has expanded generation capacity of a well-diversified mix with close to 90 percent of energy being generated from clean sources (mainly geothermal, hydro, and wind). While e-mobility is currently at a very early stage of development in the country, adopting battery electric vehicles in conjunction with the development of mass rapid transit will be a game-changer for the country. As bus operations are currently managed by the private sector, despite the lower operational and maintenance cost of BEBs, the high capital investment cost of BEBs, in addition to the installation of charging facilities, will hinder their rapid adoption and expansion. Furthermore, BEVs receive tax benefits of reduced import duty, but electricity in the country is not subsidized. As discussed above, adopting e-mobility will have a negative impact on the revenues of the Road Maintenance Fund. Necessary adjustment/solutions in road asset management needs to be explored.

Institutional capacity building

Enhancing institutional and technical capacity in the urban transport sector will play a key role in improving urban mobility with a climate resilience lens. Technical capacity in the urban transport sector of the country and counties is currently limited, as the result of the focus on road network development in road transport in past decades. The development of a National Urban Transport Policy will emphasize the importance of urban mobility, and development of a holistic institutional capacity building program in urban mobility is recommended to achieve low/zero-carbon development. The program can cover the topics of urban mobility planning, public transport planning, traffic management, land use planning (transit-oriented development), e-mobility, urban logistics, among others. In addition, it could identify a university or universities which can offer transport courses (undergraduate and master's degrees) and carry out transport-related research to expand the pool of transport experts in the country. In addition, enhancement of institutional capacity to manage the rapidly increasing vehicle fleet in the country, and developing and implementing necessary policies and programs for motorization management is also critical for sustainable urban mobility.

Table 15. Recommendations

Recommendations	Activities	Cost (US$ million)
Development of comprehensive enabling National Urban Transport Policy Framework	National Urban Transport Policy and relevant strategies	2
	Urban mobility plans (Nairobi Metropolitan, Mombasa, Nakuru, Eldoret)	2
Develop a green and reliable public transport system and NMT facilities in urban areas	Nairobi Metropolitan Area Commuter rail (294km)	3,000
	BRT Line 2 to 5	
	NMT network (85km sidewalk and 85km bike lane in Nairobi)	55
Accelerate the introduction and expansion of e-mobility	E-mobility policy and relevant strategies	1
	Electric buses Charging facilities	
		480
Institutional capacity building	Capacity building program development	TBD
	Transport courses at selected universities	TBD
	Motorization management	TBD

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