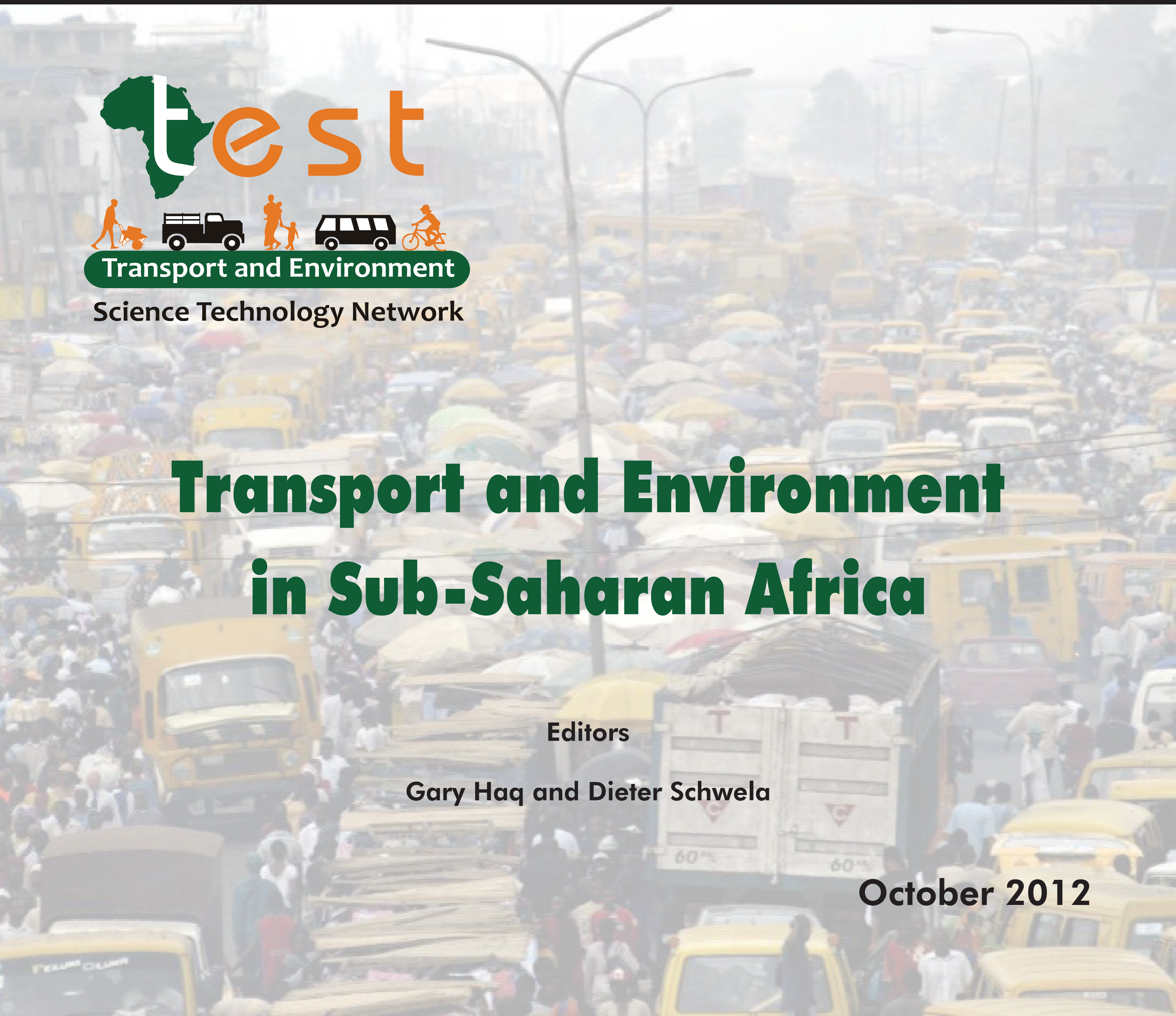

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Transport and Environment

Science Technology Network

Transport and Environment in Sub-Saharan Africa

Editors

Gary Haq and Dieter Schwela

October 2012

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The TEST Network aims to support Sub-Saharan Africa (SSA) countries in formulating and implementing sustainable transport policies which contribute to poverty reduction and sustainable economic development. TEST Network members in South Africa, Tanzania, Uganda, Zimbabwe and Zambia work in partnership with SEI and EURIST.

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Acronyms and abbreviations

APINA	Air Pollution Information Network Africa
AQ	Air quality
AQM	Air quality management
AQS	Air quality standard
AQSs	Air quality standards
BABB	Build a better bicycle
BRT	Bus rapid transit
CAI-SSA	Clean Air Initiative for Sub-Saharan Africa
CBD	Central Business District
CCS	Congestion Control Signal
CDM	Clean Development Mechanism
CIF	Climate Investment Fund
CO	Carbon monoxide
CO_2	Carbon dioxide
CPRE	Council for the Protection of Rural England
CTM	Chemical transport models
DALYs	Disability Adjusted Life Years
DFID	Department for International Development
dB	Decibels
EC	European Commission
EEA	European Environment Agency
ENM	Environmental noise management
EST	Environmentally sustainable transport
ETM	Equitable transport management
EU	European Union
GEF	Global Environment Facility
GIS	Geographic Information System
GHG	Greenhouse gases
GNP	Gross National Product
GPRS	General packet radio service
GPS	Global positioning system
GRSP	Global Road Safety Partnership
HC	Hydrocarbons
ICC	Intelligent Cruise Control
IEA	International Energy Agency
IFRTD	International Federation for Rural Transport and Development
ITDP	Institute for Transport Development Policy
ITS	Intelligent Transport System
JI	Joint Implementation
Km	kilometre
Km/h	kilometer per hour
LAMATA	Lagos Metropolitan Area Transport Authority
LOS	Level of service
MDGs	Millennium Development Goals
NGO	Non-governmental organisations
NMT	Non-motorized transport
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NRSC	National Road Safety Council
O_3	Ozone
ODA	Overseas Development Assistance
OECD	Organisation for Economic Cooperation and Development
PAYD	Pay-as-you-drive
PCFV	Partnership for Clean Fuels and Vehicles
PM	Particulate matter
PM_{10}	Particulate matter of aerodynamic diameter of less that 10 μm
$PM_{2.5}$	Particulate matter of aerodynamic diameter of less that 2.5 μm
RAMP	Rural Accessibility and Mobility Programme
RCI	Responsibility and Capacity Indicator
R&D	Research and development
RFID	Radio frequency identification
SA	Source apportionment
SADC	Southern African Development Community
SDC	Sustainable Development Commission
SGBV	Sexual and gender-based violence
SMS	Short message service
SO_2	Sulphur dioxide

SSA	Sub-Saharan Africa
SSATP	Sub-Saharan Africa Transport Policy Program
SUT	Sustainable urban transport
TAC	Trans Africa Consortium
TDM	Transport Demand Management
TfL	Transport for London
TFM	Traffic flow management
TSP	Total suspended particulates
TTC	Time to collision
UK	United Kingdom
USA	United States of America
US	United States
USEPA	United States Environmental Protection Agency
UN	United Nations
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific.
UNCSD	United Nations Council for Sustainable Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOCs	Volatile organic compounds
VRU	Vulnerable road users
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization

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1 INTRODUCTION

Transport policies in Sub-Saharan Africa (SSA) are of critical importance to the delivery of sustainable cities, healthy citizens, poverty eradication and achievement of the Millennium Development Goals (MDGs). Transport contributes to the creation and promotion of a quality of life for all sections of the community. It is also vital for trade, commerce, business, new firm formation and the widespread dissemination of entrepreneurial opportunities and participation in the labour force. However, transport has to be designed and managed in ways that are democratic and beneficial to everyone.

Road safety, traffic congestion, urban air pollution, road maintenance, accessibility and mobility problems are key challenges for SSA. Rural to urban migration has contributed to a rapid expansion of cities, increasing levels of poverty and the proliferation of slums. These factors have resulted in a widening gap between urban transport supply and demand. There has been a rise in the number of motor vehicles which has resulted in traffic congestion, air and noise pollution and death and injury due to road crashes. Inadequate public transport and limited shared road space for pedestrians have contributed to a poor quality of life for the most vulnerable in African society.

In terms of transportation technology and policy, Africa lags behind developed countries. The challenge for Africa is to address continuously growing transport (energy) demand, without hampering growth in mobility. Potential solutions can be found by examining past and present international responses (Akinyemi, 2003). Can lessons be learnt from the transport policy of other countries in the areas of air pollution, road safety and traffic flow management? If so, how likely is it that these lessons can be implemented and used in developing transport policy in Africa?

1.1 Motor vehicle pollution

Transport is a major source of polluting air emissions. Greenhouse gas (GHG) emissions from the transport sector in SSA countries have been rising. Motor vehicle emissions of sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), soot, dust and fine particulate matter (PM) contribute to deteriorating air quality in the majority of Africa's largest cities. Particulate matter emissions from the transport sector are a major problem and contribute to increased mortality and morbidity in the urban population. The lack of emission controls on vehicles, and poor monitoring and enforcement systems, further exacerbate pollution problems (Lusaka Agreement, 2008; Nairobi Agreement, 2008). In addition, the high costs of materials, equipment, inadequate maintenance policies and low institutional capacities have resulted in inadequate levels of maintenance of highways and rural roads in many African countries. In addition, noise pollution in SSA cities is also on the rise due to the growth of an ageing vehicle fleet.

1.2 Road safety

The road safety situation throughout the African continent is one of the worst in the world. With only 2.8 per cent of the world's motor vehicles, its road fatality share is almost four times greater (11.1 per cent) (WHO, 2009). In several African countries, a motor vehicle is over a hundred times more likely to be involved in a fatal road crash than in the United Kingdom (UK) or the United States of America (USA) (Jacobs *et al*., 2000). Pedestrians constitute a most vulnerable group in road traffic accidents due to their mobility needs being neglected in transport planning. In the United Nations regions of Middle Africa, Eastern Africa, Western Africa, and Southern Africa regions 1890, 380, 350, and 170 people per 100,000 vehicles, respectively die as a consequence of road crashes, compared to 60, 100 and 190 in the low-income and middle-income countries of Europe, Latin America (including the Caribbean), and Asia, respectively (WHO, 2009). School-children in SSA countries walk long distances on road without pedestrian sidewalks and are, therefore, exposed to a high risk of road accidents. Risk factors for road traffic deaths and injuries include drink driving, excessive speed, and poor infrastructure design and management. Road traffic deaths and injuries impose a huge economic burden on SSA countries, amounting to 1-3 per cent of Gross National Product (GNP) in most countries (WHO, 2011).

1.3 Traffic flow management

Transport congestion in SSA cities is on the rise with some cites approaching gridlock. It is therefore one of the main threats to sustainable development in region. Traffic congestion and air pollution are strongly linked to poverty. In SSA many poor people live in dwellings close to busy roads where ground-level pollution is high. People exposed to air pollution can suffer from cardiovascular and respiratory diseases, which in addition are exacerbated by use of open stoves indoors for cooking and heating. Traffic congestion also leads to loss of time and lost work hours which directly affect the economy.

In recent years the above concerns related to the transport sector has led to political concern in SSA. Various regional agreements have helped to improve certain aspects of the situation. Since the Dakar Agreement of 2001 SSA is almost completely free of leaded gasoline and similar regional agreements are starting to address high sulphur fuels and the other transport issues in a more integrated way (e.g. Lusaka Agreement, 2008; Nairobi Agreement, 2008).

1.4 Trends in Sub-Saharan African transport

The urban population of Sub-Saharan Africa have been growing at rates of 3.7 to 5.4 per cent each year between 1950 and 2010. These have been and will continue to be the highest in the world. African city-based population percentages (normalised to that of the year 2000) are growing faster than their counterparts in all other regions of the world and are estimated to continue to do so in the next two decades (UN, 2012).

While most of the vehicle population is in developed countries, motor vehicle pollution in developing countries is rapidly worsening due to increasing vehicle fleet growth, increasing distances travelled, and high rates of emissions from the vehicle fleets. The causes of the high emissions rates include high proportions of polluting two-stroke engine vehicles, road congestion, which increases emissions per kilometre travelled, inadequate emissions controls, poor maintenance, high average age of the vehicle fleet, and poor fuel quality including high sulphur content in diesel (PCFV, 2012).

By 2030, the share of urban areas in East Africa will increase - from 7.5 per cent of the average annual population increase in 1950-2000, to 22.6 per cent of that expected during 2000-2030 (UN-HABITAT, 2011). While a major portion will live in low income settlements and slums and non-motorised transport still will remain dominant but becoming more and more dangerous.

Transport's share of these global emissions is 25 per cent (IEA, 2010). This is a large component of total carbon dioxide (CO_2) emission and reducing emissions from the on-road transportation sector can yield rapid and longer-term climate benefits (Unger *et al*., 2010). Africa's proportionate contribution to global CO_2 emissions is small and in 2008 stood between 2.9 and 3.6 per cent (IEA, 2010). However, future growth in the major sectors is likely to occur mostly in the developing world. This emphasises the urgency and importance of reducing transport's CO_2 emissions in African countries.

1.5 Scope of the report

Published data in SSA on transport congestion, air pollution (including GHGs and noise) and road safety tend to be variable or of poor scientific quality and based on many perspectives (WHO, 2004; Schwela, 2007). There is a need for government agencies, academic institutions, industry and stakeholders to gain a better understanding of the nature and cause of transport problems and how improvements can be made using current science and technological advancements. Comprehensive research is required to support policy and institutional development that incorporates the needs of pedestrians, non-motorised traffic modes and focuses on inter-modal compatibility (Khayesi, 2003). The lessons learned in motorised countries (i.e. the neglect of pedestrian safety and need for community participation) should be shared with SSA countries in the hope that some of the adverse impacts of motorisation and development can be avoided

The aim of the Report is to provide an introduction to the transport and environment issues in SSA countries. It focuses on the key transport-related areas of air and noise pollution, road safety, traffic flow management, equity and climate change. In addition, best practice cases studies from SSA and internationally in these areas are identified. Finally, the Report outlines conclusions and recommendations to assist the development of sustainable transport systems in SSA countries.

2 URBAN AIR AND NOISE POLLUTION

2.1 Introduction

Urban air pollution in cities of SSA appears to be on the rise with respect to many key pollutants due to rapid urbanisation, increase in motorization and economic activity. In some cities where monitoring has been performed levels of air pollution exceed WHO recommended guidelines (WHO, 2006). Key air pollutants comprise NO_2, SO_2, CO, PM, ozone (O_3) and – in countries where the phase-out has not been completed - lead.

One main cause of urban air pollution is the use of fossil fuels in transport. Pollutant emissions have a wide range of direct and indirect effects on human health, ecosystems, agriculture and materials. There is a growing need in SSA to determine the state of urban air quality and the challenges posed to solve it and identify the most effective measures to protect human health and the environment. Urban outdoor air pollution is responsible for an estimated 75,500 premature deaths each year in Africa and 49,100 in Sub-Saharan Africa (WHO, 2007).

This chapter is based on information on air quality (AQ) in 27 SSA countries collected by the Clean Air Initiative in Sub-Saharan African Cities (CAI-SSA), the United Nations Environment Programme (UNEP) and the Air Pollution Information Network Africa (APINA) and compiled in a report of the World Bank (Schwela, 2007). These countries are Benin, Botswana, Burkina Faso, Burundi, Cameroon, Republic of the Congo (Congo-Brazzaville), Democratic Republic of the Congo (Congo-Kinshasa), Ethiopia, Gabon, Ghana, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Nigeria, Rwanda, Senegal, Swaziland, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

2.2 Air Quality Management in SSA

Policies All SSA countries in the World Bank report are parties to the United Nations Framework Convention on Climate Change (UNFCCC) and the Montreal Protocol on Substances depleting the Ozone Layer. Most countries have also signed the Kyoto Protocol. Legislation on environmental protection (Environment Protection Act) has been developed in the majority of countries. Only Congo-Kinshasa, Guinea, Liberia, Malawi and Rwanda seem to not have Environmental Protection Acts.

The Environment Protection Act covers air pollution. Comprehensive legislation specific for air pollution sometimes exists (e.g. in the Atmospheric Pollution Prevention Act of Botswana). The Environment Protection Act is complemented by regulations and rules, which specify fuel parameters, emission standards and air quality standards (AQS). While 16 countries have set fuel specifications for gasoline and 14 for diesel, only five countries have promulgated emission standards for vehicles and eight have set AQS (e.g. Figure 2.1 for diesel sulphur content). In eight SSA countries (Benin, Republic of Congo, Equatorial Guinea, Gabon, Kenya {excluding Nairobi}, Mali, Somalia, Togo) the diesel sulphur content is above 5,000 ppm, in eighteen countries (Angola, Burkina Faso, Cameroon, Central African Republic, DR Congo, Djibouti, Eritrea, Ethiopia, The Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Madagascar, Mauritania, Senegal, Sierra Leone) between 2,000 and 5,000 ppm, in Nigeria between 500 and 2,000 ppm, and in seventeen countries (Botswana, Burundi, Chad, Lesotho, Malawi, Mozambique, Namibia, Niger, Rwanda, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe) between 50 and 500 ppm (PCFV, 2012).

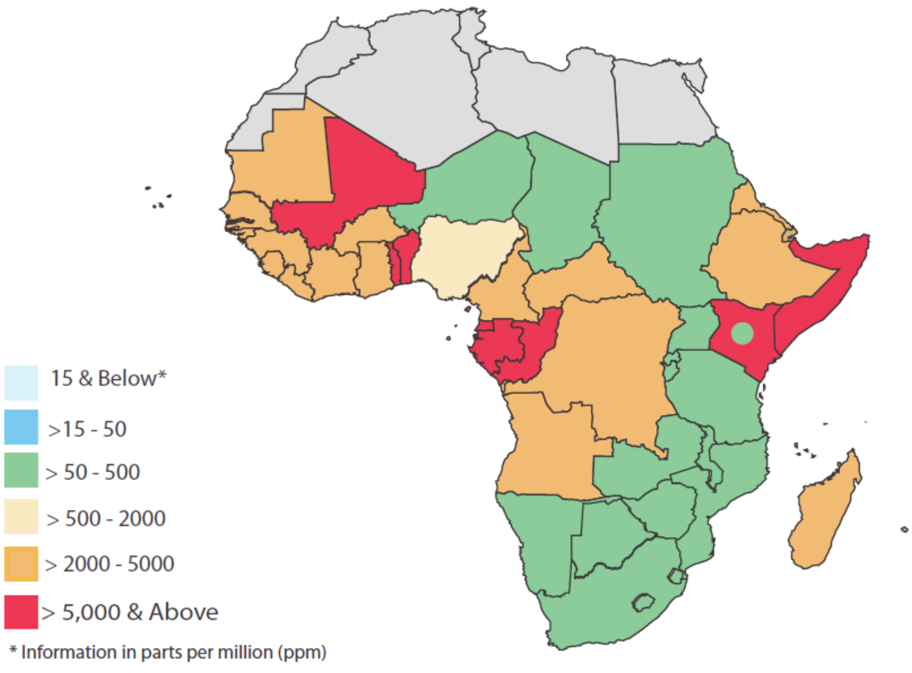


Figure 2.1: Status of diesel sulphur content in Sub-Saharan Africa *Source: PCFV (2012)*

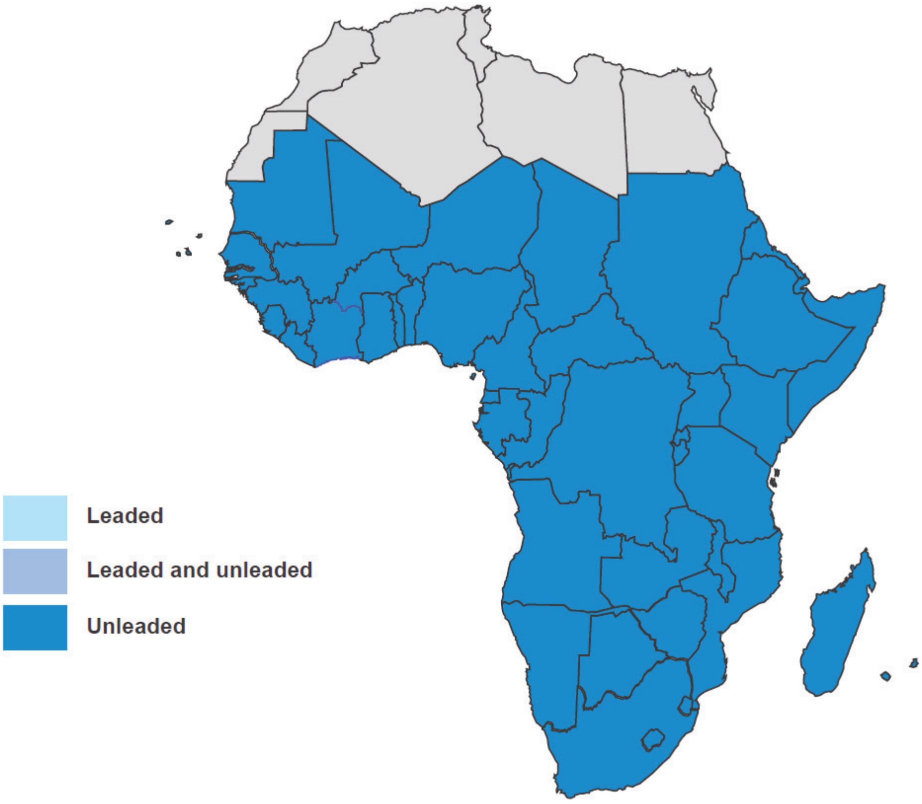


Figure 2.2: Lead phase out in petrol in Sub-Saharan Africa

Source: PCFV (2011)

Table 2.1: Phasing out of lead in Africa

Year	Country
2001	Sudan
2003	Cape Verde; Eritrea; Ethiopia; Ghana; Mauritania; Mauritius; Nigeria
2004	Benin; Cameroon; Central African Republic; Chad; Ghana; Niger; Tanzania
2005	Angola; Burkina Faso; Burundi; Côte d'Ivoire; Republic of Congo; Democratic Republic of Congo; Djibouti; Equatorial Guinea; Gabon; Guinea; Guinea-Bissau; Kenya; Liberia; Madagascar; Mali; Mozambique; Rwanda; São Tomé and Principe; Sénégal; Sierra Leone; Somalia; The Gambia; Togo; Uganda
2006	Botswana; Lesotho; Malawi; Namibia; South Africa; Swaziland; Zimbabwe
2007	Zambia
No information about the year	Comoros; Réunion; Seychelles

Source: PCFV (2010); Burke (2004)

A substantial development in SSA countries is the phasing-out of lead, which started in 2003 and is completed in all SSA countries (see Figure 2.2 and Table 2.1).

Emissions Source apportionment (the estimation of emissions of different source types) has been performed in Ethiopia for PM_{10} and is reported for GHGs by only two countries: Congo Brazzaville and Togo. Five countries have set or proposed emission standards for mobile sources, either petrol- or diesel-driven or both: Botswana, Burkina Faso, Kenya, Madagascar, and Uganda. These standards relate to emissions of CO, CO_2, nitrogen oxides (NO_X), hydrocarbons (HCs) and volatile organic compounds (VOCs). Emission standards for stationary sources exist or are being set in four countries: Botswana, Burkina Faso, Kenya and Mauritius. Mauritius has developed a relatively comprehensive set of emission standards for several source types and a number of pollutants (Schwela, 2007).

More recently, the World Bank analysed the existing data on transport emissions (World Bank, 2009). The results are summarized in Table 2.2.

Air quality monitoring. The review of Schwela (2007) showed the following situation: Out of 27 countries only seven have operational routine monitoring systems: Botswana, Ethiopia, Ghana, Madagascar, Tanzania, Zambia, and Zimbabwe. Ethiopia performs occasionally monitoring campaigns; Senegal is initialising a monitoring network in Dakar. In Zambia, monitoring is performed by industrial companies; in the other countries the Environmental Protection Agency or the ministry of Environment is responsible for monitoring. All other countries either do not have installed any monitoring system or a monitoring station which was initially operational broke down and could not be revamped. Out of the 19 countries without monitoring at present, only Nigeria appears to have experience from previous monitoring campaigns. The current situation is shown in Table 2.3 (World Bank, 2009).

Air pollutant concentration monitoring is used to test compliance with air quality standards (AQS). AQS have been set or proposed in nine of the 27 countries – i.e. Botswana, Burkina Faso, Ghana, Kenya, Mauritius, Nigeria, Tanzania, Uganda, and Zambia.

Impacts. Information on the impacts of air pollution on human health and the environment is rare in SSA countries. Three countries – Benin, Botswana and Ghana – have performed a few studies each on health impacts. Zimbabwe has compiled some anecdotal evidence on health effects. In Burkina Faso and Senegal estimates on the costs of air pollution in terms of per cent reduction of the gross domestic product have been performed. Guinea, Mali, Uganda and Zambia suggest on the basis of qualitative and anecdotal observations that respiratory symptoms and other public health impacts may be due to air pollution. In addition, Mali, reports an increase of accidents due to reduced visibility caused in part by particulate matter pollution. The most comprehensive studies

Table 2.2: Emission data in Sub-Saharan African countries

Country	City	Emissions data
Benin	Cotonou	Total road and vehicle emissions
Burkina Faso	Ouagadougou	Cars per population; transport mix; vehicle age; pavement; total road and vehicle emissions; fuel sulphur content
Cameroon	Douala	Cars per population; transport mix; vehicle age; pavement
DR Congo	Kinshasa	Cars per population; transport mix; vehicle age; pavement
Ethiopia	Addis Ababa	Cars per population; transport mix; vehicle age
Gabon	Port Gentil	Total fleet; fleet condition
Ghana	Accra	Cars per population; transport mix; vehicle age; pavement
	Kumasi	Total fleet emissions
Guinea	Conakry	Cars per population; transport mix; vehicle age; pavement
Ivory Coast	Abidjan	Cars per population; transport mix; vehicle age; pavement
Kenya	Nairobi	Cars per population; transport mix; vehicle age; total fleet
Mali	Bamako	Cars per population; transport mix; vehicle age; pavement
Nigeria	Aba, Benin City, Ibadan, Kaduna, Kano, Maiduguri, Port Harcourt, Warri, Zaria	Total fleet emissions; full national emissions inventory
	Lagos	Cars per population; transport mix; vehicle age; total fleet emissions; full national emissions inventory
Republic of Congo	Brazzaville	Total fleet emissions
Rwanda	Kigali	Cars per population; transport mix; vehicle age; pavement
Senegal	Dakar	Cars per population; transport mix; vehicle age; pavement; PM from roads; emissions
South Africa	Cape Town, Durban	Vehicle-km-travelled; transportation; live vehicle count per province; mobile sources inventory
	East Rand, Johannesburg, Pretoria	Vehicle-km-travelled; transportation; live vehicle count per province
	Sasolburg	Vehicle-km-travelled; transportation
Sudan	Al-Khartum	Total fleet; fleet condition
Tanzania	Dar es Salaam	Cars per population; transport mix; vehicle age; pavement; total fleet; fleet condition;fuel usage
Uganda	Kampala	Cars per population; transport mix; vehicle age; pavement; total fleet; total petrol consumption; fuel mix

Source: Adapted from World Bank (2009)

Table 2.3: Air pollutant monitoring in some Sub-Saharan African countries

Country	City	Air pollutants	
Ethiopia	Addis Ababa	CO, O_3, PM_{10}, EC, OC, Cl-, SO_4^{2}-, NO^-, NH_3^+	Etyemezian *et al.* (2004)
Sudan	Al-Khartum	CO	Eljack (2004)
Kenya	Nairobi	CO, HC	Annonymus, 2006; Dickson (2004)
Tanzania	Dar es Salaam	SO_2, NO_2, PM	Kitilla (2004); Msafiri (2004); VP (2006)
South Africa	Johannesburg	SO_2, NO_X, PM	Naidoo *et al.* (2006)
Nigeria	Lagos, Port Harcourt	SPM, SO_2, NO_2, NO_X, H_2S, HC, CO, CO_2, NH_3, Pb, Cd, Mn, Zn, V, Cr	Osuji & Avwiri (2005)
Ghana	Accra	PM_{10}, O_3, SO_2, NO_2, CO, Pb, Mn	Nerquaye-Tetteh (2009)
Burkina Faso	Ouagadougou	PM_{10}, NO_2, VOC, benzene	Savadogo & Ouedraogo (2009)
Benin	Cotonou	SO_2, NO_2, PM, benzene	Wabi (2009)

Source: Adapted from World Bank (2009)

include blood lead levels in Ghana before and after the phase-out of lead, a study on the link between air pollution and health impacts. In Botswana small scale studies performed in the city of Selebi Phikwe investigated impacts of SO_2 on the population and the environment.

Finances. As health and a sound environment are basic human rights often laid down in the Constitutions of African countries, governments have the responsibility to reduce emissions of air pollutants and improve AQ. This includes the awareness among decision makers on the need to finance air quality management (AQM) to improve the health of their populations and the environment. The support of international development agencies is crucial to enhance the capacity of countries in reducing air pollution and to provide incentives for sound AQM.

Based on available information shown in the synopsis of Table 2.4, on a relative scale of "Absent" to "Comprehensive", AQM in SSA is largely in the "Absent", "Initial" or "Early" stages given that 21 out of 27 SSA countries fall into these three categories (Schwela, 2007).

AQM can be considered comprehensive only in South Africa and advancing in Ghana; the AQM capability of Botswana, Madagascar, Zambia and Zimbabwe can be judged as being at an intermediate stage of AQM. Seven countries are at an early stage of AQM: Benin, Burkina Faso, Ethiopia, Mozambique, Nigeria, Swaziland and Tanzania. In eight countries – Cameroon, Congo-Kinshasa, Kenya, Mali, Mauritius, Senegal, Togo and Uganda – AQM is at an initial (very early) stage. AQM is practically absent in seven countries – Burundi, Congo-Brazzaville, Gabon, Guinea, Liberia, Malawi and Rwanda. The results show that AQM is in its early stages in many SSA countries and many components of AQM are not yet in place.

2.3 Key issues in Air Quality Management

An effective AQM strategy is dependent on a number of factors. These include emission inventories, air quality monitoring networks, air quality prediction models, exposure and damage assessments, as well as health and environment-based standards..

Source apportionment Source apportionment (SA) is the determination of the contribution (fraction, percentage or portion) of air pollution sources at a location of interest. Air pollution originates from sources such as industries, power plants, cars, buses, trucks, boats, deserts (windblown dust), waste deposits, and open burning. The development of effective control strategies to protect public health and the environment from exposure to air pollution requires knowledge of emission sources that contribute to the pollutant concentrations at the receptor. Pollutant concentrations are obtained from ambient air samples collected at a receptor location.

Two essentially different approaches are used in source apportionment:

- Source-oriented approach; and
- Receptor-oriented approach.

The ***source-oriented approach*** starts from an emissions inventory and uses dispersion models in the form of chemical transport models (CTMs) to estimate the contribution of each source at a receptor location. . Calculations use emission and source characteristics (stack height, exit velocity of stack gas, pollutant concentrations in exhaust gas) and known meteorological parameters (wind speeds, wind directions, temperature, mixing heights and atmospheric stability classes) to predict pollutant concentrations at specific receptors. These types of model can be validated by comparison of the predicted (modelled) spatial and temporal distribution of pollutant concentrations with measured concentrations.

Receptor-oriented approaches are mathematical or statistical procedures that use and compare the profiles of gases and particles (chemical and physical characteristics) at sources and receptors in a given area to estimate the presence and fraction of source contributions at receptor locations. Unlike CTMs, receptor models do not use pollutant emissions, meteorological data and chemical transformation and deposition mechanisms to estimate the contribution of sources to receptor concentrations. Receptor models cannot identify the contribution of individual sources if several sources of the same type and emission characteristics are located in the area considered.

Emissions inventory. An emissions inventory is generally defined as a comprehensive listing of sources and an estimation of the magnitude of air pollutant emissions in a geographic area during a specific time period. Rapid Emission Inventories provide a simplified and user-friendly framework for emissions inventory preparation. Rapid Emission Inventories are suitable for use in different developing and rapidly industrialising countries and are compatible with other major international emissions inventory initiatives.

A range of factors influence emission of pollutants from mobile sources including:

- Vehicle/fuel characteristics
  - engine type and technology; fuel injection, type of transmission system, other engine features
  - exhaust, crankcase, catalytic converters, exhaust gas recirculation
  - age, mileage, engine mechanical condition and adequacy of maintenance
  - fuel properties and quality

- Fleet characteristics
  - vehicle mix (number and type of vehicles in use)
  - vehicle utilization (kilometres per vehicle per year) by vehicle type
  - age profile of the vehicle fleet
  - emission standards in effect and incentives/disincentives for purchase of cleaner vehicles
  - adequacy and coverage of fleet maintenance programs
  - clean fuels programs

- Operating characteristics
  - altitude, temperature, humidity (for NO_X)
  - vehicle use patterns—number and length of trips, number of cold starts, speed, loading, aggressiveness of driving behaviour
  - degree of traffic congestion, capacity and quality of road infrastructure, and traffic control systems
  - transport demand management programs.

Table 2.5 shows the major emitted compounds of different engine types.

Dispersion model A dispersion model estimates concentration levels at any point in space and, depending on the availability of meteorological information, for any time. Dispersion models are useful for determining the spatial and time distribution of pollutants from different sources in an urban area. Dispersion models allow one to estimate concentrations from existing and planned sources and the contribution from transboundary air pollution in a particular country. Dispersion modelling also helps determine the most appropriate sites for monitoring.

Air pollution dispersion phenomena are decisively influenced by atmospheric processes which are commonly classified with

Table 2.4: Synopsis of country AQM capability

Country	Key pollutants	Sulphur content of diesel [ppm]†	Inspection & maintenance for mobile sources	Emissions inventory	Routine monitoring	Health impact assessment	Projects or plans with AQ benefit ongoing	Estimated stage of air quality management
Angola		3,000						
Benin	SO_2, NO_X, NO_2, O_3, CO, HCs, PM.	10,000	No	No	No	Two studies	Yes	Early*
Botswana	SO_2,NO_X, NO_2, O_3, CO, HCs	500	No	Yes, but incomplete	Yes	Few qualitative studies	No	Intermediate**
Burkina Faso	PM, SO_2, HCs, NO_X, SO_2	5,000	No	Yes, but elementary	No	No	Yes	Early*
Burundi	Pesticides, Persistent Organic Pollutants, Pb	5,000	No	No	No	No	No	Absent#
Cameroon	PM, CO, HCs, NO_X, SO_2.	5,000	Yes	No	No	No	No	Initial†††
Cape Verde		3,000						
Chad		5,000						
Congo-Brazzaville	PM, CO, HCs, NO_X	10,000	No	No	No	No	No	Absent#
Congo-Kinshasa	PM, SO_2, NO_2, CO, HCs	5,000	No	No	No	No	Yes	Initial†††
Côte d'Ivoire								
Djibouti		5,000						
Ethiopia	PM_{10}, CO, SO_2, O_3	10,000	No	No, but source apportionment for PM_{10}	No, only campaign	No	No	Early*
Gabon	PM, CO, HCs, NO_X, SO_2	8,000	No	No	No	No	No	Absent#
Ghana	SO_2, NO_2, O_3, CO, PM_{10}, manganese	5,000	In progress	No	Yes	Three studies	Yes	Advancing+
Guinea	PM_{10}, $PM_{2.5}$, NO_2, SO_2, formaldehyde, benzene	5,000	No	No	No	No	No	Absent#
Guinea-Bissau		5,000						
Kenya	PM, CO, HCs, NO_X, SO_2	10,000	No	No	No	No	Yes	Initial†††
Lesotho		500						
Liberia	PM, CO, NO_X, SO_2.	5,000	No	No	No	No	No	Absent#
Madagascar	PM, CO, HCs, NO_X, SO_2	5,000	Yes, mobile sources	No	Yes	No	Yes	Intermediate**
Malawi	PM, SO_2, CO, NO_X, HCs	500	No	No	No	No	No	Absent#
Mali	PM, NO_X, CO, HC, VOC, SO_2, Pb	10,000	No	Yes, for transport	No	No	No	Initial†††
Mauritania		5,000						
Mauritius	PM, NO_X, CO, SO_2	2,500	No	No	No	No	Yes	Initial†††
Mozambique	PM_{10}, $PM_{2.5}$, Black Carbon, SO_2, NO_X, CO_2, O_3.	500	No	Being developed	No	No	Yes	Early*
Niger		10,000						
Nigeria	CO_2, CO, NO_X, O_3, SO_2, TSP, PM_{10}	5,000	No	Yes, of 1990	No, one non operational station	No	Yes	Early*
Rwanda	Not identified	5,000	No	No	No	No	No	Absent#
São Tomé e Principe		3,000						
Sénégal	PM_{10}, $PM_{2.5}$, CO	5,000	No	No	Being initialised	No	Yes	Initial†††
Sierra Leone		5,000						
South Africa	PM_{10}, $PM_{2.5}$, NO_X, SO_2, O_3, CO, Pb	500	Yes	Yes	Yes	Yes	Yes	Comprehensive++
Sudan		11,000						
Swaziland	Not identified	500	No	Qualitative	No	No	Yes	Early*
Tanzania	PM, CO, NO_2, SO_2, O_3, Pb	5,000	No	No	Yes	No	Yes	Early*
The Gambia		5,000						
Togo	Not identified	10,000	No	Yes, initial	No	No	No	Initial†††
Uganda	PM, CH_4, H_2S, NH_3, dioxins and furans, HCs, NO_X, SOx, re-suspended dust	5,000	No	No	No	No	Yes	Initial†††
Zambia	SO_2, NO_2, PM, black smoke, dust, CO, CO_2 and odours	7,500	No	Yes, initial, in copper belt	Yes	No	Yes	Intermediate**
Zimbabwe	SO_2, NO_2, PM, CO, VOCs	500	Yes, for stationary sources	No	Yes	Anecdotal evidence	No	Intermediate**

*† This table is not meant to compare the stages of AQM capability across countries. The parameters on which AQM capability was estimated are not the "ideal set of parameters for doing this but the "best available common parameters" in SSA countries. The scale from "Absent" to "Comprehensive" is a relative scale with respect to the countries covered in this report and not an absolute scale."††Source: PCFV (2011a); # Absent = None of the topics addressed; ††† Initial = Any one topic addressed; * Early = Any two topics addressed; ** Intermediate = Any three topics addressed; + Advancing = Any four topics addressed; ++ Comprehensive = All topics addressed.*

Table 2.5: Summary of pollutant types and emissions for some typical engine and fuel combinations

Engine Type	Fuel Type	Vehicle Type	Major Emissions*
4-Stroke cycle	Gasoline	Cars (also trucks, aircraft, motorcycles)	HC, CO, NOx
Diesel	Diesel Oil	Trucks, buses, tractors (also cars)	NO_x, SO_x, soot, particulates
2-Stroke cycle	Gasoline/oil mixture	Motorcycles, outboard motors	HC, CO, particulates
Gas turbine	Jet	Aircraft, marine applications	NO_x, particulates

Source: Schwela (2007)

regard to their spatial scale. The following scales are distinguished (EEA, 1996):

- Macroscale (characteristic lengths exceeding 1,000 km);
- Mesoscale (characteristic lengths between 1 and 1,000 km);
- Microscale (characteristic lengths below 1 km).

The following model categories relevant for transport emissions can be distinguished (EEA, 1996):

- Gaussian model, the most common air pollution model (e.g. AERMOD, see US EPA, 2004);
- Semi-empirical model, which is characterised by drastic simplifications and a high degree of empirical parameterisations (e.g. box model, see Lents *et al*., 2009);
- Eulerian model, which solves numerically the atmospheric diffusion equation (e.g. ABC, see Röckle *et al*., 1995)
- Lagrangian model, which uses a number of fictitious particles to simulate the dynamics of dispersion parameters (e.g. LASAT, see Janicke, 1983);
- Chemical module, which calculates the chemical transformation in the air (e.g. CAMx, see US EPA, 2009).

Gaussian and semi-empirical models are applicable for micro- to meso-scale dispersion phenomena while Eulerian, Lagrangian and chemical modules are applicable for all scales (local, local to regional, regional to continental, and global.

Monitoring network A monitoring network is a set of monitoring devices exposed at different sites in an urban, suburban or rural area. Monitoring devices may be passive (diffusive) samplers, active samplers, automatic analysers, remote sensors and biological devices.

The design of an air quality monitoring programme will depend upon the monitoring objectives, the measuring strategy and the pollutants to be assessed. For the relevant air quality parameters or selected indicators the concentration of an air pollutant and associated averaging time need to be specified. Specifications are also needed on where, how, and how often measurements should be taken.

It is normally not possible to measure all the air pollutants present in the urban atmosphere. We therefore have to choose some indicators that should represent a set of parameters selected to reflect the status of the environment. They should enable the estimation of trends and development, and should represent the basis for evaluating human and environmental impacts. Furthermore, they should be relevant for decision-making and public awareness raising.

The selected parameters for air quality are related to air pollutants for which air quality guideline values or standards are available. The interrelationships between the indicators and other related compounds might vary from region to region due to differences in emission source profiles.

Air quality indicators should:

- provide a general picture;
- be easy to interpret;
- respond to changes;
- allow international comparisons;
- be able to estimate trends over time provided sufficient data are available

Measurement techniques should be reasonably accurate and cost-effective. The quality of data should be ensured by a Quality Assurance/Quality Control (QA/QC) plan. For further details see Haq & Schwela (2008a).

Epidemiological studies are investigations of the distribution and determinants of health-related states or events in specified populations. They can be classified as either observational or experimental. Observational studies are studies in which the investigator observes but takes no action to intervene. Studies are termed "prospective" if the population is observed over time as events occur. Studies are termed "retrospective" or "historical" if existing records are used and exposure and health outcome are ascertained after they have occurred (Beaglehole *et al*., 1993).

Epidemiological studies are categorised as

- Cross-sectional studies that examine the association between an environmental exposure and prevalence of a certain disease (the proportion of the population affected) at a particular point in time or during a short period of time.;
- Ecological studies in which the investigator compares aggregate measures of exposure (average exposure or proportion of population exposed) with aggregate measures of health outcome rates for the same population.;
- Cohort studies in which the study population consists of individuals who are at risk of developing a particular disease or health outcome. The individuals are divided into groups ("cohorts") according to their exposure status.;
- Time-series studies in which repeated observations of exposure and health endpoints are made over time within the same study population.; and
- Case-control studies that examine the association between exposure and the health outcome by comparing individuals who develop the health outcome (called "cases") and those who, though also a sample of the source population from which the cases are identified, do not develop the health outcome (called "controls").

Further details can be found in Rothman & Greenland (1998) and Haq & Schwela (2008b).

Rapid epidemiological assessment methods include the use of the WHO environmental burden of disease approach (WHO, 2003) and applying known exposure-response relationships for air pollution impacts to estimate mortality and morbidity in terms of disability-adjusted life years (DALYs). This approach requires knowledge of exposures (air pollutant concentrations and durations). The SIM/Air model can estimate the health impacts on the basis of modelled emissions, simulated concentrations and known exposure-response relationships (Guttikunda, 2011).

Environmental studies Rapid Environmental Impact Assessment Studies include: checklists for assessing the potential environmental impact of industries and power plants, especially on agriculture, protected sites, forests and biodiversity; and estimations of the potential threat of O_3 pollution in reducing agricultural crop yields.

Air quality management AQM aims to maintain and/or achieve a level of air quality, which protects human health and the environment. Improvement of deteriorated air quality is necessary to enable further growth of developing countries as air pollution impacts heavily on human health and the environment resulting in high financial costs. Many countries, which have developed an effective AQM approach have discovered that the benefits received from emission reductions are usually much higher than the cost of implementing emission reduction measures (Lents *et al*., 2009; Haq & Schwela, 2008c).

Along with the factors described above are a range of cost-effective pollution control measures and the legislative powers and resources to implement and enforce them. These include focusing only on key air pollutants and the application of rapid AQM procedures.

An important part of AQM is the setting of air quality standards (AQS) and associated exposure times. This is facilitated by using WHO air quality guidelines (WHO, 2000a; 2000b; 2006).

The main components of an integrated AQM strategy relating to transport in a developing city will generally include:

- cleaner vehicle and fuel technologies;
- traffic management, and economic and financial measures to discourage the use of private cars and motorcycles and to encourage the use of public transport and non-motorised transport modes;
- public transport improvements;
- institutional and policy-oriented reforms and public participation.

2.4 Challenges for AQM in SSA

In addition to water and solid waste problems, SSA is facing substantial challenges in terms of urban air quality. Despite some progress being made to address air pollution in SSA countries, air pollution continues to pose a threat to human health, environment and quality of life in cities. The combination of increasing migration, motorisation and uncontrolled urban growth has all contributed to the intensification of air pollution.

Some of the challenges are: old vehicles without emissions control, increased vehicle fleets, absence of proper vehicle maintenance, lack of cleaner fuels, absence of or poor regulatory framework specific to vehicle emissions, and poor enforcement of laws and regulations when they exist.

Policies Most SSA countries address AQM in an ad hoc fashion. Only South Africa is well on the way to developing a fully-fledged AQM system although Madagascar and Ghana are making good progress. Benin's legislation refers only to mobile sources which are apparently considered the most significant source. Thus, industrial sources, uncontrolled fires, waste deposits and transboundary air pollution are disregarded. Botswana's air pollution legislation is very old and covers only industrial sources. Updating this legislation would make the AQM approach more realistic.

In the Republic of the Congo (Congo Brazzaville), the legislation relating to air pollution is diluted in many partly overlapping texts among the different sectors of the environment, energy and transport. This makes an integrated approach to AQM difficult. Guinea, Liberia, the Democratic Republic of the Congo (Congo-Kinshasa), Rwanda and Uganda have no official legislation for regulating and managing air pollution. Regulations on fuel parameters for petrol and diesel do not exist. In view of the likely substantial PM concentrations and their potential health impacts the introduction of legislation regulating, the need for AQM is urgent. Kenya is in a similar situation since a comprehensive urban AQM programme is absent.

In Nigeria, little activities in relation to AQM have taken place and *ad hoc* measures have been adopted. This procedure increases the risk of the wrong decisions being made. Togo's policies on energy development and transport and the strategy to combat air pollution tend to be piecemeal rather than integrated policies. As a consequence they are not suitable for rational AQM. In addition, the implementation of these strategies has not yet started due to lack of funding and logistics.

Zambia's legislation aims to control pollution but is not legally binding with regard to air quality monitoring. This means monitoring is not performed by the government but rather delegated to industry. This implies that exposures related to vehicle emissions are only controlled via fuel specifications and emission standards if adopted.

Governance Challenges in almost all 27 African countries include the lack of monitoring equipment; poor awareness and lack of stakeholder participation including the public and the media. In addition, design and implementation of AQM strategies are often based on poor knowledge and inadequate regulatory, institutional, planning, and lack of technical, social, and financial capacities for AQM. For example in all African countries, industrial facilities are obsolete and poorly maintained. Growing vehicle fleets mostly consist of old cars, trucks and buses. The institutional set-up is often characterised by responsibilities shared by several ministries without a lead agency for the implementation of environmental goals, policies and strategies. Roles and responsibilities are often not well defined, documented, communicated and enforced. Human resources and specialised skills are lacking in many countries as are technological and financial resources.

Awareness of the impacts of air pollution from transport on human health and the environment, risk perception and risk communication are poorly developed in most SSA countries. Awareness-raising is essential in order to strengthen the participation of all stakeholders such as the public, academia, industry, NGOs in AQM and particularly in projects on health impacts due to air pollution. Specialized programmes and training modules are necessary to enhance capacity in AQM.

Emissions Emission inventories do not exist in 26 out of 27 SSA countries. This lack of emissions inventories mean that quality assured emission data are not available and dispersion modelling cannot be applied. A good starting point for all countries, therefore, would be to compile rapid inventories of all sources using well-known procedures such as that developed by the WHO and the Global Atmospheric Pollution Forum (WHO, 1993; GAPF, 2010). These rapid assessment systems start from emissions factors for key compounds and allow estimate the emissions of stationary and mobile sources in a cost-effective manner. An emissions inventory also allows the verification of source apportionment estimates.

Air quality monitoring Air quality monitoring is variable in most SSA cities. Where monitoring networks existed in the past they have often broken down after a short time. There is only limited or no spatial coverage of cities by outdoor AQ monitoring. Therefore baseline data do not exist in most countries, and they are of limited spatial representativity in the seven countries, which perform monitoring. The case of Nigeria shows deficiencies in the maintenance of monitoring systems and in procuring spare parts. Monitoring is not systematic with regard to the selected pollutants and the coverage of urban and peri-urban areas.

Air quality modelling Air quality modelling is hardly applied in the 27 countries. This is due to the lack of quality assured emission data and source apportionment experience.

Impacts There is a lack of short- and long-term studies of health, environmental and economic impacts due to air pollution in all 27 African countries. This shortcoming is also reflected by the absence of air quality monitoring capability in 19 SSA countries. Insufficient institutional capability and the lack of national health surveillance systems may also be causes of the scarcity of health and environmental studies. Without a health surveillance system, it is impossible to assess the contribution of air pollution to morbidity and mortality.

Finances There is a need to fund AQM on a sustainable basis. However, African cities often give a low priority to AQM funding. There is also a lack of sufficient funding for capacity building and awareness raising; poor knowledge of existing market mechanisms; and a lack of adherence to the 'polluter pays' principle.

Much has to be done to strengthen and enforce existing legislation, making monitoring networks operational to deliver data of known quality and developing initial emission inventories which permit implementation of control measures in SSA cities.

2.5 AQM

Some countries such as Benin, Burkina Faso, Burundi, Cameroon, Congo Brazzaville, Congo Kinshasa, Gabon, Guinea, Kenya, Liberia, Mali, Mauritius, Rwanda, Swaziland, Togo and Uganda are in an early stage of AQM. The phase-out of lead has been completed and some of these countries have set fuel specifications. An Environment Act exists but public awareness, media and other stakeholder involvement is limited. First steps towards rational AQM would be to strengthen the political will of governments to address air pollution, to raise public awareness about adverse impacts of air pollution on human health and the environment. Among the measures to continue improving air quality there is the reduction of sulphur in diesel; for this purpose a cost-benefit analysis needs be carried out. Another action would be to develop and implement initial monitoring stations using cost-efficient sampling methods. By installing a small monitoring network, the contribution of industrial sources, power plants, area sources and that of transboundary dispersion of air pollutants could be assessed. In order to be able to interpret monitoring data in terms of their potential impact on human health and the environment, AQSs should be adopted, which are reasonably enforceable. WHO air quality guidelines may be used in setting standards and averaging times since the criteria for the derivation of air quality guidelines set by WHO are also valid for setting standards. Experience from developed countries may be used to collect information on the number of standards-exceeding values not leading to adverse health or environmental effects. A participatory approach in setting standards, which involves stakeholders (e.g. industry, local authorities, non-governmental organizations, media and the general public), assures –as far as possible – social equity or fairness to the parties involved. The provision of sufficient information and transparency in standard setting procedures ensures that stakeholders understand the environmental, health and socio-economic impacts of such standards.

AQM is based on the precautionary, polluter pays and prevention principles. It seeks to protect human health and the environment and ensures a cost-effective approach using best available control technologies.

Figure 2.3 outlines a simplified framework for AQM and shows initial building blocks for AQM including monitoring data analysis, identification of sources and their relative contribution, action planning (including economic analysis), and implementation.

Rational AQM includes several approaches: command and control, application of economic instruments, co-regulation and stakeholder voluntary initiatives, and self-regulation. Education and information of the population is also an integral part of AQM.

Action plans and rapid assessment methods can be used to initiate air quality management. Rapid inventory assessment methods allow the development of initial emission inventories. A number of easy-to-use USEPA dispersion models are available. Hybrid monitoring networks are minimal sets of monitors with one or few automatic analysers and a larger number of diffusive tubes for gaseous compounds. For PM monitoring simple and easy-to-use devices are available such as 'minivols' and 'dustTraks', calibrated to urban PM or corrected correspondingly (Schwela *et al*., in preparation). Rapid epidemiological assessment methods help estimate health effects due to exposure to air pollution by using known exposure-response relationships. A simple tool incorporating emissions, estimated concentrations, estimated health impacts and control actions can be used such as the SIM/Air programme which allows the optimisation of the costs of health impacts due to air pollution with the costs of source controls (Guttikunda, 2011).

Due to limited availability of financial and human resources and data on air pollution in many SSA countries, low cost solutions are to be identified, which can be implemented within the SSA context. Table 2.6 summarises the tools that can be useful for various SSA countries to enhance their AQM capability (Haq & Schwela, 2008c).

Table 2.7 presents low cost policy instruments that can be used in AQM while Table 2.8 summarises the low cost AQM tools.

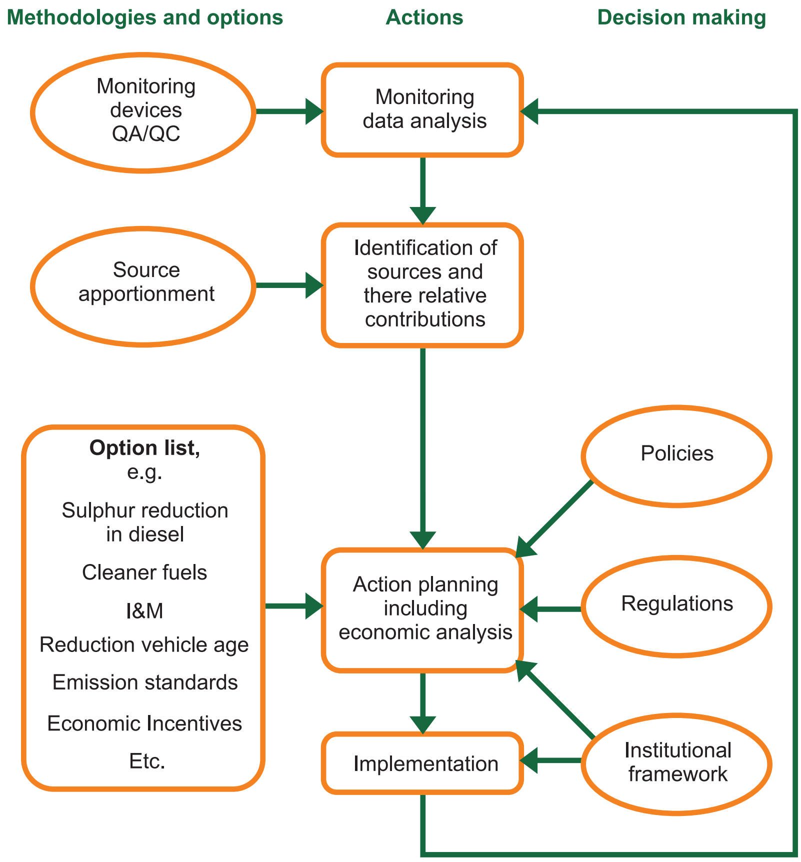


Figure 2.3: A framework for air quality management (Schwela, 2007)

Table 2.6: Tools that can be applied in SSA countries to enhance AQM capability

Country	Air quality standard setting	Initial Emissions inventory*	Routine monitoring**	Health impact assessment†
Benin	WHO guidelines	Rapid inventory assessment (RIA)	Hybrid network (HN)	More studies needed
Botswana	National standards exist	Completion and update by RIA	Is being performed	Rapid epidemiological assessment (REA)
Burkina Faso		Completion and update by RIA	Hybrid network	
Burundi	WHO guidelines	Rapid inventory assessment		
Cameroon				
Congo-Brazzaville				
Congo-Kinshasa				
Ethiopia				
Gabon				
Ghana	National standards exist		Is being performed	More studies needed
Guinea	WHO guidelines		Hybrid network	Rapid epidemiological assessment
Kenya	Exist			
Liberia	WHO guidelines			
Madagascar			Is being performed	
Malawi			Hybrid network	
Mali		Completion and update by RIA		
Mauritius	National standards proposed	Rapid inventory assessment		
Mozambique	WHO guidelines	Completion and update by RIA		
Nigeria		To be updated and amended by RIA		
Rwanda		Rapid inventory assessment		
Senegal			Is being initialised	
Swaziland	WHO guidelines	Rapid inventory assessment	Hybrid network	Rapid epidemiological assessment
Tanzania			Is being performed	More studies needed
Togo		To be enhanced by RIA	Hybrid network	Rapid epidemiological assessment
Uganda		Rapid inventory assessment		
Zambia		To be amended for vehicles	Revamping or hybrid network	
Zimbabwe		Rapid inventory assessment	Is being performed	

****RIA = Rapid Inventory Assessment; ** HN = Hybrid Network; † REA = Rapid Epidemiological Assessment*** **Source: Schwela & Haq (2008)**

Table 2.7: Summary of low cost policy instruments for air quality management related to transport in SSA Countries

Component	Objective	Low Cost Option
Policies	The overall objective of policy instruments is to include and/or strengthen the concept of air quality management in relevant policies and legislation of SSA cities and countries.	Traffic flow management
		Regulation and control of public bus transport
		Segregated lanes
		Non-motorized transport (NMT)
		Ban the import of obsolete vehicles and phase-out old vehicles still circulation.
		Physical restraint.
		Parking policies
		Road pricing
		Use of low sulphur fuels in vehicles

Table 2.8: Summary of low cost tools for AQM in SSA Countries

Component	Objective	Low Cost Option
Emissions	The objective for emission reduction is to include and/or strengthen enforceable, affordable, sustainable and highly effective measures to assess and reduce emissions. These include: • short-term strategies to reduce emissions to adequately address the overall problem; • use of end-of-pipe and best available control technology solutions to prevent pollution; and • effective measures to reduce air pollution which are fully coordinated with other measures	Rapid Emission Inventories
Modelling	The objective for air quality modelling is to support and strengthen national and local air quality estimates and allow source apportionment and estimations of transboundary pollution. This includes quality assured emission data; regional harmonisation of dispersion models and quality assured topographical and meteorological input data for more advanced models.	Simple Dispersion Models
Monitoring	Harmonisation of monitoring networks and devices; Monitoring of air quality in urban and peri-urban areas; and Hotspot monitoring.	Rapid Air Quality Monitoring Techniques
Health and Environmental Assessment	The objective for health and environmental assessment is to establish and/or strengthen national and local programmes which monitor the health and environmental impact of air pollution in a harmonised way. This includes: Undertaking long-term studies of health and environmental impacts due to air pollution; Strengthening institutional capability; Assessing of health, environmental and economic impacts of air quality; Augmenting and disseminating information on health and environmental impacts; Ensuring spatial and time representativity of monitoring sites for actual exposure of humans and the environment.	Rapid HIA

2.6 Environmental noise

The WHO (2000) Guidelines for Community Noise define environmental noise (also called community noise or residential noise) as noise emitted from all sources, except noise at the industrial workplace. Major sources of environmental noise include road, rail, air and sea traffic. In general, larger and heavier vehicles emit more noise than smaller and lighter vehicles (exceptions: helicopters; two- and three- wheeled motorized road vehicles).

There are different types of transport related environmental noise:

- ***Road vehicle noise*** is mainly generated from the engine and from frictional contact between the vehicle tyres and the ground and air. In general, road contact noise exceeds engine noise at speeds higher than 60 km/h.
- ***Railway noise*** depends primarily on the speed of the train, but also on the type of engine, wagons, and rails and their foundations as well as the roughness of wheels and rails. Small radius curves in the track can lead to wheel squeal. Noise can be generated in stations because of running engines, whistles and loudspeakers and in marshalling yards because of shunting operations. High-speed trains create sudden, rises in noise. At speeds above 250 km/h, the proportion of high frequency sound energy increases. Additional noise can arise in areas close to tunnels, in valleys or in areas where the ground conditions help generate vibrations.
- ***Aircraft*** operation generates substantial noise in the vicinity of both commercial and military airports. Aircraft takeoffs are known to produce intense noise, including vibration and rattle. At landings intense noise is produced by the landing gear, automatic power regulation, and application of reverse thrust. In general larger and heavier aircraft produce more noise than lighter aircraft. The sound pressure level from aircraft typically depends upon the number of aircraft, the types of airplanes, their flight paths, the proportions of takeoffs and landings, and the atmospheric conditions.
- Sources of **sea traffic noise** include ships, ferryboats, jet skis, and sea motors which all are emitting high noise levels.

Many developed countries have regulations on environmental noise from road, rail and air traffic. In contrast, few developing countries, particularly in SSA have regulations on environmental noise. In developed countries, monitoring of compliance with, and enforcement of, noise regulations are weak for lower levels of urban noise that correspond to occupationally controlled levels (>85 dB $L_{Aeq,8h}$). Recommended guideline values based on the health effects of environmental noise are often not taken into account. Apart from the WHO Guidelines for Community Noise (WHO, 2000) the WHO has published the night noise Guidelines for Europe (WHO, 2009) and estimated the global burden of disease due to environmental noise exposure (WHO, 2011).

Figure 2.4 shows a range of noise readings for different activities (NZ-MoE, 2011). If the dBA scale is applied to everyday activities then 0 dBA identifies the threshold of human hearing. A quiet bedroom would generally have a noise level of a little under 40 dBA and a busy office 60 dBA. At around 65 dBA verbal communication starts to become difficult. A daily Leq of greater than 65 dB(A) is normally taken as an absolute upper acceptable limit and is used in regulations concerning sound insulation. A heavy truck travelling along a road close to where the noise is being measured may produce 90 dBA in a few metres distance from the source, a level of noise that may cause hearing impairment if people are continuously exposed to it. Older style or large jet aircraft may produce more than 100 dBA. A noise level of 120 dBA represents the threshold of pain.

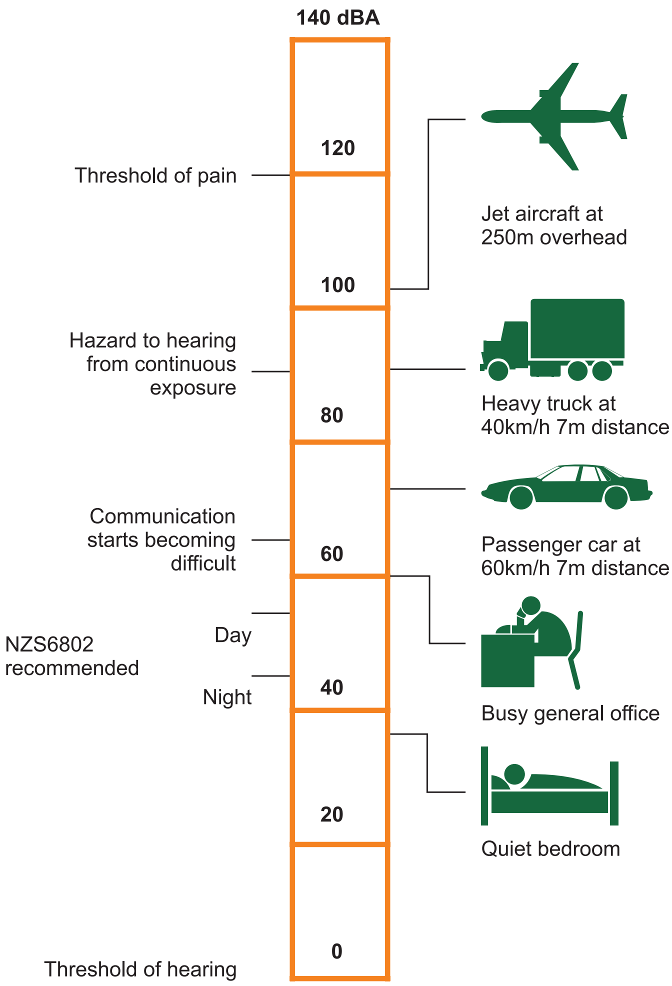


Figure 2.4: Range of noise readings for different activities

Source: NZ-MoE (2011)

The extent of the environmental noise problem is large. In the EU-27 almost 67 million people (i.e. 55 per cent of the population living in agglomerations with more than 250,000 inhabitants) are exposed to daily road noise levels exceeding 55 dB L_{den}. Daily exposure to railway noise and airport noise in these agglomerations is lower but still significant, with respectively 5.6 and 3.2 million people exposed to levels above 55 dB L_{den}. With almost 48 million people exposed to levels exceeding 50 dB L_{night}, road noise is also by far the largest source of exposure to night-time transport noise (EEA, 2009). Almost 21 million people (i.e. 17 per cent of the population living in transport hot spots in agglomerations with more than 250,000 inhabitants) are exposed to road noise of 60 dBA L_{den} and 55 dBA L_{night}. These levels of night-time road noise have detrimental effects on health (EEA, 2009).

The noise pollution problem is also severe in the cities of developing countries and is caused mainly by traffic. Data collected alongside densely traveled roads were found to have equivalent sound pressure levels for 24 hours of 75–80 dBA (WHO, 2000). Roadside sound pressure levels for 8 hours between 67 and 85 dBA were observed in South Asian countries (Schwela, 2006). Corresponding noise-induced impacts included persistent hearing loss and sleep disturbance.

Table 2.9 presents the status of noise management in the SADC countries. It shows that all SADC countries, with the exception of South Africa, have not developed noise management plans. Most have not established emission standards or noise sound pressure level limits. Modelling or monitoring noise level is also absent in most SADC countries (DBSA/SAIEA 2007;. 2012).

Table 2.9: Legislation, policies/strategies/programmes and environmental noise management in SADC countries

Country	Environmental Protection Legislation	Year	Major responsible authorities	Policies/ Strategies/ programmes	Emission standards	Sound pressure standards	Noise impact assessment	Noise manage-ment plan
Angola	Constitution	1992	Ministry of Urbanisation and Environment (MUE)	Programa Nacional de Gestao Ambiental	No	No	No	No
	Environment Framework Act	1998		Estrategia Nacional do Ambiente				
	Decree on Environmental Impact Assessment	2004						
	Land Use Planning and Urban Development Act	2004	MUE & Ministry of Agriculture and Rural Development					
Botswana	Constitution		Ministry of Environment, Wildlife and Tourism	Vision 2016	No	No	No	No
	Environmental Impact Assessment Act	2005	Department of Environmental Affairs					
	Atmospheric Pollution (Prevention Act	1998						
Democratic Republic of Congo	Constitution	2006			No	Yes	Yes	Yes, of mining projects
	Mining Code	2002						
Lesotho	Constitution	1993	Ministry of Tourism, Environment and Culture	Vision 2020	To be established	No	No	No
	Environment Bill	2006	National Environment Council (NEC)	National Environmental Action Plan (NEAP)				
	Environment Act	2001	Department of Environment	National Action Plan (NAP)				
				SADC Policy and Strategy for Environment and Sustainable Development				
Madagascar	Constitution	1992	Ministry of the Environment, Water and Forests	Plan National d'Action Environnemental (PNAE)	No	No	No	No
	Charte de l'Environnement	1990 1997 2004						
Malawi	Constitution	1994	Ministry of Natural Resources and Environmental Affairs	NEAP	No	No	No	No
	National Environment Management Act	1996	Environmental Affairs Department	Vision 2020				
Mauritius	Environment Protection Act	1991 2002	Ministry of Health and Quality of Life	Vision 2020	No	Yes	No	No
	Public Health Act			NEAP				

Country	Environmental Protection Legislation	Year	Major responsible authorities	Policies/ Strategies/ programmes	Emission standards	Sound pressure standards	Noise impact assessment	Noise manage-ment plan
Mozambique	Constitution	2004	Ministerio para a Coordenacao da Accao Ambiental (MICOA)	No	No	No	No	No
	Environment Law (Lei do Ambiente	1997						
Namibia	Constitution	1990	Ministry of Environment	Vision 2030	No	No	No	No
	Environmental Management Bill	2007?	Directorate of Environmental Affairs (DEA)					
Seychelles	Constitution		Ministry of Environment	No	Yes	No	No	No
	Charter of Fundamental Human rights and Freedoms	1993	Division of Environment					
	Environmental Protection Act	1988 1994						
South Africa	Constitution	1996	Department of Environmental Affairs and Tourism (DEAT)	Environmental Management Policy	Yes	Yes	Yes	Yes
	National Environmental Management Act (NEMA)	1998	Provincial department of DEAT					
	National Environmental Management: Air Pollution		Local Authority					
Swaziland	Swaziland Environment Authority Act	1992	Swaziland Environment Authority (SEA)	National Development Strategy - Vision 2022	No	No	No	No
	Environmental Management Act	2002	Ministry of Economic Planning and Development (MEPD)	Swaziland Environment Action Plan (SEAP)				
			Ministry of Tourism, Environment and Communication					
Tanzania	Constitution	1998	Office of the Vice President	National Environmental Policy (NEP)	No	No	No	No
	Environmental Management Act	2004	Ministry of Environment					
Zambia	Environmental Protection and Pollution Control Act (EPPCA)	1990	Environmental Coucil of Zambia (ECZ)	National Conservation Strategy	Are being developed		No	No
			Ministry of Environment and National Resources	National Environmental Action Plan				
Zimbabwe	Environment Management Act	2002	Environmental Management Agency	Draft National Environmental Policy (2003)	No	No	No	No
			Ministry of Environment and Tourism	National Conservation Strategy (1987)				

2.7 Key issues for environmental noise

There are many models for policy processes. Figure 2.5 presents an example of a policy process for community noise management. Table 2.10 presents recommended policy measures for transport-related noise emissions.

Governments have a responsibility to set up policies and legislation for controlling environmental noise. There is a direct relationship between the degree of noise exposure of the public and the level of development in a country. As a society develops, it increases its level of urbanization and industrialization, and the extent of its transportation system. Each of these developments brings an increase in noise load. Without appropriate intervention the noise impact on communities will increase (see Figure 2.6). If governments fail to enforce strong noise policies and regulations, they will not be able to prevent a continuous increase in noise pollution and be ineffective in combating noise.

Legislation usually determines policies for noise regulatory standards at the municipal, regional, national and supranational levels. A country's risk management strategy, socio-political considerations, technical feasibility, costs of compliance and the existence of international agreements influence strongly regulatory standards. In general the following issues are taken into consideration:

- Identification of the adverse public health impacts that are wished to be avoided.
- Identification of the population to be protected.
- The type of parameters describing noise and the limit applicable to the parameters.
- Applicable monitoring methodology.
- Enforcement procedures to achieve compliance with noise regulatory standards.
- Emission control measures and emission regulatory standards.
- Emission standards.
- Identification of authorities responsible for enforcement.
- Resource commitment.

Noise regulatory standards can set the reference point for emission control and abatement policies at the national, regional or municipal levels, and therefore can strongly influence the implementation of noise control policies. Exceeding regulatory standards raises an obligation to develop abatement action plans at the municipal, regional or national levels which address all relevant sources of noise pollution.

Transportation noise Transportation noise includes noise from road traffic, rail traffic and air traffic and is the main source of environmental noise pollution. Usually larger and heavier vehicles emit more noise than smaller and lighter vehicles. Exceptions include helicopters and 2- and 3-wheeled road vehicles. The noise of road vehicles is mainly generated from the engine and from frictional contact between the vehicle and the ground and air. Railway noise depends primarily on the speed of the train, the rails and their foundations, as well as the roughness of wheels and rails. Small radius curves in the track, such as those that may occur for urban trains, can result in high levels of high-frequency sound referred to as wheel squeal. Noise can be generated in stations because of running engines, whistles and loudspeakers, and in marshalling yards because of shunting operations. The introduction of high-speed trains has created special noise problems with a sudden rises in noise.

Aircraft operations generate substantial noise in the vicinity of both commercial and military airports. Aircraft take-offs produce intense noise, including vibration and rattle. The landings produce substantial noise in long low-altitude flight corridors and when reverse thrust is applied.

Mapping, modelling and monitoring

Environmental noise modeling describes the process of theoretically estimating noise levels within a region of interest at a certain time. The output of an environmental noise model represents an estimate of the spatial variation of noise levels at a fixed time. Characterizing feature of a noise model are three key approximations to: the sound sources; the physical environment (e.g. buildings, topographic and atmospheric conditions) and the transmission paths of sound pressure levels to the receiving sites. Repetitive calculations for each source, each transmission path and each receiving site and summing up the contribution of each source and transmission path at each receiver site results in the sound pressure levels at the receiver sites (i.e. in the region

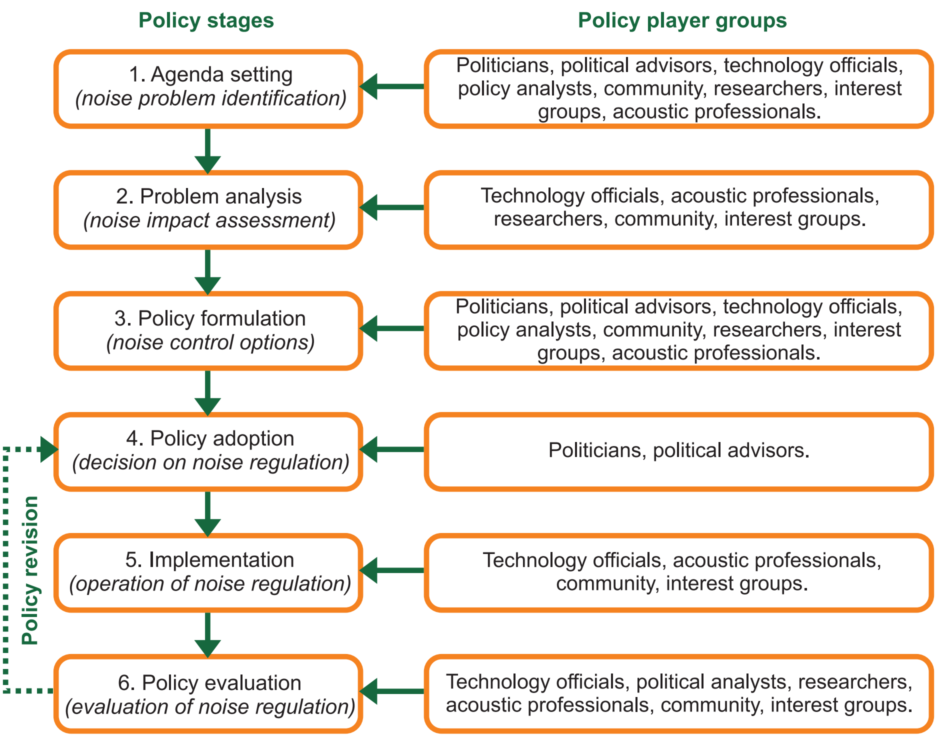


Figure 2.5: A model of the policy process for community noise management *Source: Adapted from Hede (1998)*

Table 2.10: Recommended Noise Management Measures (adapted from WHO, 2000)

Legal measures	Examples
Control of noise emissions	Emission standards for road vehicles; EU Directives
Control of noise transmission	Regulations on sound-obstructive measures
Noise mapping and zoning around roads, airports, harbours	Initiation of monitoring and modelling programmes
Control of noise emissions	Limits for exposure levels such as national emission standards; noise monitoring and modelling;
Speed limits	Residential areas; hospitals
Enforcement of regulations	Low Noise Implementation Plan
Minimum requirements for acoustical properties of buildings	Construction codes for sound insulation of building parts
Engineering Measures	
Emission reduction by source modification	Tyre profiles; low-noise road surfaces; changes in engine properties
New engine technology	Road vehicles; aircraft; ships
Transmission reduction	Noise screens
Orientation of buildings	Design and structuring of tranquil uses; using buildings for screening purposes
Traffic management	Speed limits; guidance of traffic flow by electronic means
Passive protection	Insulation of dwellings; façade design
Implementation of land-use planning	Minimum distance between busy roads and residential areas; location of quiet areas; by-pass roads for heavy traffic; separating out incompatible functions
Education and information	
Raising public awareness	Informing the public on the health impacts of noise, enforcement of action taken, noise levels, complaints
Monitoring and modeling of sound-scapes	Publication of results
Sufficient number of noise experts	University or high school curricula
Initiation of research and development	Funding of information generation according to scientific research needs
Initiation of behaviour changes	Speed reduction when driving; use of horns;

Source: WHO (2000)

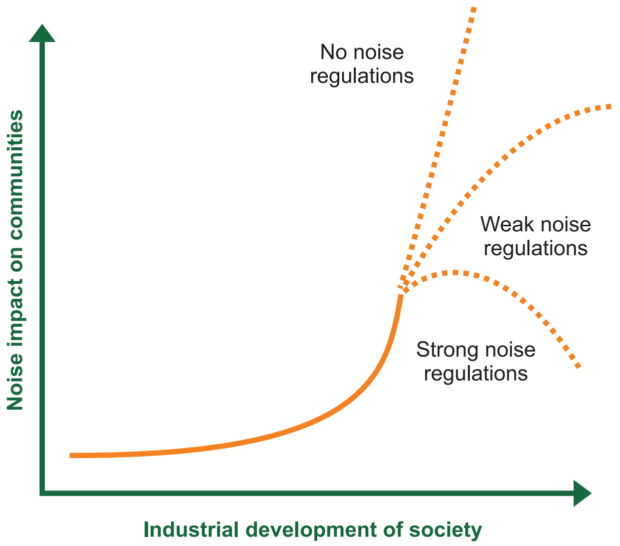


Figure 2.6: Relationship between noise impact and development
Source: Hede (1998)

of interest). Applying these calculations to each point of a uniformly distributed grid enables a noise contour map to be developed to depict regions of equal sound pressure levels.

Common uses of environmental noise predictions include:

- Assessment of an existing sound pressure field for source apportionment of the contribution of different sources. This information can serve to rank sources and find effective mitigation measures to reduce noise levels.
- Forecast the impacts or benefits of planned changes to an environmental noise field. Changes may refer to noise reduction measure in an existing commercial/industrial installation or modifications of the transmission path of sound, e.g. barriers or enclosures.
- Complementing the results of sound pressure level monitoring in space and time.
- Assisting the design of monitoring networks and helping find the most effective monitoring strategy.

Key information to all predictive studies is the systematic representation of the noise sources to be investigated, and the physical environment through which noise will transmit to the receivers (see Table 2.11).

Table 2.11: Requirements for specifying a noisy environment

Stage	Minimum requirements	Other information that may be required
The noise sources to be investigated	Number of sound sources Total sound power output of each source Directional characteristics of each source Height of each source Frequency characteristics of each source	Time variations of emissions Information to determine which value or range of values best correlates to the conditions for which the assessment will apply. For example, a worst-case assessment would imply the use of the highest possible value irrespective of how frequently it may occur, whilst an assessment which related to 'typical' conditions could necessitate the use of an averaged value or some typically recurring upper value
The physical environment through which noise will transmit to the receivers	Separating distances between all relevant noise sources and receivers Reflecting/obstructing structures Height(s) of receiver(s)	Ground terrain profile Characteristics of the ground cover Meteorological conditions relevant to the intentions of the assessment (e.g. worst case such as downwind propagation, or generally recurring long term conditions). These may include wind direction and speed, variations with wind and temperature with height above ground, temperature, and humidity

Source: NPL (2010)

A number of different approaches are used in environmental noise modelling. These include practical engineering methods, approximate semi-analytical methods, numerical methods, hybrid models, ray-tracing models, and Lagrangian sound particle models. NPL (2010) provides extensive guidance on the reliability of models and the risk of their application in environmental noise assessment.

Environmental noise measurements are made for planning purposes, or to investigate noise nuisance complaints. Noise sources under investigation in environmental noise measurements include all forms of transportation such as aircraft, highways, railways; quarries and mining facilities; industrial and commercial properties; construction work; and neighbourhood noise. Equipment includes sound level meters, noise dosimeters, and noise monitoring terminals with automatic calibration.

Detailed information on monitoring objectives, instrumentation, monitoring sites, sampling, and calibration and quality assurance can be found in WHO (1999).

Routine noise monitoring is expensive if spatial coverage is intended. Therefore a network of noise monitoring terminals is seldom applied.

Impacts

Adverse health effects of noise include noise-induced hearing impairment; cardiovascular effects, cognitive effects; disturbance of rest and sleep; psychophysiological, mental-health and performance effects; effects on behaviour and annoyance as well as interference with intended activities.

Hearing impairment is typically defined as an increase in the threshold of hearing. Hearing deficits may be accompanied by tinnitus (ringing in the ears). Noise-induced hearing impairment occurs predominantly in the higher frequency range of 3,000–6,000 Hz, with the largest effect at 4,000 Hz. But with increasing $L_{Aeq,8h}$ and increasing exposure time, noise-induced hearing impairment occurs even at frequencies as low as 2,000 Hz. It is expected that environmental and leisure-time noise with a $L_{Aeq,24h}$ of 70 dB(A) or below will not cause hearing impairment in the large majority of people, even after a lifetime exposure (WHO, 2000). The main social consequence of hearing impairment is the inability to understand speech in daily living conditions, and this is considered to be a severe social disability.

Cardiovascular effects Sufficient evidence exists for the association between aircraft noise and high blood pressure and the use of cardiovascular medication. Road traffic noise exceeding 60-65 dBA during day-time and 50-55 dBA during night-time suggests an increase of cardiovascular risk (Babisch and van Kamp, 2009; WHO, 2011).

Cognitive performance is adversely affected by noise through speech interference. Speech interference is basically a masking process, in which simultaneous interfering noise renders speech incapable of being understood. Environmental noise may also mask other acoustical signals that are important for daily life, such as door bells, telephone signals, alarm clocks, fire alarms and other warning signals, and music.

The inability to understand speech results in a large number of personal disadvantages and changes in behaviour. Particularly vulnerable are those with impaired hearing, the elderly and children in the process of language and reading acquisition, and individuals who are not familiar with the spoken language.

Sleep disturbance is a major effect of environmental noise. It may cause primary effects during sleep, and secondary effects that can be assessed the day after night-time noise exposure. The secondary, or after-effects, the following morning or day(s) include reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance.

Social and Behavioural Effects of Noise. Noise can produce a number of social and behavioural effects as well as annoyance. These effects are often complex, subtle and indirect and many effects are assumed to result from the interaction of a number of non-auditory variables. The effect of community noise on annoyance can be evaluated by questionnaires or by assessing the disturbance of specific activities. However, it should be recognized that equal levels of different traffic and industrial noises cause different magnitudes of annoyance. This is because annoyance in populations varies not only with the characteristics of the noise, including the noise source, but also depends to a large degree on many non-acoustical factors of a social, psychological, or economic nature. The correlation between noise exposure and general annoyance is much higher at group level than at individual level. Noise above 80 dB(A) may also reduce helping behaviour and increase aggressive behaviour. There is particular concern that high-level continuous noise exposures may increase the susceptibility of school children to feelings of helplessness (WHO, 1999; 2009; 2011).

Stronger reactions have been observed when noise is accompanied by vibrations and contains low-frequency components, or when the noise contains impulses, such as with shooting noise. Temporary, stronger reactions occur when the noise exposure increases over time, compared to a constant noise exposure. In most cases, LAeq, 24h and L_{dn} are acceptable approximations of noise exposure related to annoyance. However, there is growing concern that all the component parameters should be individually assessed in noise exposure investigations, at least in the complex cases. There is no consensus on a model for total annoyance due to a combination of environmental noise sources (WHO, 1999).

Environmental noise management

The aim of environmental noise management (ENM) is to maintain a low noise soundscape that protects human health and wellbeing but also provides protection of animals. ENM is a tool which enables governmental authorities to set objectives to achieve and maintain a low noise soundscape and reduce the impacts on human health and animals. Governmental authorities in collaboration with other stakeholders can determine the individual steps of the implementation of this process according to:

- local circumstances with respect to background noise levels and technological feasibilities;
- cultural and social conditions;
- costs and benefits of noise reduction; and
- financial and human resources available.

An effective ENM strategy is dependent of a number of factors such as source knowledge, noise monitoring networks, transmission of noise prediction models, exposure and damage assessments, health based standards together with a range of cost-effective noise exposure control measures and the legislative powers and resources to implement and enforce them. Figure 2.7 presents a simplified cycle of ENM.

Finances Funding is required to strengthen, implement and enforce existing legislation and regulations, enhance capacity for source apportionment, noise exposure modelling and mapping, noise impact assessment and developing control measures. It is important to raise awareness of all stakeholders including the public on the issues of noise exposure and the possible noise impacts.

In view of the necessity of financial sustainability of ENM, the precautionary principle, the polluter pays principle and the prevention principle should be applied (WHO, 1999).

2.8 Enironmental noise policy measures

There are several routes to sustainable transport and noise abatement. First, noise emissions can be reduced at their source, through measures relating to vehicles, tyres and road surfaces.Second, traffic management measures such as speed limits, night time curfews, and improvements in traffic flow can lead to reduced noise levels. Third, transport demand management can reduce the number of trips and consequently noise. Transport demand management promotes sustainable travel choices by building houses at relatively high density in compact settlements, by supporting city and town centres, and by designing streets in ways which make walking, cycling and public transport easy (CPRE, 2007). Fourth, noise emissions can be reduced by means of barriers and/or insulation measures.

Challenges for environmental noise management in SSA

Policies

- Low government commitment to ENM policies and their enforcement
- Limited
  - co-ordination and integration of ENM policies with other sectoral policies and plans
  - collaboration of different responsible agencies
  - institutional capacity to implement and enforce ENM legislation and policies
- Absence of appropriate review mechanisms, which form a part of ENM policies and legislation
- Regional differences in regulation of emission sources and consideration of secondary pollutants
- Deficiencies in setting times for Noise standards and for permitted frequency of exceedances
- Lack of
  - criteria for guidelines/standards
  - stakeholder participation in the formulation and implementation of ENM policy (particularly of health communities, producers, transport associations, enforcement institutions, transport planners, urban planners, financial institutions)
  - detailed cost-benefit analysis of ENM outlined in policy
  - monitoring and quantitative data on environmental noise levels and their impact on human health and environment
  - open and transparent reporting
  - public awareness raising
  - Use of obsolete emission and environmental noise standards

Governance

- Conflicts through duplicated responsibilities
- Introduction of inappropriate technical equipment and ignorance on its usability
- Prevalence of ad hoc awareness raising with a focus on raising alarm
- Poor information on how the public can contribute towards effective ENM
- Deficiencies in the appropriate information and dis-

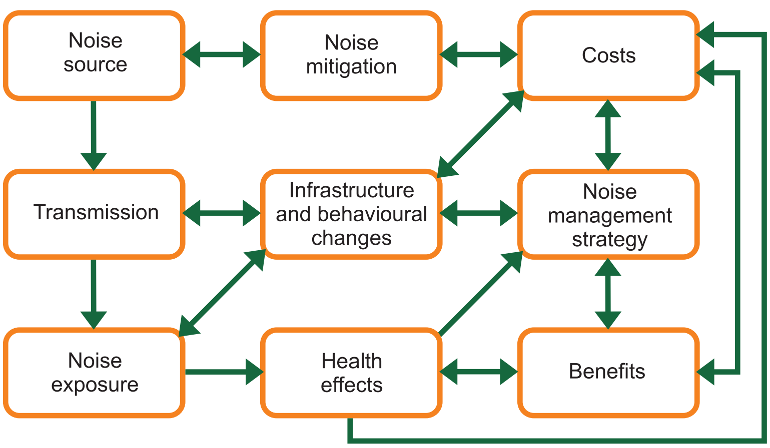


Figure 2.7: A model of the policy process for ENM

semination to the public (e.g. illiteracy)
- High cost of awareness raising programmes
- Design and implementation of ENM strategies is often based on incomplete knowledge
- Potential of mis-interpretation of environmental noise reporting and information
- Insufficiency of adequate communication strategies among stakeholders
- Inadequate regulatory, planning, technical, social, institutional, and financial capacity for ENM
- Lack of
  - baseline research on awareness among stakeholders
  - rules and regulations, particular in neighbouring jurisdictions
  - marketing skills in awareness raising programmes
  - accountability of agency of staff for inefficient use of funds in ENM (e.g. donated funds)
  - human resources, especially of staff with specialized skills
  - reporting to upper management in agencies (e.g. brief to Minister)
  - clear public mechanisms to appeal on new laws and policies
  - inter-agency communication
  - financial resources

- Short term strategies to reduce emissions which fail to adequately address the overall problem
- Use of end-of-pipe and best available control technology solutions rather than solutions to prevent pollution
- Use of ineffective measures to reduce noise pollution which are not fully coordinated with other measures
- Deficiencies in the dissemination and exchange of solutions, best practice and lessons learnt (positive and negative)
- Lack of
  - emission inventories and quality assured emission data
  - periodical update of emissions standards
  - regional harmonisation of emissions standards
  - low-cost and effective alternative technologies

Modelling

- Lack of
  - quality assured emission data
  - source apportionment experience
  - regional harmonisation of propagation models
  - quality assured topographical and meteorological input data for more advanced models

Monitoring

Absence of

  - and/or limited coverage of outdoor sound pressure level monitoring systems
  - periodic review of sound pressure level monitoring issues
- Limited existence of baseline data
- Deficiencies in the maintenance of monitoring systems and in procuring spare parts
- Poor quality data and limited dissemination
- Little focus on control and quality assurance of monitoring programmes
- Lack of
  - collaboration among different monitoring agencies
  - standard operating procedure for monitoring, data analysis and presentation
  - harmonisation of monitoring networks and devices
  - monitoring of sound pressure levels in urban and peri-urban areas
  - hotspot monitoring

Health and economic risk assessment

- Lack of long-term studies of health and economic impacts due to environmental noise exposure
- Insufficient institutional capability
- Poor information and assessment of health and economic impacts of environmental noise

Finances

- Low priority funding for ENM
- Under-funding of ENM in developing countries
- Inefficient use of resources
- Lack of
  - accountability, transparency and good governance with regard to financing
  - sufficient funding for capacity building
  - knowledge of existing market mechanisms
  - co-operation and co-ordination among funding agencies
  - adherence to the "polluter pays principle"

At-source measures that reduce overall emissions, traffic management and transport demand management measures are preferable to noise exposure measures reducing emissions at the local level (EC, 2004; 2005; Ohm, 2006; GEF, 2009).

At-source measures

Measures that tackle the basic sources of noise are technical measures to reduce noise emissions from vehicles, tyres and road surfaces. At-source measures are generally more cost-effective than those of noise barriers and building insulation (Nijland *et al*., 2003; Larsen, 2005). Measures to reduce the noise from tyres and vehicle propulsion can achieve noise reductions at relatively low cost. Moreover, at-source measures such as reduction of noise emissions from vehicles and tyres are a direct application of the polluter pays principle since the costs are borne by the car driver.

However, at-source measures at the vehicle level have the disadvantage that penetration of the vehicle fleet takes several years for tyres and almost a decade for motor vehicles (den Broer and Schroten, 2007).

Traffic flow management

Traffic flow management includes measures to reduce the number of vehicles on the road, measures to smoothen traffic flow by road bypasses, roundabouts and intelligent tuning of traffic lights, speed limits and night time bans on trucks and lorries. A smaller number of vehicles reduce not only noise but also air pollutant and GHG emissions. Less cars plying on the roads also improve road safety. Specific traffic management measures may reduce noise levels between 2 and 7 dBA (Berndtsen *et al*., 2005):

- traffic calming (≤ 4 dBA);
- 30 km/h zone (≤ 2 dBA);
- Roundabouts (≤ 4 dBA);
- Round-top/circle-top road humps (≤ 2 dBA);
- Speed limits (≤ 4 dBA);
- Night time restrictions on heavy vehicles (≤ 7 dBA).

Speed limit enforcement, especially for speeds between 50 and 80km/h in urban areas has a positive effect on transport noise.

Traffic management measures involve only limited investments and have a direct effect because they can easily be enforced. However, the costs associated with potential travel time losses may be significant.

Sustainable transport and planning

Transport demand management can reduce the number of vehicles by promotion of public transport, encouraging cycling and walking, congestion charges and parking management. In order to influence travel behaviour it is imperative that (SDC, 2009):

- the future needs of a community are considered and captured through good quality planning before infrastructure is put in place;
- destination analysis is applied to predict travel behaviour and trip generation. This should ensure that, from inception to maturity, appropriate sustainable travel choices can be provided both within and beyond urban areas;
- opportunities be taken within the planning process to make cycling, walking and public transport the modes of choice. Theses modes must be made more convenient for the majority of journeys than car usage, in order to promote genuine modal shift. They should be supported by the necessary management and regulatory measures;
- housing, schools, health centres, employment needs, existing land-use and transport facilities are considered in an integrated approach;
- the connectivity between urban areas, major zones of employment, retail/leisure facilities and the existing road and rail network is duly considered;
- the need to travel is reduced by good urban design which maximises sustainable transport;
- all stakeholders and the general public are informed and consulted.

Urban design and planning

Urban planning is currently characterized by an over-emphasis to serve motorised transport. Therefore an alternative hierarchy should be envisaged which serves all users including pedestrians in a balanced way. Urban design should consider the following hierarchy in any street design process (SDC, 2009):

- Pedestrians
- Cyclists
- Public transport use
- Specialist service vehicles (e.g. emergency service vehicles, waste, etc.)
- Other motor traffic

Urban design features that encourage sustainable transport and reduce noise include:

- Comprehensive direct networks for walking, cycling and public transport, with routes for private motor traffic taking a lower priority. This may include providing additional routes for sustainable modes. Providing sustainable modes can give them an advantage over private car users and so reduce the tendency for people to drive, especially for short journeys, and produce noise.
- Limited private vehicle access to homes and services.
- Situating key services such as health centres and schools in central locations within urban or suburban areas.
- Traditional compact city layouts. A compact city is an urban area with 'walking neighbourhoods'. These are typically characterised as having a range of facilities within 10 minutes' walking distance (around 800 metres). The propensity to walk or cycle is influenced by distance and attractive, safe, stimulating and quiet surroundings.
- Creation of environmental, low noise emission zones in residential areas whose streets are designed as places for people instead of just motor traffic.
- Reduction of the dominance of motor vehicles through shared space streets and squares to improve conditions for cyclists and pedestrians.
- Car-free areas within urban areas.
- Pedestrianised shopping areas, which are served by direct cycle routes and public transport.

Promoting cycling and walking

In smaller towns of up to 10,000 dwellings, the majority of journeys should be feasible on foot or by bicycle. For larger urban areas, walking and cycling may need to be implemented by additional measures, such as public transport. In order to make walking and cycling more convenient and attractive, the following measures may be useful (SDC, 2009):

- A cycling and walking infrastructure that offers direct, continuous, and, uninterrupted routes to shopping areas, schools, and community facilities.
- Secure bike storage in cycle stands.
- Create and/or improve cycling and walking facilities that link shopping areas, schools, and community facilities to the surrounding areas
- Improve road safety by pedestrian walks, footbridges, lighting, etc.)
- Provision to pedestrians and cyclists of additional links not accessible to motor vehicles.
- Provision of cycle centres, e.g. for bike rental.

Reduction in car dependency

Encouraging a reduction in car dependency is a key component of promoting sustainable transport that emits less noise, air pollutants and greenhouse gases. Reduced car dependency can be promoted by the following measures (SDC, 2009):

- Creation of completely, or partially, car-free sites.
- Limitation of car spaces and/or charge for residential car parking.
- Restriction of car parking to residents with disabilities and visitors.
- Restriction of car access at certain times of day.
- Limitation of car access to the periphery of urban residential areas.
- Design of roads and streets that favour low car flow.
- Preferential treatment for eco-friendly, low-noise cars and scooters.
- Provision of alternative access to local taxi services, home delivery vehicles, and on-demand public transport provision.

Providing access to public transport

Public transport (trains, light rails, buses, and trams) should provide direct and fast connections to key destinations such as urban centres, major employment and leisure zones. Public transport will need to be frequent, reliable and easily accessible. Urban residents could be given vouchers for free travel funded by the taxpayers. This will help to cut car use and reduce noise emissions.

One suburban train carrying 1,000 people keeps 800 cars off the road, substantially reducing pollution. Apart from the air and noise pollution improvements that would be gained by encouraging public transport use, land use would be more efficient. A double track railway requires a land reservation only 25 metres wide compared with a 100 metre wide reservation for a six-lane freeway. A double track railway can carry over 20,000 people per hour in either direction, over four times the capacity of a six-lane freeway.

Goods vehicles

Road freight transport is growing rapidly, and with it the noise from trucks and their tyres. Trucks have become significantly quieter thanks to technology forcing standards, but louder tyres undermine the overall effect. For truck tyres, the spread between loudest and quietest currently available models is 10dB (T&E, 2008).

Goods to be delivered into and out of urban areas should be performed by eco-friendly vehicles in order to reduce noise, air pollution and the carbon footprint of the goods moved. This may include freight transfer centres and/or low-emission delivery vehicles. In addition, it is necessary to remove freight from roads in favour of less environmentally damaging rail.

Night time driving or flight bans

In its Night Noise Guidelines the WHO recommends a limit $L_{night,outside}$ of 40 dBA for Europe for the protection of human health (WHO, 2009). $L_{night,outside}$ is an annual average of equivalent sound level $L_{Aeq,8h}$ outside the bedroom. The WHO Guidelines for Community Noise recommend a level $L_{Aeq,8h}$ of 45 dBA (WHO, 2000). Adverse health effects are observed at levels above 40 dBA $L_{night,outside}$ such as sleep disturbance, insomnia, increased awakenings, and increased use of drugs and sedatives. At level of 45 dBA $L_{night,outside}$ 21,862, 134,651, 477,289, and 180,184 inhabitants are exposed at Amsterdam, Frankfurt, London, and Paris airports.

In Austria, Switzerland and some States of Germany night time driving bans exist for heavy freight vehicles (Katalyse, 2001). In the U.K. more than 40 per cent of supermarkets are subject to curfews on delivery lorries, usually from 10pm to 7am (Times, 2006). These curfews are however challenged by new legislation. Curfews for motorcycles exist also in cities and towns of Germany (BVDM, 2010). Such traffic curfews, however, are beneficial only if located at the subjective night of exposed persons (Griefhahn *et al*., 2008).

In Europe, there is considerable debate among stakeholders about night-time flight bans. Governments and aircraft carriers hold that night time flights are necessary while nongovernmental organizations claim that in spite of technological progress to reduce the noise from individual aircrafts people still suffer from the same or higher noise levels due to the increases in number and size of starting and landing aircraft (e.g. BANG, 2004). The European Court decided in 2001 that the economic benefits of night flights are insufficient to outweigh the detrimental impact on people's quality of life. However, in 2003 the European Court's Grand Chamber overturned the previous ruling. Many of the Europe's leading business centres, including Berlin, Düsseldorf, Frankfurt, Hamburg, London-Heathrow, Munich, Zürich enjoy night-time passenger curfews of 6-8 hours (HBA, 2010). Of the approximately 300 US airports listed in the Boeing airports database, 73 are listed as having night-curfews (Boeing, 2010). Airports without such regulations include Amsterdam, Barcelona, Madrid, Paris-CDG, and Tokyo.

Community and education initiatives

Community and education initiatives can have significant impacts in making transport and travel patterns more sustainable. For example, Perth's TravelSmart programme, piloted in 1999, achieved a 90 per cent increase in cycling, 20 per cent increase in public transport use and a 16 per cent increase in walking trips, resulting in a 10 per cent reduction in car use as driver only trips in its South Perth trial. A year later these travel behaviour changes had largely been sustained (SDC, 2009).

Barriers and insulation

If at-source measures are insufficient to comply with noise limits, noise barriers and insulation of dwellings can reduce the propagation of noise. On average, noise barriers reduce noise levels by 3-6 dBA, depending on their design and height (den Boer and Schroten, 2007). Roadside noise barriers are only useful for protection of dwellings close to motorways and bypass roads in urban and non-urban areas where pedestrians do not cross. For dwellings located farther away from motorways and bypass roads or at higher elevations roadside noise barriers do not provide a solution. Other disadvantages of noise barriers include:

- aesthetic impacts for motorists and neighbours;
- necessity to design custom drainage that the barriers may interrupt;
- costs of design, construction and maintenance.

The average cost of a noise barrier is approximately € 300 per m^2, depending on its construction and the materials used (den Boer and Schroten, 2007). Noise protection can also be achieved through the installation of soundproof windows and insulated walls.

2.9 Understanding air and noise pollution in SSA

As the cities in SSA undergo urbanization, motorization and economic development the environmental risks to human health due to air pollution generally increase at lower levels of development. Outdoor air quality becomes a serious public health issue as air pollutant emissions increase due to industrialization and the use of an ageing (second-hand) vehicle fleet. As cities develop further, environmental controls are eventually tightened and, in consequence, community-level risks of air pollution tend to decline (Smith, 1997; McGranahan, 2001). In wealthy cities strict regulations and the implementation of abatement technology reduce air pollutant emissions to make them comply with air quality standards. This process is connected with substantial financial costs for the community. In many poor cities of SSA countries strict regulations for air quality are not in place and there is little capacity and capability for air quality monitoring and management.

With increasing urbanization and motorization environmental noise also becomes a major challenge in SSA cities. Strict regulations to reduce noise emissions are mostly absent in SSA countries. Noise levels are increasing but remain unknown since they are not monitored or estimated using noise propagation models. The health impacts of exposure to noise are often unrecognized since epidemiological studies are also lacking in SSA countries.

This process of tightening environmental controls to reduce air and noise pollution is only in a very early stage in SSA cities. AQM and environmental noise management are in their infancy due to the many other challenges to be met by SSA cities such as household sanitation, access to clean water, indoor air pollution, vector-borne diseases and the acquired immunodeficiency syndrome (Aids). In major SSA cities such as Dar es Salaam, Kampala, Lagos, Nairobi air pollutant concentrations and noise levels are suspected to be high due to the increasing vehicle fleets which are old and poorly maintained second-hand cars, trucks and lorries. Although the phasing out of lead in gasoline between 2003 and 2007 was a great success and will have substantially reduced lead concentrations in the air as well as the lead content of blood in children and adults, the high sulphur content of diesel in many SSA countries is still a matter of concern.

More specifically, the following challenges exist in SSA countries:

Air pollution

- AQM policies are still ad hoc in most countries
- Legislation is often incomplete as it does not cover all types of sources including transboundary air pollution
- An integrated approach to air pollution is often difficult due to diluted legislation
- Comprehensive urban AQM programmes are absent
- Implementation and enforcement of existing legislation is poor
- Public awareness of air pollution is poor
- Stakeholder participation is poor
- Regulatory, institutional, planning, technical, social and financial capacities are inadequate
- Awareness of the impacts of air pollution on human health, risk perception and communication are poorly developed
- Emission inventories, even initial ones are lacking in SSA cities
- Air quality monitoring equipment is lacking
- Baseline air quality data does not exist
- Existing air quality data are obsolete
- Air quality modelling is rarely applied
- Short-term and long-term studies on health impacts of air pollution are lacking
- A sustainable basis for financing AQM is lacking
- Indoor air pollution due to open stove cooking and heating is hardly addressed

Noise pollution

- Low government commitment to ENM policies
- Legislation is often incomplete as it does not cover noise issues
- An integrated approach to ENM is lacking
- Comprehensive urban ENM programmes are absent
- Implementation and enforcement of eventually existing legislation is poor
- Public awareness of noise challenges is poor
- Stakeholder participation is poor
- Regulatory, institutional, planning, technical, social and financial capacities are inadequate
- Awareness of the impacts of noise pollution on human health, risk perception and communication are poorly developed
- Noise level monitoring equipment is lacking
- Baseline noise data does not exist
- Noise propagation modelling is rarely applied
- Short-term and long-term studies on health impacts of noise exposure are lacking
- A sustainable basis for financing ENM is lacking

Integrated air quality and environmental noise management systems are needed to address the deteriorating environmental quality in SSA cities and to protect human health and wellbeing.

3 ROAD SAFETY

3.1 Introduction

The importance of road safety is in many ways self-evident. The loss of life, injury, disability, suffering and distress associated with road crashes are intrinsically alarming and a major public health and quality of life problem.[1] The Global Status Report on Road Safety (WHO, 2009) has captured the wide ranging significance of death and injury in the road traffic environment:

- There are 1.2 million fatalities each year and 90 per cent of these are in low and middle-income countries such as SSA countries
- There are 20-50 million injuries each year and many of these injuries produce life-long disabilities
- Africa has the joint highest road crash fatality rate of all WHO regions at 32.2 per 100,000 population data
- Death and injury on the roads exacerbates poverty by depriving households of the main income earner and imposing a heavy burden on health services
- The global cost of death and injury in the road traffic environment is estimated to be US $518 billion
- Fifty per cent of all fatalities are amongst vulnerable groups (e.g. pedestrians, cyclists and public transport users)
- Death and injury burdens are heavily skewed towards lower income groups
- By 2030 road crashes will be the fifth leading cause of death (it is currently the ninth leading cause of death). This puts road crash deaths ahead of diabetes and HIV AIDS

Of particular concern to African countries are the wider economic and health impacts associated with crashes. In Kenya, for example, road traffic injury patients represent between 45-60 per cent of all admissions to surgical wards. Similarly, studies in India show that road traffic injuries account for 20-50 per cent of emergency room registrations, 10-30 per cent of hospital admissions, and 60-70 per cent of people hospitalized with traumatic brain injuries (WHO, 2009: 4).

Most discussions about road safety are understandably conducted at the national level. It is the nation state that takes on the responsibility for highway construction and maintenance, speed limits, drug and alcohol abuse on the part of drivers and the ways in which the legal system deals with reckless and dangerous driving and its impacts. Notwithstanding the importance of the national level debate, the real impact of road safety failures is experienced in towns and cities, urban areas and rural areas and on individual streets and it is essential that policy deals with the detailed geography of road safety (Whitelegg, 1987). The importance of geographical disaggregation has been established by Khayesi (1997) in his account of pedestrian death and injury in Nairobi:

> *"The picture that emerges from the data presented … is one of increasing loss of life and injuries that accrue to pedestrians in Nairobi. Between 1977 and 1994, Nairobi experienced a rising trend in the number of road traffic accidents. A total of 54,350 road traffic accidents occurred in Nairobi during this period. These accidents resulted into 6,005 deaths. Pedestrians constituted the largest number of road traffic fatalities (3,929 or 64.5%). The second largest victims were passengers (1,189 or 19.8%). They were followed in relative importance by drivers (615 or 10.2%), pedal cyclists (183 or 3.0%) and motor cyclists (89 or 1.5%). This aggregate pattern is more or less repeated for individual years."* (Khayesi, 1997)

Khayesi concludes his examination of pedestrian safety in Nairobi by emphasising the importance of pedestrian-oriented planning and creating pedestrian friendly streets and a change in emphasis away from traffic planning as something intended to facilitate the movement of vehicles.

3.2 Current Trends in road safety in SSA

Road safety policy debates cannot be adequately understood and resolved by the use of numbers and yet numbers tend to dominate road safety discussions. The number of citizens killed, injured or disabled as a result of road crashes is under-recorded in low-middle income countries (WHO, 2009) and the numbers discussed here are not accurate and do not convey the full scale of the problem. Dhliwayo (1997) discusses "serious" under-reporting and the possibility that in Africa "the police do not record more than half of the deaths that occur as a result of a road crash". There is also an ethical question originally debated in Sweden as part of the evolution of the Vision Zero road safety policy (Whitelegg and Haq, 2004). How many deaths are acceptable to politicians and professionals? The Swedish answer is "zero" and this answer has a resonance in Africa. The life of an African child is just as important as the life of a Swedish child and the total road system and its interaction with human beings and vehicles can be re-engineered to eliminate fatalities.

WHO (2009) reports that for the Africa region the total number of fatalities in road crashes recorded by official statistics was 52,302 but the WHO modelled figure is 234,768. These are one year figures for the latest year for which data were available. The modelling methodology and involves a two stage procedure to correct for serious underreporting of fatalities (WHO, 2009).

The first stage is to standardise all fatality data so that it meets the WHO 30-day criterion. A road crash fatality is one that takes place within 30 days of the incident.

The second stage is to use this 30-day standardised data in a negative binomial regression equation that predicts fatalities (the road traffic mortality outcome) as a function of a set of independent variables described as exposure factors (Ej), risk or preventative factors (Rj), mitigating factors (Mj) and gross national income (Ij). This can be expressed as:

$$Yj = f\,(Rj,Mj,Ij,Ej)$$

The relationship between the outcome and the independent variables is a non-linear function. The number of deaths (Yj) is a non-negative integer count data and a negative binomial regression model was chosen were the assumption for the dependent variance and Poisson's particular case of negative binomial model are adequately satisfied. The modelled road traffic death rate is associated with the 90 per cent confidence interval (WHO, 2009:233). Table 3.1 summaries basic road safety data for six selected SSA countries.

1 Here the word "accident" is not used when discussing road safety as we (as well as WHO) do not regard road crashes, injuries and fatalities as accidental but as being predictable and preventable.

Table 3.1 Road Safety data for selected SSA countries (mainly 2007 data)

	Population in millions	Reported deaths	Reported non-fatal injuries	% deaths that are pedestrians
Mozambique	21.39	1502	7065	68
South Africa	48.57	14920	219978	39
Tanzania	40.45	2595	16308	37
Uganda	30.88	2838	12058	35
Zambia	13.34	1037	13819	26
Zimbabwe	11.92	1266	9258	50

Source: Country tabulations in WHO (2009)

These numbers even though they are from an extremely authoritative source do not appear plausible when compared with Dhliwayo (2007) and the claim that in Africa in 1999 between 750,000 and 1 million people died in officially reported road crashes. In a similar vein MDawarima (2007) has estimated annual fatalities in Zimbabwe at 2000 per annum which is approximately 50 per greater than the WHO figure in Table 3.1. This actual or potential data unreliability is problematic but the main thrust of the Swedish Vision Zero road safety policy is to de-couple the discussion and the policies and the need for action from the actual numbers. There is no logical cut-off point below which deaths are acceptable and above which they are not acceptable. The thrust of the Swedish Vision Zero road safety policy which is discussed later is that the road traffic environment can be designed using systems thinking so that the consequences of mistakes in that environment do not cause fatalities or serious injuries. This principle has been adopted in the WHO (2004) conclusion that "road traffic crashes are predictable and preventable". This is also the view adopted in this report. Figure 3.1 presents recent trends in road traffic deaths for the six TEST countries.

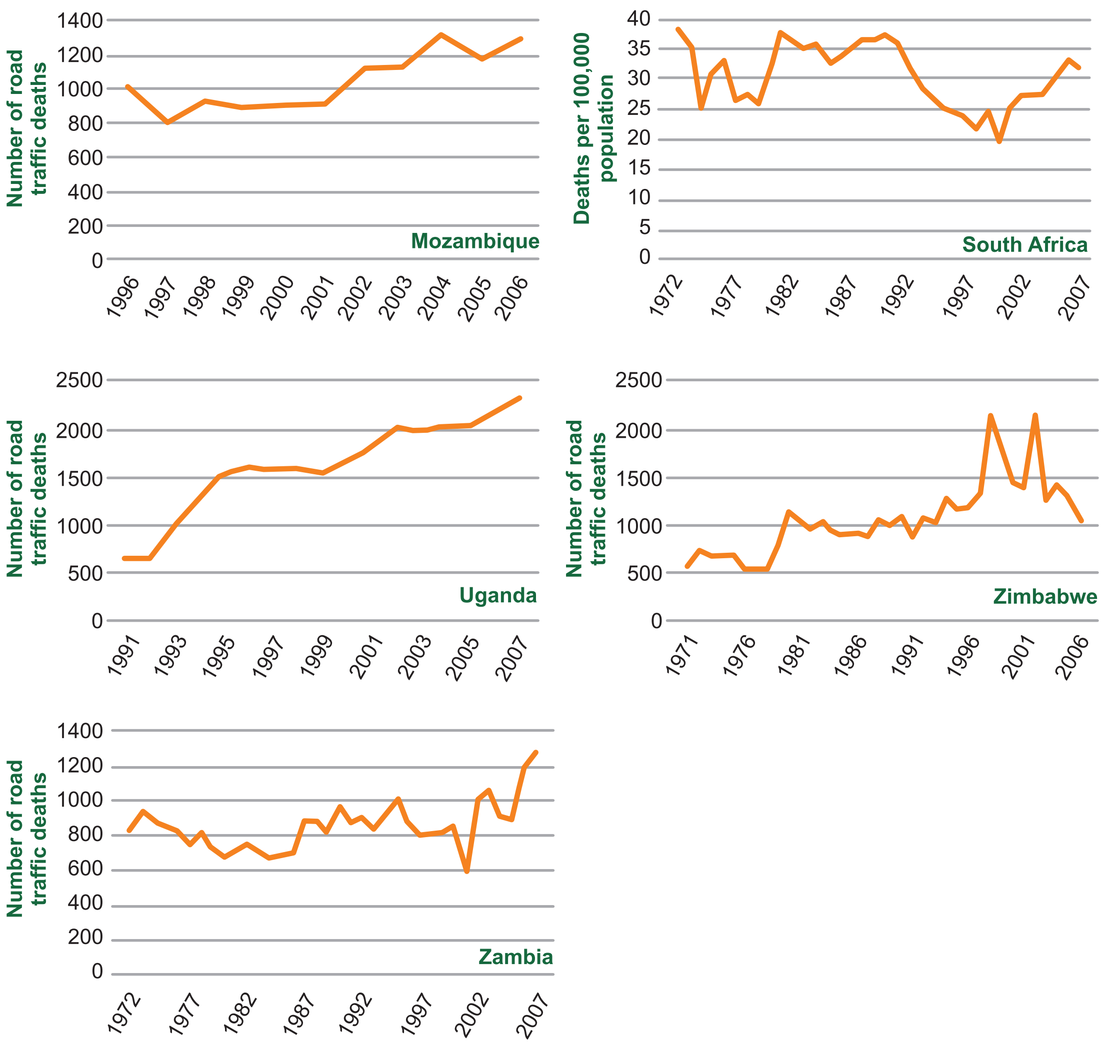


Figure 3.1: Trends in road traffic fatalities in selected SSA countries

Source: (WHO, 2009)

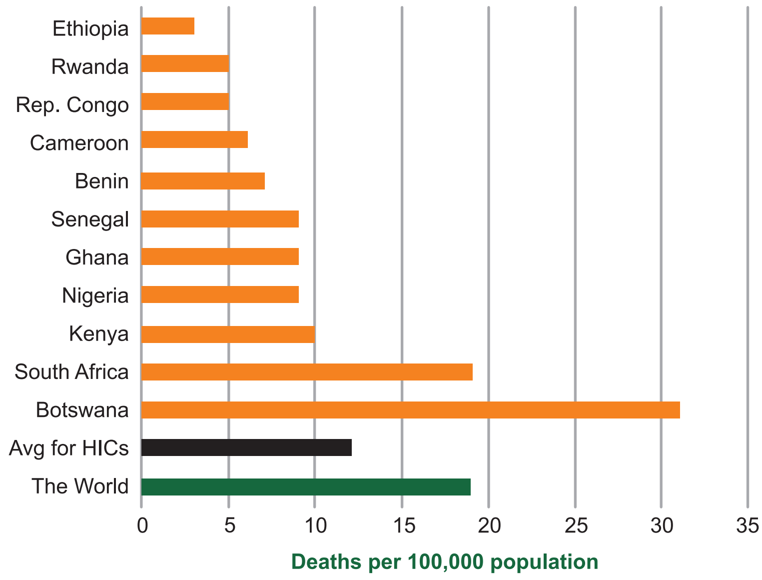


Figure 3.2: Road traffic death rates in selected African countries *Source: Krug (2007)*

Figure 3.2 presents Krug (2007) data on road traffic death rates and these are illustrated graphically

South Africa and Botswana are clearly experiencing severe road safety problems with death rates considerably in excess of those in Nigeria and Ghana. This indicates that there is potential to improve the situation by moving towards the Ghanaian/Nigerian rates even though those rates are themselves capable of improvement.

Future Trends

WHO (2004) has illustrated future trends in fatalities from road crashes with specific reference to SSA (see Figure 3.3)

The data presented in WHO (2004) show that for SSA there were 59,000 deaths in 1990 and these are predicted to rise to 144,000 deaths by 2020. This is an 80 per cent increase over the period 2000-2020. These data have been adjusted to take account of under reporting but unfortunately not utilising the same methodology as that adopted in WHO (2009). In WHO (2004) crude correction factors were applied to the reported data to correct for the variation in reporting periods and to standardise fatality data on the 30-day period (a death more than 30 days after the incident is not a fatality and all deaths within 30 days of the incident are recorded as deaths).

After the 30 day standardisation there is a further correction based on the literature on road safety from low income countries to adjust upwards the number of fatalities. This is explained in some detail in WHO (2004). The implications of these two different systems of dealing with underreporting are that the numbers are not directly comparable but the trend over time estimates in Figure 3.3 (WHO, 2004) are internally consistent and still very useful and show an 80 per cent increase in fatalities in SSA in the period 1990-2020.

In Africa the prediction is that road crash deaths will be the seventh leading cause of death in 2030 and the fourth leading cause of Disability Adjusted Life Years (DALYS) lost in 2030 (see Figure 3.4) (Krug, 2007).

3.3 Key issues in road safety management

Key issues in road safety management (World Bank, 2002) include:

Road crash rate. It is common practice to relate the number of crashes, collisions and casualties to demographic and other information and to compare this relationship between countries. The most meaningful statistic for international comparison is the crash rate (in units of deaths, casualties or crashes per million vehicle kilometres). Adequate information on vehicle usage is not readily available for many countries in SSA. Hence it is usual to compare the fatality risk per 100,000 population.

Economic perspective on traffic safety. Road crashes cost approximately 1 to 3 percent of a country's annual Gross National Product. World Bank estimated that developing countries currently lose in the region of $100 billion every year (World Bank, 2002). These costs inhibit the economic and social development of developing countries. Road safety improvements reduce these losses. Governments should see expenditures on road safety as an investment and not as a cost.

Developing a road safety plan. A national road safety plan with measurable medium- or long-term road safety targets is a prerequisite for achieving sustainable improvements in road safety. The plan should build capacity of local institutions and provide sources of financing for road safety. UNESCAP has developed guidelines for road safety plans which can be adopted and adapted for SSA countries (UNESCAP, 1999).

Institutional responsibility of road safety. The participation of many different organizations and sectors is required to improve road safety in SSA. The World Bank has given examples for how to entertain a concerted effort by a National Road Safety Council (NRSC), which consists of a multidisciplinary team of road safety manager and specialists supported by a permanent Secretariat, led by a senior government official (World Bank, 2002).

Monitoring and Evaluation. In order to track progress of road safety activities and estimate the safety impact a simple and effective monitoring and evaluation system is needed. For action plans in SSA countries, initial focus must be on institutional strengthening and capacity building to achieve the goal of reducing the numbers of casualties. Monitoring and evaluation systems are, therefore, an integral part of action plans to improve road safety.

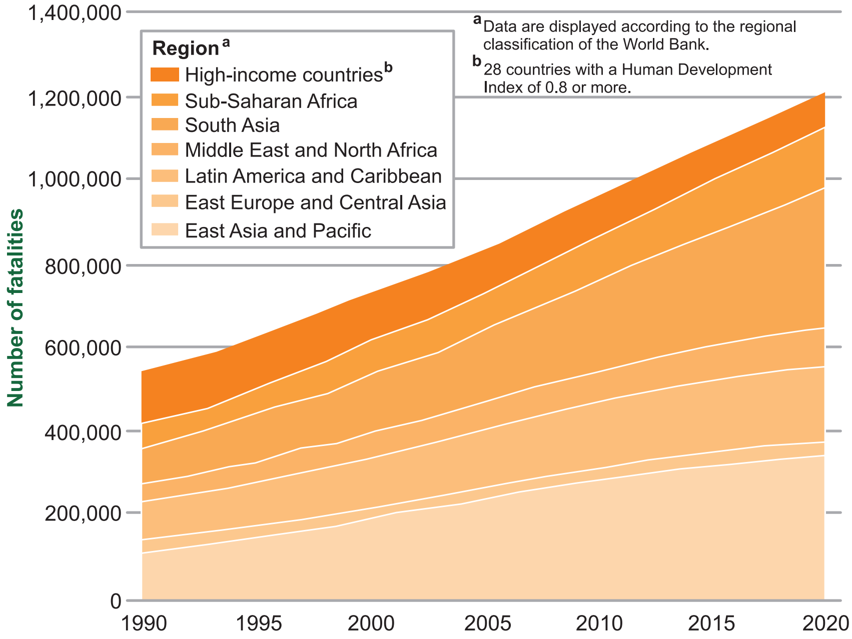


Figure 3.3: Road traffic fatalities, adjusted for underreporting, 1990-2020

Source: WHO (2004)

Predictions for Africa - 2030	
Leading cause of DEATH in Low-income countries, 2030	**Leading causes of DALYs in Low-income countries, 2030**
1. Ischaemic heart disease	1. HIV/AIDS
2. HIV/AIDS	2. Perinatal conditions
3. Cerebrovascular disease	3. Unipolar depressive disorders
4. COPD	**4.ROAD TRAFFIC ACCIDENTS**
5. Lower respiratory infections	5. Ischaemic heart disease
6. Perinatal conditions	6. Lower respiratory infections
7. ROAD TRAFFIC ACCIDENTS	7. Diarrhoeal diseases
8. Diarrhoeal diseases	8. Cerebrovascular disease
9. Diabetes melitus	9. Cataracts
10. Malaria	10. Malaria

Figure 3.4: Predictions of leading cause of death in Africa

*Source: **Krug (2007)***

Information system and analysis of data. Information is the cornerstone of all road safety activity including the assessment of road crashes, injuries and causalities and for monitoring the success of road safety efforts. The information system should identify

- what categories of road users are involved in crashes;
- what driving and behaviour patterns lead to crashes; and
- under what conditions crashes occur, in order to focus on safety activities.

Stored data are to be analyzed and reported in a standardized form.

Financing road safety. A sustainable funding source is required for the implementation of road safety measures. Two sources for financing road safety which are becoming more popular are road safety levies on insurance premiums, and fuel levies. These levies may be used to improve and maintain a safer road network in a cost-effective way.

Designing roads to improve road safety. Road crashes can be prevented by better planning and more safety conscious design of the road network. Considering road safety aspects of new roads and highways and traffic management procedures during the design, construction and maintenance phases of road projects is able to reduce crashes, injuries and fatalities. An integral design is less expensive than fixing potholes and improving the borders of roads at a later stage. Vehicle and road standards and driver testing requirements from developed countries should be adopted with careful consideration of their consequences since the traffic fleet, vehicle use and road usage in SSA countries is very different from that in developed countries.

Road safety audits. The main aim of a road safety audit is to ensure the consideration of safety problems from the beginning to reduce future problems. It includes the systematic checking of the safety aspects of new roads and highways and traffic management procedures during the design, construction and maintenance phases of road projects. In SSA countries road maintenance is often limited to fixing potholes and cleaning drainage facilities, without replacing missing traffic signs, guard-rails, road markings and other safety features essential to create a safe road network.

Children's traffic education. Teaching safety skills to children can provide lifelong benefits to society. Training is needed in schools by professional teachers, trained in the safety issues relevant to children.

Publicity programmes. Road user education and awareness raising is an important part of any road safety strategy. Such activity must be based on analysis of information and should be designed and monitored in a systematic way to ensure success.

Driver training and testing. As road user errors are contributing to the vast majority of road crashes, the primary objective of any road safety programme is the education of drivers in safety issues and the development of skills in defensive driving. Driving examiners in SSA countries should be given special training. The ability of drivers to drive safely in traffic on real roads should be tested periodically.

Traffic law and enforcement. Effective traffic law enforcement can play an important role in reducing traffic crashes, injuries, and fatalities. Traffic Police should be enabled to deal effectively with road safety violations. In many SSA countries the Traffic Police are often grossly under-resourced and under-trained to fulfill this duty.

Vehicle safety standards. Improvements in vehicle design, occupant protection and vehicle maintenance have made a significant contribution to crash reduction in developed countries. Protection measures for occupants include seat belts, headrests, air bags, and special seats for children. The proper maintenance of safety related vehicle components can be achieved by periodic vehicle inspections combined with frequent random checking of vehicles on the road. Overloading of heavy goods vehicles is also a serious safety hazard for all road users in SSA countries.

Emergency medical services. Timely and proper treatment of road casualties is essential for reducing the severity of injury to crash victims. Driver education on first aid procedures and correct transportation of crash victims is important. A single emergency telephone number can facilitate the simultaneous alerting of police, ambulance and other rescue services and help reduce response times.

Road safety research. Road safety research aims to improve knowledge about factors contributing to road crashes, effects of different countermeasures, and development of new and more effective safety measures. It forms the framework of knowledge for making better decisions of road safety policies including a cost-effective resource allocation. Research and Development is an important part of safety work and should be incorporated into national road safety programs.

3.4 Challenges for road safety management

There are ten key challenges that require highly co-ordinated actions on the part of national, regional, city and local government agencies to bring about a step change in the quality of life and safety of citizens in SSA. These include the following actions.

Changing mindsets to recognise the importance of high quality pedestrian space and cycling routes. This includes providing access to buses in both urban and rural African communities. High levels of safety and security and segregated provision are needed to ensure that pedestrians can walk in safety and cyclists have segregated routes available to them where they are protected from traffic. The challenge is to find ways of influencing politicians and professionals so that they both recognise and act on the highest possible priorities that can be given to the safety of citizens in the road traffic environment.

Adjusting urban planning and the provision of education and health care facilities to deal with safety and security. The accessibility of these facilities to the poor, women, children and those with mobility difficulties must be carefully audited and planned to give maximum consideration and safety to these groups. This will involve detailed participatory processes with these groups so that citizens can engage with experts to work together to improve the local built environment in ways that citizens feel are essential to feelings of safety, security and a good quality of life. The challenge is to adopt an holistic approach embracing the location of health and education facilities, the avoidance of major road crossings when planning connections between residential areas and facilities and the design, funding and implementation of high quality pedestrian crossings where it has not been possible to avoid road crossings.

The provision of public transport services requires a shift away from fragmentation, poor quality control and poorly maintained vehicles and towards the Curitiba (Brazil), Bogotá (Colombia) and New Delhi (India) Bus Rapid Transit (BRT) models. Where vehicles are modern, clean and safe and passenger loading, unloading and road crossing opportunities are well-designed to maximise safety and security. The challenge is to move beyond the historical legacy of old vehicles, badly maintained vehicles and vehicles stopping in the roadway and unloading passengers in fast flowing road traffic with no or minimal facilities to guarantee safety.

Education and awareness raising on the part of all road users about mutual responsibilities. Car, truck and bus drivers are an important part of an overall, co-ordinated approach to road safety improvements and should have a high standard of knowledge and training and awareness of the vulnerabilities and susceptibilities of children, the elderly and those who cannot move very fast across wide roads. The challenge is to design educational and marketing material that is cost-effective, delivered in a consistent way over several years, has a high impact and can be part of a shift in societal and behavioural norms towards the "zero tolerance" model. The objective is to produce socially acceptable zero tolerance of behaviours that increase risk of death and injury in the road traffic environment.

The WHO (2004) recognises the importance of speed and of reducing speeds in the road traffic environment so that even if a child pedestrian is hit by a vehicle the victim has a very good chance of survival. This is the bio-mechanical principle and the need to shift the whole road traffic system in the direction of ensuring "that a mistake in the road traffic environment does not incur the death penalty". The challenge is to persuade politicians, engineers and road safety professionals of the importance of speed reduction and to implement measures that will ensure speeds of approximately 30 km/h in urban areas are not exceeded. A further challenge is to devise ways of ensuring that police officers carry out their enforcement duties in a highly professional way and in the absence of bribery and corruption. The importance of speed reduction to 30 km/h (20mph) is summarised by WHO (2004) as follows:

> *"In the majority of serious and fatal crashes, injuries are caused because loads and accelerations, exceeding those the body can tolerate, are applied by some part of the car. Pedestrians, for example, incur a risk of about 80 per cent of being killed at a collision speed of 50 kilometres/hour (km/h). At speeds of over 30 km/h, motorists and pedestrians and cyclists increasingly make mistakes, the consequences of which are often fatal. The human tolerance to injury for a pedestrians hit by a car will be exceeded if the vehicle is traveling at over 30 km/h"* (WHO, 2004:11).

The mechanical condition of vehicles is also an important part of a wide road safety effort. The challenge is to ensure that all motorized vehicles are maintained in excellent mechanical order and tested so that defects in braking, tyres and other safety critical sub systems are eliminated.

The WHO (2004) attaches a great deal of importance to developing institutional capacity to deal with road safety issues. The challenge is to design and develop a wide ranging model of co-operation between all the agencies identified by WHO so that a genuinely multi-sectoral effort is focused on improving safety and reducing road traffic danger. The main stakeholders or agencies that are essential to co-operative and multi-sectoral working are police, government at all levels, media, professionals, NGOs and special interest groups, industry and citizens.

3.5 Road safety policy measures

The Tysoland Declaration (2007) was drafted and adopted at an international road safety summit in Sweden. It lays down principal rights of citizen's road traffic safety. These rights serve to protect them from the loss of life and health caused by road traffic. They rest on the general assumption that no road user wishes to harm either himself or herself or any other fellow human being, whatever the circumstances under which they are using the roads.

The declaration is closely linked to Swedish national road safety policy (Vision Zero) adopted in 1997 by the Swedish Parliament. Vision Zero adopts the principle that no one should be killed or seriously injured in the road traffic environment and the design and function of the road system should be adapted to achieve this goal (Whitelegg and Haq, 2004)

One of the remarkable things about road safety policy is that the main categories of intervention that can be relied upon to produce dramatic reductions in death and injury have been known for many years. Plowden and Hillman (1984) explored the various approaches to road safety intervention making very clear recommendations and followed this up with a more detailed scientific investigation of speed twelve years later (Plowden and Hillman, 1996). There is very little new to be discovered.

Many of Plowden and Hillman's conclusions and policy recommendations are reproduced in WHO (2004) especially as they impinge on wider societal issues of pedestrian environments, land use planning, walking, cycling and public transport:

Principles of Road Safety in the Tylosand Declaration

1. Everyone has the right to use roads and streets without threats to life or health.

2. Everyone has the right to safe and sustainable mobility: safety and sustainability in road transport should complement each other.

3. Everyone has the right to use the road transport system without unintentionally imposing any threats to life or health on others.

Source: European Transport Safety Council (ETSC, 2010)

Exposure to road injury risk can be decreased by strategies that include:

- Reducing the volume of motor vehicle traffic by means of better land use
- Providing efficient networks where the shortest or quickest routes coincide with the safest routes;
- Encouraging people to switch from higher-risk to lower risk modes of transport;
- Placing restrictions on motor vehicles users, on vehicles or on the road infrastructure.

Source: WHO (2004) page 109

Better land use strategies and policies will have the effect of reducing the volume of motorized traffic which then reduces risk especially in the urban environment. Land use policies that resist the development of low density suburbs and prioritise high density urban development on previously used land produce lower levels of traffic generation and reduce volume (Newman, Beatley and Boyer, 2009) The design of new developments that actively prioritise walking and cycling provision have the same effect and planning controls that require a clear transport strategy that aims to reduce motorized traffic reduce risk and improve safety (British Standards Institution, 2008).

The relationships between speed and the probability of death and injury in the road traffic environment is the clearest example of a restriction that can produce significant improvements in road safety. WHO (2004) presents empirical evidence on this. Detailed research in London (TfL, 2003) has shown that in the 78 20 mph (30 km/h) zones across London in a comparison of before and after there were reductions in the killed and serious injury (KSI) rate of 50 per cent for pedestrians, 61 per cent for child pedestrians, 50 per cent for cyclists, 68 per cent for powered two-wheelers and 77 per cent for car occupants. Area wide 20 mph (30 km/h) speed limited zones are an effective risk reduction measure with impressive results in KSI reduction.

Effective road safety interventions especially in the specific conditions of SSA must embrace:

- Reducing the exposure to risk as described above by WHO (2004) focusing on land use policies and traffic reduction
- Attention to detail in the physical environment in which pedestrians, cyclists and public transport users move around to design intrinsic safety into all aspects of the design process (width of pedestrian pavements, safe and secure road crossings, segregated routes for cyclists, high quality design for bus and tram stops to eliminate danger from motorized traffic)
- Speed reduction along the lines suggested by the empirical research in London (TfL, 2003)
- The elimination of poor quality bus services and vehicles in a privatised system and their replacement by new vehicles, much improved regulation and safety checks and a highly co-ordinated and integrated bus service network that gives a high priority to the situations facing passengers as they walk to and from and wait at bus stops. These situations must be audited and checked to minimise risks from motorized vehicles

3.6 Road safety case studies

Beijing project of improving vulnerable road users safety at intersections

The Vulnerable Road Users Safety project was implemented in Beijing (China) and involved the Global Road Safety Partnership (GRSP). In China, the main death and injuries at the road intersection are among vulnerable road users (VRU) – pedestrians, cyclists and motorcyclists. 43 per cent of the crashes which happened at the intersections were related to VRU.

The GRSP launched a three-year project in Beijing to improve VRU safety at intersections in the period 2006-2008. In Phase I of this project, a situational study was undertaken. In Phase II, the chosen countermeasures were implemented and data after/before was collected and analyzed for evaluation.

The project aimed to improve the VRU safety at junctions as well as provide a good practice manual and involved: Beijing Transportation Research Center of Beijing Municipal Committee of Communications, Being University of Technology, Beijing Traffic Management Bureau and GRSP.

Measures included collecting data before/after the implementation of low cost engineering countermeasures (channelization, barrier, pedestrian island, road signs, etc.). As well as comparing the data to check potential improvement and evaluate the use of the countermeasures. Table 3.2 summaries the key impacts of the initiative.

The countermeasures in this project are all normal solutions for the local traffic police, neither expensive nor unique. Therefore financial support is not the main constraint instead multi-sector cooperation and a systematic way of implementation is key.

The Eldoret non-motorized safety project

Between 1995 and 1999, an important Program on non-motorised transport (NMT) was undertaken in Kenya and Tanzania, as part of the Urban Mobility Component of the SSA Transport Policy Program (SSATP) and with financial support from the Dutch Ministry of Foreign Affairs.

The Programme consisted of two parts. The first part primarily served to establish Pilot Projects Units within the Municipal Government. In the second part, user participation was established and interventions were carried out to test implementation scenarios and monitor methods. The Programme was implemented in Nairobi and Eldoret (Kenya) as well as Dar-es-Salaam and Morogoro (Tanzania).

In the Eldoret case, the Eldoret Transport Users Committee identified the portion of Kisumu Road leading to the Sosiani Bridge as unsafe and a high priority for intervention. Kisumu Road enters the town of Eldoret over the Sosiani Bridge and is an important pedestrian and bicycle route into the Central Business District (CBD). Overtaking of slow vehicles by many fast moving motor vehicles at the approaches on both sides of the bridge endangered the safety of cyclists and pedestrians. The average speed of inbound vehicles was 48 km/h and the maximum observed speed 82 km/h, with outbound average speed of 51 km/h and the maximum observed speed of 72 km/h. The above speeds, combined with driver attitudes towards other road users, made it quite unsafe for pedestrians and cyclists.

Table 3.2: Key impacts of the initiative

Name	Problems	Solutions	Impacts	Future improvement
Xidan	Many conflicts between left turn bicycles and motor vehicles, due to lack of channelization for left turn bicycles to cross the junction.	Set up the waiting line for left turn bicycles for two-step crossing	The total number of conflicts had reduced from 22 to 16, in which serious conflicts has declined from 12 to 5. The average speed and 85% speed have slightly reduced	
	Some pedestrians cross the street on the ground without using the existing fly-over bridges or underpass which is high risk of crashes and conflicts.	Install leading sighs and barrier to guide pedestrians using existing facilities	The number of pedestrians crossing the junction on the ground declined from 27 to 12 per hour in peak hours.	
Da Wang	Lots of conflicts between right turn vehicles and bicycles/ pedestrians, due to high volume of right turn vehicles and vehicles turn right on red without giving way.	Set signal for right turn vehicles	The total number of conflicts declined from 32 to 19 and the number of serious conflicts declined from 14 to 7. While the speeds of right turn vehicles might be increased, as well as the movement of bicycles, due to non-separated traffic flows.	Set the right turn vehicle signal together with a separated lane for them
	Many buses stop at the north exit which was very closely to the junction where there was a high volume of passengers.	Build a long platform for passengers waiting, set the median barriers to guide people use zebra crossing line, paint a zebra crossing line between the bus stop and sidewalk	With the median barriers, 95% of passengers cross the street via the zebra (35% before). 43% of passengers use the zebra when they get off the bus after painting the zebra crossing line.	
Dongsi Shi Tiao	The junctions are too big for the pedestrians to cross in one stage	Install a refuge island for pedestrians to wait for a second stage crossing	89% of the pedestrians use the refuge island to cross the junction during peak hours, and 79% of them feel much safer when crossing the street (survey size wa 200). The average walking speed declined from 1.3 to 0.9 m/sec.	
Dongsi Shi Tiao (roundabout)	Only few bicyclists used the bicycle lanes because the barriers separated bicycles from motor vehicles were set inappropriately	Increase the width of bicycle lane; change the shape of the guiding line into a straight line; set a barrier to separate the bicycles and motor vehicles	The compliance rate of bicyclists has been increased at most of the sections, 5%-17% averagely.	

Before and after pictures at Dongsi Shi Tiao intersection *Source***: *GRSP (2008) (GRSP copyright to be checked)***

Before and after pictures at Da Wang intersection for bus situation improvement *Source***: *GRSP(2008) (GRSP copyright to be checked)***

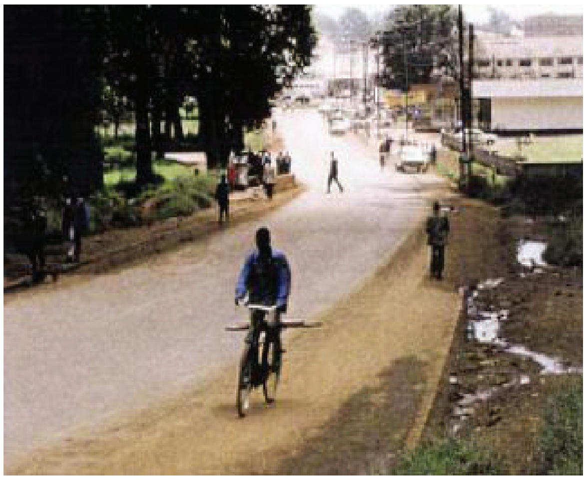
The key actors involved in the project include the World Bank/Urban Mobility Component of the SSA Transport Policy Program (SSATP), Eldoret Municipal Council and the Users of NMT (*Eldoret Transport Users Committee*).

Of the three intervention measures identified, the first two were aimed at NMT Safety:

1. Build special infrastructure for pedestrians and cyclists

2. Introduce traffic calming. measures to reduce vehicle speed and thus improve safety for NMT users

3. Interventions to improve the supply NMT.



Kisumu Road Prior to Intervention

The package of interventions on Kisumu Road included installation of new medians in combination with raised zebra crossings, pedestrian and cycle tracks and drains. The purpose of the medians on both sides of the approaches to Sosiani Bridge was to reduce speeds, making it impossible to overtake other vehicles. The intervention consisted of two new sections of 1.0 metres wide medians on 290 metres long sections of road on both sides.

Median on Kisumu Road Outbound from CBD

The cost of the medians was approximately US $25/m length. The cost of complete redesign of the bridge approaches (including medians, pedestrian and bicycle tracks, drains and raised crossings) was a total of US $21,000.

The project resulted in reduced accident rates (mainly due to reduced motorized vehicle speeds), reduced journey times and increased flows of NMT users, which in itself increased visibility and therefore safety of cyclists and pedestrians. Inbound average speeds were reduced from 48 km/h to 21 km/h and the maximum observed speed from 82 to 35 km/h. A similar reduction occurred with the outbound speeds. This is a speed reduction of 56.3 per cent. Traffic safety estimates a prevention of one fatal accident, three serious injuries and six vehicle/vehicle collisions per year. This corresponds to an estimated benefit of US $5,500 (3,000 for fatality, 250 per serious injury and 300 per vehicle-vehicle collisions).

There was a 13 per cent increase in cyclists, during the first three months after the opening (180 cyclists per day, inbound; same weather conditions). This increase represents a shift from minibus to bicycles.

The estimated annual cost savings associated with the above initial modal shift was approximately US $10,000. This implies a benefit-cost ratio of 2.3 for a modal shift from minibus to cycling (see Table 3.3).

Lessons for Africa

In most SSA African cities, half of the trips are made on foot. Pedestrians and cyclists are the most affected by the growing number of road accidents. Therefore, the lessons learnt from the above case studies, in particular the NMT Program in Kenya and Tanzania are a valuable tool to improve the daily mobility of those who are the most affected by such a crisis. The dissemination of the NMT assessment, together with World Bank NMT guidelines are expected to contribute to improving mobility.

The case studies demonstrate that significant improvements can be made through relatively small interventions. There is a need to increase awareness amongst politicians, planners, engineers and the public of the importance of addressing the needs of NMT users. The two areas of weakness of the Eldoret project were:

- Lack of true empowerment of the local authorities participating in the project (the NMT Consultants were firmly in charge of the process)
- Lack of dissemination of lessons learned to other key stakeholders

3.7 Unstanding road safety in SSA

It is important to note that road traffic crashes are predictable and can be prevented (WHO, 2004). It is, of course, possible to produce examples of incidents which are unique and not predictable, for example, a complete failure of the braking system on a large truck in Maputo causing the truck to crash into a queue of people waiting for a bus.

At a general level in any society it is possible to adopt a high level policy objective that says: "there shall be no deaths or serious injuries" in a road traffic environment. This then requires a completely new system-wide and integrated approach to risk reduction to deal with all those circumstances that may arise. In the case of the large truck killing people in a bus queue it is of course at the micro level not predictable. At the macro levels it is predictable that if we do not have a robust system of checks on the mechanical condition of trucks then such incidents will be more likely.

We can reduce this and take steps to reduce the risk. At the population level we know that pedestrians have a 90 per cent chance of surviving a car crash at 30 kph or below but less than a 50 per cent chance of surviving impacts at 45 kph or above (WHO, 2004: 77). A total system-wide speed control system can predict this level of death and take steps to prevent it. Also the system must have the ability to learn.

Table 3.3: Performance indicators in pilot areas: Eldoret Interventions

<table>
<tr><th>Intervention</th><th>Parameter</th><th>Target</th><th>Before</th><th>Post1</th><th>Post 2</th><th>Change (%)</th></tr>
<tr><td rowspan="2">Kisumu Road Bridge

Raised and middle islands</td><td rowspan="2">Cyclists waiting time</td><td>10 sec or less</td><td>60%</td><td>30%</td><td>71%</td><td>11% change means road is safer and cyclists wait less</td></tr>
<tr><td>10 sec or more</td><td>40%</td><td>60%</td><td>29%</td><td>Doubtful results hence repeat in post intervention 2</td></tr>
<tr><td rowspan="2">Kisumu road NMT count</td><td>Pedestrians footpath usage</td><td>10%</td><td>86%</td><td>99%</td><td>98%</td><td rowspan="2">Increased use of footpath is 12%</td></tr>
<tr><td>On the carriageway</td><td>10%</td><td>14%</td><td>1.5%</td><td>2%</td></tr>
<tr><td>At Harambee junction using carriageway</td><td>Cyclists count</td><td>10%</td><td>57%</td><td>7%</td><td>9%</td><td>Number of cyclists went down because day of count was national exam day</td></tr>
<tr><td rowspan="4">NMT count on Kisumu Road</td><td>Fewer cyclists on road</td><td>10%</td><td>100%</td><td>50%</td><td>84%</td><td rowspan="2">16% reduction achieved</td></tr>
<tr><td>Cyclists on new track</td><td>10%</td><td>N/a</td><td>50%</td><td>16%</td></tr>
<tr><td>Fewer pedestrians on road</td><td>10%</td><td>40%</td><td>0.5%</td><td>0.4%</td><td rowspan="2">Pedestrians now use NMT track</td></tr>
<tr><td>Pedestrians on new track</td><td>10%</td><td>60%</td><td>99.5%</td><td>99.6%</td></tr>
<tr><td rowspan="2">Street Links -
Uganda Road Muliro-D link</td><td>Cyclists on track</td><td>1%</td><td>N/a</td><td>12%</td><td>7%</td><td rowspan="2">Majority of cyclists prefer carriageway to cycle tracks</td></tr>
<tr><td>On carriageway</td><td>1%</td><td>N/a</td><td>88%</td><td>93%</td></tr>
<tr><td rowspan="2">Kago - Tagore link</td><td>Cyclists on track</td><td>1%</td><td>N/a</td><td>8%</td><td>5%</td><td rowspan="2">Majority of cyclists prefer carriageway to cycle tracks</td></tr>
<tr><td>Cyclists on carriageway</td><td>1%</td><td>N/a</td><td>92%</td><td>95%</td></tr>
<tr><td rowspan="2">Tagore - Paul's Bakery</td><td>Cyclists on track</td><td>1%</td><td>Not measured</td><td>Not measured</td><td>5%</td><td rowspan="2">Pedestrian monopoly of cycle track</td></tr>
<tr><td>Cyclists on carriageway</td><td>1%</td><td>Not measured</td><td>Not measured</td><td>95%</td></tr>
<tr><td rowspan="2">Walking time Market road to Footbridge</td><td>Pedestrian speed minutes</td><td>-</td><td>8</td><td>6</td><td>4</td><td rowspan="2">Faster speed due to improved surface</td></tr>
<tr><td>Km/h</td><td>-</td><td>2.25</td><td>3</td><td>4.5</td></tr>
</table>

*Source: **SSATP (2002)***

If an incident should happen that is deemed "not predictable" then all lessons from it can be learnt and implemented across the system as a whole to prevent similar things happening in the future. Effective learning shifts the non-predictable element into the category that is predictable. This predictability and preventability is a vital part of the Swedish Vision Zero road safety policy which also exists under different names in Denmark and Norway and brings with it a serious overall system wide effort to deal with all components of the road traffic system including the vulnerability of the human body to damage when hit by one tonne of metal (Whitelegg and Haq, 2004).

Fatalities in SSA can be dramatically reduced and this will require highly co-ordinated interventions across many areas of governmental and public health responsibility. There are no technical, financial or other barriers to achieving a major public health gain in SSA and a gain that will produce substantial benefits in terms of quality of life for African citizens, poverty reduction and much improved access to education, health care, jobs and training opportunities.

The fundamental challenge in road safety is to produce the road safety paradigm shift (WHO, 2004). This is summarised below in Figure 3.5.

Road injury prevention and control - the new understanding

- Road crash injury is largely preventable and predictable; it is a human-made problem amenable to rational analysis and countermeasure
- Road safety is a multisectoral issue and a public health issue - all sectors, including health, need to be fully engaged in responsibility, activity and advocacy for road crash injury prevention
- Common driving errors and common pedestrian behaviour should not lead to death and serious injury - the traffic system should help users to cope iwth increasingly demanding conditions
- The vulnerability of the human body should be a limiting design parameter for the traffic system and speed management is central
- Road crash injury is a social equity issue - equal protection to all road users should be aimed for since non-motor vehicle users bear a disproportionate share of road injury and risk
- Technology transfer from high-income to low-income countries needs to fit local conditions and should address research-based local needs
- Local knowledge needs to inform the implementation of local solutions

Figure 3.5: The Road Safety Paradigm Shift

Source: WHO (2004: 7)

4 TRAFFIC FLOW MANAGEMENT

4.1 Introduction

Traffic congestion is becoming a common occurrence in many major urban centres in SSA as the number and use of motor vehicles increases. Traffic congestion impedes economic development and has a number of social and environmental impacts. Congestion occurs when the volume of traffic is greater that the available capacity on a particular road or intersection. At this point the road becomes saturated and results in slower speeds, long trip times and an increase in vehicle queuing and air pollution. There are a number of specific circumstances that can cause or aggravate traffic congestion (e.g. road works, damage to roads and road crashes). These can have a ripple effect across the road network reducing the road capacity at a given point or over a certain length and resulting in a sustained traffic jam.

Traffic flow management (TFM) is a set of strategic practices utilized by transport authorities to ensure uniform vehicle flow and to avoid delays due to congestion and ultimately to improve safety.

Traffic flow theories aim to describe, in a precise mathematical way, the interaction between vehicles and their operations (the mobile component) and the infrastructure (the immobile component). The latter consists of the road network and all its elements: control devices, signage, marking etc. The scientific study of traffic flow had its beginnings in the 1930s with the application of probability theory to the description of road traffic and the pioneering studies conducted by Bruce D. Greenshields at the Yale Bureau of Highway Traffic; the study of models relating volume and speed and the investigation of performance of traffic at intersections. The 1950s saw theoretical developments based on a variety of approaches, such as car-following, traffic wave theory (hydrodynamic analogy) and queuing theory.

This chapter provides a summary of traffic flow theory. It gives an overview of traffic flow trends in SSA. Key issues and management challenges and policy measures and their relevance to SSA countries are discussed.

4.2 Current trends in traffic flow management in SSA

Increasing traffic congestion makes it impossible to sustain economic growth. Although congestion and delays are phenomena that influence many African countries the extent of the congestion and delays experienced and the economic, social and environmental impacts are rarely quantified an assessed. Little published data on traffic congestion trends for the African continent are available. However, qualitative statements for various countries were available from the Trans Africa Consortium (TAC) (2008). Table 4.2 summaries these qualitative statements.

The Trans Africa Consortium (2008) concludes that, besides infrastructure challenges, poor road discipline also hinders transport improvement. Drivers observe driving rules only when absolutely necessary, and this is also one of the main causes of urban congestion. Furthermore, vehicle braking systems are often worn out earlier than expected. This may be due to urban drivers constantly braking due to the road conditions, but more frequently because of traffic congestion.

4.3 Key issues in traffic flow management

Traffic flows are measured using specific attributes. These attributes are:

- Rates of flow or volume (vehicles per unit time),
- Speeds (distance per unit time),
- Density (vehicles per unit distance),
- Gaps, headways, time-to-collision and shockwaves,
- travel time or delay over a known length of road, and
- Driver behavioural aspects.

Traffic Volume, Speed and Density

Flow rates are collected directly through point measurements, and by definition require measurement over time. They cannot be estimated from a single snapshot of a length of road. Flow rates and time

Table 4.2: Qualitative congestion statements for various African countries

Country	Statement
Central African Republic	The inadequate road infrastructure is unable to cope with this growing road traffic which results in congestion and various forms of pollution.
Tanzania	The existing transport system is mainly characterised by congestion and delays, poor vehicle condition and increasing road accidents.
Uganda	The rapid development of the bicycle and motorcycle taxi (“boda-boda”) service, in recent years, is to be noted. The problem of the use and operation of these small capacity units is that they are inefficient and a major source of traffic congestion in the urban areas; particularly in Kampala City.
Côte d’Ivoire	The spectacular proliferation of informal transport in a context of an insufficient supply has resulted in the degradation of the urban transport system, causing congestion, unsafe roads and pollution.
Nigeria	The rapid urbanization of its metropolitan area, combined with inadequate or poorly executed development plans, has given rise to numerous transportation problems in this metropolis. These include increasing traffic congestion, the worsening state of disrepair of roads, deteriorated physical attractiveness and comfort of road-based public transport, rising levels of road accidents and increasing rates of traffic-related emission and atmospheric pollution alongside the growing menace of “Okada” (motorcycle) transporters.
Mauritius	In the wake of the country’s prosperity, some transport problems appeared, such as the severe congestion afflicting all traffic entering and leaving Port Louis, the capital, during peak hours. This problem has become more acute in the last five years as more people have acquired cars and started to use them to commute to work.
Mozambique	Government is adopting a medium and long term strategy to relieve congestion in urban centres by allowing access to large buses only, with minibuses serving the outskirts.

Source: Trans Africa Consortium (2008)

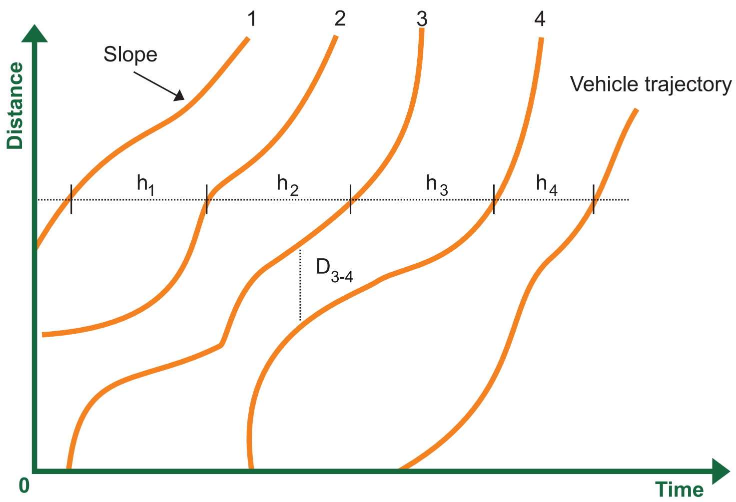


Figure 4.1: Time-space diagram *Source: Based on Koutsopoulos (2004)*

headways (i.e. the distance between the front of one vehicle and the front of Vehicle behind) and are related to each other.

Flow rate is the number of vehicles counted, divided by the elapsed time.

Speed is the distance travelled by a vehicle during a unit of time. It can be expressed in kilometres per hour (km/h), miles per hour (mi/h), metres per second (m/s) and feet per second (ft/s).

The speed of a vehicle at any time, *t*, is the slope of the time-space diagram for that vehicle at time *t* (see Figure 4.1). The time headways are indicated with h_1, h_2 etc. and $D_{3\text{-}4}$ is the physical distance between vehicle three and vehicle four (Vanderschuren, 2006).

Speed can refer to the velocity of an individual vehicle at a point in time, as in the time-space diagram. However, speed can also be aggregated and averaged over a number of vehicles:

Space mean speed is the averaging speeds of vehicles over a highway section at an instant of time.

Time mean speed is the averaging speeds of vehicles over a time period at a particular spot.

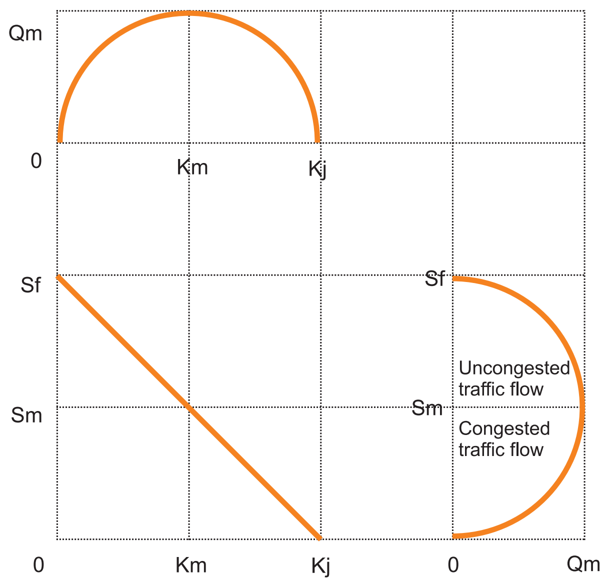
Traditionally, the analysis of traffic flows was very much based on the relationship between the aggregated variables ***speed*** (S), ***density*** (K) and ***volume/flow*** (Q).

Volume or flow is the equivalent hourly rate at which vehicles pass a cross section on a highway.

Density or concentration is the number of vehicles travelling over a unit length of the highway per unit time. The unit length is usually one kilometre, thereby making vehicles per kilometre (veh/km) the unit of density.

Figure 4.2 provides a simplified version of the relationship between speed, flow and density.

The relationship between the density (veh/km) and the corresponding flow of traffic on a highway is generally referred to as the fundamental diagram.



Q_m is the optimal traffic flow (veh/h)
S_m is the speed corresponding with the optimal flow (km/h)
U_f is the free flow speed (km/h)
K_m is the density corresponding with the optimal flow (veh/km)
K_j is the jam density (veh/km).

Figure 4.2: Speed, flow and density relationship *Source: Based on Greenshields and Weida(1952)*

The following theory has been postulated with respect to the shape of the curve depicting this relationship (Garber and Hoel, 2001).

- When the density on the highway is zero, the flow is also zero because there are no vehicles.
- As density increases, flow increases and speed tends to decrease.
- However, when density reaches a maximum value, generally referred to as the jam density (K_j), the flow must be zero because vehicles will tend to come to a complete standstill (so no flow).
- It follows that as density increases from zero, the flow will initially increase from zero to a maximum value (Q_m). Further continuous increases in density will then result in a continuous reduction of the flow, which will eventually be zero when the density is equal to the jam density. Note that the shape of the curve is parabolic in the Greenshields model (see Figure 4.2, top left-hand corner). Several other models for the fundamental diagram have been proposed but they all show the above properties, except for some models that allow for the occurrence of discontinuities in flow.
- Speeds that are/can be realised on the freeway are directly related to the fundamental diagram (included in Figure 4.2).

The shape and values of the curves in Figure 4.2 depend on the prevailing traffic and roadway conditions on the segment of the road under study and on its length in determining the density. Moreover, actual data generally shows discontinuities in the neighbourhood of the capacity level (maximum flow). These discontinuities are a result of aggregation of the data and the fast transition from freely moving traffic to congestion in practice.

Gap, Headways, Shockwaves and Time-To-Collision

Volume, speeds and densities, as described above provide aggregated information. To improve traffic flows, the detailed functioning and the aspects of individual vehicles need to be understood. In traffic flow theory the distance between the rear end of a vehicle and the front of the next vehicle is called a gap. The distance between the front of vehicle A and the front of Vehicle B is called the headway (see Figure 4.3).

In practice it is not possible to measure the distance between vehicles. Equipment is used that measures the time between two vehicles passing a certain point. In this case a time gap or time headway is established.

Traffic flows often encounter so called bottlenecks. A bottleneck occurs when the infrastructure challenges the traffic flow. A reduction in lanes is an example of a bottleneck. Instability of traffic flows and measurement of individual vehicles can provide an indication of the safety risk. Moreover, instability is one of the key factors responsible for traffic congestion.

Figure 4.4 provides a simplified time-space diagram (see also Figure 4.1). Here it is assumed that all vehicles travel at the same speed with the same distance between them. The lines are, therefore, linear. At a certain moment in time, the second vehicle's speed drops due to a bottleneck. All following vehicles will need to reduce speed too.

The area in the triangle between the first vehicle speed slope, the shockwave line and the recovery shockwave gives an indication of the severity of the shockwave. Shockwaves, depending on the slope of the shockwave and the recovery shockwave, can 'travel' forwards

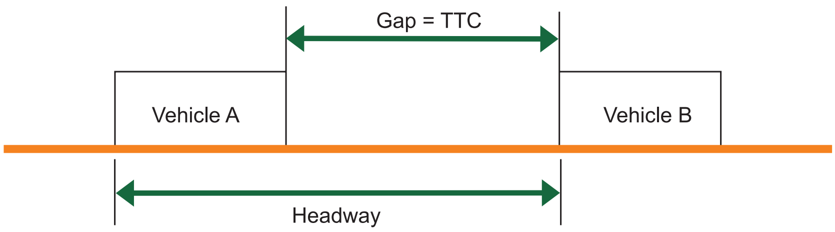


Figure 4.3: Vehicle gap and headway

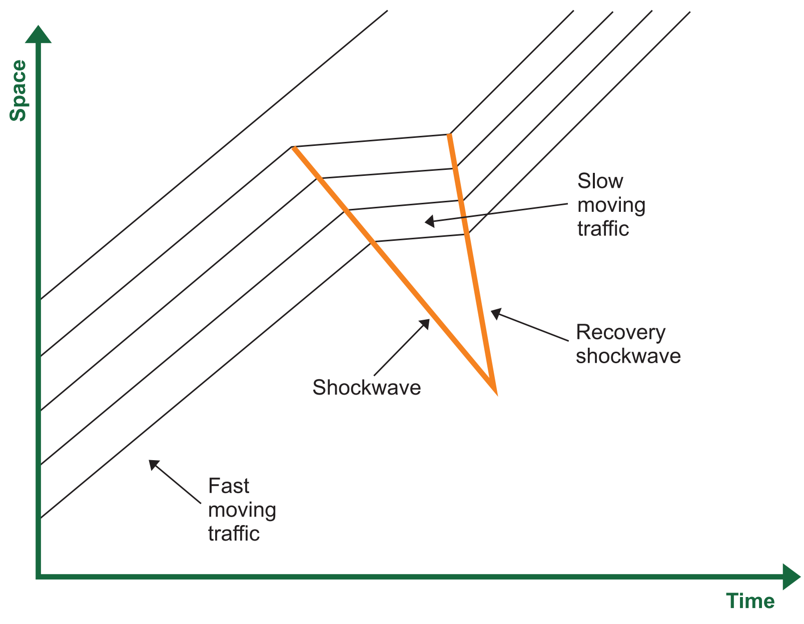


Figure 4.4: Shockwave illustration based on vehicle trajectories

Source: Based on Koutsopoulos (2004)

or backwards. As indicated, shockwaves are an indication of irregular traffic flows and a road safety risk.

Another indication for a safety risk is the Time-To-Collision (TTC). The time–to-collision was first introduced and applied by Hayward (1972). A TTC value at an instant t (t could be when a loop is passed or at set intervals, i.e. every minute for example) is defined as the time that remains until a collision between two vehicles would have occurred if the collision course and speed difference remained the same (Hyden, 1996). The higher the TTC is, the safer the situation.

Figure 4.5 provides an illustration of the TTC with two vehicle trajectories. It illustrates graphically the relationship between the distance and time based on TTC.

To determine how safe a situation is, a TTC threshold value is needed. Hirst and Graham (1997) indicate that the TTC of four seconds could be used to discriminate between cases where drivers unintentionally find themselves in a dangerous situation from cases where drivers remain in control. The same study indicates that a TTC warning system at four to five seconds produces many false alarms. The TTC warning system seems to work optimally at three seconds. A study investigating Intelligent Cruise Control (ICC) found that a minimum TTC value of 3.5 seconds is needed for non-ICC drivers and 2.6 seconds for ICC drivers. Nevertheless, the 2.6 seconds value is regarded as a safety concern (Hogema and Janssen, 1996). Based on this literature, it can be concluded that a TTC of less than three seconds is regarded as a safety risk.

Travel Time and Delay

Bottlenecks will lead to an increase in travel time and delays. The physical characteristics of the road network, such as street widths and intersection density have a strong effect on traffic flow. Traditionally, this ease of a traffic flow is measured at the ***Level Of Service*** (LOS). Figure 4.6 shows the level of service areas within the speed-flow diagram. The LOS varies between A and F, where A is a very good LOS and F is a very bad LOS. It is possible to indicate the LOS in the speed-flow part of the fundamental diagram.

Driver Behaviour

Cumming (1963) categorised the various sub-tasks that are involved in the overall driving task and paralleled the driver's role as an information processor. To model Intelligent Transport Systems (ITS) (information and communication technology applied to transport infrastructure and vehicles) that improve transport outcomes such as transport safety, transport productivity, travel reliability, requires the modelling of longitudinal (car following) and lateral behaviour of vehicles.

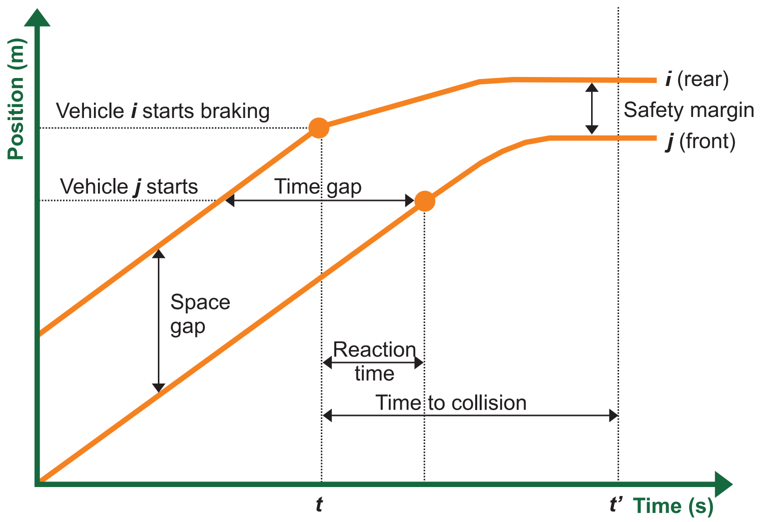


Figure 4.5: Time-To-Collision notion illustrated with vehicle trajectories *Source: Adapted from Minderhoud and Bovy (2001)*

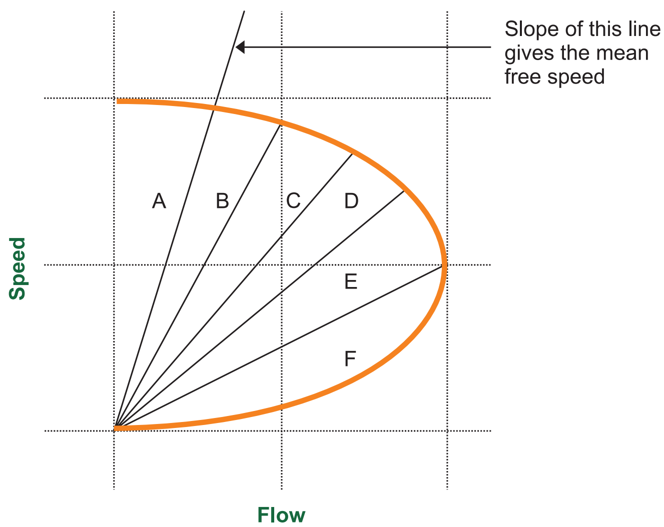


Figure 4.6:Level of Service areas within the speed-flow diagram *Source?*

In car following, inertia also provides direct feedback data to the driver, which is proportional to the acceleration of the vehicle. Inertia also has a smoothing effect on the performance requirements of the operator, since the large masses and limited output of drive-trains (group of components that generate power and deliver it to the road surface, water, or air e.g. engine, drive shafts) eliminate high frequency components of the task.

Car following models have not explicitly attempted to take all of these factors into account. The approach that is used assumes that a stimulus-response relationship exists that describes the control process of a driver-vehicle unit. The stimulus-response equation expresses the concept that a driver of a vehicle responds to a given stimulus according to a relation:

$$\text{Response} = \lambda \text{ Stimulus} \quad (4.1)$$

Where:
λ is a proportionality factor.

Stimulus is composed of many factors: speed, relative speed, inter-vehicle spacing, accelerations, vehicle performance, driver thresholds (i.e. alertness, aggression) etc.

Gap Acceptance and ***Lane Changing*** are the main aspects with regards to the modelling of lateral driving behaviour. A driver entering into or going across a traffic stream must evaluate the space between a potentially conflicting vehicle and itself and decide whether to cross or enter or not. "Gap" means the time and space that a subject vehicle needs to merge adequately safely between two vehicles. Gap acceptance is the minimum gap required to finish lane changing safely. Therefore, a gap acceptance model can help describe how a driver judges whether to accept or not.

Lane changing refers to overtaking and generally estimates if the space available in the bordering lane is enough for the vehicle to move into and back. The required space is dependent on the characteristics of the driver, the vehicle and the road. The available space depends on the characteristics of the vehicles in the bordering lane (might be oncoming) and the vehicle in front. Drivers have to perceive all these characteristics, process them and come to a decision.

Humans differ in perception capabilities, e.g. the ability to estimate distances can vary substantially between persons, and they differ in the acceptation of risk. The total acceptance process depends on many factors, of which only a subset is observable. This has led to the introduction of models to estimate the probable distributions of potential outcomes.

The modelling of gap acceptance is done in several ways. Possible components included are the mean gap, the critical gap, the offered gap, the accepted gap, the acceleration gap and the rejected gap. For the modelling of these gaps, a distribution is applied. An example of the distributions is provided in Table 4.1.

Mandatory lane changes, desired lane changes and overtaking movements are generally included in lane-changing models (see Figure 4.7). The desired lane change between cross-sections a and b is carried out in order to get into a better starting position for the mandatory lane change between cross-sections b and c. A driver is prepared to accept a higher risk at a mandatory lane change than at a desired lane change (Hoogendoorn *et al*., 2005).

An overtaking, see Figure 4.8, will primarily be carried out to maintain the desired speed or to deviate less from it. The overtaking consists of two parts: a lane change to the left and a lane change to the right (assuming that driving takes place on the right-hand side). These are more or less independent manoeuvres (Hoogendoorn *et al*., 2005).

The different traffic flow theories and modelling of specific variables allow a better understanding of driver behaviour and traffic congestion and can assist in transport planning. In developing countries, vehicle ownership represents growing affluence and social status. Faced with rising transport demand and growing negative environmental impacts, city authorities need to develop approaches to address their transport needs and manage traffic flow.

4.4 Challenges in Traffic Flow Management in SSA

In almost all parts of SSA, cities are grappling with the multiple challenges of an expanding urban population, rapid motorization and worsening traffic congestion. These factors are decreasing the quality and quantity of mobility options. The success or failure of managing transport and traffic flow will be dependent on how cities respond to these challenges and the level of integrated approaches taken to address the problem of increasing car fleets, congestion and limited road space while meeting the need to provide low-cost mobility for the masses.

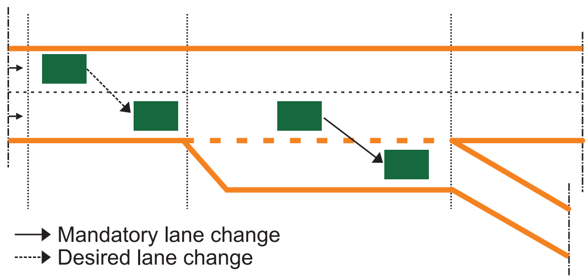


Figure 4.7: Mandatory and desired lane change *Source: Hoogendoorn et al. (2005)*

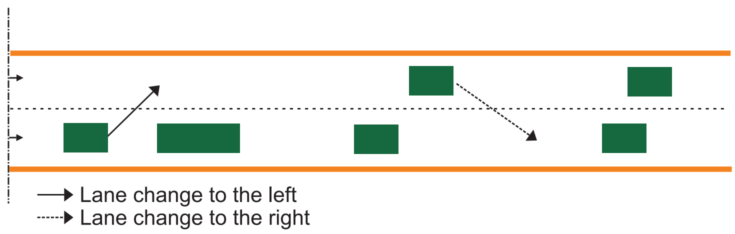


Figure 4.8: Lane changes at an overtaking *Source: Hoogendoorn et al. (2005)*

Table 4.1: Distribution of the gap acceptance indicators

Main gap (class)	Distribution critical gap	Number of offered gaps	Number of accepted gaps	Distribution of accepted gaps	Number of rejected gaps	Distribution of rejected gaps
5	0.00	0	0	0.00	0	0.00
7	0.00	30	0	0.00	30	0.50
9	0.33	30	10	0.11	20	0.83
11	0.67	30	20	0.33	10	1.00
13	1.00	30	30	0.66	0	1.00
15	1.00	30	30	1.00	0	1.00
Sum		**150**	**90**		**60**	

Source: Brilon et al. (1997)

The first challenge is to make cities authorities aware of the importance of efficient, affordable mass transit and NMT as a means of ensuring traffic flow and economic growth.

Secondly, it is necessary to provide governments with knowledge how to implement cost-effective models that result in a maximum of environmental, social and economic benefits and thus solve Africa's urban transport problems in the most sustainable way possible. These models will have to include knowledge on how to address:

- ineffective public transport and its poor network integration
- the non-existence of any transport demand measures (i.e. parking policies, road access limitation, road pricing)
- the poor quality of cycling and walking infrastructure
- the lack of integrated land use policies (to reduce travel distances and demand).

An '*Avoid-Shift-Improve'* approach could provide the opportunity to "leapfrog" to a transport system that provides efficient, convenient and attractive alternatives to the private car (see Figure 4.9). However, there will be political, technical and financial barriers to overcome when targeting such a "paradigm shift":

Political structure and political will

Large scale infrastructure projects may face potential public opposition and pressure from single interest groups, established market participants against change may prevent the implementation of new approaches toward urban transport. Hence all governments need strong support to address those risks.

Technical and institutional capacity

Even if political will exists, weak institutional settings could be a high risk to reform processes and new projects. In many African cities, multiple agencies exist with a certain mandate to rule traffic (municipal traffic department, police, transport ministry, transport directorate etc.). This leads to confusion, unaccountability and limits the ability of authorities to take decisions.

For measures that are envisaged to improve the transport system efficiency it is possible that insufficient capacities at the technical and institutional levels can result in a failure of the measures. The importance of institutional conditions is often undervalued; while others such as infrastructure provision is a significant challenge, especially in terms of financing.

Disregard of new regulations or Underutilization of new services or travel options

It is possible that the implementation of the planned measures does not result in the expected impacts on traffic flow. This may be due to poor design, lack of enforcement, lack of road safety, too expensive fares, or the lack of public awareness about new options or regulations.

4.5 TFM policy measures

Policy measures taken around the world to improve traffic flows and reduce congestion can be categorised as measures that avoid, shift or improve traffic flows. Measures can also have a combined impact and can influence each other, having a positive or negative effect. Figure 4.9 provides an overview of potential measures and indicates whether the measure would have a long, medium or short term effect as well the extent of investment and education required.

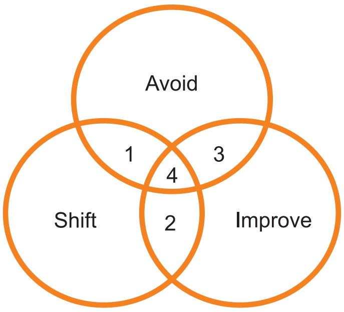
In general, short to medium term measures with limited investment requirements are most likely to be adopted in the African context. TDM, ITS and traffic management are the most promising measures. These measures should be complemented by specific campaigns. Various financial (dis)incentives are also promising. Nonetheless, the implementation might require legal changes, which take time.

TDM measures generally try to avoid and/or shift transport to more sustainable modes. TDM, also called Mobility Management, is a general term for strategies that result in more efficient use of transportation resources. Most individual TDM strategies have modest impacts, affecting a small portion of total vehicle travel, but their impacts are cumulative and synergistic. An integrated TDM program can often reduce 20-30 per cent of private vehicle travel where it is applied. Some studies suggest that comprehensive implementation of TDM strategies, to the degree that they are economically justified, could reduce total vehicle kilometres travelled by more than a third (www.vtpi.org). TDM measures, such as car/ride sharing, adaptive work schedules, tele-working, tele-learning or tele-shopping, can be pursued to decrease mobility and congestion growth.

Traffic management generally improves and/or reduces traffic flows, through the reduction of stop and go, improved navigation information, improved information and processes to clear incidents and provide priority to more sustainable modes (such as public transport).

Traffic management and ITS measures focus on the improvement of traffic flows. The focus is on increased throughput (volume), speeds and densities, while reducing gaps, headways, time-to-collision and shockwaves. In parallel, travel times and delays are often reduced.

Impaired levels of infrastructure maintenance have been identified as one of the negative forces on traffic flows, contributing to congestions. In SSA countries substantial investment will be required to improve infrastructure maintenance to acceptable levels. Due to the substantial maintenance backlog, this will require a large amount of time and investment.



AVOID	1	SHIFT	2	IMPROVE	3
•Land Use Planning (L, LI)	•Urban Infrastructure (Re)Design (M, I)	•Inter-modal Infrastructure Development (M, I)	•Taxes and Charges (M, F)	•Training of Transport Operators (S, SI&E)	**•Traffic Management (M, I&E)**
•Vehicle Occupancy Management - car sharing (M, E)	**•Travel Demand Management (S to M, E)**	•Incentives for New Technology Adoption (S, SI)	•Rebates and Subsidies (M, F)	•Training of Human Resources for Traffic Management (S, SI&E)	•Fleet Management (S, E)
•Vehicle Load Management (M, E)		•Improved Non-Motorized Transport Infrastructure (M, I)	**• Marketing Campaigns (S, SI)**	•Vehicle Design Improvements (M, LI)	
•Logistics Management (M, E)		•Provision of Integrated Public Transport Systems (M, LI)	**•Infrastructure Maintenance (M, I)**		
•Information Technology Substituting Travel (M, I&E)			**•Intelligent Transport Systems (S to M, I)**		

L = Long term
M = Medium term
S = Short term
LI = Large Investment
I = Investment
SI = Small investment
F = Financial (but not investment)
E = Education

Figure 4.9 Traffic flow improvement and congestion decrease measures *Source?*

CASE STUDY

Beijing Traffic Demand Management during Olympic Games

The fifteenth summer Olympic Games was held in Beijing (China) on 8-24 August 2008. In order to meet the traffic demand of the Olympic Games, achieve the successful operation of transport for the Olympics as well as the city, Beijing took a series of integrated measures aimed at improving the traffic situation. TDM was one of main measures adopted by the Beijing Olympics Organizing Committee.

Objectives

The objective of the Beijing TDM is consistent with the whole Olympic traffic planning. It was aimed at reducing the total amount of motor vehicles on the road and ensuring the road network could meet transport demand during the Beijing Olympic Games and Paralympics Games. The TDM programme also aimed to guarantee the provision of public transport for the citizens and minimize the impacts to normal citizens' daily work and life. As well as to reduce motor vehicle exhaust emissions and contribute to improving air quality.

Before and after TDM measures Yongshen Quan, Haihong Ma, etc, 2010. *Source?*

Measures

Reducing the total amount of motor vehicles

From 1-19 July (Phase I) all emission vehicles were banned on the road. A total of 30 per cent of the motor vehicles which belonged to Beijing administrative area were suspended.

From 20 July to 20 September (Phase II) emission vehicles were banned on the road. Motor vehicles with odd license plates numbers were only able be used on the road on odd days. Even license plates numbers cars on even days. Based on this measure, 70 per cent of the motor vehicles which belonged to Beijing administrative area were suspended

Established road lanes for Olympic traffic

Increased public transport

Beijing Public Transport Group increased the number of buses and added 34 Olympic bus lines which reduced the waiting time. In addition, Beijing subway operating company improved the frequency and capacity of trains. Meanwhile, passengers who had valid tickets for the Olympic Games had the free bus and subway service.

Logistics guarantee measures

A "Green Car Team" was organized to take the responsibility of food and production delivery. These cars were selected by Beijing Traffic Management Bureau and met high environmental standards.

Other measures

The punishment for vehicles that violate the rules was increased. Times for work and shopping were change in order to have different peak hours.

Impact

These measures resulted in a reduction of 1.8 million motor vehicles on the road. The morning peak hours of public bus changed from 6:30-8:00 to 6:30 -9:00. The bus trips increased from 152,000 to 167,000 per day. Approximately 350 bus lines expanded their operational hours, morning departure time shifted to 5:30 and night departure time shifted to 22:00. The average speed of buses increased from 14.5 km/h to 20 km/h – an increase of approximately 30 per cent. During the Olympic Games, nearly 4.5 million people shifted to public transport each day with the passenger volume reaching a new record 0f 21.1 million.

Meanwhile, Olympic TDM indirectly changed the modal share of traffic. According to the Beijing Transport annual report, in 2006, the modal share of Beijing citizens was: car 31.6, public bus 24.4 and subway 5.8 per cent. The proportion of public transport was lower than the car. After the implementation of TDM measures, the daily passengers transported by public transport were more than 20 million. The proportion of public transport in all traffic modes increased to 45 per cent – a 14.8 per cent increase compared to 2006.

Lessons for Africa

This case study provides lessons for TDM for a large-scale event. The traffic plan and supply of infrastructure should focus not only on the special event, but also on normal/daily demand of the city.

An integrated traffic planning system that used TDM measures was essential for a large-scale event such as the Olympics. However, the strength of policies and the necessary supporting conditions were important, especially the role of public transport and the risk assessment of traffic safety which reduces security risk and increases the capacity to deal with emergency issues.

CASE STUDY

The Guanghzou Bus Rapid Transit Project (BRT)

In 2007 the city of Guangzhou (China) with a population of approximately 10 million people undertook preliminary engineering designs and road works for a Bus Rapid Transit (BRT) system. The BRT system was planned by Guangzhou Municipal Technology Development Corporation in collaboration with ITDP. The BRT has been operated since October 2008.

Guangzhou's BRT system aimed to rival the renowned TransMilenio system of Bogotá (Colombia) by delivering average bus speeds of more than 25 kilometres (15.5 miles) per hour, and carrying more than 25,000 passengers per hour in one direction at peak periods.

The passenger capacity, which is delivered at a higher speed and under better service conditions, is more than double than any other existing or planned BRT system in Asia. In contrast to TransMilenio, Guangzhou's BRT buses also operates outside the bus way, eliminating the time and inconvenience of transfers.

The first BRT corridor developed is 23 kms (14.3 miles) and has 29 stations, starting from the city centre and extending eastward along Zhongshan Avenue. More than 600,000 daily passengers use this BRT corridor. One hour is saved in travel time each day for commuters travelling along the full corridor into the city centre in the morning and returning in the evening. Total passenger time savings from the new system exceed 100,000 hours each day, or more than 36 million passenger-hours each year.

Objectives

The overall goal of this project was to create the technical and institutional basis for implementing metropolitan sustainable transport networks and systems and establish a demonstration corridor for sustainable urban mobility. To reach this goal, the project intended to build awareness and understanding among policy makers, stakeholders and the general public in Guangzhou on the importance and benefits of establishing suitable and sustainable transport systems in the city.

BRT Station rendering *(Source: ITDP / GMTDC) (Copyright?)*

Measures

The buses being withdrawn from general traffic and taken into the BRT lanes account for up to one third of all the traffic in the western part of the Zhongshan Avenue corridor. In Zhongshan Av the travel speed for mixed traffic increased from 12 km/h to more than 30 km/h.

Impact

The BRT has had a major positive impact on the mixed traffic along the BRT corridor, especially in Zhongshan Avenue. The buses being withdrawn from general traffic and taken into the BRT lanes account for up to one third of all the traffic in the western part of the Zhongshan Av corridor. In Zhongshan Av the travel speed for mixed traffic increased from 12 km/h to more than 30 km/h. This positive impact comes from signal phase changes as well as the huge traffic impact of withdrawing more than 400 buses per hour from the mixed traffic lanes in this location.

In addition, there has been:

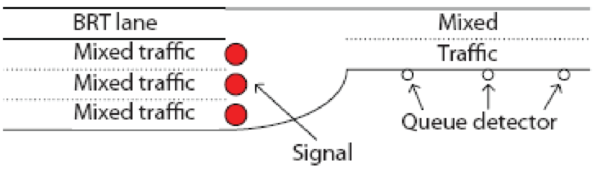
- mixed traffic improvements (including bikes and pedestrians) at the same time as the bus priority measures. For example, in one of most congested parts of the city (Gangding), 24 metres out of the road width of 42 metres (kerb to kerb) was allocated exclusively to buses, which had benefits also for other all modes.
- a reduction in delays and improvement of speed for all modes due to reducing signal phases from 4-phase to 3 phase or 2 phase
- benefits from locating stations located away from intersections with a 20 per cent increase in bus passenger throughput, car throughput and increase in speeds. However, the increase in car speed is temporary. For cars moving from other parallel corridors into the BRT corridor reduces speed.

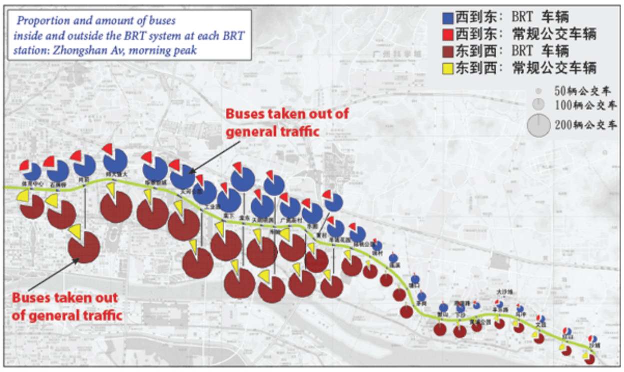
The BRT has improved the conditions for all modes.

Mixed traffic operation through constrained points

The standard BRT configuration was applied to most of the Zhongshan Avenue corridor. However, there were some points such as flyovers the standard configuration has to be modified. The favoured option at flyovers was to end the BRT lane and operate in mixed traffic. This approach was applied in other corridors in the city.

Although it is possible to simply terminate the BRT lane at approximately 50m before the bottleneck without any special control, a better approach is to install a special traffic light signal to control congestion on the grade separated section (or bridge or other restricted point). This signal is based on average occupancy of the controlled link, and is especially useful even without bus lanes to avoid congestion and related air pollution in tunnels. The general approach is illustrated below. This device is known as a congestion control signal (CCS).

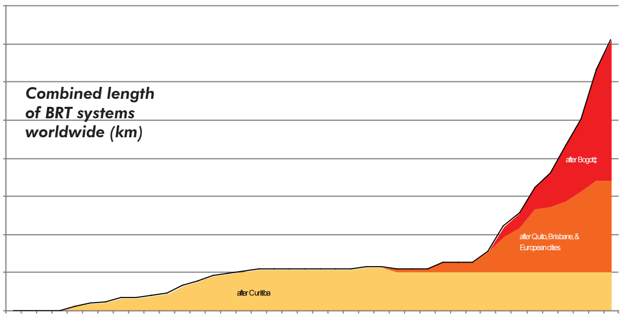




Lessons for Africa

Urban transport best practices such as BRT and bike sharing have spread in much the same way that other technologies spread. The graph below shows the growth of total BRT kms in the world. The figures begin with Curitiba (Brazil) which led way with its first class BRT system. However, this extensive replication resulted in poorly developed BRT systems in being developed. It was not until new 'gold standard' BRT systems were opened in Quito, (Ecuador); Brisbane (Australia); and finally TransMilenio in Bogotá (Colombia), did BRT begin to be adopted internationally. Cities in Africa are in a well positioned to adopt BRT with minimal external intervention.

Gangding Bus station before and after the BRT implementation



Global Expansion of BRT Systems after Key Milestones

Source: ITDP Copyright?

CASE STUDY

Lagos Bus Rapid Transit Project

Lagos (Nigeria) is a megacity with approximately 13 million residents. Before 2008 Lagos did not have an organised public transport system. Public mobility was exclusively based on a fleet of 75,000 minibuses (danfo), some midi-buses (molue) and shared taxis (kabu-kabu). This led to an unsafe system with poorly maintained rolling stock, low capacity, high prices (private operators) and the need for numerous transfers.

With the political changes in 1999 the need for a reformation of the transport sector was recognized. This resulted in the Lagos Urban Transport Project (LUTP) which aimed to build capacity and identify key actions and investments. In 2002 the Lagos Metropolitan Area Transport Authority (LAMATA) was established as a key authority to address transportation issues in the city. LAMATA worked with the World Bank and other national and local agencies to implement its objectives.

Objectives

Traffic development in Lagos had three main objectives related to economic growth competitiveness, poverty reduction and better accessibility and improved environmental quality via reduced congestion.

The BRT-Lite system (partial segregation of buses) aimed to provide a low cost and efficient service. This would provide buses with high safety standards which would be fast and frequent and improve overall traffic flow. The system would assist in improving environmental quality and address social inequalities.

Lagos Rush Hour *(Source: Mobereola, Dayo) (Copyright?)*

Measures

In a BRT-Lite system only 65 per cent of buses are physically segregated through concrete curbs and another 20 per cent through road markings. Bus shelters were built at every stop instead of elevated platform: The shelters protect waiting passengers from the sun and include a ticket counter allow passengers to queue orderly in front of the bus doors.

The cost of BRT-Lite scheme was significantly lower (US $1.7 million per km instead of approx. $6 million). The planning and building of the first corridor took only 15 months. It was 22 km and was built on a radial highway between *Lagos Island* (Central Business District) and the quarter *Mile 12* in the north. BRT buses operate everyday from 6 am to 10pm with a headway of 30-60 seconds.

In order to develop knowledge of the BRT-Lite system and to explain the benefits to its users, the planning authority LAMATA started several public participation measures. Different user types were identified and addressed in an appropriate way. Media campaigns to inform the public were undertaken. Key stakeholders such as local chiefs or community leaders were informed and Senior LAMATA officers attended community meetings. All this give a public face to LAMATA and fostered confidence in the initiative.

BRT lanes and stations are only permitted to franchised bus companies. Other private commercial buses have to use normal car lanes.

The BRT-Lite system began operations in March 2008. In addition to the measures taken in the field of mass rapid transit, improvements in road infrastructure such as a fully connected newly built ring road. With regard to traffic flow improvement, traffic light signalling was installed widely and road junctions rebuilt with advanced traffic routeing as well as proper signing and marking.

Important is the re-organisation of the bus parks which congest road often nowadays. They shall be moved from the road side to off-road multi-level bus parks.

Impact

The implementation of a BRT-Lite system together with other measures has improved traffic flow and journey times. There has been a 40 per cent reduction in journey times along the BRT corridor. Waiting times fell on average by 35 per cent. The average speed of buses increased significantly from 15 to 25 km/h – an increase of 66 per cent. Fewer transfers are necessary for the same route.

First BRT Corridor Lagos *(Source: Mobereola, Dayo) Copyright*

Important is that note that not only public transport users benefit from the measures. Traffic flow improved generally through the implementation of a BRT system with high capacities. The franchise system for the BRT infrastructure has increased efficiency. The total number of buses has been reduced by 35 per cent while providing the same performance. Conditions for other road users have been improved.

Lessons for Africa

There are probably two main success factors for creating a BRT system in SSA cities. Firstly, consistent commitment and support from authorities and government at all levels - from national government to local community leaders. Only this unity and overall agreement will make the implementation of the BRT possible. The foundation of LAMATA, the overall planning and operation authority was a crucial step in this, because it is important that there is one institution which has sufficient responsibilities and trained staff to plan the system.

Secondly, a successful strategy of public and institutional participation and engagement. LAMATA was keen to be seen as reliable partner who listens to citizens. The public was informed in via large media campaigns and community meetings. Local community leaders were involved in parts of the system design. Since the introduction of a BRT system will have an impact on Mini-bus drivers it is important to involve the main transport unions.

4.6 Understanding traffic flow management in SSA

Traffic flow challenges and congestion are not only a developed world phenomena. SSA cities suffer severely from traffic congestion and reduced levels of transport services. Identified measures of improvement, specifically the ones highlighted (TDM, ITS, traffic management and campaigns and maintenance) are transferable to Africa. They will improve transport service delivery and reduce levels of congestion.

Other measures, such as vehicle design improvement (smaller vehicles, car to car communication) will only be transferable to the African continent after Research and Development is completed. The African continent has neither the financial, nor the human resources, to invest in R&D.

Improved traffic flows and reduced congestion does not only improve the level of transport service delivery, but also decreases pollution and energy consumption contributing the wellbeing of the urban dweller.

5 TRANSPORT AND EQUITY

5.1 INTRODUCTION

Transport plays an important role in economic and social development of people. It can be a powerful catalyst to sustainability by providing 'interconnectivity, learning and development', that are essential to the empowerment of socially marginalised and disadvantaged groups, including poor men and women living in isolated habitats (UNCSD, 2010). Alongside this role, there is a growing concern the contribution transport makes to environmental pollution and its effects on human health and wellbeing - now and in the future. This concern has raised issues of how to achieve a sustainable transport system that reduces GHG emissions without impeding development. This is a considerable challenge. However, promising examples are emerging that indicate that building on the principle of social equity, transport can contribute towards promoting sustainability both for the environment and for the livelihoods of poor men and women living in often difficult to reach rural areas. Achieving this at a larger scale needs a paradigm shift in the current thinking on transport and development pathways.

The social and economic dimensions of transport use show that the poor and marginalised groups living in rural areas often walk or use cycles, rickshaw vans, animal carts etc. that are environment-friendly and do not account for GHG emissions. Focusing on the transport behaviour of these groups may hold a key not only to achieving social equity and sustainability in transport, but also to simultaneously making progress towards the goals of low-carbon development and growth.

Low carbon transport have a number of co-benefits which include: air pollution abatement, enhanced health protection and reduced road traffic injuries fatalities, reduced congestion, increased energy security and improved productivity. However, the potential benefits from improving social equity in SSA have not been researched in great depth. This is an important area where knowledge sharing among practitioners and researchers need to develop and expand on the existing anecdotal evidence.

The chapter provides an overview of concepts and tools that are available to address sustainability and equity in transport. It outlines examples from SSA that highlight context-based transport initiatives that can simultaneously tackle the issues of equity and development. Finally, lessons learnt that can lead to up-scaling of these small-scale initiatives are examined.

5.2 Sustainability in Transport

Sustainable development in transport, though a compelling concept, continues to pose tremendous political, economic, social, institutional, and technological challenges. Various studies have proposed a variety of wide-ranging and diverse definitions. A sustainable transport system may fulfill basic access and development needs of people, human and ecosystem health while promoting equity within and between successive generations. Viewed in this way, sustainable transport systems may have the potential to facilitate the achievement of the MDGs, particularly, alleviating extreme poverty and hunger, achieving universal primary education, contributing to gender equity through improved mobility, improving health, ensuring environmental sustainability and developing partnership through linking people and places (Czuczman, 2008).

Goldman and Gorham (2006) provide an overview of efforts to develop and operationalise the notion of 'sustainable transport' into useful policy guidance. They identify two broad categories of policy directions that have been offered: those that envision sustainable transport as a pathway, and those that envision it as an end-state.

Sustainability policy as a pathway focuses on policies to push society along a path that is 'more sustainable' than present trajectories, as measured by a set of indicators. This approach avoids attempting to define a particular outcome that would mark the 'attainment' of sustainability. Examples of these initiatives are the European initiative Sustainable Urban Travel (SUT) programme (1997–2001) and the World Business Council for Sustainable Development's (WBCSD) Sustainable Mobility programme that focuses on directional indicators for sustainable mobility. These approaches have the advantage of being relatively easily understood by policy makers, and, in principle, easily conceptualized as specific policy initiatives. However, they fail to grapple with the complexities and contradictions of sustainable transport and the larger social and economic systems in which transport is embedded. They essentially focus on 'mobility' often ignoring 'accessibility' and human activity systems in which transportation occurs.

Sustainability as an end-state vision attempts to operationalise the concept of sustainable transport though defining a vision of what a sustainable system might offer and develop indicators to assess this development. Goldman and Gorham cite the experience of OECD's Environmentally Sustainable Transport (EST) project that developed a definition of sustainable transport. Sustainable transport does not endanger public health or ecosystems and meets needs for access consistent with the use of renewable resources below their rates of regeneration, and, the use of non-renewable resources below the rates of development of renewable substitutes (OECD, 1996). This definition, developed in 1996, is based on the fulfillment of the following criteria: health standards for NO_X, O_3, PM and noise; international objectives for transportation sector emissions of CO_2; and ecosystem protection objectives relating to land protection in urban areas. This vision clearly focuses on the environmental component of sustainability, public health and ecosystems. The EU Council of Transport Ministers adopted a more expansive definition of sustainable transport in 2001. This approach sees sustainable transport as a system that takes into account basic accessibility needs of the human population (SUMMA, 2005).

Due to the multiple dimensions of sustainable transport, it is unlikely that any single policy measure can by itself help attain a sustainable transport system. Therefore, policy packages need to address the different dimensions of sustainability using various models and tools to assess their impacts (Valerio, 2010). Trial and innovations seem to be an important path towards sustainability, particularly in the developing country contexts.

5.3 Equity in transport planning

Equity is another complex concept which has many interpretations. Vasconcellos (2001) notes that equity relates to the targeting of transport policies to ensure an equitable appropriation of space, from the standpoint of accessibility, safety and environmental protection. It is a situation in which people are granted satisfactory living conditions and opportunities in respect to socially accorded services (for instance education, health, and access to the city), irrespective of their individual physical, economic, social, religious or ethnic characteristics.

> *Equity and equality are different concepts. Equality occurs when equal coverage of bus services in a neighbourhood in terms of space and time is ensured. Conversely, equity implies the consideration of the specific characteristics of people. The*

spatial and temporal coverage of bus services may be equal but not equitable once individual differences among people - age, gender, income, physical conditions – may interfere in their ability to use such services. Therefore, inequitable conditions may end up denying access to formally 'equal' opportunities. An equitable condition is therefore superior to a formally equal one and the search for equity in transport is inevitably a difficult task for planners in developing countries, for both political and economic reasons.

Source: Vasconcellos (2001, p.245)

Litman (2010) has taken the concept further in an attempt to operationalise it. He suggests that e*quity* can be referred to the distribution of costs and benefits and whether this distribution is considered appropriate by the users (Litman, 2010). He identifies two major categories of equity: *horizontal* and *vertical*.

Horizontal Equity is concerned with the distribution of impacts between individuals and groups irrespective of their ability and need. According to this definition, individuals and groups should receive equal shares of resources, bear equal costs, and in other ways be treated the same. This is also called *fairness* and *egalitarianism* and rests on treating everybody equally regardless of income, gender, race or other social attributes. Consumers should get what they pay for and public policies should refrain from favouring one group over the others.

Vertical equity is concerned with the distribution of positive and negative impacts of any policy or action between individuals and groups that differ in abilities and needs, either by income or social class such as gender or ethnicity, or physical disabilities. It is also termed as *social equity, environmental equity or social inclusion*. It takes into account the overall inequities in the society. Ideas of equity and social justice in transport planning tend to support transport planning tools that provide affordable modes, discounts and special services for economically and socially disadvantaged groups. Vertical equity is also concerned with groups that differ in transportation ability and need, and the degree to which transportation system meets the needs of those with special constraints, for example, physical disabilities and other special needs.

Economically disadvantaged people are often unable to afford the most convenient travel modes such as a car or live in more remote locations so are often transportation disadvantaged. Conversely, because people who are transportation disadvantaged have more difficultly accessing education, employment and affordable goods, this contributes to them being economically disadvantaged.

Source: (Litman, 2010: p6).

There may be cases in transport planning where horizontal and vertical equity concerns can overlap or even pose conflicts. For example, horizontal equity requires that users bear the costs of their transport facilities and services, but vertical equity often requires subsidies for disadvantaged people. Therefore, transport planning often involves making tradeoffs between different equity objectives. For example, short-term equity goals to make automobile travel more affordable to lower-income groups may pose a conflict with the long-term goal of increasing accessibility options for non-drivers by creating more multi-modal transportation systems and more accessible land use patterns.

In practice, equity impacts of transport planning decisions are many and diverse. Transport planning decisions can have effects on:

- people's opportunities and quality of life;
- location and type of development that occurs in an area, and therefore accessibility;
- various indirect and external costs, such as congestion delay and accident risk;
- the share of most household, business and government expenditures and financial burdens;
- employment and economic development which have significant distributional impacts.

Assessing transport equity is equally difficult as assessing its sustainability. Designing transport equity indicators, categorizing social groups and people, identifying and measuring impacts can be contentious. How this design is made significantly affects the outcome (i.e. the distribution of costs and benefits across the social groups). This is not straightforward and can reflect biases of the designer.

Martens (2006) notes an often recurring bias in the current planning practices which tend to value 'mobility' over 'accessibility', and motorized modes over non-motorized modes. Notwithstanding the fact that there is may be inherent biases of a political nature in any trade-off, this can also reflect a lack of data and more importantly complications in using the data and relevant tools. However, recently progress has been made in improving the tools for equity, particularly in the developed countries.

5.4 Equitable transport management in SSA

Equitable transport management (ETM) is here defined as a set of strategic practices to ensure that externalities in the costs of automotive journeys such as costs for air pollutant and GHG emissions, land use, the uninjured components of crash costs, congestion costs, parking costs, and others are internalized (adapted from ALC, 2004a). Currently the monetary costs of roads, the productivity costs of congestion and the health costs of air pollution and climate change are inequitably spread among motorists and non-motorists. A driver pays neither directly nor equitably for other costs such as congestion, air pollution, GHG emissions or habitat loss. These costs are distributed throughout the population and some of them, particularly those of GHG emissions will be borne by future generations. Mechanisms are therefore needed to make transportation pricing fair, equitable and economically efficient (ALC, 2004b). One such mechanism is road pricing which includes congestion pricing, area tolls, and high occupancy toll lanes (VTPI, 2011). Principles have been developed for efficient congestion pricing (Vickrey, 1992).

Equitable road pricing, in conjunction with similarly managed parking pricing and pay-as-you-drive (PAYD) insurance, would redistribute traffic away from rush hour peaks and would significantly reduce the number of automotive journeys by 10 to 30 per cent. As congestion continues to mount and the money and space for more roadways dwindles, electronic road pricing is the only equitable, effective and efficient solution.

A universal scheme for electronic road pricing has been infeasible until now. The use of fixed infrastructure (gantries) restricts flexibility of both placement and control policies. The widespread deployment of global positioning system (GPS) as a metering mechanism requires a broad vision and a standard body of policies − policies that reach beyond a constrained set of roadways, or the financing of a new highway

Two fundamental components are required to create the possibility of fair, equitable and efficient road pricing (ALC., 2004b):

- Social and political readiness − the critical recognition that road pricing is the only viable, long-term solution to automotive congestion, air pollution and climate change.
- Convergence of size, speed, cost and capability of a critical set of enabling technologies –GPS, geographic information system (GIS), radio frequency identification (RFID), short message service (SMS) and general packet radio service (GPRS), as well as appropriate security and privacy mechanisms.

It is now economically, politically and socially possible to deploy road-pricing, the only feasible, global, mechanism to manage congestion, air pollution and GHG emissions from road transport. It helps address three critical urban problems: lack of funding, congestion, pollution and GHG emissions.

In SSA countries leadership and investment is needed to achieve this paradigm shift.

5.5 Tools for equitable transport development

The assessment tools for equitable transport and mobility have highlighted the need to better understand the issues concerning social equity. Social equity may be viewed as equity of opportunity and equity of outcomes. Also, there are several types of inequities that an equitable transport needs to respond to. These refer to inequities of accessibility, access time, speed, comfort, cost and space appropriation by various categories of people who may experience numerous impacts (Vasconcellos, 2001). There are also a variety of tools for measuring these impacts. Tools play an important role in this as a particular decision may seem equitable when evaluated by a particular tool but inequitable when using a different tool. Despite the recent advance in knowledge, few resources exist to provide guidance on how to assess equity in an objective, comprehensive and effective way.

Titheridge and Solomon (2007) note that tools for a rigorous assessment of *transport poverty* that can provide benchmarks against which provisions can be evaluated, extend well beyond the remit of the transport disciplines. The fundamental question is about access and mobility as related to social, economic, and possibly psychological needs. Thus, devising a methodology will involve not only different disciplines, and users from different categories of people, but will require policy-makers to make a number of value-judgments on what may be considered desirable and what is actually possible. A range of benchmarks to measure the accessibility of destinations and quantitative travel surveys are used to achieve objectivity. However, these are underpinned with values and reflect biases depending on who is surveyed, what is counted and how it is measured. These affect the range of options and impacts considered and how solutions are selected. Titheridge *et al.* (2009) also highlight the importance of involving those at whom social exclusion and accessibility policies are addressed in developing suitable benchmarks and indicators.

A set of social, economic and environmental criteria for sustainable transport has been proposed (Joumard and Nicolas, 2010). The social criteria are intricately link to equity. These are:

- *Accessibility*: This is access to employment and to major public services. For example, accessibility to hospitals, administrative services can be measured either in terms of the number of opportunities reached in a given time using a private car or public transport, or in the necessary time to reach a given number of opportunities
- *Environmental equity*: Who is exposed to local pollution, to noise and to the impact of habitat fragmentation?
- *Mobility cost*: What is the share of household revenue dedicated to daily mobility, according to income group and distance from the centre, and what the impact of an intervention might be, especially in the long term, if it causes local changes?

All these criteria would need to be assessed according to household type, and classified according to income group and geographical zone. The tool can be broadened to include city and regional planning for improving accessibility alongside transport alternatives (Joumard and Nicolas, 2010: p.141).

In an attempt to incorporate social justice into transport modelling, Martens (2006) argues that current transport evaluation practices exaggerate the benefits of automobile-oriented improvements and undervalue improvements to alternative modes, because they are based on *demand* (the amount of transport that people can afford) rather than *need* (the amount of transport that people need to access basic services and activities). Unlike demand-based models that apply a seemingly neutral methodology, the development of a need-based model will explicitly require establishing the norms and values held. Martens, in advocating a social justice approach to sustainable transport suggests that:

- Evaluation of transport improvements should be primarily based in terms of *accessibility* rather than *mobility*. For example, in addition to travel time savings to vehicle travellers, improvements should be evaluated based on the number of public services and jobs accessible to people, taking into account their ability to access them, travel time and costs. This recognizes the value of all modes of transport (including walking, NMT, public transit and telecommuting) and land use improvements to improve accessibility.

- The monetary value attached to a specific accessibility gain should differ between individuals or population groups in reverse relation to their current levels of accessibility to reflect the principle of diminishing marginal benefits. In this, accessibility gains, as a proxy to travel time savings, for the mobility-poor should be valued higher than that for the mobility-rich accessibility-constrained people tend to gain relatively more from a given transportation improvement. The use of accessibility gains as the primary benefit of transport improvements would thus have the advantage from a social justice perspective as it would direct the attention in transport planning and cost-benefit analysis to equity in terms of accessibility and accessibility gains, rather than focus on the absolute size of travel time savings.

Litman (2010) notes that transport equity impacts tend to be evaluated inconsistently, or simply dismissed as intangibles. This is due to the fact that equity implications are viewed as un-measurable and thus can be ignored. To address this, it is important that a set of concrete indicators are designed that are measurable and can reflect progress toward the equity objectives set beforehand. Indicators can be selected to reflect various equity issues and perspectives, and, to acquire reasonable data for analysis requirements. He identifies five equity objectives and possible indicators for each that can affect equity analysis. These are described Box 5.1. These can be expanded, elaborated and disaggregated to meet specific planning requirements.

Box 5.1

Horizontal Equity

1. Treats everybody equally, unless special treatment is justified for specific reasons.

- Policies and regulations are understood by the public and applied without bias.
- Per capita public expenditures and cost burdens are equal for different groups.
- Service quality is comparable for different groups and locations.
- Different modes receive public support approximately in proportion to their level of use.
- All groups have opportunities to participate in transportation decision-making.

2. Individuals bear the costs they impose.

- Transport user fees and tax payments reflect the full costs imposed by each person or trip, unless a subsidy is justified on equity grounds.
- Subsidies provided for equity or economic objectives are efficiently targeted.

Vertical Equity

3. Progressive with respect to income.

- Lower-income households pay a smaller share of their income, or gain a larger share of benefits, than higher income households.
- Affordable modes (walking, cycling, ridesharing, transit, car sharing, etc.) receive adequate support and are well planned to create an integrated system.
- Special discounts are provided for transport services based on income and economic need.
- Transport investments and service improvements favor lower-income areas and groups.

4. Benefits transportation disadvantaged people (non-drivers, disabled, children, etc.).

- Investments and policies help create a more diverse, less automobile-dependent transport system that effectively serves non-drivers.
- Land use policies improve non-motorized accessibility.
- Transportation services and facilities (transit, car sharing, pedestrian facilities) reflect universal design (they accommodate people with disabilities and other special needs, such as using strollers and handcarts).
- Special mobility services are provided for people with special mobility needs.

5. Improves basic access: favors trips considered necessities rather than luxuries.

- Transportation services provide adequate access to medical services, schools, employment opportunities, and other "basic" activities.
- Travel is prioritized to favor higher value travel, such as emergency trips.

Source: Litman (2010)

These equity indicators are generic would need to be reviewed in the context of SSA where requirements of basic access and basic mobility (meaning people are able to reach services that are considered important for life and livelihoods), categories of people requiring these access and mobility, and physical conditions (reflecting roads and vehicles types in use) can be very different to those prevailing in developed countries. However, it remains true that there is no single way to evaluate transportation equity. Equity evaluation will depend on the types of equity objectives, socio-economic contexts, judgments used to categorise people, selection of impacts to be considered and tools to measure them.

5.6 Transport and equity casestudies in SSA

This section highlights various initiatives in selected SSA countries that provide emerging insights into how a focus on increased accessibility and mobility can integrate equity and development. Though these developments are still anecdotal and provide only locally specific experience, they do have potential to provide for important lessons in conceptualising equity in comparatively resource-and-accessibility disadvantaged contexts.

Build a Better Bicycle Project in Mozambique

(Extract from Cunha, 2006)

Build a Better Bicycle (BABB) project in Mozambique aims to empower rural women through micro-financed access to appropriate bicycles. Its approach is two-pronged as it encompasses bicycle delivery through an empowerment methodology that involves encouraging a gradual power shift towards reducing gender inequalities without radically upsetting traditional community structures. The project, designed by an international organization called *Jacana*, works with rural women in Mozambique. In view of the prevailing gender inequality in the Mozambican context, *Jacana* decided to develop a project targeting rural women to address the burden of their domestic and seasonal labour. As well as the barriers that women and girls face in socio-economic status, education, health, and rights over their bodies, through transport solutions that take women's specific needs into account. *Jacana* established a set of indicators based on the assumption that bicycles have multiple impacts that can improve access to social services, employment and political participation. Viewing bicycle's impact from this broad perspective makes it possible to trace the relationship between women's bicycle ownership and access to health care services, water, education, income generation opportunities and participation in community activities. The existence of linkages between these spheres of social action and appropriate means of transport became clear in a pilot project in the district of Moamba, 70 kilometers from Maputo. In this project, a group of women subsistence farmers chose the criteria for selecting the recipients of a limited number of bicycles. They also defined the terms under which the bikes would be paid for, identified people to be trained as bicycle mechanics, and, developed monitoring and evaluation indicators. BABB's innovative approach of combining a bicycle access project with a women's empowerment framework, has brought significant improvement in access to services in remote rural areas in Mozambique. Research on factors that determine primary school enrolment in Mozambique showed that girls whose families acquired a bicycle and used it to collect water had a 32 per cent higher probability of enrolment than girls whose families did not use a bicycle for household chores.

The Miracle Health Train in South Africa

Extract from: IFRTD, 2009)

Phelophepa is locally known as a miracle health train is an innovative sixteen carriage train used to deliver much needed primary healthcare to South Africa's rural poor. It offers services that include a pharmacy; cancer screening and education clinics; psychology, optometry and dental clinics as well as diabetes, prostate and smear testing services. It is the world's first and only fully fledged primary healthcare train run by South Africa's state owned rail carrier, Transnet, who cover around two-thirds of its running costs; the remainder of the costs are met by a mixture of corporate sponsors, including Roche and Colgate, charities and individuals. The train travels from January to September, spending a week at each stop. Nineteen permanent staff and 36 final year medical students are onboard and together they treat the estimated 45,000 patients a year, with thousands more benefiting from the train's outreach programmes and healthcare training. *Phelophepa* is based on local ownership and thus it must be invited by the community who also delegate local people that will lead the preparations, make up a steering committee, responsible for deciding who will work on the train and the best people to participate in training courses. Thus the community is in charge, and that is deemed as why it works.

Phelophepa also plays a vital role in rural health education. It imparts knowledge of prevention to rural villages to continue the work once it has moved on. This sustainable approach is encapsulated in the train's 'Edu-Clinic'. Sixteen people are nominated at each stop to complete five-day courses in basic health and hygiene. The train's staff also visits selected schools, offering health screening and education for pupils and teachers. Some nominal fees are charged for services as free services can make people feel helpless and dependent, whilst payment gives them dignity. Any donations are put into a fund to help those patients who are unable to pay.

Donkeys as Pack Animal in Tanzania

(Extract from Sieber, 2000)

A study of the economic effects of the Makete Integrated Rural Transport Project in Tanzania concluded that the use of donkeys had enabled farmers to transport larger harvests from the fields to the market. It also showed that farmers with donkeys were able to use more fertiliser, because it could be transported easily from the market place to the homestead, and from the homestead to the fields. In Matamba, each animal made nearly 100 trips a year and carried a total of 8 tonne-km. Most of these trips were undertaken for carrying crops from the fields, making trips to the market and carrying grain to the mill. The main effect of the donkeys seems to be that crops were quickly transported from the fields to the collection points. Donkeys were used to carry 15 per cent of the household's total transport burden. They reduced the amount of work and drudgery, especially for women. These economic benefits were assessed by estimating the amount of time saved. Assuming that the average load of a donkey was three times that of a human being, a donkey could reduce the annual transport burden by 93 trips which amount to 133 hours per year. A monetary value of the time savings could be attributed by using the opportunity costs of time that was represented by the income increase generated by working the saved time in their fields. The annual monetary benefits for time savings amounted to US $10 per household. More time could be saved if donkeys were used for water and firewood collection, but men own the animals, while women have the tasks of undertaking most of the domestic transport volume.

Use of Peace Bikes to Help Reduce Female Violence in Uganda

(Extract from: UNDP, 2008)

The 'peace bikes' campaign, launched in 2008 aims to support and broaden women' s contribution to advance peace, security and recovery among war affected communities in Northern Uganda. The campaign is part of UNDP's sexual and gender-based violence (SGBV) project, which emphasises building on the strengths and resources of affected communities and women's leadership to empower beneficiaries to own and sustain the recovery and development process. It gained support from the local administration who hailed the 'peace bikes' that had come at the right time as people returned to their home areas from the displacement camps. The conflict badly affected the population in northern Uganda, inflicting widespread trauma and poverty, and many women were victims of sexual and domestic violence, and were vulnerable to HIV/AIDS. The peace bikes aim to contribute to a reduction in SGBV cases in communities by enabling the women to mobilize communities to prevent sexual and violent conflict. The SGBV programme trained more than 700 women, including local councillors and leaders in the four districts, in peace building, negotiation and conflict resolution to prevent all forms of violence, particularly that against women and girls. However, they often are unable to fully undertake their work in the communities because of difficulties in reaching some areas. Most of the roads in the areas where people have returned from displacement camps are in very poor condition after years of neglect and long distances are difficult to cover on foot. The bicycles help women's groups reach the dispersed rural population through means they can afford and maintain. Women are also trained to repair and maintain the bicycles, these skills help increase the lifespan of the bicycles, while also offering the women practical means of earning income.

Recognising the Uses of Indigenous Transport Modes in Zambia

(Extract from: Muchiya)

The Zambia Rural Accessibility and Mobility Programme (RAMP) was initiated in 2006. The main aim of RAMP is to contribute to poverty reduction through facilitation of enhanced mobility and access to socio-economic goods and services for rural communities. Through the Indigenous Modes of Transport (IMT) initiatives, the RAMP programme has helped with the provision of transportation means which are applicable to a rural setting, these include: cattle, donkeys, bicycles and trailers, motor cycles, tricycles, barrows and canoes. Providing rural areas with tracks, footpaths and waterways without providing the necessary means of transportation would be of little benefit to the local community. While transport means such as donkeys and wheel barrows may seem trivial to some planners they can considerably increase the amount of produce carried from one point to another, and also reduce the time to complete certain tasks.

Inspired by emerging markets and good roads in Zambia's Western Province, rural farmers growing rice in the Zambezi flood plains have grown more rice by accessing their fields more easily with the use of dug out canoes; The proceeds from these rice sales have contributed towards the construction of classes at a community school. Similarly, in the Central Province, the improvement of trails linking commercial farms to rural settlements has encouraged farmers to go into the production of fingerlings to supply the commercial fish ponds in the area. This project has also been stimulated by the government's provision of wheelbarrows and other necessary inputs to the farmers. The farmers also use the proceeds from their sales to purchase other farming inputs like seeds and fertilizers. In addition, they grow some of the fish to table size for their own consumption.

RAMP has been responsive to the needs of the rural farmers by addressing the problem of rural mobility from within the rural communities. This is unlike the earlier approaches by developing country governments which embarked on the construction of feeder roads without taking into consideration how rural farmers would actually get to these roads when the track and path network in their villages was almost non-existent.

Motorbike Ambulance in Remote Areas in Zimbabwe

(Extract from: George, 2004)

The Uhuru ambulance in Zimbabwe reaches parts of the country where four-by-fours cannot reach. The Riders for Health Programme started Uhuru (Swahili for "freedom") which is a combined motorbike ambulance (low-tech 200cc Yamaha), water pump and goods vehicle. Accessories for the Uhuru are locally made including the stretcher and a pop-up seat for women in labour. When the rear wheel is attached to a water pump, it can pump 120 litres of water. Although it may not be a comfortable ambulance, it provides for women in labour a better alternative to walking 10 km or giving birth in a field.

Riders for Health runs more than 500 bikes and 500 four-by-fours for the Zimbabwean Ministry of Health in collaboration with the Academy of Vehicle Management in Harare. Riders for Health train health workers to undertake a simple service of their own bikes each day (e.g. changing oil filters) to ensure *zero breakdowns*. The initiators of this programme focused on breakdown management, whereby they started providing training preventive mechanics. It soon started bringing in results.

The Uhuru is being trialled in fifteen Zimbabwean districts and two in Kenya. It is usually ridden by female health workers. In Binga district in Zimbabwe, there are ten health workers with motorbikes and maintenance training. In the neighbouring province of Gokwe, there are three. Binga's malaria rates have fallen by 20 per cent in one year while there has been not change in Gokwe's despite the two areas having similar conditions. Although it is not possible to link the reduction directly to the use of motorbikes the greater availability net and supervising of spraying by health workers may have contributed to the reduction to the number of people contracting malaria.

Co-benefits

The above examples illustrate the potential benefits of well designed transport interventions aimed at addressing the needs of the marginalised poor in remote areas. The interventions have the potential of achieving a number of benefits. These include improved health, productive capacity and income, empowerment and building peace and cohesion in conflict ridden communities, as well as increasing mobility by improving the types of intermediate transport modes are available. However, more research is needed to explore benefits that can be gained when social equity is integrated into transport planning and development in SSA. This is an important area where knowledge sharing among practitioners and researchers need to develop and broaden existing anecdotal evidence that so clearly highlight the benefits that an equitable transport paradigm can deliver.

The Institute for Development Studies (IDS) (2006) note that transport infrastructure and services have a strong influence on:

- timely and affordable delivery of basic services: health, education, water and sanitation
- facilitation of economic growth through international, regional and national trade
- empowerment of vulnerable groups such as women, by reducing time spent on domestic tasks
- links with the market economy and the outside world: transport connects communities to markets and information, puts isolated people in touch with services and representatives, sustains important social networks and enables freedom of movement.

5.7 Specific issues: poverty, gender, age, and transport disability

An important factor contributing to poverty in rural areas, in developing countries, is low accessibility. Often the rural poor use a considerable amount of time to meet their everyday needs. The amount of time spent in collecting water, obtaining fuel, getting to the school, the clinic, the grinding mill or the market has been seen as wholly unproductive even 'wasted' time, however important getting to the supplies, services and facilities. Edmonds (1998) argues that the more inaccessible are the essential destinations, the more time has to be spent in reaching them, and in this sense, inaccessibility is equivalent to isolation which is a dimension of poverty and a constraint to development. DFID (2009) observes that in many countries growth is stunted because the costs of transportation and communications are too high to enable easy movement and trade preventing economies of scale and technology transfer, and holding back productivity gains which are the source of income growth.

Although the MDGs do not explicitly relate directly to transport, transport improvements are clearly essential to their achievement. Linkages between poverty and remoteness have been emphasised in a number of studies (Porter 2002, Bird *et al*., 2002). Lack of adequate transport and poor access is suggested as the most significant factor restraining agricultural development and limiting efforts to poverty alleviation (Christiansen *et al*., 2003). Poor access also affects trading costs; it is closely linked to diverse aspects of poverty and social exclusion (Booth *et al*., 2000).

Halving extreme hunger and poverty, reducing maternal mortality, achieving universal primary education, and empowering women are four of the eight MDGs with important access and transport implications. However, the relationship between transport and the MDGs is not just about access to services, it is also about empowerment, social capital, time poverty and personal security, amongst others. To fulfill its role as a 'critical catalyst' for the delivery of MDGs, transport sector needs 'to consolidate a more pro-active cross-sectoral role' and to address challenges in realising a pro-poor agenda. It is also important to establish a clear mechanism to ensure that appropriate travel data is systematically collected and monitored against meaningful transport and poverty indicators (Czuczman, 2008).

Gender

Incorporating gender equity into transport development implies addressing questions such as how interventions in transport can affect women and men, taking their specific needs for accessibility and mobility into account. Men and women have different travel characteristics following from their different transport needs and use patterns that result in different implications for transport planning. Gender differences in transport use are common in terms of:

- the purpose of the travel (domestic tasks and caring activities are disproportionately higher for women compared to men)
- character of trips (women often make chained trips linking multiple activities)
- means of travel used (women mostly use public transport, non-motorized vehicles and slow-speed modes in non-peak hours)

- typical distances travelled (short-distance frequent trips are common for women while men often travel longer distances)
- access to transport modes (male ownership dominant for personalised vehicles) (Turner *et al.* 2006).

Women's transport behaviour is therefore very different to that of men and given their different needs and capacity. If women's transport uses are taken seriously in policy and planning, this would lead to a shift away from heavy reliance on private motorization to substantially different pathways that promise co-benefits for both livelihoods and low-carbon transport development.

Studies in Africa, especially in rural areas show that women and girls spend more time and effort than men on transport (due to household chores such as fetching water and firewood), have less access to public services (including health), face greater safety and security risks while travelling, and have less control over resources. In Tanzania, for example women spend four times as much time on transport-related tasks than men do (IFRTD, 2007). By improving mobility and accessibility and reducing the transport burden for women this 'time poverty' may be reduced and women and girls can free time for education, health, social activities and income-generation; they can also have more time to rest, to enjoy social life, to participate in community activities (Fernando and Porter, 2002). Improved transport accessibility to health care and attended births, including access to emergency transport, can reduce significantly maternal and child mortality rates, contributing to achieving MDGs. Experience from many countries also shows that better transport can help improve girls' school enrolment, as time can be saved from household chores can be used to attend school. Also, if good road accessibility can provide safety and security to allow for bicycles and reliable buses, then the enrolment of girls is likely to increase. However, women's access to transport modes might not have changed much since Peters' (2001) empirical study noted that even access to intermediate means of transport such as wheelbarrows, carts, bicycles or animals is often heavily gendered, i.e., only a few women have access to them.

Fernando (2010) points out that the gendered nature of the transport institution means that it rarely takes the care economy (unpaid housework and taking care of household members, i.e., children, the sick or the elderly) into account when designing transport interventions. Instead it prioritises the market economy that includes gainful employment, sellable products, and marketable services. This has implications for gender equity, as the care economy is predominantly female, while men rarely have to combine gainful employment and care responsibilities. Similarly, the agenda of road safety tends to narrowly focus on road crashes and their victims, but often ignore the burdens of care women need to shoulder as a consequence of road injuries and fatalities. Other aspects of safety such as sexual harassment on the road hardly appear in transport planning (Fernando, 2010).

Age

In recent years mobility in old age seems to have caught the attention of transport researchers. Though most of the research has focused on developed countries, they provide useful insights on the transport needs of the elderly people and how they differ from that of the younger generations. Schwanen and Páez (2010) indicate that on average, elderly people are more often immobile "in the sense of not leaving the house on a given day, make fewer trips on days they go out, use non-car transport modes more frequently, and travel over shorter distances" and tend to travel less outside peak hours or at night. They further noted that these characteristics are far from homogenous and are partly structured according to such factors as gender, ethnicity, disability, residential location, and social and support networks, among others. A study in Norway found that the level of fulfillment of mobility needs varies between different groups of the elderly, indicating considerable inequity among them. A substantial number of elderly people experience reduced mobility for certain types of trips, for example, mainly in leisure-related trips. The gender difference in the mobility pattern was found to be significant. Older women were found to have more mobility problems and more limited out-of-home mobility (Siren, 2005). Studies in the UK show that travel patterns of elderly people differ markedly from the national average in terms of their mobility requirements and aspirations. For example, elderly persons make very few trips for work or educational purposes, but they make more food shopping trips. Elderly people value just being able to get 'out and about.' (Titheridge *et al* 2009). These findings indicate that general indicators may not be suitable for evaluating the travel needs of elderly people, as these indicators do not reflect the types of journeys elderly people do make and aspire to make. Indicators, which are based on journey time thresholds, as is often the case in developed countries, do not reflect older people's attitudes to travel, as often journey time is not an issue for the elderly. In order to compare potential policy options, these micro-level details need to be documented.

In SSA, reduced mobility or lack of mobility is a serious problem for elderly people as often they cannot afford to 'retire' in the absence of a formal and adequate pension system. Reduced mobility due to infirmity and lack of access to transport, or being unable to afford it, may limit older people's access to work and vital health care, thus reinforcing their poverty. Porter (2010) found that ill-health and infirmity may bring result in substantial problems for older people in a 'walking world' where pedestrian transport dominates among all ages. It can be particularly difficult for older women in rural areas - women are often engaged in trading that can pose serious problems in the old age if heavy loads have to be transported on foot (Ipingbemi, 2010).

The era of HIV/AIDS has left grandparents in many countries supporting and caring for grandchildren when the middle generation is missing or incapacitated due to parental deaths and ill health. Often elderly caregivers have to make prolonged travel and their living arrangements are disrupted (Ssengonzi, 2009). Many of these elderly carers lack financial support from the child's parents and struggle to provide for children in their care. The situation can be particularly difficult for women. This is because elderly women are often expected to care for HIV/AIDS affected children but tend to be poorer. Women also often suffer from ill-health due to the demand of load carrying from childhood for fuel wood and water collection, and marketing of agricultural produce.

The implications of the travel patterns of elderly people for transport planning are only beginning to emerge. Planning for an equitable transport system would require further empirical evidence to focus on age and variable ability of all users to access transport (including physical disadvantages). The large differences observed among elderly people represent a situation that poses important challenges for transportation planning and policy.

Transport disability

Transport disability has a major impact on the lives and life choices of many disabled people. A lack of accessible means of independent travel often creates social exclusion for many disabled people who were found to travel less often than the general public. This has implications for disabled people's access to education, employment, health services, social events and leisure pursuits (Wilson, 2003). The importance of accessible transport for disabled people is now becoming widely recognised. In recent years western countries have attempted to improve ways disabled people travel around. Measures have included adapting vehicles particularly in the public transport sector and improving policies, laws and regulations against discrimination.

In SSA countries, policies towards closing the accessibility gaps for people with disabilities are only beginning to be reflected in policies. Most African countries do not have special transport arrangements for people with disabilities. Venter *et al*. (2002) noted that in South Africa and Mozambique people with physical, visual and hearing disabilities account for 7 and 10 per cent of the population (Venter, 2002). This is a considerable number of people who needs to be taken into account in transport policies and provisions. Given this, Mashiri *et al*. (2005) found that throughout the developing world the existing transport system fails to serve the needs of the majority of people with disabilities. This non-provision is made worse by lack of legislation, guidelines, regulation and enforcement mechanism to ensure accessibility of the built environment, including the levelling of pavements and access to public transport services. The issue is compounded to some extent by funding considerations and is largely influenced by welfare rather than rights based approach. South Africa is one country where relative progress has been made in including aspects of disability into the transport system. Very little information exists about the extent of transport disability and the consequences of this negligence for poverty alleviation has not yet been fully understood.

5.8 Understanding transport and equity in SSA

An equitable and sustainable transport system can be developed when all users' needs and expectations are taken into account equally. This chapter has presented the concepts, tools and practical experience in tackling the issues. A number of key lessons can be taken from this.

Firstly, there is a great need to integrate best practice into existing transport planning for up-scaling at the community, regional and national levels. This needs to be undertaken in collaboration with government institutions in order to achieve faster up-scaling. Civil society organisations are capable of piloting innovative technologies, strategies and approaches. However, the scaling up of such approaches is a role for Government as it will often involve removing structural constraints such as changing policies or the development of appropriate policy measures.

Secondly, transport planning needs to be developed in collaboration with local community institutions and the government. Participatory planning with active involvement of the community is critical to an equity based transport. Civil society networks can facilitate creating effective linkages between community members and government institutions.

Thirdly, systematic gathering of relevant information on land use change, transport needs of various sections of the population, access to transport modes both of the users and non-users, and sharing this information to all concerned is required. This would assist in building an accurate and informative performance and implementation indicators for benchmarking, monitoring and evaluation.

Finally, equity and sustainability must be recognized as being central issues in transport planning. This includes active integration of poverty alleviation, gender, age and disability issues into transport development policy, planning and implementation. A combination of transport modes, including NMT, should be promoted taking into account the affordability of the users, but also ensuring environmental, social and economic co-benefits are achieved.

6 TRANSPORT AND CLIMATE CHANGE

6.1 Introduction

Climate change is a major threat to sustainable development in Africa and the achievement of MDGs (Africa Partnership Forum, 2007). Africa is the continent least responsible for climate change and at the same time especially vulnerable to the effects which include reduced agricultural production, worsening food security, increased incidence of both flooding and drought, spreading of disease and an increased risk of conflict over scarce land and water resources. This overall context calls for clear evidence of effort and success in reducing GHG emissions wherever possible whilst at the same time recognising Africa's development needs.

The development "need" has been further developed as the "greenhouse development rights (GDR) framework" which sets out for every country the cumulative responsibility for carbon emissions and a new indicator, the "Responsibility and Capacity Indicator" or RCI to quantify national mitigation and adaptation obligations (Baer *et al*., 2008). A nation's responsibility is defined as the contribution it has made to climate change, and is specified in the GDRs standard case as its cumulative emissions since 1990. A nation's capacity is defined as the national income not demanded by the necessities of everyday life. The RCI shows clearly that SSA countries have very low cumulative emissions and a proportionately low allocation of the burden for cutting carbon emissions. The United States and the European Union have a very large burden in line with their cumulative emissions and responsibilities for climate change problems. Least developed countries as a whole which include Mozambique, Tanzania, Uganda, Zambia and Zimbabwe have been allocated a burden sharing responsibility for reducing global carbon emissions of 0.1 per cent. South Africa is classified as "Upper Middle" in terms of income and on the same methodology has been allocated 1.0 per cent. The USA has a 33.1 per cent responsibility, EU (27) a 25.7 per cent responsibility and China 5.5 per cent (Baer *et al*., 2008).

Any discussion of carbon emissions and climate change in Africa must incorporate the burden sharing principles and the overriding need to protect the right to sustainable human development (Baer *et al*., 2008). This in turn requires careful attention to a sectoral approach (e.g. energy and transport) that can deliver sustainable human development and at the same time make a contribution through the careful selection of alternative development paths to GHG reduction. This chapter outlines some the policies measures and interventions that could be taken by SSA countries to reduce GHG emissions from the transport sector.

6.2 transport and climate change in Africa

Figures 6.1 and 6.2 show the growth trajectory of fossil fuel CO_2 emissions in Africa (absolute and per capita) over the past 60 years.

The growth of transport related CO_2 emissions to 2050 by world region has been estimated by the World Business Council for Sustainable Development (see Figure 6.3).

Although Africa's proportional contribution globally is small the steep growth trajectory up to 2050 is a cause for concern and a strong stimulus for the development of transport policies and interventions that can deliver economic and social progress at a much reduced level of CO_2 emissions.

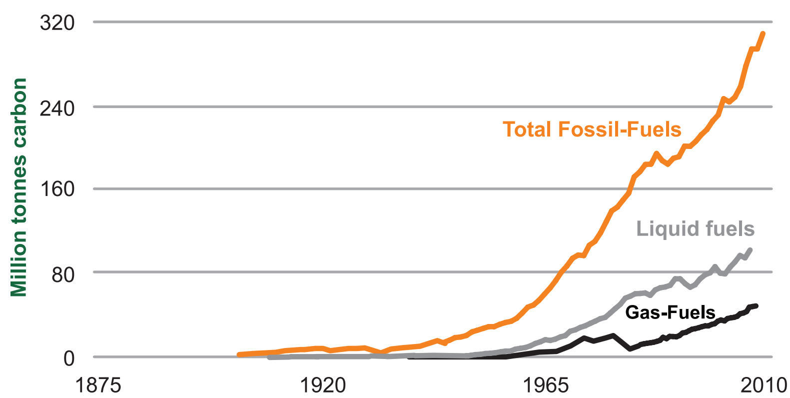


Figure 6.1: Total fossil fuel CO_2 emissions for Africa

Source: Boden et al. (2010)

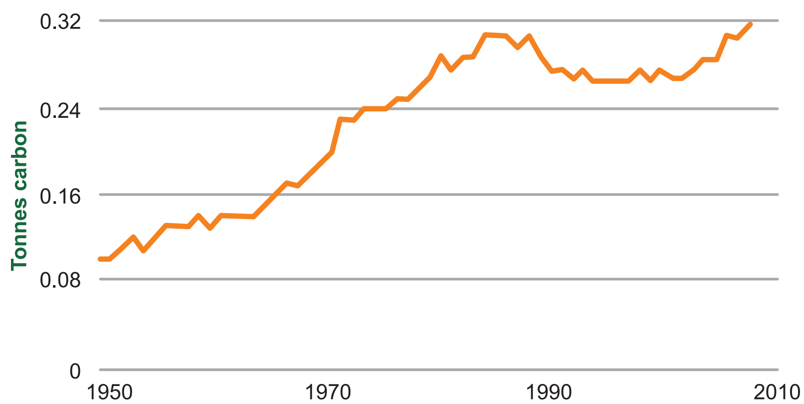


Figure 6.2: Per capita CO_2 emissions for Africa

Source: Boden et al. (2010)

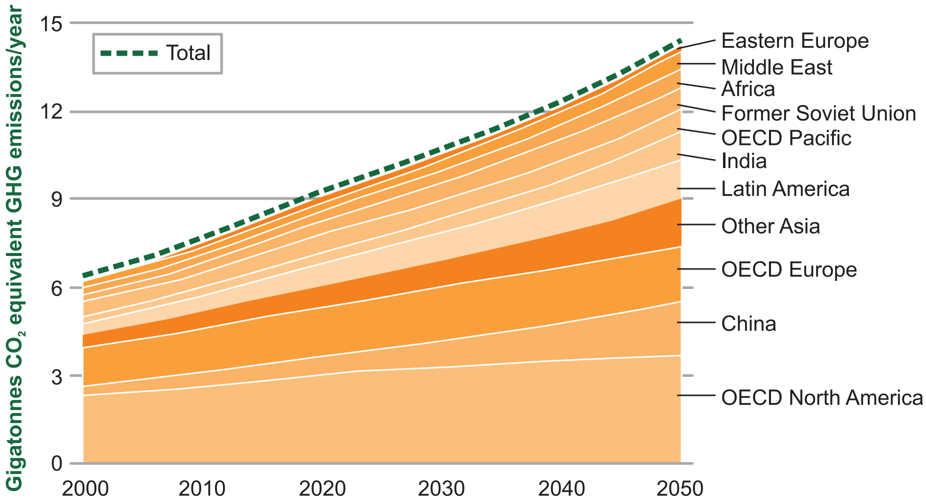


Figure 6.3: Transport related well-to-wheels CO_2 emissions by region

Source: ***WBSCD (2004)***

6.3 Key Issues

Quantifying carbon emissions from transport

If carbon emissions from transport are to be managed and steered towards low carbon outcomes it will be necessary to establish a simple, low cost and effective system of monitoring these emissions. Various options for monitoring and reporting have been discussed and include a recommendation that the basic data should include the following information for the national territory (ABD, 2010):

- Data on the stock of motor vehicles by fuel type (e.g. car, sports utility vehicles, light truck, two-wheeler, heavy trucks, motorcycles)
- Data on buses and trains e.g. numbers of buses by fuel type, locomotives by fuel type and electricity generation mix or for those countries where there are electrified railway services
- Data on the annual average number of kms travelled by each vehicle
- The total number of passenger-kms (pkm) and tonne-kms (TKM) of transport output

From these data a basic CO_2 inventory from the transport sector can be assembled and these data used to track change over time as well as monitor the impact of policy interventions. Measuring the effectiveness of policy interventions is very important and it will be necessary to demonstrate (for example) that a BRT project or programme of support for NMT has produced a measurable impact on reducing CO_2 emissions. This can only be determined by the collection of data and maintenance of a transport carbon data base.

Linkages between urban density, transport-related energy consumption and CO_2 emissions

Energy consumption can be a useful surrogate measure for tracking CO_2 emissions. There are links between urban density and transport-related energy consumption and CO_2 emissions. Newman and Kenworthy (1989) derived an inverse relationship between urban density and transport related energy consumption per capita in world cities (see Figure 6.4).

The statistical methods used to produce this graph have been criticised. The key criticisms of Newman's and Kenworthy's work included the lack of control for variables known to affect fuel consumption such as gasoline price and income, and the lack of complete multivariate analysis (Karathodorou *et al*., 2010).

Many cities in Low and Middle Income countries are developing rapidly and spreading into adjacent rural areas. If this is not carefully managed to maintain densities and accessibility levels it will shift the urban area up the curve so that the energy consumption and CO_2 emissions per capita rise. This can be avoided by policies and strategies that control urban boundaries establish design densities and pay attention to local accessibility so that destinations are within easy walking and cycling range of trip origins. Spatial planning and land use planning to reduce transport CO_2 emissions is an issue of critical importance across a wide range of national, regional and city-wide governmental functions. Detailed information on urban form and carbon emissions can be found in Ewing *et al*. (2008) and case studies dealing with sustainable urban forms in developing countries can be found in Jenks and Burgess (2000).

Leapfrogging

Leapfrogging is the idea that in any developmental sequence it is possible to leapfrog or skip a phase if enough evidence has built up around the undesirability of the intervening phase. For example, from pre-industrial city to a city organised around the freeway and the car to one organised around sustainable mobility. This idea has been described in the case of transport by Dalkmann *et al*. (2004) and puts forward the view that it possible to "miss out" the hyper-motorization phase and move directly to an eco-efficient, highly accessible, sustainable city level of development. In practical terms this is already being delivered in a partial way in several megacities around the world (ITDP, 2010):

- New pedestrian facilities in Mexico City
- Bicycle hire in Hongzhou in China
- Bus Rapid Transit (BRT) in Johannesburg, South Africa

The BRT in South Africa is the first BRT system on the African continent and has set a new standard for high quality facilities

Integrated policy approach to maximise the co-benefits

A number of different co-benefits from carbon reduction have been identified in ADB (2009). These are summarised in Table 6.1:

An example of co-benefits is the linkage between NMT (walking and cycling) and wider societal benefits especially to low income groups. Whitelegg, Williams and Basu (2003) explored this in the context of Calcutta/Kolkata (India). Policies that prioritise walking, cycling and in the case of Kolkata, rickshaws have an impact on reducing air pollution, providing employment for over 100,000 of the poorest group in West Bengal and make a valuable contribution to the mobility and access needs of poorer groups which in turn contributes to larger scale ambitions to reduce poverty. A further example is road safety policy.

Box 6.1

Key concepts

Greenhouse gas GHG is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. The accumulation of GHGs is responsible for climate change. The primary GHGs in the Earth's atmosphere are carbon dioxide, methane, nitrous oxide, ozone, and water vapour.

GHG emissions inventory A GHG emissions inventory identifies and quantifies the man-made and natural sources and sinks of GHGs in a given area (urban, regional, country). It is essential for addressing the contribution of the area to climate change. The inventory should adhere to (1) a comprehensive and detailed set of methodologies for estimating sources and sinks for GHGs and (2) a common and consistent mechanism to compare the relative contribution of different sources (adapted from USEPA, 2011). For transportation CO_2 is the most important GHG.

Sustainable development. Sustainable development is defined as a 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987).

Land use planning. Land use planning means the scientific, aesthetic, and orderly disposition of land, resources, and ecosystem services with a view to securing the physical, economic and social efficiency, health and well-being of urban and rural communities (adapted from CIP, 2011). Land use planning includes the following disciplines:

- Architecture
- Landscape planning
- Environmental planning
- Geography
- Landscape architecture
- Regional Planning
- Spatial planning
- Transportation Planning
- Urban design
- Urban planning

Urban density. Urban density is the number of people inhabiting a given urban area, excluding non-urban land-uses (open spaces, agriculture, water bodies). High-density cities are commonly considered as more sustainable than low-density cities.

Chapter 3 discussed the impact of death and injury in the road traffic environment on those groups in society who do not have access to the car. A clear set of integrated sustainable transport policies will make significant contributions to policy areas that are often dealt with in isolation whereas there is enormous potential to reduce death and injury, reduce air pollution, increase access to jobs, education and training and provide employment and all delivered within a policy framework dedicated to the harvesting of co-benefits.

Other examples of co-benefits include projects aimed at improving the social and economic conditions of women in low and middle income countries (see Chapter 5).

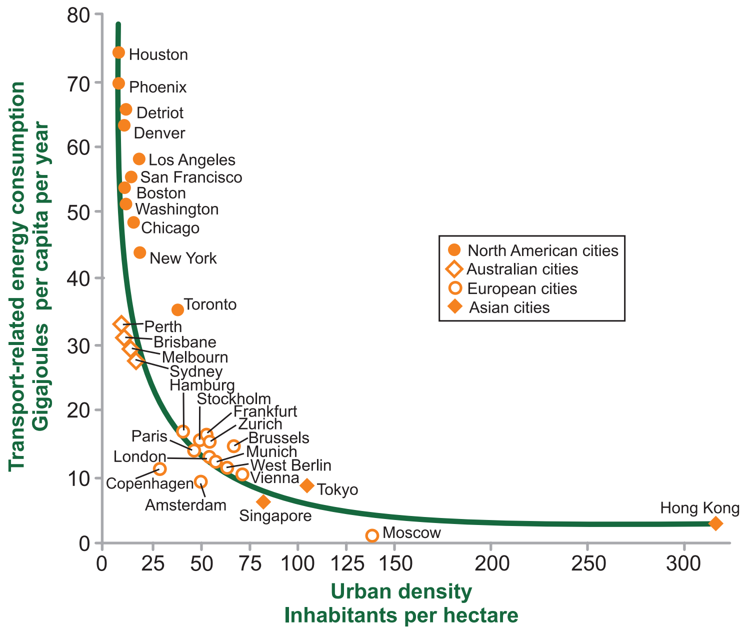


Figure 6.4: Urban density and transport related energy consumption

Source: Newman & Kenworthy (1989); AEMD (2007)

Table 6.1: Overview of recent studies related to co-benefits in the transport sector

Benefits Quantified and/or Results	Study/ Research Project
In Beijing, social costs of climate change amount to CNY1.4 billion per annum, which was valued higher than noise (CNY0.9 billion per annum), accidents (CNY1 billion per annum) but less than air pollution (CNY19.8 billion per annum), and congestion (CNY22.8 billion per annum).	Kreutzer & He (2009)
The handbook covers all environmental, accident, and congestion costs and considers all transport modes. The handbook derives its findings from research generated in European countries. It recommends methods for calculating external cost figures; best available input values for such calculation (e.g., value of one life year lost); estimated default unit values of external cost for different traffic situations (e.g., air pollution cost of a vehicle in euro per km)	Mariachi (2008)
This study has estimated the contribution of heavy goods vehicles in the EU-27 to emissions of CO_2 and air pollutants, noise, traffic accidents, and congestion. The total external costs associated with heavy goods vehicles transport was around €144 billion, with infrastructure costs (51%), traffic accidents (30%), and congestion (24%) making up the bulk of these costs. The authors found the costs of noise (18%) and air pollution (16%) comparable to congestion and other costs, while those of CO emissions (5%) made the smallest contribution.	den Boer et al. (2009)
Central Road Research Institute study on the Delhi Metro has quantified the benefits of Delhi metro. If the social and economic benefits are quantified, then the Delhi Metro Rail Corporation has helped the city of Delhi save Rs 20,725.1 million by 2007, of which the travel time savings constitute 35%. Delhi Metro has also prevented 28,800 tons of carbon dioxide from being emitted into the atmosphere every year.	Delhi Metro Corporation (2008)
This research suggests that accounting for benefits from the reduction of urban air pollution due to the metro has increased the economic rate of return by 1.4 per cent.	Murthy *et al*. (2006)
Bangalore Metro Rail Corporation estimated the benefits of the Bangalore Metro Rail including the potential co-benefits. The benefits quantified amounted to Rs11,550 million where the share were traffic decongestion (33.79%), reduced fuel consumption (24.63%), savings in travel time (28.14%), reductions in accidents (7.59%), and reduction in air pollution (5.84%).	TERI and WBCSD (2008)

Source: ADB (2009)

6.4 Challenges for climate change and transport in SSA

The vehicle fleet in SSA is strongly growing in number with a high proportion of the vehicle fleet consisting of second-hand imported cars and trucks, which would not be licensed any more in their countries of origin. Inspection and maintenance is often absent or insufficient. This means poorly maintained and inefficient vehicles on the roads increasing vehicle exhaust emissions which affect urban air quality and contribution to climate change (see Chapter 2).

Financing is a key challenge for many SSA countries with limited budgets and competing priorities. If sufficient financial resources were available better traffic flow management in many African countries could be achieved (see Chapter 4). However the current existing financing framework is often skewed towards supporting road construction and motorization which will lead to more car dependent mobility patterns.

To understand the challenges for new investments in Africa's urban transport systems it is necessary to reflect on the current financial framework (ITDP, 2010).

1. **Domestic public finance** is mainly used to build and maintain infrastructure to cater to increasing levels of motorized traffic

2. **Official Development Assistance** (ODA) flows are directed towards development based on the motorization model, reflecting both the requests of recipient countries as well as the menu of technical assistance provided by donor organisations

3. **Private flows** are also directed towards the development of goods, services and infrastructure that support the motorization model of transport development

4. **Climate funds and mechanisms** Climate finance, whose main purpose is to provide resources to support climate mitigation (or adaptation) actions, has grown rapidly over the past decade. Most of these instruments can be classified as either:

   – Climate Funds – funded by voluntary contributions from member countries, provide financial resources (in the form of grants or concessional loans) for capacity building, technology transfer or investments in activities contributing to the mitigation of and adaptation to climate change. Examples of these funds are the Global Environment Facility (GEF) Trust Fund and the Climate Investment Funds (CIF).
   – Carbon market mechanisms – It channels an incentive to reduce GHG emissions by means of creating a market for emissions allowances and credits. The carbon market channels financial resources to low-carbon investments through, inter alia, project-based mechanisms such as the CDM and joint implementation (JI). The allocation of emission rights and the ensuing financial flows are enabled by trading schemes like the European Union Emissions Trading Scheme (EU-ETS)

Unfortunately and so far climate funds have been limited in their support for sustainable transport. Firstly, they have been very limited in scale (reflecting the level of commitment by donor countries and the limited size/scope of carbon markets). Secondly, they have been associated with difficulties in providing practical levels of access to resources. This has been due to the stringent requirements in proving additional GHG savings have been made (additionality) and calculating incremental costs of the proposed actions.

6.5 Carbon reduction policy measures

Dalkmann and Brannigan (2007) have summarised the range of policy options that can deliver low carbon/low cost transport solutions (see Figure 6.6). They describe this as the ASI strategy:

A= Avoid so that through land use planning and accessibility planning destinations are co-located with residential areas and distances are kept short. This leads to a lower level of car use and a higher level of use of NMT. Curitiba in Brazil and Singapore have developed spatial strategies and land use patterns that lead to lower CO_2 emissions from transport than cities that pursue low density developments or extensive suburbanisation. Petersen (2002) presents a detailed checklist for policy makers in developing cities on how to manage land use and urban structures to reduce the prevalence of car use, increase the use of NMT and reduce CO_2 emissions.

S= Shift so that wherever possible transport demand can be shifted from cars to public transport, walking and cycling and freight can be shifted from truck to rail and water. The objective is to transfer demand to less carbon intensive modes

I= Improve so that vehicles that use fossil fuel can be designed to be more fuel efficient

ITDP (2010) focuses on ten principles and associated examples that can bring about sustainable and improved quality of life in urban areas with multiple benefits including reduced CO_2 emissions. These ten principles (see Table 6.2) are all worthy of detailed consideration in SSA cities and all are relatively low cost and much cheaper than huge highway, freeway and car parking projects. They are summarised in Table 6.2:

6.6 Transport and climate change risk management in SSA

In relation to transport, climate change risk management (CCRM) is a generic term referring to an approach to climate-sensitive decision making in the transport sector. CCRM seeks to promote sustainable transport by reducing GHG emissions from transport and the vulnerability associated with climate change risk. CCRM involves strategies aimed at maximizing positive and minimizing negative outcomes due to transport issues for communities in fields such as agriculture, food security, water resources and health.

Climate change can be an obstacle to development and reduces the chances of achieving the MDGs in Africa. Integrated transport-related CCRM may reduce adverse climate related impacts in many climate sensitive sectors and promote growth, essential to enabling poor individuals to escape poverty.

Incorporating climate change information into transport decisions allows the risks associated with climate change to be better managed and reduces vulnerability among the poor. Effective CCRM also has the potential for synergistic results, as mitigation of GHGs also reduces air pollutant emissions and noise from transport and adaptation to climate change can help promote growth, essential to enabling poor individuals to escape the poverty trap.

Information on climate change has substantially increased in recent years. Yet the benefits of the gained knowledge are largely failing to reach African decision-makers. An analysis of the reasons for this revealed that data on the impacts of climate change and the availability of ecosystem and climate services are hardly available in SSA, and the incorporation of climate considerations into transport policy and practice is non-existent. Only in a few cases has climate change information been used in policy decisions on non-transport areas where national authorities, development projects, or private-sector operators have recognized the value of climate information and have sought to introduce it in their decision making (IRI, 2007).

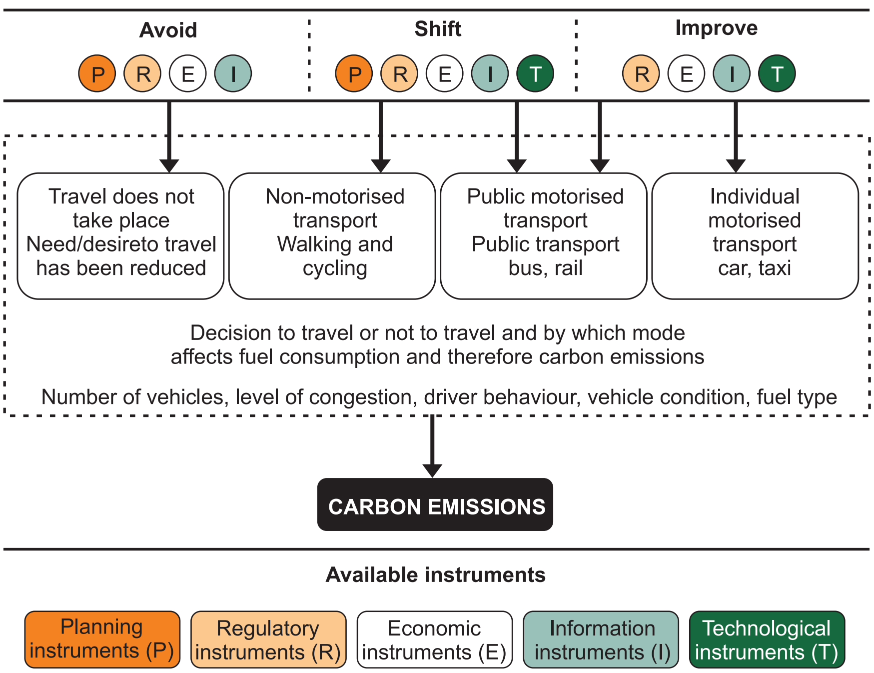


Figure 6.5: The ASI strategy and CO_2 mitigation

Source: Dalkmann and Brannigan (2007)

Table 6.2: The ITDP 10 principles for producing a high quality of life and reducing CO_2 emissions through low cost interventions

1. Walk the Walk!	1.1 Invite people to walk everywher in the city	1.2 Invite people to linger
2. Powered by People!	2.1 Make cycling convenient	2.2 Make cycling safe
3. Get on the Bus!	3.1 Focus on the passenger	3.2 Promote convenient, cost effective solutions
4. Cruise Control!	4.1 Slow down - increase space and safety for people	4.2 Balance access with opportunities to linger
5. Deliver the Goods!	5.1 Going the last mile	5.2 Regulate for results
6. Mix it Up!	6.1 Foster a fine-grain mix of uses in the three dimensions	6.2 Keep ground floors active where people walk
7. Fill it in!	7.1 Build density around transit nodes	7.2 Revitalize the existing before building new
8. Get Real!	8.1 Embrace diversity and enhance social networks	8.2 Protect cultural assets
9. Conncet the Blocks	9.1 Protect fine grain environments	9.2 Make new city blocks short and easy to walk
10. Make it Last!	10.1 Quality of materials, design and production	10.2 Robustness and re-use

Source: ITDP (2010)

Thus, what is needed is an integrated approach that incorporates climate change information into multidisciplinary transport planning and projects. It is essential that this approach be participatory, involving all stakeholders in transport issues so as to ensure that their real needs are met. The tools for GHG mitigation and climate change adaptation developed and deployed though this approach will substantiate the decision making of stakeholders by providing relevant information on transport and environment science and technology transfer. The better management of transport and climate change risk will increase the resilience of infrastructure systems, and strengthen the capacity to adapt to future climate change phenomena such as extreme weather events. Climate change risk management through GHG mitigation and climate change adaptation has to be perceived as a core development issue for SSA countries.

The International Research Institute for Climate and Society provides policy recommendations on an approach of incorporation of CCMR for non-transport areas in SSA, which can be adapted to transport issues (IRI, 2007). These are:

- Recast climate change risks as a development issue;
- Encourage institutional innovation, networks and partnerships that can develop and implement transport-related CCRM programmes;
- Strengthen research in support of climate change risk forecasting and the interaction of climate change with the transport sector;
- Promote systematic knowledge sharing by knowledge management systems.

6.7 Understanding transport and climate change in SSA

There is a considerable body of knowledge in the transport sector on the kinds of transport developments, initiatives and infrastructures that can contribute to sustainable human development in developing countries while producing lower levels of CO_2 emissions from the transport sector (GTZ, 2002). The adoption of an ASI strategy can facilitate the move to low carbon transport. Finance will be a challenge to many SSA countries that will have to address competing social, economic and environmental priorities. However, it is clear that a number of measures have potential co-benefits that are low carbon but could help improve the quality of life of many African urban dwellers. Measures such as bus regulation and planning, promoting NMT, land use planning and bus rapid transit which assist SSA countries avoid (i.e. “leapfrog”) the hyper-motorization phase often associated with development.

7 CONCLUSIONS AND POLICY RECOMMENDATIONS

Transport policy decisions and the detailed spatial, sectoral and social group beneficiaries of transport spending and strategies have a hugely important impact on the lives of hundreds of millions of people in SSA. In this report we have undertaken an assessment of the scale of these problems and deployed high quality scientific analysis and insight to identify trends, challenges and opportunities. There are a large number of well documented ways in which we can improve the quality of life of Africa's citizens. We can improve air quality and public health, remove the scourge and distress caused by death, injury and disability as a result of road crashes and increase the likelihood of widely disseminated economic gains to all sections of society.

In this social-technical-economic complex there are important democratic considerations. What do African citizens want for the future of their families, their communities their regions and their country? Given a choice of living in poverty, pollution, traffic danger and poor quality access to important health, education and training opportunities or living in a thriving, opportunity-rich, clean and safe environment it is already very clear that the latter is preferable to the former. If all the policies and strategies already identified in the chapters in this report are adopted with a will and a "no excuses" enthusiasm for achieving success then hundreds of millions of citizens will benefit.

Recent years have seen significant progress in poverty eradication in China and India (Brown, 2008). The number of people living in poverty in China dropped from 648 million in 1981 to 218 million in 2001. This, according to Brown is the greatest reduction of poverty in history. Gains are also being made in India, Thailand, Vietnam and Indonesia but not in SSA (Brown, 2008):

> *"Sub-Saharan Africa with 800 million people is sliding deeper into poverty. Hunger, illiteracy and disease are on the march, partly offsetting the gains in China and India. Africa needs special attention ... extreme poverty in these countries is now higher than in 1990"*

A transport policy for SSA must be embedded in a poverty eradication policy and poverty eradication must deliver real gains in transport as it affects 800 million SSA citizens. This policy synergy provides a huge opportunity to deliver successful outcomes and they will not deliver if they move along in non-communicating parallel tracks. So how can they be more closely integrated?

Transport policy at every level in SSA countries from national ministries to city-wide administrations and those agents involved in delivering new and improved transport infrastructure must focus on five central organising principles. These are:

- Creating the maximum possible accessibility conditions for all social groups and all income level and genders so that all citizens can access health care, education, training and jobs with minimal effort, costs and expenditure of time on the journey. This has to be done for men and women and all age groups (see Chapter 5).
- Creating a safe, secure urban environment with the minimum possible risk of death and injury from road crashes for men, women, children, the elderly, pedestrians, bus users and cyclists (see Chapter 3).
- Ensuring that all public health measures deal with the debilitating, costly and economically damaging consequences of air pollution and noise on human health (see Chapter 2).
- Freeing up urban road space by improving traffic flow conditions in a way that stimulates economic activity and job creation and avoids the generation of new traffic that can cancel out the gains from congestion relief unless this is properly planned (Zeibots and Elliot, 2011) (see Chapter 4).
- Reducing GHG emissions through the "avoid, shift, improve" strategy (see Chapter 6).

SSA has some very serious transport problems but these present all decision-takers and policy makers with opportunities to re-shape traditional policies to produce a step-change improvement in quality of life for citizens and to deliver the urgently needed poverty alleviation outcomes already agreed. We have shown how those policies and interventions can be re-shaped and the task now is to orchestrate the political and professional support and unwavering commitment to deliver all these virtuous outcomes. Lester Brown in the concluding page of his book "Plan B 3.0" (Brown, 2008) reflecting on the meta problems of poverty, population, climate change, pollution and the erosion of the earth's capacity to support itself said "The scale and urgency of the challenge we face has no precedent, but what we need to do can be done. It is doable"

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