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Transport Sector Working Paper

Appendix B

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Executive Summary

This paper is one of a series of papers, which form an initial discussion point in the development of a National Strategy on Climate Change and Low Carbon Development for Rwanda. It should be read in conjunction with the 'thinkpiece', which proposes a vision for 2050, objectives and guiding principles and strategic pillars for the national strategy. This paper reviews the 'Transport Sector' covering the technology and operation of transport systems and services in Rwanda. The paper concentrates on global best practice and covers the various policy levers that can be implemented in order to facilitate a change in the current system.

Transport in Rwanda is taking steps in the right direction, a number of projects are being undertaken in order to reduce the cost of transportation, which has an additional effect to reduce fuel use and emissions. Key to this is the improvements to the quality of the road network, both in rural and urban areas. This will increase the efficiency of the current fleet, as well as allowing for smaller and alternative vehicles to be utilsed. It is also key that future and environmental effects are taken into account when considering projects. Transport infrastructure lasts for many generations, the United Kingdoms rail network is reliant on 200 year old Victorian decisions on route and infrastructure. Correcting mistakes made in planning is costly and preventable.

With this in mind it is necessary in the short term to build up an accurate picture of current transport demand and future scenarios. This will enable accurate models resulting in plans for the requirement for future development and the construction of the necessary policy actions to enable the desired change. With this information as a foundation analysis of the various options and the required policy levers to implement them should be defined. The medium term should see the role out of pilot technologies, identified as the most promising by the studies carried out in the short term. The enabling polices should also be introduced setting up for a long-term full roll out of the systems.

Contents

Acronyms and Abbreviations

AC	Alternate Current
AFC	Alkaline Fuel Cell
BEVs	Battery Powered Vehicles
BRT	Bus Rapid Transit
CAC	Command and Control
CAFE	Corporate Average Fuel Economy
CapEx	Capital Expenditure
CCTV	Closed Circuit Television
CH_4	Methane
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO_2	Carbon Dioxide
CO_2e	Measurement of greenhouse gases global warming impact equal to that of one tonne of carbon dioxide
COE	Certificate of Entitlement
CNG	Compressed Natural Gas
DC	Direct Current
EIB	European Investment Bank
FONERWA	Rwanda Fund for the Environment
Gg	Gigagram
GHG	Greenhouse Gases
GIS	Global Information System
GoR	Government of Rwanda
HEV	Hybrid Electric Vehicle
HLTA	Hybrid-Lighter-Than-Air
ICE	Internal Combustion Engine
ITS	Intelligent Transport System
KfW	German development bank (Kreditanstalt fur Wiederaufbau)
kW	Kilowatt
kWh	Kilowatt-Hour
LCA	Lifecycle Assessment
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
LTA	Lighter-Than-Air
LRT	Light Rapid Transit
MDG	Millenium Development Goals
MCFC	Molten Carbonate Fuel Cell
MININFRA	Ministry of Infrastructure
MRT	Mass Rapid Transit
NG	Natural Gas
NO_x	Nitrogen Oxide gases
PAFC	Phosphoric Acid Fuel Cell
PAYD	Pay-As-You-Drive
PEMFC	Polymer Electrolyte Membrane Fuel Cell
PHEV	Plug-in Hybrid Electric Vehicle
R&D	Research and Development
SOFC	Solid Oxide Fuel Cell
SO_x	Sulfur Oxide
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
VQS	Vehicle Quota Systems

Overview

This paper is one of eight sector working papers written as part of the process of developing a National Strategy on Climate Change and Low Carbon Development for Rwanda. It follows on from the Baseline Report produced in February 2011, which provides the local context for each sector, including current programmes and development plans. This paper focuses on Transport while the other working papers cover Energy, Water, Agriculture, Land, Forestry, Built Environment and Mining. Finance and Education are incorporated into the working papers rather than standing alone. The paper should be read in conjunction with the 'thinkpiece', which proposes the Strategic Framework including a vision for 2050, objectives, guiding principles and enabling pillars. The aim of each paper is to identify the vulnerabilities and opportunities facing the sector, to review global best practice and relevant case studies, and to propose an action plan for addressing climate change and low carbon development in the short, medium and long term. This action plan is put forward to stakeholders in Rwanda for review and comment. As the title suggests, the working papers are aimed at prompting discussion with stakeholders, rather than being the final word. The sector working papers, thinkpiece and stakeholder input will be used to compose the final Strategy in July 2011.

Vision - a visionary aim for transport in Rwanda by 2050

In 2050 Rwanda will posses an efficient inclusive integrated transport system, which is fully energy secure and resilient to both climate change and increasing demand. This will be achieved by:

- A fully sustainable multi-modal transport system that is based on efficient technology and operational systems
- A low a cost to entry as possible
- Based on a fully secure domestic energy supply
- Socially inclusive encompassing the majority of the Rwandan nation
- Robust in terms of adaptation to climate change and future demand
- Regionally competitive domestic transportation industry supporting the national economy
- Sufficient access to capacity, in terms of finance, knowledge and governance

In comparison with this the current system is:

- Based on fossil fuel and is highly reliant on a single mode, combustion engined road transport
- Relies on imported fuel supply with security and cost concerns
- Infrastructure, technology and operational systems are neither resilient to climate change nor capable in their current form of withstanding increasing demand
- Rwandan transport services are dominated by foreign companies and limited in rural areas
- Availability of finance and human capacity is limited

Introduction

1.1 Overview of Transport Sector in Rwanda

Transport is key in economic development. Without transport, the movement of goods and services (trade) is impossible. The cost of such transport is one of the key variables that can promote, or constrain, economic growth. And transport systems are expensive and time-consuming products to implement. They are infrastructure heavy, and usually involve a huge number of stakeholders, including government regulators, global manufactures, national and regional operators and private owner operators, all with their own focus areas and demands. Globally, road vehicles dominate motorised transport. They rely almost exclusively on an expensive, environmentally unsound and diminishing resource, oil.

The transport sector in Rwanda is no exception. It is currently dominated by internal combustion engined (ICE) road transportation, both for passengers and cargo. National and international transportation is dominated by the road sector with a limited amount of people and materials moved by water and air. This has a significant effect of prices in Rwanda, as lack of modal competition and demand for imported fuel keeps transport costs high. Currently over 40% of the cost of goods is attributed to transportation, keeping prices high and reducing the competitiveness of Rwandan exports. GHG emissions from transport are approximately 5.4% of Rwanda's total emissions, some 269.9 Gg of CO_{2eq}. Local pollution is a concern due to the age and condition of the Rwandan fleet. Ozone levels exceed both US and Japanese environmental standards.

And developing the sector is a significant and important challenge. The terrain and location of Rwanda, being hilly and landlocked, has a number of challenges to overcome. The hills and valleys result in a highly dense road network, 0.56km/km^2, the maintenance of which consumes the majority of the governments transport budget. It also restricts the application of some 'traditional' transport modes, particularly efficient bulk carriers such as rail and maritime transport, though it should be noted a rail link to Dar-es-Salaam is currently being developed. When investment does occur, the physical characteristics of Rwanda adds significantly to the expense, such as construction of earthworks and the cost of importing supplies and equipment. The climate also plays a factor, with intense rainfall washing out road surfaces and requiring damage mitigation strategies, such as drainage channels and slope stablisation. Investment in transport is also hampered by limited access to finance, both for the public and private sectors. As well as these internal factors, there are external factors, some of which Rwanda can influence, such as regional regulations (Rwanda is part of the East African Community) and those it can't, such as the development of algal biofuels.

It is within this context that this paper aims to present both the technical and policy options available, with examples of global best practise as a starting point for stakeholder discussion. The options will be briefly analysed on key metrics to help identify those options most likely to succeed if implemented in the Rwanda context to achieve the vision.

1.2 Opportunities and Vulnerabilities

There are a number of opportunities and vulnerabilities facing the transport sector in Rwanda. These were identified during the stakeholder engagement process in Rwanda during the baseline stage. These cover all issues and opportunities raised, whether relevant to low carbon growth and climate change or not. These vulnerabilities and opportunities are summarised in tables 1.1 and 1.2.

Table 1.1: Vulnerabilities in transport sector

Economic/ Finance	Social/ Capacity	Technology/ R&D	Political	Legal/ Institutional	Environment/ Climate	Communication/ Information
High fuel prices	Poorest most vulnerable	Poor quality fleet	International transport (land) is reliant on neighbours	Weak institutional capacity	Land use competition – particularly biofuels	Poor vehicle data
Reliance on imported oil Susceptible to price spikes	Poor access to transport services in rural areas	Possible oil reserves	Energy security issues	Legal framework not fit for purpose	Local pollutants already an issue	Poor demand data
Single mode reliance prevents competition	Lack of Rwandan professionals – civil engineers, surveyors etc.	Dependent on International suppliers	Changing export and import levels – could case friction	Large Regional Projects – challenging to complete	Infrastructure susceptible to climate change particularly increasing precipitation	Poor usage data
Terrain and location	Demand for private cars	Need for 4x4 due to road state	Regional suppliers of oil	Focus on implementation not policy	Ozone	
Little national transportation industry				Vehicle Regulation	Intense rainfalls difficult to design for	
High maintenance costs					Increasing heat	
International transportation dominated by foreign companies						
Low access to capital						
Costly and difficult to create infrastructure						
Demanding schedule						

Table 1.2: Opportunities in transport sector

Economic/ Finance	Social/ Capacity	Technology/ R&D	Political	Legal/ Institutional	Environment/ Climate	Communication/ Information
Small fleet size – low number of owners	Dense road network eases accessibility	Novel technologies	Strong government leadership	Transport specific agency	Small size of country	Detailed GIS system
Low embedded value in current transport fleet	GoR encourages training at all levels	Mass Transit	Become a regional source of knowledge	Efficiencies in logistics	Availability of water bodies	Society sensitised to change
CDM for mass-transit	Abundance of local labour force	Low fuel demands – biofuels an option	Regional Transport Hub	Strong leadership		Mobile phone system already used to communicate
	Populous used to walking	Source of methane and biogas		Maintenance Program		Broadband availability
	Currently low mobility levels – any change is a gain	Low carbon electricity power source		Dry Ports		
	Society used to following regulations	Little embedded infrastructure				
		Low technology - appropriate and cheaper				
		Increasing quality of roads				

1.3 Focus Areas

These opportunities and vulnerabilities were then refined to the focus areas summarised in table 1.3. These focus areas were defined during the engagement process with stakeholders. They focus on the challenge of providing affordable access to services in aid of development, improving the efficiency of the system to minimise climate impacts and the key issue behind developing and implementing these programmes.

Table 1.3: Focus Areas

Focus Area	Option 1	Option 2	Option 3	Option 4
Access	Labour intensive technology	Modal diversification		
Efficiency	Current Fleet Regulation	New Vehicle Regulation	Advanced technology	Logistics
Implementation/ Planning	Finance	Capacity	Institutional/ Legal Framework	Data

1.4 Sectoral Overlap

As a key factor in the economic process, the transport sector has many users and operator and overlaps with other sectors:

- **Energy use** – Transport is a key user of energy supplies and future systems must be integrated with energy sector strategy
- **Mass transit** – Efficient, multi-modal transport systems are often centred around mass transit systems. This has an impact of the design and construction of urban areas and land use. This is covered in detail in the 'Cities and the Built Environment'.
- **Goods** – Any sector that produces goods, such as agriculture, industry and mining, will require access to transport to enable the passage to markets.
- **Water transport** – The possibility of water transport should carefully consider the risk and opportunities associated with the water, particularly in the opportunity in transporting both water and goods via canals.

It is important that any development take into account the needs of these associated sectors when defining transport strategy.

Global Best Practice

The status of transport is recognised by the Government of Rwanda and is receiving significant investment through the Rwandan transport Development Agency. These steps were summarised in the baseline report and it is the aim of this paper to investigate further options, which have the potential to make Rwandan transport sustainable and robust to both climate change and increasing demand. To achieve the required change in the current system there are a number of options, from changing technology to altering consumer demand and these are introduced below.

2.1 Labour Intensive Systems

Often dismissed as 'backward' or 'un-developed' labour intensive transport, walking, cycling etc. are seeing a huge increase in use in developed countries. They are cheap, highly accessible and flexible systems that have health and social benefits, in addition to the transportation benefit. Many global cities, including London, Bogota, Paris, Amsterdam and Beijing are either attempting to increase or have increased the level of journeys taken by these modes. London, Paris and Beijing, the later once famous for the huge number of bicycles, amongst others, have introduced rental schemes to increase the number of bike users within the city[3]. Investments include hire systems, infrastructure (both in terms of transport corridors and end of journey facilities) and bike friendly policies such as education, tax breaks and legal support. A number of project around the world are promoting bicycles as a solution to low carbon mobility, not just within the developed nations, but within newly industrialised, emerging and less developed economies[4-7]. And bicycles need not be solely for personal transport, globally, cargo-bikes are used to transport significant cargo loads in urban and rural areas[8-10].

Case Study 1 – Best Practice

Swiss Transport – Runs like clockwork

As a small land locked mountainous country in Europe, Switzerland has invested heavily over the long-term in transport infrastructure, to produce an efficient multi-modal system. Switzerland's location, at the centre of Europe, has made this investment profitable, with constant flows of goods and people over the Alps. The Swiss model follows a multi-modal system, of various railway gauges (narrow gauges are more suited to mountainous areas), road, air and water transport. These investments have been supported by various policy measures, centred around regulation and taxation[2].

2.2 Internal Combustion Engine Vehicles

The most obvious method to improve the sustainability of transport in Rwanda is to improve the standard internal combustion engine (ICE) technology. The efficiency of current petrol engines is 20-30%[11] and diesel engines are 35-45%[12]. Improving the sustainability of ICE light goods vehicles centres around the reduction in fuel consumption. This can be achieved by improvements in the efficiency of the propulsion and non-propulsion systems. Propulsion system improvements include improvements to the transmission system and the engine efficiency itself. Non-propulsion methods include improved aerodynamics, reduced rolling resistance and weight reduction.

2.2.1 Transmission

Transmission improvements can hugely affect the overall efficiency of vehicles. Recent studies suggest that by increased gearing ratios and developments in bearings, gear sealing elements as well as the use of hydraulics could see a 5% increase in efficiency from 89% to 94%[13].

2.2.2 Engine Efficiency

The current internal combustion engine can be improved in a number of ways. Naturally aspirated spark ignition gasoline engines can be improved by reducing the friction on the internal parts, smart cooling systems, variable vale lift and timing, cylinder deactivation, variable compression engines and gasoline direct-injection. Another option is to use turbo charging, which utilises the waste gasses, to increase the power output, reducing the required capacity and thus fuel use of the engine. Diesel engines are also an option, with improvements in injection and valve technology reducing the emissions from these traditionally smokey engines.

2.2.3 Aerodynamics

As with any object that moves through the atmosphere, vehicles are affected by drag. Whilst current vehicle aerodynamics is highly developed, there are possibilities for further refinement. Current experimental vehicles have a 30-50% reduction in drag coefficient compared with current commercial products. These experimental designs, which sit low to the road, are impractical for general use road but current estimates an annual reduction in drag coefficient between 0.9% and 2.5% per annum[14-16].

2.2.4 Rolling Resistance

Rolling resistance is resistance caused as an object rolls over a surface. It is mainly caused by deformation of the object or the surface, though significant secondary causes are wheel radius, forward speed, surface adhesion and relative micro-sliding. Ignoring the improvements possible in reducing deformation in the surface (i.e. improving the road surface), improvements to the rolling object (tire) can be achieved though developments in materials, design and operation with a 10% reduction in rolling resistance achievable within the next ten years[17].

2.2.5 Vehicle Weight Reduction

Reducing vehicle weight is a common strategy in all transport modes to reduce energy consumption. Reducing vehicle mass results in the inertia forces that propulsion has to overcome being lowered, reducing the power, and therefore energy, requirement for the vehicle. Weight reduction in current designs can be achieved by the direct substitution with lighter materials, redesigning the vehicle to minimise weight and a down sizing of the fleet. A 10% reduction in vehicle mass from the average new vehicle can cut fuel consumption by approximately 7% at an annual rate of 1%[15].

2.3 Energy Source

The gasoline fuelled internal combustion engine dominates the current transport system. The

Case Study 2 – Worst Practice?
Houston – Where car is king

Houston, as with many American cities was built around the principle of cheap private fossil fuelled transport, private cars providing 71% of journeys. This has developed a city with little in the way of public transport (8 miles of light rail), centred on a ‘hub-and-spoke’ freeway system, served by multiple loops, consisting of 739 miles. This has led to a sprawling city of some 1,558km^2, a population density of 1,505 people per km^2, compared with 5,847 people per km^2 in Tokyo. This leads to a highly in-efficient, in terms of energy, system, reliant on an increasingly expensive fuel supply[1].

sustainability of this as a form of transport is undermined by dwindling oil supply and concerns over the emissions produced. In order to solve this a number of alternative energy or fuel sources have been investigated.

2.3.1 Biofuels

A commonly discussed option, and one that is currently being explored in Rwanda, is the use of biofuels. Biofuels are produced by converting biomass (plant matter) into liquid fuels by a number of different processes. Biofuels can be broadly split into three generations: first generation, which encompasses edible feedstock's such as sugars and oils; second generation which is the conversion of waste biomass, such as lignocelluloic matter; and third generation which is produced industrially through algae bioreactors. Combustion of the biofuels pure or as an addative in conventional fuel can be achieved in standard ICEs or in modified engines, which allows these fuels to be a 'drop-in' solution to low carbon transportation. There are a number of issues with biofuels, which include food and land security for first and second generation, as well as technical issues with the mass manufacture of third generation biofuels. For all biofuels, their low-carbon, and therefore sustainable credentials rely on the production cycle. Land use change and refinement processes can turn a supposedly zero-carbon fuel source into one that emits more than gasoline[18]. An issue with all biofuels is the production level, first and second generation biofuels require significant land area to produce the necessary volume for global fuel supply and algal (third generation) require a breakthrough in mass production techniques[19, 20].

Case Study 3 – Compressed Natural Gas Busses in Delhi, India

The Indian City of Delhi is part of the national capital region with about 14.3 million inhabitants. Due to the rapid increase in vehicle kilometres driven and the poor technical conditions of the vehicles, the load of ambient air with automobile pollutants is extremely high. Between 1998 and 2002 all busses and 12,000 taxis and 13,500 three-wheelers were converted from diesel to compressed natural gas. This was achieved by a variety of policy options from intervention (provision of infrastructure) and regulation (banning of older vehicles and new diesel vehicles) and financial incentives (supporting vehicle replacement).

2.3.2 LPG

Liquid Petroleum Gas (LPG), a hydrocarbon fuel, is a mixture of gasses, primarily propane and butane, which can be burnt in combustion engines. As the boiling point of LPG is low, varying from 229°K to 273°K and requires heavy, insulated containers that can contain the pressurised liquid. While still a fossil fuel, LPG produces a 13% reduction in CO_2 emissions when burnt[21]. It is widely used globally, in both dual-fuel and LPG only vehicles.

2.3.3 Methane

Methane or Natural Gas (CH_4) is a hydrocarbon gas produced during the decomposition of organic matter. It is widely available form a variety of sources, such as geological deposits and decaying landfill sites. At room temperature methane is a gas and is therefore has a low energy density. This can be improved by compressing (CNG) or cooling and liquefying (LNG). CNG is stored at 20Mpa resulting in a energy density approximately a quarter of that gasoline. At a constant compression ratio CNG has a 10-15% power reduction when compared to a standard gasoline powered ICE due to CNGs higher octane rating[22]. LNG is approximately 2.5 times the energy density of CNG, but still only 60% of diesel[23]. The cooling required for LNG (-400°K) prohibits it use in smaller vehicles, but has been applied in larger vehicles such as busses and heavy goods[24]. On combustion NG results in an approximately 15-25% reduction emission reduction (kg $CO_{2\text{-eq}}$/km) over diesel[21, 25, 26].

2.3.4 Electricity

Another option is to move away from liquid fuels to other forms of energy. Electricity is an obvious choice and to reduce emissions to the absolute minimum, it is necessary to remove the combustion of carbon-based fuels from generation, by the use of renewables energy sources. The use of electricity to power transport hinges on providing a method for the vehicle to access power, either through permanent connection to the transmission grid, via over-head power line or induction technologies, or by converting it into transportable forms, such as chemical or potential energy. There is also a significant efficiency to be gained by electric motors as they are approximately 90% efficient[27].

Most vehicles rely on a storage method to carry sufficient energy to power them. In conventional vehicles this is liquid petrol and diesel (chemical energy) stored in a tank. Electric vehicles must utilise a different storage method to transport its electrical power supply. These internal power supplies are then re-charged or re-placed when discharged, providing energy to propel vehicles. Chemical batteries are most common, but other methods include kinetic, thermal and radioactive sources. The latter two are for specific applications, such as jet fighter ejector seats and deep space probes, but both chemical and kinetic systems have transport applications.

Chemical

As the de facto standard for the storage for electrical energy, chemical battery powered vehicles (BEVs) are a common theme in sustainable transport. BEVs rely on chemical reactions, which converts chemical energy to electrical charge. There are a number of chemical compositions, which can be used to store charge, each with advantages and disadvantages, which are compared in table 2.1 It is this battery technology that is restricting the growth of BEV technology and a breakthrough in weight, volume and re-charging rate is required to allow it to compete with ICE systems.

Hybrid Electric Vehicles

An intermediate step between converting from a purely ICE transport system and a purely electrical transport system is the Hybrid Electric Vehicles (HEVs). HEV systems use an ICE engine to propel the vehicle and to charge a BEV system when not required for drive and also through regenerative braking. There are three types of system, parallel, series and series-parallel hybrids. Parallel systems have both the Ice and electric engines connected to the mechanical transmission, both or individually driving the wheels. Series systems have the ICE solely generating electricity to power the electric motor, which in turn drives the wheels. Series-parallel systems are a combination of the two with the ICE both generating electricity and providing power to the transmission and are currently the typical installation (Toyota Prius). Hybridisation also varies by degree, with full hybrids, where the electric drive train can propel the vehicle and mild hybrids where the electric drivetrain can only assist the ICE drivetrain.

A further sub-type of HEV systems are plug-in hybrid electric vehicles (PHEVs), where a HEV system is charged from the grid. This extends the distance of purely electric driving minimising the use of ICE but also offering the security of a gasoline system as back up.

Fuel Cells

Another option for using electricity in transport is the use of hydrogen. Hydrogen can be produced

Case Study 3 – Introducing Technology Kathmandu – Batteries in the Himalayas

With rapidly increasing air pollution in Kathmandu Valley, the Nepalese Government banned (1991) further registration of diesel operated three wheelers, which had seen an explosion of use between 1989-92, and all use in 1999. It replaced these with lead-acid battery powered vehicles, locally manufactured, with assistance from US-AID. To reduce the impact of the increased cost associated the batteries are leased and there are favourable electricity tariffs to charging stations. This project has successfully introduced an emission free alternative to the diesel three-wheeler based on a domestic industry with a visible improvement in air quality.

using grid electricity, which can then be used in fuel cell powered vehicles. Fuel cells convert hydrogen fuel and oxygen from the air into water, producing electricity in the process, which is then used to drive an electric motor. By converting chemical energy directly into electrical energy, fuel cells skip the inefficient intermediate conversions to thermal and kinetic energy found in ICEs. Although first demonstrated 170 years ago[35] only recently has it been possible to use fuel cells in vehicle drivetrains due to developments in energy density[36]. Compared to ICE systems, fuel cells produce much less waste heat and consequently offer a much higher theoretical efficiency. Unlike batteries, fuel cells can run continuously with sufficient input of reactants (fuel and oxidant), working best with pure or reformed hydrogen[37, 38] but some can operate directly on alternative fuels such as methanol or hydrocarbons[39]. Fuel cells are typically classified according to the electric conductor (electrolyte) that they use:

- Polymer electrolyte membrane fuel cell, or proton exchange membrane fuel cell (PEMFC)[40]
- Alkaline fuel cell (AFC)[41]
- Phosphoric acid fuel cell (PAFC)[42]
- Solid oxide fuel cell (SOFC)[39]
- Molten carbonate fuel cell (MCFC)[43]

Fuel cells offer a number of advantages: they can be run on a variety of fuels, reducing reliance on any one single fuel source; fuel cell emissions are also lower than those of ICEs, emissions of SO_x, NOx, and particulates are virtually zero; If running on pure hydrogen, emissions of greenhouse gases like CO2 are low or zero at the point of use, but the method of hydrogen production must be taken into account; If running on a hydrocarbon fuel, CO_2 will be produced, though less than for an ICE due to the greater efficiency of fuel cells. Fuel cells are approximately 40-60% efficient, around twice that of ICE. Future developments may increase that to 80%[11, 44]. Fuel cells are also more efficient at partial load, which is the typical running condition for automobiles. Because of their scalability of power, fuel cells are suited to a wide range of applications, from mobile phones and laptops to power plants. In vehicles, fuel cells could be sized to provide all the power required, only the base load, only the recharging of batteries, or only an auxiliary power unit.

Despite great progress in recent years, fuel cell vehicles face significant challenges, particularly with durability. Transport systems must be durable and reliable, able to withstand large changes in temperature and humidity, and to withstand load cycling (acceleration and deceleration) with minimal performance degradation (3-5%) over a lifetime of

Table 2.1: A Comparison of chemical battery technologies for vehicles (Source: [28-34])

Composition	Energy Density (Wh/kg)	Peak Power (W/kg)	Energy Efficiency (%)	Life Cycle	Cost (USD/ kWh)	LCA Score	Status	Notes
Lead-acid	35-50	150-400	>80	500-1000	100	503	Mature, proven technology	Little scope for development,
Nickel-cadmium	50-60	80-150	75	800-1350	>550	544	Mature technology	Toxicity and safety issues
Nickel-metal hydride	70-95	200-300	70	750-1350	530	491	Proven technology	Safe, longevity in calendar and lifecycle
Sodium-nickel chloride	90-120	130-160	80-95	1000-1200	240	234	In development	High operating temperature,
Lithium-ion	80-130	200-300	>90	1000-3200	>800	278	In development	Safety concerns, short calendar life

5000 hours[45]. Fuel cells cannot yet achieve this, with undesired reactions, corrosive electrolytes in some cases, and high operating temperatures prematurely degrading performance. Fuel is another complicating factor as hydrogen is not widely available, is difficult to store, and has low volumetric energy density. The alternative is to reform other hydrocarbon fuels into hydrogen on-board the vehicle, but this is complex, expensive, and reduces the overall vehicle efficiency due to inefficiencies in the reforming process[46]. The biggest current limitation, however, is the cost and availability of fuel cell systems. Compared to a cost of just 30 USD per kW for a mass produced ICEs[45](500,000 units), an 80 kW automotive PEMFC system operating on direct hydrogen costs approximately 75 USD per kW[47] though such production levels appear to be many years away, The cost increases for low volumes, such as those found in initial proof of concept and evaluation vehicles, with costs nearer to 700-800 USD per kW[47]. The major cost in fuel cell systems is the relatively large amount of platinum needed for catalysis.

Kinetic Storage

Another method for transporting electrical energy is by converting it into kinetic energy. This can be stored by a variety of methods and can then be used to power vehicles.

Compressed Air

The conversion of electrical energy to compressed air for transport is not a new one. It has been utlised throughout the 20th century in both industrial and commercial applications, powering mining tools and tramways. The conversion of electricity to compressed air to motive power has thermodynamic losses during compression and expansion, resulting in a 53% efficiency in conversion[48]. The primary benefit of compressed air vehicles is they are zero emission at source, with the low level of technical requirement to construct and operate, particularly in the end of life cycle. The emissions of such vehicles, as with BEV systems is dependent on the emissions of the source used to generate electricity. Issues centre on the energy density of compressed air, with a vehicle with 150km range requiring 70kg of compressed air, compared with approximately 6.5kg of gasoline. Other problems are up front costs, which in compressed air vehicles are focused on the compressors and the tanks, particularly if on–board compression and lightweight carbon fibre tanks are used.

Flywheel systems

These systems store energy by converting the initial energy source to rotating energy in a rotor or flywheel at high velocity. Its use as a primary energy source for transportation has been limited to bus and rail systems. One example is the Gyrobus, which was a post-war system of transport used in continental Europe. The system used a flywheel, which was charged at stations along the route. Other options include rail vehicles

Another option is in Kinetic Energy Recovery this is where energy that would normally lost during breaking is recovered and stored in a flywheel (or other battery)[49]. This energy is then used during acceleration. And is currently allowed in Formula One.

Hydraulic Accumulator

Another option is to use compressed hydraulic fluids. This is mainly used in industrial applications such as industrial lifting devices, though Volvo Flygmotor experimented with them on buses in the 1980's and Ford recently demonstrated the technology on the hydraulic Expedition UPS truck[50].

Direct Access

By directly connecting the vehicle to the transmission grid the issues with recharging, system weight and storage systems can be by-passed. This method is commonly used on train networks by either an electrified third rail or overhead cables, and can use either AC or DC current. The main issues with this approach are the fixed nature of routes, the associated costs of the infrastructure and the safety aspect of exposed high voltage power supplies. They tend to be applied on fixed route systems such as trolley-busses and wheel-on-rail mass transit systems. Another option is the use of inductive charging. With this system electric power is transferred via electromagnetic induction. The system can either be a permanent connection, with little or no battery back up or as a charging system for BEVs, either at base stations or at on route points, such as traffic intersections. The system is still in development and shows an approximately 70% transfer efficiency[51].

2.3.5 Common issues

All these options have a number of common issues when compared with ICE vehicles, which have been the defacto transport standard for the past 100 years, with the associated benefits of investment and development.

Range

Limited vehicle range is a common issue with all these alternative technologies when compared with ICE vehicles. This is due to the poor energy density of the storage device or associated mass in increased technology. BEVs on the market today have a range between 80 km for lead acid batteries (0.23 km/L) and 320 km for lithium ion (Li-ion) technology (0.72 km/L)[52] were as gasoline return values of 10-20km/L. Kinetic storage systems have, as well as poor energy density, an associated mass with the storage system. A compressed air vehicles requires 70kg of mass for 150km range, 1950's flywheel Gyrobusses could travel 6km using a 1500kg flywheel. This compares to 600-1000 mile ranges in current commercial light goods vehicles.

Infrastructure

All these technologies require changes or improvements to the current infrastructure. At the basic level improvements in road surface reduce the rolling resistance of the vehicle, thus improving efficiency. Good quality roads also allow for lighter, and therefore more efficient vehicles to be used. Currently vehicles need to be 4x4 to cope with the rough surfaces. The terrain and climate of Rwanda make constructing sufficient quality roads an expensive option. There is also the concern of increasing demand. More advanced infrastructure such as recharging systems, be they electrical or gaseous, and the required operational infrastructure to provide the supplies have both inherent cost and complexity. There are also issues to be consider with the recharging action, safety when using pressurised explosive gasses as well as time, recharging a Lead-acid battery can take many hours as opposed to minutes for gasoline. These all have cost associated with them in terms of both finance and consumer acceptance. There are also transmission losses to be considered.

Generation

While some of the proposed alternative systems are primary energy sources (methane) all others require generation from a variety of primary sources. While some of these are relatively carbon neutral, such as the use of hydro and wind power some are not so car must be taken when describing alternative energy sources as carbon neutral. They may be zero emission at the 'tailpipe' but not necessarily at the 'well'.

Cost

Compared to ICE systems the majority of technologies discussed here can be currently considered as experimental. This has associated costs in development, construction and operation of such methods.

Acceptance

As with all new technologies there is a significant education and acceptance phase where the consumer is introduced to and learns how to use such technology and systems.

2.4 Rail Technology

Electrified rail transport has distinct advantages over ICE road transport, most importantly very low operating emissions and competitive travel times[53]. Suburban commuter trains can reduce emissions considerably provided good occupancy rates are achieved, with the additional benefits of reduced inner-city congestion and improved urban air quality[54.

High-speed intercity trains have competitive travel times with domestic air travel combined with higher carrying capacities, while reducing emissions considerably[55]. Despite the benefits of electric rail, diesel trains still dominate in many areas of the world. In Great Britain for instance, 33% of the railway system is electrified, and in the United States the grade of electrification is even lower. Developments in technology follow the same principles as road vehicle with improvements in prolusion efficiency, transmission efficiency, reduction in vehicle mass, rolling resistance and improvements in aerodynamics[56]. The installation of rail system is demanding in terms of finance, land area, planning and management. As a fixed route system careful consideration is required in route planning. Heavy rail routes offer a high capacity solution to transport, but under utilisation can negate the efficiency of the system. Rwanda along with Tazania and Burundi is developing a rail link between Dar-es-salaam and kigali. This is finacially supported by the African Development Bank and is expect to cost in the region of 10 billion USD. A 'rail' technology that is suited to mountainous terrain is cable-propelled transport, commonly called cable cars. Engineless units are propelled by a cable pulled by a stationary engine and have been implemented in Colombia to access unplanned urban areas (see case study 5).

Case Study 5 – MetroCable Transit System, Medellin, Colombia

Metrocable is a gondola lift system implemented by the City Council of Medellín, Colombia with the purpose of providing a complementary transportation service to that of Medellín's Metro. It was designed to reach some of the least developed suburban areas of Medellín and is largely considered to be the world's first Cable Propelled Transit system. The initial conception of this system was indirectly inspired by the Caracas Aerial Tramway (also known as the Mount Avila Gondola) which was designed primarily to carry passengers to a luxury hotel. It consists of three lines (J,K and L) which operates over 4.5km of cable infrastructure. Line K cost 26 million USD and is 1.8km in length. gondolas used as transit offer many advantages such as cost-effectiveness, low emissions and energy efficiency, one of the disadvantages of gondolas is the risk of power outages. In case of a hazard or an emergency it is not possible to exit the cabins. Medellín Metro is ameliorating this problem by providing a communication system in every vehicle should an emergency occur.

2.5 Aviation

As a land locked country, aviation plays an important role in Rwanda's global transit links. Aviation's impact can be reduced by (i) technological developments, which increase the efficiency of the airplane, (ii) applying low-carbon fuels, analogous to the road transport sector, and by (iii) improved operational efficiency[57]. Aircraft efficiency can be achieved via reducing the weight of the aircraft, increasing the efficiency of the propulsion system and last but not least improving the aerodynamic efficiency of the airplane itself by improved design. Up to now, weight reduction achieved by application of novel materials is being offset by increases in entertainment systems and aerodynamic changes[58]. Evolution of current engine architecture could lead to a 20-30% decrease in specific fuel consumption by the pinnacle of design in 25-30 years[59]. Efforts to reduce drag by improved design include winglets (up to 5% fuel saving) and silicon paints (1-2%) as well as smoother more integrated designs with improved aerodynamic efficiency. Over the next few decades these endeavours are estimated to result in a further 10-15% reduction in fuel consumption[60]. However, overall reduction in fuel burn is limited, with the current aircraft architecture, to an estimated 30-50%, the majority of which is provided by propulsion developments. In order to reduce fuel consumption and emissions further, manufacturers and consumers have to move away from traditional 'tube-and-wing' designs and embrace novel aircraft architectures. An example of such is the Blended Wing Body, which offers the possibility to reduce fuel burn by 32% with a load of 500+ passengers (in the A380 payload area). However consumer acceptance will be crucial as these novel designs bear a significant financial risk to aircraft manufacturers[61]. Moreover, impact from these novel technologies will be delayed due to long development times for new aircraft and fleet lifetimes up to 30 years.

The scope for low-carbon aviation fuels is considerably smaller compared to road transports fuels as aviation fuels have to be combustible under harsh conditions[62]. In the case of aviation it is not foreseeable that alternatives to highly energy dense hydrocarbon fuels, such as kerosene or HRJs, will penetrate the market. Operational changes including the improvement of air traffic management could see a 12% reduction in emissions. Another option currently under development and which may be a viable option is Hybrid Lighter-Than-Air (HLTA) HLTA systems are a combination of lighter-than-air (airships) and traditional fixed-wing and rotorcraft systems. Where as fixed-wing and rotor craft systems rely on dynamic lift, such as aerodynamic forces or vectored thrust, and airships rely on static lift due to buoyancy of lifting gasses, HLTA use a combination of both[63]. As the lifting force is 'free' with no further energy inputs required to maintain lift, LTA and to a lesser extent HLTA systems are inherently low energy, and therefore low emission systems. They have the ability to lift large payloads, delivering them point-to-point, over long distances with minimum requirements in infrastructure, capital cost and most importantly energy requirements. The technology is currently in development, though military systems are to be in-service in Afghanistan by fall 2013.

2.6 Water

There is an opportunity for waterborne transport both on Lake Kivu and the Akagera River. Waterborne transport is highly efficient for bulk transport but is restricted by availability of navigable waterways. In Rwanda this is restricted to Lake Kivu without substantial infrastructure improvements, though a number of rivers, such as the Akagera could be made navigable with the use of locks and dredging. This affects the cost and sustainability of the transport systems and requires significant study before systems are applied.

2.7 Operational Improvements

As well as technological changes, a number of operational improvements can be applied to transport systems, irrespective of their fuel source, which will increase efficiency and therefore increase sustainability.

2.7.1 Traffic Flow

Restricted traffic flow, be it due to excessive loading of infrastructure or poor management is a significant contributor to emissions in urban areas. This can be solved by a field of mathematics and engineering which studies the interactions between vehicles, drivers and infrastructure in order to produce a road system with efficient traffic movements, minimising traffic congestion. The solutions are based on highly complex modelling systems with the physical tools to achieve this being signage and traffic control devices, such as traffic lights and calming measures. The relationship between traffic flow and emissions is complex, with first order effects of improved traffic flows, higher speeds and fewer acceleration events reducing emissions, but second order effect, the attraction of taking further trips and travelling longer distances can mitigate any improvement, often within the first year. There are third order effects such as users relocating to take advantage of improved travel times, but this can be very long term[64].

2.7.2 Intelligent Transport Systems or Smart Transport Systems

Intelligent Transport Systems (ITS) is the addition of information and communication technology systems to transport infrastructure and vehicles to enable a flow of information that allows improvement in efficiency by reducing transportation times, vehicle wear and fuel consumption. The technology applied can vary depending on requirement, but falls within the areas of navigation, traffic control (either in the form of signals or more advance navigation and artificial intelligence), driver information (variable message signs) and observation (CCTV and number plate recognition)[65].

2.7.3 Logistical and fleet management

Logistical activities comprise freight transport, storage, inventory management, materials handling and all the related information processing that are involved in production and distribution systems. This can be achieved by a combination of infrastructure, such as dry ports, information systems such as computerised vehicle routing and scheduling and multi-modal operations. Efficient logistics not only reduces emissions, but also economic costs, increasing domestic competitiveness. A number of global cities have introduces 'green' logistics schemes, covering policies such as restricted zones, clean vehicles, co-ordinated transport, congestion mitigation, charging and information systems[66].

2.7.4 Demand Management

The technical options presented are mitigation strategies, lowering the energy use and/or emissions generated by transportation. Another option is to reduce the volume of transportation through demand management. Demand for transport can be controlled in many ways, utilising number of different policy options. These can be either command and control actions, such as banning vehicle use on over timescales or areas, or to incentivise the desired behaviour, through providing information on the true cost of journeys and economic incentives such as scrappage schemes. These options are discussed in greater detail in the policy section, particularly economic levers.

2.7.5 Substitution

Another method for reducing increasing transport sustainability is by substitution. This can be modal, where low occupancy ICE vehicle can be replaced by high occupancy mass transit, or by removing the need for transport entirely, as with telecommunication. This can be enforced by a hard polices, such as car sharing lanes, and soft polices, such as car sharing and car clubs.

Policy Levers

3.1 Policy Options

There are five categories of policy instruments, which may be used independently or as a combination to enable the desired change.

- Information
- Intervention
- Economic
- Regulation
- Market-based

3.2 Information

Information based policies are based on the provision of information, education and advice services and are aimed at increasing government involvement in decision-making. This can vary between providing information or increasing access to information to changing peoples preferences and attitudes, the various options are discussed in table 3.1.

These policy options generally leave the decision on behaviour on the consumer and the effectiveness of such policies relies on the consumers' capacity and incentives to act on the information and alter their behaviour accordingly. Another issue is the method of information delivery which depends on the messages target, timing and done in a credible way. An example of this is eco-driving campaigns, which aim to inform and educate drivers to drive in a fuel-efficient and environmentally friendly way. Gains of approximately 10% are discussed as a feasible target. Information and education policies are necessary, but individually not sufficient, to trigger behavioural change. Similarly, advertising and marketing may go a long way in changing peoples behaviour. Advertising campaigns promoting a modal shift towards public transport, for instance, may thus be more successful if targeted at people in the process of important life transitions. Other information polices include car sharing, car clubs, teleworking

Case Study 6 Singapore – Integrated Urban Transport Solutions

Despite its world-class transport system, its rail and bus network operates entirely without government subsidies. Singapore has four main forms of public transport: bus, Mass Rapid Transit (MRT), Light Rapid Transit (LRT) and taxi, which account for 60% of all daily trips. Most of the services are operated by two private companies, which are regulated by the Public Transport Council who review quality and fares. The Council also insists on physical (e.g. MRT-bus-taxi interchanges) and fare (e.g. smart-card) integration in order to make connections in public transport as seamless as possible. Although public transport is not subsidised, the government finances over three-quarters of the price of replacing operating assets: the operator is only required to pay the historical value of assets, so that less of an increase in fares is necessary[76]. The average cost for commuting trips by public transport is less than 2% of individual income, and therefore very affordable. Even Singaporean taxis are very affordable and make up 11% of all travel[77].

Table 3.1: Types of Information Policies

Option	Description
Provision of Information	Information is provided to the public.
Public Education Campaign	These are often used to raise awareness of particular issues and present basic information.
Reporting and disclosure requirements	Government imposes regulations, which require agents to provide information. These regulations may cover issues about the information including frequency and detail.
Labeling	Manufacturers are required to state information on products in a particular format.
Advisory Service	An expert provides information and advice to a person or business.
Representation Service	An expert is appointed to act on behalf of a person or business.

and teleshopping which all have potentially to reduce CO_2 emissions and congestion, though evidence for this reduction is rather mixed as it is unclear whether these measures lead to overall reductions in road transport. Another method of information policy is the support for research and development. It is essential that governments provide incentives to undertake research and development, so that new low carbon technologies in the transport sector can be demonstrated and applied on a large scale.

3.3 Intervention

By providing or commissioning goods/services the government can intervene directly in the system (table 3.2). Financing can either be through direct taxation or by private sector funds under Private Finance Initiatives or Public Private Partnerships. The advantage of direct intervention is that it ensures service provision, but can result in a distortionary impact of the taxes required to support it. Commissioning services can result in the private sector provider not acting the way the government requires. Though this can be controlled to some extent through contract and regulation application, but these may result in perverse incentives and incur significant costs in monitoring and enforcement. By involving private finance, some of the risk of provision is removed from the government.

A common intervention policy is the provision of public transport. If the service is commissioned, rather than directly provisioned then public transport fares are often subsidised. Other options include the provision of infrastructure with private companies operating the services (British railway and Bogota BRT). The physical policies which incentivise walking and cycling, including crime reduction, well-maintained and clean pavements, attractive street furniture, safe crossings with shorter waiting times, dedicated cycle paths, Are usually intervention based policies with the government (national or local) providing the necessary systems. The Netherlands carried out the first and probably the most successful official bicycle policy in the world. Polices include: reducing journey times by bicycle compared to car, reducing the number of stops and increasing car parking costs and safety[78].

3.4 Economic Instruments

Economic instruments can be defined as either changing the prices/costs faced by agents or

Table 3.2: Types of Intervention Policies

Option	Description
Direct Provision of Service	Government directly provides service in the public sector
Commissioning of Service	Government contracts the non- public sector (e.g. firms, charities) to build/operate particular services.

Table 3.3: Types of Economic Policies

Option	Description
Taxes	The government raises the price paid by the consumer or costs faced by industry.
Charges	Government charges for services that are consumed
Subsidies and Vouchers	The government reduces the price paid by the consumer or the costs faced by industry.
Tax Credits	The government reduces the cost of an activity at the margin.
Benefits and Grants	Similar to subsidies but used when the emphasis is on who receives the subsidy rather than the goods/services that are being promoted
Tradable Permits and quotas	Systems under which a right to produce a good/service (or by- product) is created and a market is created to allow companies to buy or sell these rights.
Franchises and licenses	Awards and auctioning of the right to produce a good/service is sold.
Government loans, loan guarantees and insurance	Government directly provides loans and/or provides a subsidy for the loan (e.g. through guarantees or insurance).

changing the budget within which agents operate (table 3.3). As with information policies, economic policies are decentralized actions, leaving the option to take action with the user, often leading to a more efficient outcome.

There are a number of key aspects of these economic policies that should be considered:

- Cost of administration – all economic policies must be administered and the cost for this should be carefully considered
- Excess burden of taxation – taxes collect less revenue than the loss in welfare to the consumer of the product being taxed
- Unproductive activity – taxation may lead to activity, such as lobbying and accounting loop holes to reduce or avoid the tax completely
- Elasticity – the degree of behavioural change depends on how responsive agents are to changes
- Incidence of taxation – who bears the burden of taxation
- Costs of taxation – taxation options have additional costs in terms of the cost of taxation raised to finance them
- Additionality – some of those receiving subsidies, grants, etc. may have behaved in the same way without the incentives. This problem can be overcome with careful targeting (e.g. means testing), although this can raise costs
- Competition – subsidies, tax credits, vouchers, benefits and grants can distort competition
- Length of concession/franchise – there is a trade-off between problems of monopoly associated with long concessions and lack of investment associated with short franchises. Some of these problems can be overcome with regulatory review and provisions in regulatory contracts (e.g. monitor price).
- Numbers of suitable bidders – there must be enough companies interested in the franchise/license for there to be a successful bid.
- Barriers to entry – this is created by the expertise of the existing contractors and the insider knowledge that they have making it more likely that existing contractors will win future contracts. Disclosure requirements may help to alleviate the problem but could enhance ability of firms to collude.
- Size and liquidity of market for permits – the potential benefits from trading permits

and quotas will depend on the permit/ quota market operating efficiently

Economic polices can be either command-and-control or incentive based. Command-and-control (CAC) policies are governmental regulations that force a change through increasing cost. They are favoured by policy makes due to the feasibility and effectiveness, though they are not efficient.

Common economic polices include taxes on usage of a vehicle including carbon taxes, are proxies for emission taxes. A carbon tax is a tax on the carbon content of the fuel in question or on the estimated CO_2 emitted in the fuel combustion process. There are some countries in Europe that have implemented a carbon tax, but the efforts have never been coordinated or agreed at EU level. These countries are Finland, which introduced a carbon tax in 1990, Sweden and Norway in 1991, the Netherlands in 1992, Denmark in 1993 and Italy in 1999[72].

A vehicle registration tax, based on the pre-tax price, fuel consumption, cylinder capacity, vehicle length, CO_2 and/or other emissions is also commonly used[69]. Registration taxes are typically charged when the vehicle is registered for the first time. The exceptions are Belgium and Italy, where the registration tax is levied every time the vehicle changes ownership[70]. Annual ownership taxes, sometimes also called annual circulation taxes or vehicle excise duties, are usually levied on private and commercial vehicles in most countries. Another way of providing incentives is to give subsidies to efficient vehicles and feebates. A showcase example of this type of subsidies is the ‘Ecoauto Rebate Program’, which was run in Canada between March 2007 and March 2009. The idea behind it was to encourage Canadians to buy new fuel efficient vehicles[71].

Although fuel taxes were originally introduced as revenue raising instruments, they are now also increasingly being regarded as Pigouvian taxes to internalise road transport externalities. Virtually all countries have mechanisms in place for collecting fuel duties. Thus, in addition to being fairly effective and internalizing the global warming externality, they have the advantage of already being in place. In addition, they are easy to monitor and enforce, inexpensive to collect, and guarantee some level of price stability. They vary widely from one to another and no other product seems to be subject to such divergent treatment[73].

Another type of charge in road transport is congestion charging. It restricts certain areas to those who are able or willing to pay. It is a policy that is advocated by economists but faces significant public and political opposition.

Parking charges can be divided into three groups: parking charges for using a space on a public road, charges for using a space in a private parking lot and charges for parking at the workplace.

Pay-as-you-drive (PAYD) insurance differs from standard insurance in that the premium is dependent on the annual distance travelled. As in standard insurance, the premium can be conditioned on the driver’s rating factor[74], which is a function of age, crash record and region[75]. The advantage of PAYD insurance over conventional insurance is that it price-discriminates more successfully between travellers on the basis of the distance they drive, which is correlated to their willingness to pay for insurance.

A number of European and other countries have scrappage schemes in place as an incentive to

Case Study 6 – Return to older technology
Beijing – Back to the Bike

Under the recent economic development china, and Beijing has seen an increasing level of motorisation, with the associated increase in environmental pollution. The leadership of Beijing introduced a number of polices at developing bike use in the city with the aim of achieving 28% of journeys by 2010. Polices included developing infrastructure, investment in R&D, regulation of other transport modes (motorbikes particularly) and managing the integrated transport system.

remove older, more polluting vehicles from the roads. In December 2007 France introduced a system of bonuses and penalties on the purchase of new vehicles with a bonus between €200 and €5000 on vehicles emitting less than 130 grams of CO_2 per km and penalties between €200 and €2,600 for vehicles emitting more than 160 grams of CO_2 per km.

3.5 Regulation

Regulation is the restriction of actions, either positively (you must do) or negatively (you cannot do) (table 3.4).

Regulation is a common response of government, but they have a number of issues to consider:

- Information requirements – As a centralized process that forces consumers to act in certain ways governments need considerable information of the costs and benefits of alternative actions
- Costs – these include the costs of compliance and monitoring compliance, and costs of lobbying against regulation.
- Inflexibility – it is difficult to design regulation that is sensitive to different individuals and circumstances.
- Time – regulation takes time to develop, bring into force and administer effectively, by which time the problem may have disappeared or changed.
- Limits to regulation – to prevent excess regulation, government has imposed limits and developed processes for developing regulation that policy makers must comply (e.g., Regulatory Impact Assessment).

Fuel standards are a very common command-and-control (CAC) regulatory policy. They are standards that countries impose on motor vehicle fuels and have reduced the emissions of benzene, sulphur dioxide and other harmful pollutants. Much less common are regulations on CO2 emissions from fuel. One exception is the Low Carbon Fuel Standard, introduced by the state of California in 2007.

Vehicle standards are CAC policies that typically regulate vehicle safety, tailpipe emissions and fuel efficiency. In general, different countries set their own vehicle standards, although the EU sets standards for all its members. An example is the Corporate Average Fuel Economy (CAFE) in the US, enacted by Congress in 1975 and still in place as of 2009. The purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and vans. CAFE standards in the US have typically been 'technology-forcing' as opposed to 'technology- following'[67]. Technology-forcing standards are standards set at a level, which, although feasible, remains to be demonstrated in

Table 3.4: Types of Regulation Policies

Option	Description
Price and market regulation	Laws or rules that set out the prices companies can charge for particular goods/services and/or how companies can organise themselves and their relations with other companies.
Product and consumption regulation	Laws or rules relating to how products are produced – these can cover: characteristics of product/service, how the product/service is produced, who can produce a product/service etc.
Standards	Rules which set minima/maxima for particular characteristics of goods/services and production techniques.
Prescription and prohibition legislation	Rules which state what an agent must/must not do.
Rights and representation legislation	Rules which provide agents with rights and/or representation.

practice, and in the case of the US, have pushed technological advances forward.

Restrictions are CAC polices which ban vehicles, which don't meet certain criteria. An example of restrictions based on emissions is the Low Emission Zone (LEZ) in London. These policy force those who must enter the zone to meet the standards set by the policy, though some vehicles can be excepted from the rule.

Restrictions to circulation have been widely implemented in towns and cities throughout the world. It is very common to see pedestrianisation of streets, which are closed to traffic at all or some times of the day. It is also common to see streets where only public transport and taxis can circulate. This type of CAC policy is equitable, in the sense that it affects all drivers and does not differentiate by their willingness to pay for using the road (i.e. by their ability to pay).

Another way of controlling vehicle use is through restrictions on vehicle ownership. The only example of a direct quantity control of this sort is the Vehicle Quota System (VQS), a policy implemented in Singapore in 1990. Prospective vehicle owners are required to purchase a Certificate of Entitlement (COE), which is a license that lasts ten years, except for taxis, for which it lasts seven. The government sets a quota on COEs for different vehicle categories a year in advance, in May each year. The allocation of COEs is done through open auction. When a person submits a bid (something which is done electronically) the current successful price is known and the person can adjust his bid. As the number of bids usually exceeds the set quota, there are usually unsuccessful bidders.

Parking restrictions can indirectly reduce traffic levels, and in doing so reduce most traffic externalities. Parking as an activity entails costs because parked vehicles use public space, for which there is an opportunity cost, as the land used for parking could be used for something else[68].

3.6 Market-based solutions

These policies rely on 'soft' intervention to encourage markets to resolve problems for themselves, most importantly through self-regulation by codes of practice and accreditation schemes. The self-regulation options are detailed in table 3.5.

In order to implement change from current or accepted practice, there are a number of different polices which can be enabled by governments in order to implement a desired change in a system. These can effect economic considerations of personal choice, enforce certain technologies or options, or enable improvements.

Table 3.5: Types of Self-regulation

Option	Description
Voluntary agreement	These are rules which a community agrees to abide by – often there are no formal sanctions
Codes of Practice	Codes of practice are similar to voluntary agreements in that they are agreed within communities (usually industries) – codes of practices tend to be consumer focused and can be certified by a central agency
Co-regulation	Between the extremes of voluntary agreement and regulation there are points in between – Co-regulation is voluntary codes of practice with significant Government involvement

Analysis

4.1 Technology Options

The technical options are summarised in table 4.1. There are a number of variables which affect all the factors compared here and the values given are for guidance only. Operational Improvement are summarised in table 4.2, as with the technical options these are just for guidance only, and are heavily dependent on available data.

Labour intensive systems, such as bicycles are a low cost option for increasing mobility. They are commonly used in rural Rwanda, for both passenger and cargo transportation. For urban use they require support in terms of infrastructure. Developed nations utilise both dedicated right of way systems and end-of-journey facilities. Within the Rwanda context the provision of dedicated rights of way would be beneficial in large urban areas, as it promote bicycle use, though end-of-journey facilities such as showers could be deemed unnecessary in the short to medium term. Future investment would be dictated by user demand. In rural areas the application of cargo-bike, through either incentivisation or direct supply by the government should be studied to define the level of benefit.

Improvements to the current internal combustion engine (ICE) fleet have both opportunities and restrictions for Rwanda. As a nation it is unable to influence the development of vehicles with improved efficiency, however it can, through various policy levers, particularly regulation, influence the vehicles in operation. Serious consideration should be given to the tightening of vehicle regulations, both at import and during the operating life, to improve fleet efficiency. Economic incentives such as scrappage schemes should be considered, but these will rely on external sources of funding as there are not the public funds available. Another key area of development should be the on-going improvement in road quality. This not only improves the current fleet efficiency by reducing rolling resistance, but improves climate resilience of the transport network. Road improvements should be graded to the importance of the route, possibly socio-economic impacts, with rural roads utilising labour intensive construction methods and main route utilising more advanced technology. An improved road system would also benefit the agricultural output of Rwanda by helping reduce losses between farm and market.

Biofuels offer a sustainable drop in solution to sustainable transport. First generation biofuels are attractive for cost, domestic supply and suitable technology, but the challenge for Rwanda is land use and food security. Even with increasing agricultural production, by 2020 there will only be 420,000ha of land surplus for biofuel production[79]. This equates to 25,000 tonnes of biofuel per annum (in a best case scenario) with demand in 2008 at approximately 160,000 tonnes of fuel, or 16% of current demand. Second-generation fuels have great potential in Rwanda as they rely on waste biomass. As an industrial operation, second-generation fuel production economic efficiency is affected by economics of scale, however the supply chain issues can be problematic, especially if it increases transport demand. Further study is required, investigating the predicted production volumes, economic and environmental costs, emissions reduction as well as impacts on agricultural productivity, as current biomass waste is returned to the fields. Algal systems are still experimental and will only be a viable option if commercialised

Other alternative energy supplies, such as electricity and the various gasses are neither currently widely available nor competitive with ICE systems in terms of cost. While the Government of Rwanda has little ability to influence their development, it is expected that these technologies will enable a fully sustainable transport system. While not applicable for Rwanda in the near term, once globally commercialised their application should be considered and the Government should be prepared for this eventuality. Studies into the impacts both environmentally and in socio-economic terms should be developed to ensure that Rwanda is both aware and prepared for the development of such advanced technologies. These should be based around predicted transport demand and economic and environmental costs particularly as the use of electric vehicles will significantly impact of energy demand and infrastructural plans.

Similarly to advanced road technologies, sustainable aviation is beyond the scope of influence of the Government of Rwanda and will only be able to influence it within the global framework. Though one particular aviation system that warrants further study is hybrid lighter-than-air systems. These are currently under development and can offer an aerial system of transport that is both economically and environmentally sound. The ability for Rwanda to influence this option is due to the lower predicted costs of development and the alternative nature of the systems. The opportunities for this technology within Rwanda should be assessed.

The current lack of rail and maritime facilities in Rwanda discounts the developments that can be made in these areas. Though the planned introduction of a rail network to Kigali offers not only efficiency improvements but also climate change resilience as the dependence on road routes is diminished.

The various operational improvements should be applied in parallel with technology changes. Traffic flow improvements, while currently not of that great of an advantage, will be of huge importance in the future. Logistic improvements and modal substitution can be influenced by government policy, but market competition should promote these changes. The most important non-technical option is demand management. By reducing the need for transport, though education, efficient systems and competitive alternatives (soft policies) can reduce the emissions and economic cost of transport systems. While transport demand is low this has a limited effect, but it is easier to enable such practice early, gaining acceptance from consumers and users.

Table 4.2: Summary of Operational improvements

	Emissions Reduction		Implementation Cost			
Option	Current[1]	Future[2]	CapEx	Operating	Infrastructure	Role[3]
Traffic Flow	Low	Medium	Low-High*	Low	Low	Government
Logistic and fleet management	Medium	Low	Medium	Medium	Medium	Private
Demand Management	Medium	Medium	Low	Low	Low	Government
Substitution	Low	High	Medium-High	Medium	High	Mix
Notes	[1]Emissions reduction against the current transport mix [2]Reduction in future emissions based on a business as usual model based on a worst case [3]The body whose role it is to implementation *Dependent on level of technology implemented					

Table 4.1: Summary of transport technology (note values for indication only all factors are greatly effected by a number of variables)

		Emissions[1]			Cost[2]									
Technology	Energy	Production	Operation	End of life	Production	Operation	End-of-life	Technology Level	Infrastructure Requirement	Current Status	Advantage	Disadvantage	Key Issue	Ability to influence[3]
Labour intensive	Glucose	None	None	None	Low	None	None	Low	Low	Mature	Highly accessible	Low capacity	Low capacity	High
ICE	Gasoline/Diesel	Medium	High	Low	Medium	Medium	Low	Medium	Medium	Mature	Common	Polluting	Sustainability	Medium
	1st Gen. Biofuels	Medium-High	Low	Low	Low-Medium	Low	None	Low	Medium	Developed	Widely Available	Competition with food production	Competition with food production	High
	2nd Gen. Biofuels	Low-Medium	Low	Low	Low-Medium	Low	None	Medium	Medium	Developing	Doesn't compete with food production	Technical production process	Collection of biomass feed stock	Medium
	3rd Gen. Biofuels	Low	Low	Low	Medium-High	Medium	None	High	Medium	Experimental	Full industrialised process	Unproven	Un-developed	Low
	LPG	Low-Medium	Medium	Low	Medium	Medium	Low	Medium	Medium	Developed	Lower emissions than gasoline	Fossil fuel	Availability	Low
	Natural Gas	Low-Medium	Medium	Low	Medium	Low-Medium	Low	Medium	Medium	Developed	Not gasoline	Range	Fossil Fuel	Low
Electricity^	Chemical BEV	None-High	None	High	Medium-High	Low	Medium	Medium-High	Medium-High	Developing	Zero operation emissions	Range	Energy generation	Medium
	HEV	Low-High	Low	Medium	Medium-High	Low	Medium	Medium-High	Medium-High	Developing	Mixed electric/ liquid fuel	Complex technology	Complex technology	Low
	Fuel Cell	Medium-High	Low	Medium	High	Low	Medium	High	High	Developing	Zero emissions in operation	Hydrogen Economy	Cost	Low
	Compressed Air	Low	None	Low	Medium	Low	Low	High	High	Developed	Zero emissions in operation	Range	Infrastructure	High
	Flywheel	Low	None	Low	Medium	Low	Low	High	High	Experimental	Zero emissions in operation	Range	Un-developed	HIgh
	Hydraulic	Low	None	Medium	Medium	Low	Low	High	High	Experimental	Zero emissions in operation	Mass	Efficiency	High
	Direct Access	Low	None	Low	High	Low	Low	High	High	Mature	Zero emissions in operation	Fixed Route	Infrastructure	Medium
Rail	Electric	Low	None	Low	High	Low	Medium	Medium	High	Mature	High load capability	Infrastructure requirement	Load Factor	Medium
	Diesel	Medium	High	Low	Medium-High	Medium	Medium	Medium	High	Mature	High load capability	Fixed route	Load Factor	Medium
Aviation*	Kerosene	Medium	High	Low	High	Medium	Low	High	Medium	Mature	Premier global transport mode	Cost	Cost/Operation	Medium
HLTA*	Kerosene	Medium	Medium	Low	Medium-High	Medium-High	Low	Medium	Low	Experimental	Vertical take-off and landing for remote areas	Experimental	Not yet commercial	Medium-High
Water	Liquid Fuel	Medium	Low	Low	Medium	Low	Low	Medium	Low-High	Mature	Low infrastructure on Kivu	High cost on Akagera	Availability of Water ways	High

Notes:

[1] Emissions in producing/operating/disposing of both vehicle and energy source

[2] Cost in producing/operating/disposing both vehicle and energy source

[3] Ability of GoR to influence development and application

^Electricity generation is dependent on renewable/fossil generation mix. Table uses current mix.

* Direct comparison between Aerial and Land based technologies is not valid

Source: Experts

4.2 Policy Analysis

Choosing the correct policy levers to enable the desired changes is a detailed and in-depth challenge. There are a number of policy levers in which to enable the necessary changes, which can be either: Information, Intervention, Economic, Regulation or Market-based in principle.

Combinations and integration of these policies can lead to positive side effects and synergies. Policy integration is crucial in order to rise to the challenges faced in moving towards a sustainable mobility model. Thus, economic policies may successfully be combined with a number of other policy measures in order to achieve a model of sustainable transport. Command-and-control economic polices are excellent tools when an activity level needs to be altered drastically, when the regulator faced significant opposition to change and as complementary actions to incentive based policies. Incentive based polices are economically efficient but do not always achieve their full potential. Taxes, charges and permits are best used when the revenue generated are used to reduce distortionary taxes in the economy, or returned to the sector in the form of public transport and development funds or a driver to change their users behaviour. Without the support of economic policies, other policy types will struggle to enable the required change. The main challenges facing transport in Rwanda is reliance on fossil fuels, rapid motorisation and urbanisation. These can be altered by economic polices (subsidies for alternative vehicles), intervention polices (mass transit systems) regulations (emission standards) and information policies. A key issue for Rwanda is that unlike global best practice, which in policy terms, is aimed at reducing congestion and current demand, Rwanda needs to reduce future demand. Policies such as road charging and restrictions are applicable for reducing current demand, but their use in preventing demand is unknown. Great care should be taken to ensure that the future needs of Rwanda are taken into account when deciding on the desired change, as well as realising it.

4.3 Climate Change Adaptation

Climate change is a threat to transportations systems in a number of ways. The most obvious is on the infrastructure systems that transport modes rely on. Routes and supporting ground works can be damaged and destroyed by excessive climatic variation, from flooding washing away surfaces and preventing access to excessive heating deforming and damaging structures. This is of increased importance in countries reliant on few modes and routes, such as Rwanda. The damaging of a key transport route can cripple a nations economy for months if not years, severely hampering development in the long term. Extreme climatic events also increase the cost of designing, constructing and maintaining transport infrastructure. Uncertainty of the effects of climate change can lead to either over engineered, and therefore high cost, systems or under engineered and therefore vulnerable to climatic events. The transport technology itself can also be affected, from reduction in vehicle efficiency to damage and system failures.

Planning systems, which prioritise the vulnerabilities of transport systems, can solve the majority of these challenges. Responses to short term events, such as flooding and heat-waves, and longer term effects, such as increases in mean temperature and water flow variation, will have to be defined and fitting solutions in terms of either investment resilient infrastructure or alternative solutions such as economic policies, such as compensation funds, must be investigated and implemented. Technology and innovation are also key actors in the process as well as the regulation and standards policy tools, which instigate their use.

The options presented here, from improving the current system to diversifying and introducing advanced technology, offer a way of not only creating a low carbon, sustainable transport system, but by also inducing resilience into the system.

Strategic Framework

Based on the focus areas and the options presented table 5.1 offers a strategic framework of polices and actions that can be implemented in order to produce a resilient and low carbon built environment sector. The time scales present are offered as a guide rather than a strict timetable.

A key aspect of implementing these actions is detailed analysis of the impacts. Regulating and restricting consumer options, while enabling the desires behavioural change, can lead to unforeseen issues, particularly increased cost to the consumer. The technical aspects actually implemented must

Table 5.1: Strategic Framework for Transport Sector

Focus Areas	Policy	Actions	Timescale	Stakeholders	Measurables	Finance
Why	What		When	Who	How	
Access	Labour intensive Transport	Physical infrastructure	Short to Long	GoR District authorities	Increase in journeys made by non-powered transport	GoR Private Sector
	Modal Diversification	Commissioning of services	Medium to Long	GoR	Increase in journeys made by transport other than cars	Donor
		Physical Infrastructure		Private Sector		
Efficiency	Current fleet improvements	Improved emissions and fuel efficiency regulations	Short to Long	GoR	Reduction in emissions per passenger km	GoR
		Quality of road network	Immediate to Long	GoR		CDM
	Regulation of new vehicles	Increasingly demanding regulations on imported vehicles	Short to Long	GoR	Reduction in emissions per passenger km	GoR
	Advanced technology	Analysis of options	Medium to Long	GoR	Increase in km travelled per unit of fossil fuel	Donors
		Introduction of alternative systems		Private Sector		Private Sector
	Traffic Management	Traffic Flow	Medium to Long	GoR	Increase in average vehicle velocity	GoR
		Intelligent Transport Systems	Long	District authorities		CDM
	Logistical Improvements	Dry ports	Short to Long	Private Sector	Reduction in transportation costs per tonne/km	Private Sector
		green logistic schemes				GoR
Implementation/ Planning	Data Collection	Accurate picture of current demand	Immediate	MININFRA	Annual statical collection on traffic flows, household energy use etc.	GoR
	Future Demand	Picture of probable future demand	Immediate to Short	GOR	University courses	Private Sector
	Capacity	Increase in both higher education and technical skills	Short to Long		Technical school graduates	

be carefully studied to ensure a successful mix between desirable outcomes, such as climate resilient systems and undesirable outcomes, such as increased building costs.

5.1 Timeline to Implementation

Application of these options is both costly and complex and requires significant study and analysis before clear options can be confirmed. In light of this the following time-line of development is proposed, focusing on in-depth analysis of the various options before a decision to implement is reached. The cross cutting nature of transport requires that the needs and developments in other sectors are main-streamed into the analysis stage, ensuring transport is not seen as a stand alone sector.

Immediate:

Define current and future demand as an aid to both planning and providing measurables for analysing the success or failure of projects. The information defined should include the current mobility of Rwandans (distance, velocity etc.) major travel flows, current emissions and current transport capacity and costs per unit distance. Future demand could be defined by scenarios etc. and should include estimation for required skill sets, finance access and cross-sectoral needs. The information and predictions should be updated on a regular, if not constant basis.

Short Term 0-5 years and ongoing:

- Gradual improvements in the current fleet possibly including:
- Road infrastructure renewal/ improvements
- Tightening of vehicle and fuel regulations
- Support of labour intensive transport
- Operational improvements (dry ports, logistics etc.)
- Analysis of alternative transport systems including require policy levers to see fruition
- BEV, HEV and PHEV
- Application of secondary and tertiary biofuels
- Mass transit
- Demand Management policy defined and implemented
- Integration of transport policy with other sectors, particularly land use

Medium to Long Term 5+ years:

- Pilot projects in alternative energy and transport systems followed by large scale role out of successful pilot schemes.

Finance

Transport systems require substantial capital expenditure, which usually is found from public investment, and could include a variety of sources beyond the general budget. Grants and concessional loans could be sought from multilateral environmental funds. A few of the funds that support low-carbon transportation initiatives include:

- Clean Technology Fund
- Global Environmental Fund
- International Climate Initiative
- Nordic Climate Facility
- KfW Development & Climate Finance
- Public-Private Infrastructure Advisory Facility
- Private Infrastructure Development Group
- Global Environmental Fund

Each fund has its own mandate, institutional requirements, and application and monitoring procedures which are outlined on the website www.climatefinanceoptions.org. Public funds could also come from Rwanda's future environmental fund, FONERWA, which should in turn be capitalized by bilateral development partners and environmental taxes, such as those described previously. Alternatively, the government could establish or facilitate the establishment of carbon projects within the transportation sector. A number of carbon markets have been created for trading certificates – called carbon credits – that denote a reduction in greenhouse gas emissions. One carbon credit represents a reduction of one tonne of CO_{2e}. Each carbon market has different rules and prices. They can be divided into two broad categories: mandatory cap-and-trade markets, and voluntary markets. The difference between the two lay in whether those purchasing carbon credits have legally binding emissions reduction commitments.

Of particular interest is the Clean Development Mechanism (CDM), which was established as a mandatory cap-and-trade scheme between countries party to the Kyoto Protocol. It has two aims: assist Annex 1 (predominantly 'industrialized') countries achieve compliance with their quantified emission reduction commitments by purchasing carbon credits from emissions reduction projects in Non-Annex 1 countries; and promote sustainable development in non-Annex 1 countries. Note that although voluntary markets generally have less strict requirements than the CDM in regards to monitoring, verification, etc., the value of carbon credits is reduced. The price of CDM carbon credits – called certified emissions reductions (CERs) – has been volatile, but an appropriate benchmark is US $15 per CER. Three methods exist to reduce GHG emissions from the transport sector:

1. Reducing emissions produced per kilometre driven - e.g. Switching to more efficient vehicles, switching to low-carbon fuels, or behavioural changes to better vehicle management
2. Reducing emissions per unit transported – e.g. Municipal public transit systems and regional railroad networks
3. Reduction trips or distance travelled – e.g. behavioural changes

Potential CDM projects exist in primarily the first two categories. Within the first category, fuel switching, such as from fossil fuels to biofuels, is permissible as a CDM project, but only in a closed-loop system in which the biofuel is sourced from dedicated farms, and used within a captured fleet to enable monitoring. Furthermore, biofuel crops must be grown on degraded land so as to prevent displacement of food crops. Though limited in scope, one could imagine a bus fleet in Kigali fuelled by biodiesel from small-scale domestic jatropha plantations on degraded land.

CDM methodologies also exist for projects that install retrofit technologies in a captured fleet of commercial vehicles that reduce GHG emissions, such as substituting direct in-cylinder fuel injection with carbureted fuel supply; as well as "feeback" or "cash for clunker" projects that accelerate the turnover of a fleet to promote newer, more efficient vehicles. Box 1 provides an example.

Within the second category of methods to reduce GHG emissions from the transport sector – reducing emissions per unit transported – CDM methodologies exist for projects that implement cable car transit systems and bus rapid transit (BRT) systems. The latter methodology is difficult in that it requires a new BRT system to reduce or replace existing carbon-intensive public transport capacities, such as existing bus systems, through scrapping, permit restrictions, economic instruments or other means. However, if the GoR decides to implement either cable car or BRT system, CDM financing could be pursued. As of yet, no CDM methodology is in place for implementing railroad networks. However, if the planned regional railroad with Burundi and Tanzania uses low carbon fuels, a CDM methodology could likely be developed.

A major barrier to implementing carbon projects is often the initial investment costs. Project implementers will incur significant costs in project development before carbon revenues will start to flow. To overcome these costs, a number of multilateral funds have been established to support implementation carbon projects through upfront financing and agreements to purchase generated carbon credits. These include; EIB-KfW Carbon Programme II, World Bank Carbon Funds and Facilities and UNDP/MDG Carbon Facility.

Box 1. The Egypt Vehicle Scrapping and Recycling CDM Programme of Activities

In order to accelerate the turnover of mass transport vehicles to newer, less carbon intensive vehicles, Egypt implemented a Vehicle Scrapping and Recycling Program in 2010. The program proves vouchers of up to EGP 5,000 (US$840) to owners of taxis, microbuses, trailer trucks and buses that voluntarily surrender their vehicles for managed scrapping and recycling. The vouchers can then be used as a down payment for loans to purchase new vehicles from participating vehicle dealers. The Vehicle Scrapping and Recycling Program is complementary to a larger Urban Transport Development Program, which has seen a law established that renders owners of mass transport vehicles aged over 20 years ineligible for renewal of their operating licenses.

The Urban Transport and Development Program received US$150 million in financing from the International Bank of Reconstruction and Development, and an additional US$100 million from the Clean Technology Fund (CTF) as an IDA-like credit. To help fund the Vehicle Scrapping and Recycling component, the World Bank has agreed to purchase a pre-determined number of CERs generated by reducing the carbon intensity of the fleet.

To illustrate, it is estimated that taxis aged over 20 years use, on average, of about 12.87 liters gasoline per 100 km. Through the scrapping program, the taxi owners will trade-in these old vehicles in exchange for new low-carbon vehicles with average fuel efficiency of 9.4 liters gasoline per 100 km. An advance payment derived from carbon finance is being used develop a proper recycling facility for the used vehicles.

Summary

Following the baseline report the following focus areas were identified as areas within the transport sector in Rwanda requiring attention: access, efficiency and planning and implementation. There are a large number of options, which when implemented, can produce a sustainable transport system while solving the demands in the development of the sector. These can be realised by a number of policy levers, which have been implemented globally with varying degrees of success. Of these options a number have been proposed in a strategic framework, which after consultation with key stakeholder, will form the basis for the draft national strategy to be presented in June. All options require careful analysis to ensure that the maximum efficiency of change is achieved while producing none, or the minimum amount of undesirable impacts.

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