solutions

Transportation

in Developing Countries

Greenhouse Gas Scenarios for South Africa

Jolanda Pretorius Prozzi
Cambridge Systematics

Daniel Sperling
University of California, Davis

Transportation

in Developing Countries

Greenhouse Gas Scenarios for South Africa

Prepared for the Pew Center on Global Climate Change

by

Jolanda Pretorius Prozzi
Cambridge Systematics

Clifford Naudé
Council for Scientific and Industrial Research: Transportek, South Africa

Daniel Sperling
Mark Delucchi
University of California, Davis

February 2002

Contents

Foreword *Eileen Claussen, President, Pew Center on Global Climate Change*

South Africa has relatively high aggregate and per capita greenhouse gas (GHG) emissions compared to other developing countries, and to world averages. Transportation sector emissions are increasing, but climate change competes with urgent economic, social, and public health concerns for government attention. As a party to the UN Framework Convention on Climate Change and an active participant in the Kyoto Protocol negotiations, South Africa may be able to address transportation emissions through projects under the Protocol's Clean Development Mechanism.

The two major forces affecting South Africa's transportation sector are the country's legacy of apartheid and privatization. Apartheid-era policies cause high greenhouse gas emissions in two ways: (1) Blacks lived in separate townships and homelands, forcing them to travel long distances to jobs in commercial or white residential areas; and (2) anti-apartheid sanctions resulted in South Africa using high-carbon synthetic fuels based on domestic coal and boosting the local vehicle manufacturing industry. Privatization in the 1980s resulted in freight transportation shifting from rail to more energy-intensive trucks. Intense competition within the trucking industry has resulted in poor maintenance and extended use of inefficient vehicles by small entrepreneurial companies. This problem is more widespread in the minibus "jitney" sector, which evolved to serve the unmet travel needs of black South Africans.

This report creates two scenarios of greenhouse gas emissions in 2020. In the high "business as usual" scenario, residual land use policies continue to aggravate transportation problems. Personal car use accelerates as car prices drop and consumer credit becomes more widely available. In the low GHG scenario, mobility, accessibility, and safety concerns drive the government to play an active role in land use and transportation policies. More efficient use of urban land and energy resources improves the quality of life and reduces GHG emissions. Low-emissions scenario strategies are not necessarily costly but require strong political commitment. Some key results are:

- GHG emissions increase 82 percent in the high scenario; but decrease 12 percent in the low scenario.
- Coordinating land use, housing, and passenger transportation policies would promote more efficient urban land use patterns that reduce travel distances and correct spatial imbalances.
- Both (1) restructuring commuter services so that rail serves the densest population centers, buses serve secondary routes, and minibus jitneys provide feeder or local services; and (2) dedicated taxes on vehicle purchases and use, would improve and help sustain public transportation.
- Changing technology, such as cleaner feedstock for synthetic fuel, would reduce GHG emissions.
- Providing incentives to domestic auto manufacturers to produce buses and minibuses instead of cars would reduce the car orientation of the transportation system.

Transportation in Developing Countries: Greenhouse Gas Scenarios for South Africa is the third report in a five-part series examining transportation sector GHG emissions in developing countries. The findings are based on a Lifecycle Energy Use and Emissions Model developed by the Institute of Transportation Studies at the University of California at Davis, which estimates GHG emissions from the transportation sector.

The Pew Center gratefully acknowledges Ogunlade Davidson of the University of Cape Town, Ralph Gakenheimer of MIT, Talia McCray of the Université de Laval, and Michael Walsh, an independent transportation consultant, for their review of earlier drafts.

Executive Summary

The performance and structure of South Africa's transportation system is largely explained by two phenomena: the legacy of apartheid and privatization. Apartheid had far-reaching impacts, even extending deep into the country's transportation and energy system. Largely as a result of these policies, the country's contributions to global greenhouse gas (GHG) emissions are high compared to those of other African nations, both in aggregate and per capita terms. Some of the transportation and energy effects of apartheid include the following:

- *Land use policies were based on race and ethnicity,* in which black residential areas were moved to the outskirts of growing urban areas and beyond, creating long commuting distances for most of the black poor.
- *Energy investments in innovative coal-based synthetic fuel processes* were greatly expanded following international sanctions during the 1970s and 1980s.
- *Import substitution economic policies* promoted the domestic motor vehicle manufacturing industry.
- *Generous company car allowances and subsidized vehicle schemes* nurtured a market for private cars to support the domestic auto industry.
- *Public transportation services designed to serve long-distance commuters with low levels of service* inspired black entrepreneurs to create informal services by minibus jitneys — van-type vehicles — for the many unserved travel needs. These services tend to be provided with inefficient vehicles resulting in higher energy consumption and emissions.

The good news is that South Africa has emerged from decades of apartheid policies with a functioning economy and extensive social and physical infrastructure. The bad news is that besides creating pervasive economic and social problems, apartheid polices led to a set of travel behaviors and transportation-related investments that increased energy use and GHG emissions.

Privatization is a second major phenomenon shaping South Africa's transportation system and its energy

and environmental performance. The country is steadily privatizing both its passenger and freight transportation systems, largely because of shrinking government funds and an inability to manage urban sprawl. The effects of privatization in the transportation sector have been positive in many ways — including expanded transit service and lower freight costs. But dwindling government subsidies and rapid growth in minibus jitney services have led to sharp ridership losses on the extensive rail and bus systems. This change has resulted in more energy use, GHG emissions, pollution, road deaths, and, paradoxically, continuing urban sprawl.

Minibus jitneys have come to dominate the provision of passenger transportation services. They are almost totally owned by black South Africans. In only two decades, jitneys have expanded to account for two-thirds of all public transportation services and over one-third of total passenger travel in South Africa. They are expensive relative to bus and rail transit, but ubiquitous, providing service to many poor travelers. Financial problems in the minibus jitney industry have led to increasingly old, dilapidated, uncomfortable, and unsafe vehicles, resulting in higher energy consumption and GHG emissions. The government is now attempting to organize and regulate the minibus jitney sector.

Privatization in the freight sector has also propelled large modal shifts from rail to truck. Until 1988, trucks were not allowed to compete with the government-owned railroad. When the freight sector was deregulated in 1988, truck use rapidly expanded, resulting in lower freight tariffs, and a large drop-off in rail use.

Overall, the combined effect of privatization and the apartheid legacy is inflated travel demand, growing use of motor vehicles and trucks, and use of high-carbon fuels. The challenge is to devise policies and strategies to redirect these behaviors and investments to create a more economical, environmental, and socially beneficial transportation system.

Numerous policy options exist to reduce GHG emissions from the transportation sector. These policies affect when, how, where, and why people travel. Options range from adopting efficient advanced vehicle technologies to various administrative controls (including parking controls and car restriction zones) and economic measures (including additional vehicle and fuel taxes).

Environmental quality is not a high priority in South Africa, one of the few countries that does not regulate motor vehicle emissions of air pollutants. However, leaders are motivated to improve mobility, accessibility, and road safety, and reduce traffic congestion. Many of the strategies targeted at those goals will restrain GHG emissions:

• *Improve accessibility and mobility.* Due to racial segregation, most South Africans live far away from employment centers and economic services. Improved public transportation is the most efficient means of enhancing mobility and accessibility. Enhanced public transportation would restrain growth in the use of personal vehicles, with associated reductions in the growth of GHG emissions.

• *Improve road safety.* Road safety is a serious concern in South Africa. Policies that improve road safety, such as enforcing speed limits, scrapping older vehicles, and improving vehicle maintenance could help reduce GHG emissions.

• *Reduce traffic congestion.* Congestion is increasing in all major areas and is expected to become a major problem shortly. Since South Africa does not have the funding to build many more roads, an improved public transportation system will be vital to ensure mobility for the vast majority of its people.

• *Increase tax revenue.* Increasing fuel and vehicle taxes — an important source of government revenue — would help pay for social expenditures and raise the cost of private vehicle use.

• *Respond to international pressure.* By ratifying the United Nations Framework Convention on Climate Change, South Africa has become part of the global community that is committed to taking responsibility for its GHG emissions.

Two transportation scenarios were designed for South Africa — one that yielded higher GHG emissions by 2020, and one that yielded lower emissions. These scenarios draw upon extensive interviews with decision-makers and experts in South Africa.

The higher GHG scenario assumes a continuation of observable and emerging trends. In this "business-as-usual" scenario, the government remains entangled in crisis management. It focuses on health, education and social unrest related to skewed income distributions, and ignores transportation concerns. Residual land use policies from apartheid continue to aggravate transportation problems. Cities remain divided and land developers give little consideration to the implications of long commuting distances. The automotive industry remains a pillar of economic development. Personal car use accelerates as car prices drop and consumer credit becomes more widely available.

In this scenario, private cars and minibuses increase their share of total passenger-kilometers from 51 percent in 2000 to 59 percent in 2020, while public transit's share decreases from 49 to 41 percent.

Minibus jitneys retain 60 percent of the public transit modal share. The effect on greenhouse gases is significant: South African emissions increase by 82 percent from 2000 to 2020.

In the lower GHG scenario, the motivation for change and government action are driven by mobility, accessibility, and safety concerns. The government plays an active role in land use policies and surface passenger transportation. Land use and housing policies are adopted that promote more efficient urban land use patterns, gradually correcting spatial imbalances and reducing travel distances. The government promotes public transportation, restructuring the minibus jitney, bus, and commuter rail sectors. Under the new structure, trains serve the routes with the densest population, buses serve the secondary routes and minibus jitneys provide feeder or local services. The sustainability of the public transportation system is ensured through revenues raised from dedicated taxes on vehicle buyers and users. South African auto manufacturers are provided with incentives to design and build buses and minibuses appropriate to the local market. Sasol, the large industrial company in South Africa that produces synthetic oil from coal, starts to use natural gas as feedstock in the production of synthetic fuel. This change would avoid the high costs of impending capital investments in coal mining, while harnessing the environmental benefits associated with the use of a cleaner feedstock.

This low-emissions scenario leads to enhanced quality of life and more efficient use of resources — urban land and energy — and decreased GHG emissions. The modal share of private cars and public transit remains approximately constant at 48 and 52 percent, respectively, but minibus jitneys suffer a significant decline in public transit modal share, from 65 percent in 2000 to 56 percent in 2020. Bus and rail transportation account for the remaining share of public transit mode share at 19 and 25 percent respectively. The result is a 12-percent decrease in GHG emissions — despite the fact that passenger-kilometers increase by about 54 percent. The strategies in the low-emissions scenario are not necessarily costly, but they do require strong political will and a commitment that has yet to be demonstrated by South African leaders.

I. Introduction

South Africa's history is one of intermittent conflicts with colonial rulers and internal struggles among its peoples. Policies and institutions that evolved from these conflicts have shaped the transportation system and affected the level of greenhouse gases from this sector. A brief overview of South African history is presented in the Appendix.

A. South Africa: The People and the Economy

South Africa is approximately the size of Texas, with an estimated population of 43.7 million people.[1] Between 1995 and 1999, the population was growing at the same rate as the economy — 2.3 percent per year — when Gross Domestic Product (GDP) is measured in the local currency.[2] However, during the same period, South Africa's economy shrank in dollar value because the South African currency has been losing value for many years.[3]

In 1999, the GDP per capita was about U.S.$3,050 (at the 1999 exchange rate)[4] and the disposable income per capita of households was approximately U.S.$1,453 (at the 1999 exchange rate).[5] This figure camouflages huge income disparities. The poorest 50 percent of the population receives only 11 percent of total income, while the richest 7 percent receives over 40 percent. Inequality of income distribution between racial groups is considerable, but inequality within racial groups is also substantial. For South Africa, the conventional poverty line that separates the poor from the non-poor equals about $2 per day (at the 1998 exchange rate). In 1998, about 19 million South Africans had average consumption levels of less than $2 per day. Poverty is not confined to any one racial group, but is concentrated among blacks: 61 percent of blacks and 38 percent of coloreds[6] are poor, compared with 5 percent of Indians[7] and 1 percent of whites.[8]

Today, more than ten years after political reforms were launched, South Africa is still coming to terms with its past and attempting to unravel apartheid policies. Since 1994, the government has been struggling — with limited success — to manage the aspirations of the majority of mostly poor black people, while allaying the fears of white South Africans and international investors. In recent years,

South Africa's black middle class has been steadily expanding as is evident from the number of black South Africans in key positions in the formal sector and the number of black students enrolled in universities and colleges. Despite this progress, South Africa is plagued by many of the same social and economic limitations affecting other developing countries, including demand for more social services, a limited tax base, limited skills in the labor force, and low labor productivity. Unemployment has increased in recent years. Unemployment estimates currently range from the official estimate of about 20 percent to unofficial estimates as high as 40 percent.[10] The country is also experiencing rapid urbanization. In 1996, 51 percent of the population resided in urban metropolitan areas. Today, it is projected that almost 60 percent of the population is living in urban areas.[11] The larger metropolitan areas produce most of the GDP and are growing rapidly.

South Africa's social challenges are great. Not only are the majority of South Africans poor and poorly educated,[12] but crime rates are high and public health is deteriorating. The HIV infection rate is especially high. A report by South Africa's Medical Research Council found AIDS to be the single biggest cause of death in South Africa in 2000. The report found that 25 percent of all deaths and 40 percent of adult deaths were AIDS related in 2000. The report claimed that without effective treatment, 5 to 7 million South Africans would die of the disease by 2010.[13]

B. Legacies of Apartheid

South Africa is burdened by the many problems common to developing countries, but also by the special circumstances arising from decades of apartheid. The legacy of apartheid permeates the entire transportation system, sometimes in surprising ways. Apartheid distorted land use decisions, transit supply, automotive investments, and vehicle purchase and use.

Inefficient Land Use

With the election of the National Party in 1948, various laws were passed to legalize and institutionalize the policy known as "separate racial development," in which cities were developed primarily on the basis of race. The "Apartheid City" development pattern was premised on serving all racial groups by allowing each to develop to independence at its own pace and in its own prescribed area. The slogan was "boundaries bring peace." Existing patterns and processes of racial separation were accelerated and institutionalized, while additional processes were developed to increase physical separation between racial groups.[14] Black

residential areas — called townships[15] — were formally moved to the outskirts of growing urban areas and beyond, to what became known as homelands.[16] The homeland policy also relocated large numbers of "non-economically active"[17] black people to these homelands.[18] Access to white areas was limited and black residential rights were abolished in many areas.[19]

The distances and commuting times between black townships and city centers were long, averaging about 28 kilometers and over an hour each way (see Table 1).

The spatial separation limited access to employment and other services. To help resolve this problem, the government subsidized bus and train transportation. The result was long daily commutes for the black poor.

Table 1

Distance from Black Townships to City Centers

	Distances Between Township(s) and Central Business Districts (km)	Average Time Spent (minutes/ one-way journey)
Johannesburg (bus/train)	20	77
Johannesburg (taxi/car)	20	44
Pretoria	52	75
Durban	20	N/A
Bloemfontein	58	86
Port Elizabeth	16	N/A
East London	21	N/A
Cape Town	19	65
Average	**28**	**69**

Source: de Saint-Laurent, 1998. *Overview of Urban Transport in South Africa.*

Note: Distances listed are the average distances between the outlying townships and the listed city's central business districts.

Urban sprawl, induced by apartheid's townships and homelands where black South Africans lived but did not work, continues to spread. There is no overall philosophy or strategy to manage urban growth. New low-cost housing is sited on the cheapest land, far from employment centers. With South African cities suffering inner-city decay, businesses and commercial centers are relocating to the suburbs. Public transportation cannot serve these diffuse travel needs efficiently.

A major effort in the mid-1990s to develop a national transport plan culminated in the 1998 government report, *Moving South Africa.*[20] The report highlights the most important challenges facing public transportation. This report and the *White Paper on National Transport Policy* (1996), both from the South African Department of Transport, forcefully articulated the importance of reducing long commuting distances. *Moving South Africa* concludes that sub-optimal spatial planning is the principal cause of high public transportation costs — and also the most difficult to reverse. As a result, the Department of Transport has adopted a policy to encourage the densification of urban areas. It is unclear, however, whether local authorities who implement the policy regard it as a priority, and whether they are prepared

to enforce it when it does not coincide with the intentions of property developers. There is no evidence that urban sprawl is being contained or even slowed.

Expensive and Carbon-Rich Synthetic Fuels

South Africa has little petroleum, but large reserves of coal. In 1950, the South African government financed the formation of the Sasol Company to produce synthetic oil from coal. The first plant, opened in 1955, suffered many technical problems and was uneconomical. However, when faced with international oil embargoes, first by OPEC countries in the 1970s and later in response to apartheid, the country accelerated its investment in Sasol.[21]

Today, Sasol is the second largest industrial company in South Africa and recognized for its innovative chemical processing technologies.[22] Sasol has formed joint ventures with leading international energy companies to develop and commercialize its technologies for converting coal, natural gas, and petroleum into liquid fuels and chemicals.

Sasol is now a privately owned company, with minority ownership by the government. The company supplies 41 percent of South Africa's liquid fuels[23] — gasoline, diesel and aviation fuel — and produces more than 120 chemical products for local and international markets in more than 90 countries.[24]

As a result of its dependence on coal for energy and liquid fuels, South Africa is a relatively high contributor to global GHG emissions, both in aggregate and in per capita terms. Accurate data are unavailable, but research shows that Sasol's synthetic gasoline and diesel fuels (made from coal) probably result in about twice as many GHG emissions per vehicle kilometer (on a life cycle basis) as gasoline and diesel made from petroleum.[25]

Inflated Motorization and Automotive Manufacturing Investments

Under the terms of the Import and Export Control Act of 1963, South Africa's Ministry of Trade and Industry adopted policies to support the creation of a domestic auto industry. Under domestic content rules, a certain percent of the value of each car must come from domestic manufacturers. Large tariffs are imposed on imported cars.[26]

Import substitution strategies were common in the world in the 1960s and were widely believed to be central to economic development. But in South Africa, there was another motivation for this policy:

the need to create a domestic manufacturing capability in response to international sanctions. Today, the auto industry in South Africa accounts for a large share of economic activity. In 1999, the industry employed an estimated 250,000 people, generated about U.S.$20 billion in revenues, and accounted for 5.4 percent of the nation's GDP.[27] Of the estimated 316,000 vehicles that were produced domestically, 65,000 were exported.[28]

However, the South African auto industry is not internationally competitive.[29] The long history of protectionism has resulted in relatively high costs. As South Africa reintegrates into the international economy, the industry is being forced to be more productive and responsive to customer desires.[30] Barring adoption of new car-restraining policies, the net effect of South Africa's reintegration is likely to be slow reductions in car prices, improved vehicle quality, and increased car sales.

Since apartheid, the government has supported the development of South Africa's auto manufacturing industry by offering direct and indirect vehicle subsidies. For instance, employees are allowed to use company cars[31] for personal as well as business use. They are only required to pay for gasoline and maintenance. They also receive monthly car allowances[32] when they use their private vehicle for business purposes, and companies provide interest-free loans to employees to purchase private cars. The report, *Moving South Africa,* assumes that 10 percent of South Africa's vehicle fleet is company cars.

These policies stimulate vehicle ownership, tilt demand toward larger and less fuel-efficient vehicles, and increase vehicle use. Company car sales appear to be much more than 10 percent of the vehicle sales since these cars tend to be resold more quickly than other vehicles. The high number of large company cars distorts the overall size and mix of vehicles. The large influx of these vehicles into the resale market depresses used car prices, enhancing vehicle sales, and introduces less efficient cars into the market than buyers would normally purchase.

Poor Public Transportation Services

The relocation of low-income, mainly black, townships and homelands to the outskirts of cities and beyond, far from employment opportunities, created the need for public transportation. Buses and trains mainly connect these areas to urban employment centers. Very little off-peak demand exists for these services, creating large inefficiencies for operators. Equipment and workers are only used intensively for short times in the early morning and late afternoon rush hours. Operators also received subsidies to

keep fares low for low-income workers. The public transportation system that evolved was largely a commuter system to serve the work trips of poor, relocated blacks. The result was low levels of service and high subsidies for long radial routes.

Beginning in the 1950s, black entrepreneurs began to provide un-metered taxi services in large sedan cars in the townships. The government allowed such services to proliferate because they relieved the government of further subsidies for public transportation. Although the government required permits for the operation of these sedan cars, it did not limit entry of new operators and eventually permitted operators to carry a maximum of 16 people. Most operators gradually upgraded from sedans to vans to carry more passengers. These vans became known as minibus jitneys, or combi-taxis.[33] Growth was explosive. Minibus jitney services now account for over two-thirds of all public transportation, and one-third of all passenger travel in South Africa. However, minibuses are often uncomfortable and unsafe because of extended service life, poor maintenance, overloading and reckless driving.

II. South Africa's Transportation Picture

With a slowing economy and growing social demands, transportation is not among the government's highest priorities. South Africa is increasingly looking for ways to harness market forces to improve efficiencies, and asking private businesses to inject additional resources. Private businesses have launched new transportation services, such as the minibus jitneys, and taken over many services previously operated by the government.

In 1990, the government transportation bureaucracy was transformed into Transnet, a public corporation wholly owned by the national government but with an independent board of directors. Transnet consists of seven subsidiary businesses: Spoornet (intercity passenger and freight rail), Portnet (harbors), Autonet (road transportation), Petronet (liquid petroleum transport), SAA (air transportation), Fast Forward (container shipments), and MetroRail (commuter rail services).

A. Road Infrastructure

The quality of the road system reached its peak in South Africa during the 1970s when construction of intercity freeways was emphasized. Rural roads were built and maintained, but usually to serve white agricultural interests. By 1980, predominantly white areas were well served, while roads in predominantly black areas were barely adequate to meet demand. The problem was exacerbated in the 1980s. Accelerating black urbanization resulted in escalating travel demand, but local authorities in predominantly black areas did not have the resources to respond with new or improved roads.

Transportation funding began to diminish in the 1980s as funding for social services and police and military needs grew. In 1988, the government abandoned the dedicated highway trust fund and diverted revenues from the national fuel tax into the general budget. Road building and maintenance were now forced to compete with other needs. Expenditures on roads decreased for both white and black areas.

To offset these dwindling funds, a variety of new funding sources were developed in the 1980s and 1990s. Tolls were introduced in the 1980s on high-volume intercity roads and expanded in the 1990s.

Fuel that had been stockpiled during apartheid was sold and used to finance a one-time investment in rural road infrastructure in the mid-1990s. Also, a small portion of the fuel tax (equivalent to about 3 U.S. cents per gallon) was re-dedicated in 1998 to design, construct, manage, and maintain intercity freeways.

None of the funding generated from the dedicated fuel levy is directed at lower-volume local and provincial roads not serving major economic activities. These roads, comprising about 84,000 and 176,000 kilometers respectively, form the bulk of the South African road network. They are the responsibility of local authorities and the nine provinces.[34]

The Department of Transport estimates that South Africa will need R170 billion for road infrastructure over the next 10 years.[35] In contrast, the government only allocated R8.6 billion for roads in 1997.[36] The government is increasingly looking to the private sector to make up for this funding shortfall.

B. Public Transportation

Urban areas are served by public and private buses, minibus jitneys and, in the six largest cities, rail transit. Cities are connected by buses, minibus jitneys, rail, and planes. These services are being gradually privatized.

Transportation choices are sensitive to income (see Table 2). At one extreme are those too poor to use any public transportation. They walk or in rare instances use bicycles. More affluent travelers rely almost exclusively on cars, a prevailing pattern beginning at incomes as low as 30,000 Rand per year (about US$7,000 at the 1998 exchange rate).

Table 2

Modal Choice by Income, Urban Commuters (1998) (percent)

Income Group (U.S.$/year)	Train	Bus	Taxi	Car	Walk/ Other	Total
<1,085	8	10	29	10	43	100
1,085 – 1,735	16	17	28	7	31	100
1,736 – 3,038	19	16	35	13	17	100
3,039 – 5,425	13	13	34	26	14	100
5,426 - 8,680	6	7	20	57	11	100
8,681 – 13,020	3	5	7	78	6	100
> 13,020	2	1	3	92	2	100

Source: *Moving South Africa,* 1998.

Rail Transit

South Africa has an extensive network of railroads that serve freight and passenger traffic, and both urban and intercity trips. Intercity rail freight and passenger traffic have been dropping for many years. Intercity passenger travel by rail alone dropped almost 80 percent between 1988 and 1995,[37] and is now a minor share of total intercity passenger traffic.

Urban rail services, offered by MetroRail, have also declined, but remain important. MetroRail is a government-owned public corporation (similar to Amtrak in the United States) that spun off in 1997 from Spoornet.

Passenger fares on commuter rail services have been subsidized since the 1950s. As costs increased over time, unprofitable passenger lines were cross-subsidized by profitable (intercity) freight services. Through the 1970s, passenger service was expanded to new housing (mostly black) and industrial developments with funding from Parliament. By the 1980s, the government was no longer able to fund the large capital requirements. Expansion of commuter rail tracks and stations was halted, and replacement of locomotives and railroad cars deferred.

As indicated in Figure 1, urban rail travel declined rather rapidly in the early 1980s. A number of factors contributed to this decline: reduced levels of government support, high levels of unemployment, and greater use of private cars. But above all this decline is tied to the deregulation of the minibus jitney sector, which resulted in many commuters switching from rail and bus to minibus jitneys. A recovery has been underway in recent years. Urban passenger rail revenue increased from 353 million Rands in 1994-95 to 561 million in 1997-98. Market share, measured by number of trips, recovered from its low of 16 percent, reaching 21 percent in the late 1990s.[38]

Figure 1

Commuter **Rail and Bus** Transportation

Source: Naudé et al., 2000; Southern African Bus Operators Association.[39]

Rail subsidies are diminishing, but still cover about two-thirds of total operating costs. Fare revenues are small for two reasons: fares are very low,[40] and fare evasion is rampant. The official fraud level is estimated at 23 percent, but may be as high as 30 percent.[41]

In 1998, the national government entered into an exclusive contract with MetroRail to provide commuter rail services in South Africa's six major metropolitan areas (Johannesburg, Pretoria, Cape Town, Durban, Port Elizabeth, and East London) for five years. The objective of this exclusive concession was to give MetroRail operating experience before the contract is put out for competitive bidding in 2003.[42] In 2003, MetroRail will have to compete with national and international bidders to provide commuter rail services.

Bus Transportation

As discussed, many bus routes were designed to connect urban employment centers with outlying black townships and homelands. A series of laws — the Black Services Levy Act of 1952, Black Transport Services Act of 1957, and the Transport Services for Colored Persons and Indians Act of 1972 — provided for the creation and subsidy of these commuter services. Services were initially provided by large white private companies. Subsidies grew rapidly. The initial funding source, a levy on employers, proved inadequate and was replaced in the late 1970s with direct funding from the national government. By the 1990s, soaring bus deficits were overwhelming the resources of the financially strapped government.

Intracity "white only" and "black only" bus services were operated and subsidized by local authorities. They focused their operations on the financial and commercial areas of the dominant central business districts, and provided services between city centers and white suburban areas. Both black and white services were well patronized. The black-only services transported blacks to jobs in white homes, but white-only services were used for many kinds of trips. Well into the 1980s, many whites commuted by bus because most middle class white families only had one car.

The current bus sector is a mix of public and private companies. Subsidized services are provided by provinces,[43] cities, and private companies. Most of these private companies are still predominantly white owned. Buses largely serve the long work trips between black townships and homelands and major employment centers. A prominent exception is unsubsidized private bus companies, such as Greyhound, Translux, and Intercape. These services greatly expanded during the 1990s, operating luxury "coach-style" buses between major cities.

Most scheduled services and routes continue to receive large subsidies (see Table 3). From 1992-93 to 1996-97, local and national government subsidies for bus transit almost doubled, from 800 million to 1,500 million (1.5 billion) Rand. In 1997, bus subsidies surpassed rail transit subsidies for the first time.[44] By 1995, almost 11,000 buses (including private intercity buses) operated throughout the country on scheduled routes. In addition, approximately 18,000 buses provide unscheduled services of which 9,200 are charter buses that serve schools and employers.[45]

Table 3

Scheduled Bus Service (1995)

	Private Buses		Subsidized	Subsidized	
	Subsidized	Unsubsidized	Province Buses	City Buses	Total
Number of Operators	28	450	6	9	493
Number of Buses	3,900	2,000	3,120	1,790	10,810
Passenger Trips (million/year)	191	121	196	116	624
Average Trip Length (km)	27	26	33	24	28
Bus Kilometers/Day (average)	187	196	223	135	190
Cost Recovery (%)*	56	105	43	48	56

Source: de Saint-Laurent, 1998. *Overview of Urban Transport in South Africa.*

*Revenue from providing bus service (excluding subsidies) as a percentage of costs incurred to provide the service.

Like rail transit, scheduled bus services have been declining since the 1980s. From 1988 to the mid-1990s, ridership plunged by about 30 percent. This decline is tied to the deregulation of the minibus jitney sector, which led many commuters to switch from rail and bus to minibus jitneys; high levels of unemployment; and greater use of private cars.

Given large and expanding subsidies for bus transit, the government is reevaluating its role. One difficulty is that subsidies are based on operator costs and amount of service, and not on ridership. This system provides no incentive to keep maintenance costs down, and operators retain buses well beyond their normal service life. This has slowed the introduction of newer, more modern buses, which has serious implications in terms of safety, pollution, fuel efficiency, and GHG emissions. The average life of buses increased from 7.7 years in 1985 to 12 years in 1998.[46]

The government is now replacing the cost-based subsidy system with competitive bidding for concession contracts.[47] Bus operators must bid to provide service on particular routes. The provincial governments make up the difference between the tendered cost of a service and the income from fares.

Minibus Jitney Transportation

The most important transportation phenomenon in South Africa, and the one that most explains the decline of rail and scheduled bus services, is the emergence of privately owned minibus jitney services. With government-owned and supported rail and bus services targeting white interests and the long trips from townships and homelands, many shorter and more diffuse trips demanded by blacks were under-served. Beginning in the 1950s, black entrepreneurs started to provide un-metered, unsubsidized, and unscheduled services in large sedan cars in townships. In 1977, regulation of these unscheduled (jitney) services was relaxed, permitting the operators to carry up to eight passengers. The result was a proliferation of services by large cars and small minibuses. In the early 1980s the passenger limit was raised to 16 people, and operators upgraded to larger vans, known as minibuses. The national government allowed these informal services to flourish. Local governments did not regulate them or limit entry by new operators. Presumably, the government realized that these private services relieved it from providing additional (subsidized) transit services. The growth of these services has been explosive, now accounting for over two-thirds of all transit service and about one-third of all passenger travel in the country in terms of passenger-kilometers. The number of minibus vehicles — the total number used as jitneys, private vehicles and as hotel and school vehicles — increased from about 50,000 in 1979 to an estimated 250,0000 in 2000.

This rapid growth is partly due to the relative ease of obtaining permits and partly to the large number of illegal operators operating without permits. In 2000, about 127,000 minibus taxis operated in South Africa, of which about 36,000 were illegal.[48]

Minibus vehicles are designed as passenger vans for family use. Manufactured by Volkswagen, Toyota, Nissan, Isuzu and Mitsubishi in South Africa, these vehicles are not designed for public transit. They are designed to seat nine people. Minibuses converted for use as jitneys are modified to fit more people — luggage space is eliminated, and four bench seats with backs, but no seat belts, are added. Four people are legally squeezed onto each bench seat, which often seat more illegally. Seating is very uncomfortable. The vehicles tend to be dilapidated because of intensive use, poor maintenance, overloading, and extended vehicle lives. The average age of minibus jitneys is estimated to have increased from 6.5 years in 1985 to 10 years in 1998.[49]

By operating with aging vehicles, affordability and profitability is ensured, but safety risks for passengers and road users are increased when vehicles are not maintained adequately.[50] Poor maintenance

and inefficient vehicles also result in higher energy consumption and GHG emissions.

With the unregulated (and unsubsidized) minibus jitney industry in anarchy, the government has embarked on measures to formalize the industry. These measures include registering associations and operators; enforcing permit requirements, vehicle roadworthiness, and traffic rules; and replacing the aging 16-seater gasoline minibus jitney fleet with more suitable 18- and 35-seater diesel vehicles.[51] Predictably, the government's efforts are being met with resistance from the minibus jitney operators.

Figure 2

Minibus Jitney Station

Photo by Johan Maritz of CSIR: Transportek

Access to credit to finance the purchase of minibuses had always been difficult for prospective jitney owners. During apartheid, South Africa's financial institutions did not lend money to black entrepreneurs; in later years, financing for minibus purchases could only be secured at significant costs because of the high risk of default. The government's Taxi Recapitalization Project aims to provide credit at lower interest rates to encourage replacement of the existing fleet with larger, more suitable and more efficient vehicles.

C. Vehicle Ownership and Travel Characteristics

The number of motor vehicles has been increasing steadily and somewhat faster than the population. Although reliable motor vehicle data have not existed since 1992, estimates for 2000 and government forecasts for 2020 are presented in Table 4. These estimates are based on 1992 registration data, which were extrapolated using data on vehicle sales, population growth, and estimated GDP growth. As of 2000, South Africa had an estimated 141 vehicles per 1,000 people, of which almost 70 percent were cars for personal use.

The motor vehicle fleet is expected to continue to increase into the foreseeable future, but this

Table 4

Motor Vehicles in South Africa

Year	Cars	Minibuses	Commercial Vehicles*	Buses	Total
1985	2,971,451	125,125	1,122,812	28,168	4,247,556
1986	3,101,860	135,321	1,164,400	28,209	4,429,790
1987	3,142,906	143,867	1,186,549	29,910	4,503,232
1988	3,170,552	151,845	1,190,525	29,095	4,542,017
1989	3,316,706	181,466	1,252,104	28,000	4,778,276
1990	3,403,605	196,243	1,273,257	28,107	4,901,212
1991	3,489,947	208,256	1,303,995	28,545	5,030,743
1992	3,522,129	217,037	1,338,737	28,354	5,106,257
2000	4,234,132	250,000	1,568,089	29,900	6,082,121
2020	6,371,100	302,800	3,070, 300	39,400	9,783,600[52]

Source: Department of Transport, *Transport Statistics, 1993.*

*Commercial vehicles include light, medium, heavy, and extra heavy vehicles, as well as construction vehicles. In South Africa, very few light duty trucks are for personal use.

increase is sensitive to economic growth and expansion of the black middle class. Real GDP growth was marginal in the late 1990s, and vehicle sales have not exceeded 1996 levels.

Car Ownership and Use

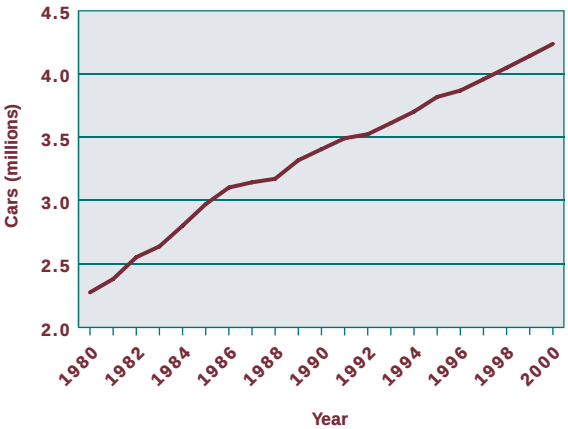
South Africa's car fleet increased rapidly during the 1980s but slowed during the 1990s.[53] The number of cars increased 4.1 percent annually during the 1980s and 2.2 percent in the 1990s (see Figure 3). The annual rate of growth in the number of cars (2.1 percent) between 1995 and 2000 is somewhat below the 2.5 percent annual growth in the nation's human population during the same time period.

The continuing growth in the car population is due in part to vehicles being kept longer before scrapping. The average age of cars increased from 7.4 years in 1982 to 10 years in 1998. The slow retirement of vehicles is presumably because of the stagnant economy and improved vehicle quality,[54] but it has slowed the introduction of safer, lower-emitting, and more energy-efficient vehicles.

Road safety is indeed a major concern. About 10,000 people are killed in road

Figure 3

Growth in **Car Population**



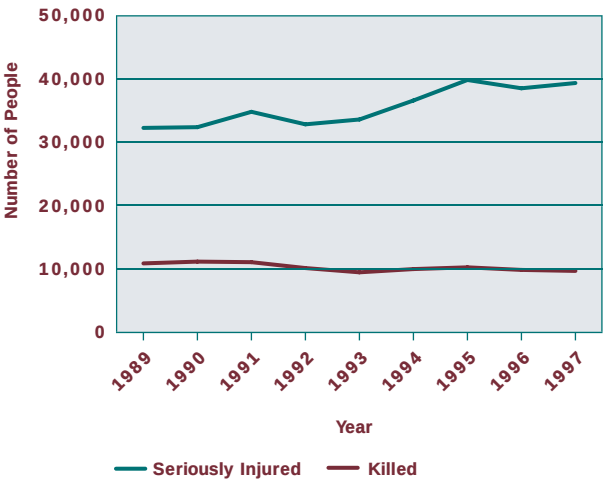
Source: Estimates based on information contained in Naudé et al., 2000.

accidents every year, and many more are seriously injured. The number of fatalities per 10,000 vehicles (17.6 in 1996) is among the highest in the world. Figure 4 illustrates a relatively constant trend in road traffic deaths and an upward trend in the number of people seriously injured between 1989 and 1997. The number of people seriously injured in 1997 was 22 percent higher than in 1989.

Cars accounted for 64 percent of the total road vehicles involved in traffic collisions in South Africa, minibus jitneys for 8 percent, light delivery vehicles for 16 percent, and all other road vehicles for the remaining 12 percent.

Figure 4

Road Traffic Casualties



Source: Statistics South Africa, *Statistics in Brief*, 2000.

Even with slowing economic growth, the number of cars is expected to continue increasing. Cars are highly attractive. They provide unprecedented comfort, convenience, and also status. In South Africa, cars have extra appeal because of diffuse land use patterns, uncomfortable and poor quality transit services, and generous company car incentives and car allowances. On the other hand, the increased use of cars to satisfy South Africa's transport needs will result in more casualties, energy use, pollution, and GHG emissions.

Non-motorized Transportation

Only about one percent of South Africans bicycle to work,[58] largely due to long distances, unfavorable weather, and safety concerns. Non-motorized road users (pedestrians and cyclists) account for approximately 30 percent of road accident fatalities each year. This is largely attributable to the fact that no infrastructure exists for non-motorized transport modes. Pedestrians and cyclists are forced to share road space with motor vehicle users that have little regard for traffic laws pertaining to speed limits, driving under the influence of alcohol, or driving on the shoulders of pavements. This makes the road environment unsafe for pedestrians and cyclists.

Bicycles are potentially a low-cost and viable transportation alternative for the poor who must

commute long distances by foot. Afribike, a South African non-profit group, recently embarked on a program to promote the use of bicycles in townships, where trips are generally shorter, the terrain flatter, and the roads safer than in metropolitan areas. Bicycles are, however, not viewed as a viable mode to commute between townships and employment centers in urban areas, given the long distances and dangerous road environment.

D. Freight Transportation

Until the late 1980s, most of South Africa's long distance freight moved by rail. The government-owned railway held a monopoly, protected by legislation that prohibited trucks from competing. The Transport Deregulation Act in 1988 deregulated freight transportation, allowing trucks to operate wherever they wanted. As expected, deregulation resulted in a flood of new trucking companies. The increased supply of capacity led to increased competition, which led to a lowering of freight tariffs. The protected rail company had become inefficient over the years, like rail companies in the United States, Europe, and elsewhere.[59] With deregulation and competition from trucks, rail suffered sharp losses in market share. Spoornet, the rail company, claims that it must lower tariffs for general (i.e., non-bulk) freight below cost to stay competitive.

There is considerable debate about whether the current state of affairs is healthy. While the largest trucking companies are well managed, profitable, and provide high levels of service, many of the newer companies are not. At the extreme are small entrepreneurial companies, often with single vehicles. The small new companies are viable because they have minimal overhead (office space and staff) and, in many cases, provide low-quality service with badly maintained vehicles. This sector is growing rapidly, and academics and researchers have expressed concerns that a situation similar to that of the minibus jitney industry is developing.

There is a concern that competition is excessive and destructive — a recurring concern in all countries that deregulate trucking. The slowing economy, combined with increased trucking capacity has further intensified competition, reducing tariffs still further for both trucks and rail. This has led some truck operators to overload their vehicles, neglect maintenance, require drivers to speed, and encourage drivers to work long hours.

A degree of consensus appears to be emerging among transportation officials that the growth in

road freight transportation has been too fast and that some freight should be encouraged to return to rail. Strategies under discussion for slowing truck growth include stricter enforcement of the country's traffic laws; full cost recovery from road freight operators, who are generally believed to pay less than their fair share of road use and related external environmental costs; and major improvements in rail services.

Research has shown that freight rail is less GHG intensive than trucks, but the data for the South African freight sector are too unreliable to estimate its GHG emissions.

E. Transportation Impacts on Energy and the Environment

The government is committed to stimulating economic growth and responding to social demands. Environmental quality is a low priority and many decision-makers view addressing this issue as a threat to economic growth.

Energy Consumption by the Transportation Sector

Transportation accounts for 18 percent of the total energy use in the country.[60] Motor vehicles in South Africa consumed about 14 billion liters of gasoline and diesel fuel in 1996 (see Table 5). Growth in energy consumption has been steady, increasing about 19 percent between 1990 and 1997. Approximately 14 percent of South Africa's total primary energy supply is imported in the form of crude oil.[61] Gasoline prices are comparable to that of the United States (about $1.38 per gallon in 1999) in absolute terms. Although rather low by international standards, gasoline is considered expensive in South Africa, given the country's relatively low income per capita. Diesel fuel costs about 15 percent less than gasoline.

Virtually all the fuel used for transportation is liquid. About 41 percent is coal-based synthetic fuel produced by Sasol.[62] The synthetic liquids are in the form of gasoline, diesel and aviation fuel. Sasol foresees that this synthetic fuel share will remain constant over the next 20 years. In recent years, Sasol has undertaken a number of studies to determine the feasibility of replacing coal with natural gas as a feedstock in the production of synthetic fuel. The company is concerned about large additional capital investments needed for additional coal mining, and is interested in harnessing some of the environmental benefits of shifting to natural gas.[63]

South Africa has few natural gas reserves, but Sasol has started to explore for gas offshore of South Africa and elsewhere along the African continent. In 2000, Sasol entered into an agreement with the national oil company of Mozambique and the Mozambique government to develop two of their gas fields —

Table 5

Vehicle Use and Energy Consumption by Mode (1996)

Vehicle Type	Vehicles	Vehicle-km (million)	Fuel Usage (kiloliter)	Fuel Consumption (liters /100 vehicle-km)
Private Cars	3,838,000	76,760[64]	8,366,840	10.9
Light Duty Commercial Vehicles	667,000	13,340	1,494,080	11.2
Minibuses	160,300	4,328	605,934	14.0
Subtotal – Gasoline	**4,665,300**	**94,428**	**10,466,854**	
Private Car	28,000	560	49,840	8.9
Minibuses	1,000	27	3,375	12.5
Buses	29,900	1,076	236,808	41.9
Light Duty Commercial Vehicles	115,500	2,310	228,690	9.9
Heavy Commercial Vehicles				
Intercity	64,760	4,986	2,154,177	43.2
Local	122,300	4,035	645,744	16.0
Subtotal – Diesel	**361,460**	**18,297**	**3,318,634**	

Source: Schutte, I.C. and W.J. Pienaar, 1996.

Notes: (1) Fuel usage estimates were made using fuel consumption data per mode. (2) Vehicle-kilometers traveled (VKT) were derived using the data in the table and estimates for average annual distance traveled (AADT) per mode: VKT for cars were estimated at 20,000 km, minibuses at 27,000 km, gasoline light commercial vehicles at 20,000 km, buses at 36,000 km, diesel light commercial vehicles at 33,000 km, and heavy commercial vehicles at 77,000 km.

the Temane and Pande fields — and to build a pipeline to transport the natural gas to South Africa. Most of the natural gas will be distributed to the industrial sector, but some will be used as a supplementary feedstock to produce synthetic fuel. The pipeline is scheduled for completion in 2004.[65]

Air Pollution

Air quality monitoring receives little attention in South Africa. The Constitution assigns responsibility for air quality monitoring and air pollution control to local authorities. The national Department of Environmental Affairs and Tourism (DEAT) sets pollution standards and monitors local compliance. But air pollution control legislation has not been updated since 1965, and most local authorities lack skills and financial resources to implement and enforce rules.

Public air quality data are sparse and uneven.[66] Ozone, nitrogen oxides, and particulate measurements have historically been conducted only sporadically. Moreover, South Africa is one of the few countries that does not regulate motor vehicle emissions, with the exception of particulate standards for diesel-powered vehicles. Few cars are outfitted with catalytic converters.

South Africa also lags behind in removing lead from gasoline. Unleaded gasoline was first introduced in South Africa in 1996. This introduction was motivated by the desire of the domestic automotive industry to stay abreast of global trends in engine technology, not by environmental concerns. Adoption

has been slow. Market penetration of unleaded fuel increased from 8 percent of total gasoline sales in 1996 to only 11 percent in 1999 despite a slightly lower price than leaded fuel. Low demand is largely attributed to the perception that unleaded fuel negatively affects engine performance.

The extent of the air pollution problem is not well understood, but there are indications of significant deterioration. Air pollution is now becoming visible in most of South Africa's major metropolitan areas, especially in Cape Town, where temperature inversions trap pollution, resulting in a visible haze.

Motor vehicles are a major source of air pollution in South Africa.[67] Estimates of the emissions attributable to motor vehicles and major industries vary significantly, but in 1995, the Department of Minerals and Energy and the DEAT estimated that South Africa's vehicles are responsible for 27 percent of nitrogen oxide and 55 percent of hydrocarbon emissions.

Greenhouse Gas Emissions

South Africa is a relatively large producer of greenhouse gases, especially among developing countries (see Table 6). According to the national GHG emissions inventory completed in 1999, South Africa was responsible for over 1 percent of global emissions in 1990. Emissions per capita were estimated at 10 tons of carbon dioxide equivalent per person per year — well above the global average of 7 tons per person per year, though considerably lower than the 20-ton average of the United States.[68]

South Africa's relatively high contribution to global GHG emissions can be attributed to its

Table 6

CO_2 Emissions for Various Countries (1998)

Country	CO_2 Emissions/Capita from Transportation (kg)	Percent of Total Carbon Emissions from the Transportation Sector
Chile	1,028	28
South Africa	1,740*	20*
China	178	8
India	120	13
Japan	1,971	22
United Kingdom	2,238	24
United States	6,082	30

Source: International Energy Agency, 2000. *CO_2 Emissions from Fuel Combustion: 1971-1998*, except for South Africa.
*Although IEA was the starting point for the South Africa estimates, the IEA numbers were adjusted by the authors to account for upstream emissions. See text on p. 20.

dependence on coal for energy and liquid fuels. South Africa is well endowed with coal, but has very little oil and natural gas and limited potential for hydroelectric power. The energy sector was the largest contributor to GHG emissions in South Africa in 1998, accounting for approximately half of the total.[69]

Official estimates indicate that the transportation sector accounts for only about one-tenth of South Africa's GHG emissions.[70] But these estimates do not include upstream emissions, for example, from oil refineries and coal processing facilities. When upstream emissions associated with transport fuels are reassigned to the transportation sector, as they are in this report, it would account for about one-fifth of the country's total GHG emissions.

III. Policies and Strategies

South Africa's economy is stagnant, human health is deteriorating, and racial tensions remain high. Although transportation is linked to many of these challenges, it is not a high national priority. Environmental issues associated with the transportation sector are an even lower priority, illustrated by the lack of air pollution standards on vehicles and the slow phase-out of lead from gasoline.

While GHG reductions from the transportation sector will not be a government priority in the foreseeable future, there are certain strategies to improve social and economic conditions that are widely embraced by government that also would restrain and even reduce GHG emissions. These policies and strategies are considered in this section.

A. Improve Accessibility and Mobility

With South African authorities at all levels of government under pressure to increase social spending on education, health and housing, subsidies for public transportation are limited. Land use sprawl and dispersed settlement patterns created by apartheid deprive public transportation of the density it needs to provide service efficiently and competitively. The government recognizes this dilemma and the need to provide better mobility and access. It has embarked upon a major review of the national transportation policy to determine how to meet the transportation needs of its citizens with limited resources. *Moving South Africa* has forcefully articulated that an improved public transit system is necessary given the poverty of so many people and their lack of access to employment and economic services. The following strategic actions were identified and deemed necessary to redirect behavior and investments to create a more economical and socially beneficial transportation system:[71]

- *Densification of transportation corridors.* Current trends towards urban sprawl should be reversed and more efficient urban land use patterns promoted by locating housing settlements and commercial activities along transportation corridors. This requires coordination among the various institutions and stakeholders in urban areas, including housing finance, utility services,

transportation infrastructure, and transportation services, as well as the use of aggressive development controls and incentives, such as lower land prices in such corridors. Land use strategies to combat urban sprawl should be complemented by transportation infrastructure investments in these corridors, including road-based public transit infrastructure such as busways — dedicated bus lanes — to facilitate express transit bus services. Significant transportation system cost savings are possible from land use densification compared to a more dispersed pattern.

• *Promote public transit services.* This could be done through road space management and favoring public transit services. In essence, public transit should be promoted over private car travel by managing peak-hour car use through controls and pricing. Charging options include parking fees and taxes, fuel levies, area pricing,[72] and electronic road pricing.[73] Controls include dedicating road space to public transit, walking, and cycling; and limiting parking.

• *Restructure the public transportation system.* Ensure better integration of rail and bus services and the optimal deployment of transportation modes based on levels of demand and distance. The performance and sustainability of the public transit system should be enhanced through innovative public-private partnerships for commuter rail, well-planned bids for bus and minibus jitney operators, and active regulation and strict enforcement of permits and routes. Enforcement measures should include permit enforcement, contract monitoring, safety enforcement, and security enforcement. International experience has indicated that competitive bidding is an effective way of improving service levels while reducing both costs and subsidies.

A separate study completed in 1997 concluded that the only apparent way of promoting public transit is through huge investments to improve the service, while at the same time curbing the use of private vehicles.[74] Although the government lacks the funds for such investments now, several low-cost strategies exist to encourage public transit usage. Other strategies can potentially generate the revenues to fund such investments, but they tend to require strong political will. Strategies could include provision of differentiated transit services at differentiated fares, restrictions on parking, and additional taxes on vehicle owners and users. The combination of vehicle restraints and enhanced transit services could make public transit a plausible alternative to private cars. At the same time, subsidies can be targeted and paid directly to the very poor to ensure affordability. One effect of restrained car use, enhanced public transportation, and better land use management would be less energy use and fewer GHG emissions.

B. Improve Road Safety

Vehicle crashes are a serious concern in South Africa. In 1997, 505,988 traffic accidents resulted in 9,691 deaths. The economic costs associated with these accidents were estimated at R12.6 billion in 1997,[75] equivalent to 1.8 percent of GDP. Road accidents not only create great suffering and death, but also impede traffic flow and further burden limited police and health service resources. The high accident rate is due to alcohol and drug abuse, lack of respect for traffic laws (including speed limits, truck weight rules, and driver license requirements), aggressive driving, unsafe stopping of vehicles next to the highways, unsafe road conditions (during bad weather, construction or maintenance), and operation of old, poorly maintained vehicles. Policies that improve road safety — such as scrapping very old vehicles, requiring better vehicle maintenance, and enforcing speed limits — could significantly reduce energy use and GHG emissions.

C. Increase Tax Revenue

The government is in desperate need of revenue. Two large sources are vehicle and fuel taxes. In most countries, personal cars are seen as luxuries and stiff taxes on vehicles and fuels are widely accepted. Currently, the overall tax component (i.e., fuel tax, road accident fund levy, equalization fund levy, and customs and excise tax) of the price of gasoline and diesel fuel amounts to about 40 percent. In 1996, fuel and vehicle taxes amounted to R15.9 billion, 13 percent of South Africa's domestic tax revenue.[76] The fuel tax constitutes by far the largest revenue source, accounting for about 64 percent of the total tax revenues from the transportation sector. In addition, two dedicated fuel levies to compensate third-party victims in motor vehicle accidents and to smooth out fluctuations in the price of liquid fuels due to exchange rate fluctuations account for 8 percent and 9 percent of total transport revenues, respectively. Most of the rest is a value added tax on vehicle purchases.

Further increases in vehicle and fuel taxes would generate substantial additional revenue for the South African government for social expenditures and conceivably improvements to public transit. Such taxes also restrain the ownership and usage of personal vehicles, thereby reducing energy consumption and GHG emissions.

D. Reduce Traffic Congestion

Traffic congestion is not a major issue in South Africa, but is becoming noticeable in most metropolitan areas, especially in South Africa's seven major metropolitan centers. Congestion is rare during off-peak hours, however. Given limited budgetary resources and lack of severe congestion, further urban road construction is unnecessary. The most cost-effective strategies are those that spread travel over a longer period during the morning and afternoon commute times. That strategy will not affect energy use and greenhouse gases, but other more fundamental long-term strategies aimed at enhancing public transportation and restraining vehicle use will ease congestion, avoid expensive road construction, and reduce energy use and GHG emissions.

E. Respond to International Pressure

Because of its recent experience with international sanctions, South Africa is perhaps more sensitive to international pressure than most developing countries and more willing to engage with international institutions. South Africa ratified the United Nations Framework Convention on Climate Change (UNFCCC) in August 1997, and has participated actively in the negotiations of the Kyoto Protocol.

Given South Africa's dependence on coal and its high CO_2 emissions, South Africa is vulnerable to international criticism of its disproportionate contribution to climate change. But it also stands to benefit from international programs and funds aimed at helping countries reduce their GHG emissions. One option for reducing GHG emissions is the Clean Development Mechanism (CDM) of the Kyoto Protocol to the UNFCCC. The unusually high GHG emissions associated with the synthetic fuel industry in South Africa present a tremendous opportunity for the developed countries who are obligated to reduce their emissions under the Protocol. Through the CDM, a developed country could finance a project to reduce GHG emissions, for example, from the South African synthetic fuel industry. A portion of the obtained emissions reductions would be credited towards the developed country's Protocol targets. Or, South Africa could finance such reductions on its own and sell the credits in the international market.

IV. Scenarios for the Future

The list of South Africa's transportation-related challenges is long but interconnected. It includes past land use policies, increased urbanization, greater private motor vehicle usage, declining bus ridership in the face of increasing subsidies, low quality public transit services, deteriorating traffic safety, limited road investments, increasing congestion, and local air pollution.

Vastly different outcomes are possible depending on the path chosen. To generate likely scenarios of such outcomes, the authors reviewed recent studies, analyzed historical data, and interviewed many stakeholders in South Africa. Two visions of the future evolved that reflect assessments of economic growth, political commitment, technology adoption, and travel and vehicle purchase behaviors. While the two scenarios reflect higher and lower trajectories of GHG emissions, they were not explicitly premised on GHG goals or strategies.

Both scenarios are premised on a real local currency GDP growth of 2.8 percent per annum.[77] This is somewhat below the most optimistic scenario of the government's Growth, Employment and Redistribution (GEAR)[78] strategy but is intended as a middle-of-the-road economic framework. If economic growth were faster or slower, emissions would be higher or lower than the scenarios indicate. Also both scenarios make specific assumptions about population growth and the effectiveness of modern treatment in addressing South Africa's health crises, specifically the spread of HIV/AIDS. Again, if population growth were higher or lower, emissions would be higher or lower, respectively, than the scenarios indicate.

The high GHG scenario is an extrapolation of observable and emerging trends: increased reliance on old personal cars and minibus jitneys to satisfy mobility and accessibility needs; diffuse land use policies that aggravate transportation concerns; continued use of coal-based synthetic fuels for 40 percent of the transportation fuel needs; and an auto industry that continues to be treated as a pillar of economic development.

The lower GHG scenario is premised on strong political will to address the mobility and accessibility needs of the population. This scenario includes adequate public transportation services; taxes on

private vehicle owners, including company cars, and user fees to fund the public transportation system; reduced dependence on coal-based fuels; and containment of urban sprawl.

The key parameters for the two scenarios are presented in Tables 7 and 8.

Table 7

Key Parameters for Scenarios

	2000	2020	
	Baseline	Low	High
Passengers per Vehicle			
Passenger Car	1.2	1.3	1.2
Minibus	4.5	5	4.5
Minibus Jitney	15.5	18.6	15.5
Bus	44.9	54	44.9
Passenger Modal Split (percent passenger-kilometers)			
Gasoline Car (private)	48	46	57
Gasoline Minibus (private)	3	2	2
Gasoline Minibus Jitney	32	8	25
Diesel Minibus Jitney	0	21	0
Diesel Bus	12	10	8
Rail Transit	5	13	8
Total Motorized Passenger-Kilometers (billion)	211	325	400
Other Parameters			
Population (millions)	43	54	60

Note: The population growth estimate of 1.1% in the low GHG scenario assumes the continued spreading of HIV/AIDS and a failure to introduce modern treatment to carriers of the disease. A population growth of 1.7% is assumed in the high GHG scenario.

Table 8

Fuel Economy and Lifecycle Greenhouse Gas Emissions

	Fuel Economy	GHG Emissions (grams/vehicle-kilometer)		
	(liters/100km)	2000	2020 Low	2020 High
Gasoline Car (private)	10.9	615	529	542
Gasoline Minibus (private)	14.0	967	738	871
Gasoline Minibus Jitney	14.0	967	738	871
Diesel Minibus Jitney	12.5	N/A	747	N/A
Diesel Bus	41.9	1,514	1,572	2,013

Notes: (1) The average electric generating mix for South Africa used in calculating GHG emissions for rail transit is 91% coal, 1% hydroelectric, and 8% nuclear power. (2) Although the same fuel economy was assumed for the baseline and for the scenarios, the feedstock for the fuel and therefore the fuel carbon content differed, which resulted in different emission factors.

A. High Greenhouse Gas Emissions Scenario

The high GHG emissions scenario is premised on a continuing reluctance to reduce greenhouse gases from the transportation sector.

The government remains entangled in crisis management, where the priorities are health and education, social unrest, and skewed income distribution. Cities remain divided and land developers continue to give little consideration to the cost implications of long commuting distances. Without effective housing and land use planning, urban sprawl is exacerbated, further undermining the economic viability of public transportation services. The de facto apartheid city remains, with most people located far from work opportunities, necessitating lengthy commuting trips and large subsidies for public transportation.

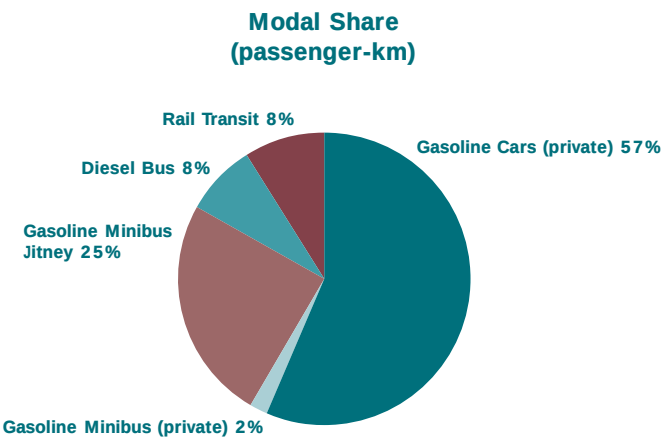
The automotive industry remains a pillar of economic development. The shift towards personal motor vehicle use accelerates as the black middle class expands, consumer credit becomes more widely available, and the quality of public transit continues to decline.

The car population grows at 4.1 percent per annum, similar to growth rates between 1980 and 1990.[79] The minibus jitney industry continues to accommodate the business aspirations of black entrepreneurs. The already over-saturated market and generally low levels of passenger comfort, however, slow the growth of minibus jitney acquisitions. The fleet grows at 2 percent per annum, only slightly above the population growth rate. Attempts to formalize the industry and to convert the gasoline minibus fleet to diesel fail due to conflict between government and the minibus jitney industry. Vehicles remain the unsuitable 16-seater variety and conversion to larger 18- and 35-seater custom-built public transit vehicles does not occur. Bus passenger-kilometers grow at 1.1 percent per annum, while increased rail ridership results in 5-percent annual growth in rail passenger-kilometers.

The net effect is that private vehicles increase their share of total passenger-kilometers traveled from 51 percent in 2000 to 59 percent in 2020, while public transit's share decreases from 49 percent to 41 percent. The minibus jitney loses

Figure 5

High Greenhouse Gas Scenario (2020)



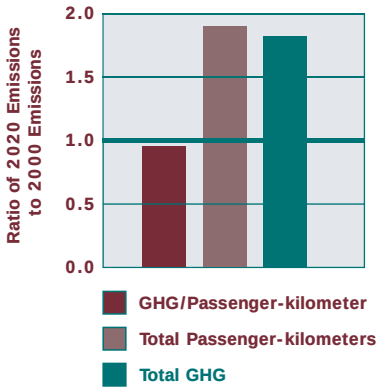
market share to the private car, but retains 61 percent of the public transit modal share. (See Figure 5).

Major cities in Gauteng province, such as Johannesburg and Pretoria, continue to expand. However, budget constraints restrict the construction of new road infrastructure, exacerbating congestion.

Although emissions per passenger-kilometer remain fairly constant in the high greenhouse gas scenario, total GHG emissions increase dramatically (by approximately 82 percent). This increase is largely due to a 90-percent increase in the amount of total passenger-kilometers traveled, mostly in private motor vehicles.

Figure 6

GHG Emissions from Passenger Transportation in South Africa (2020, High Scenario)



B. Low Greenhouse Gas Emissions Scenario

Under the lower greenhouse gas scenario, mobility, accessibility, cost, and safety concerns – rather than GHG emissions – would be the motivation for changing transportation and energy policies. However, by restraining the growth in vehicle-kilometers traveled, GHG emissions would be reduced. It could also result in a shift to less expensive petroleum fuels. The lower GHG scenario — in line with the *Moving South Africa* proposals and the *National White Paper on Transport Policy* — is premised on the government playing an active role in land use policies and passenger transportation.

In this scenario, land use and housing policies are adopted that promote more efficient urban land use patterns, correct the spatial imbalances between residential and employment locations, and reduce travel distances and times for commuting. Innovative local transportation and land use policies succeed in locating residential areas and commercial activities along transportation corridors.

The government encourages the use of public transportation over private car travel, aiming for a ratio of 80:20 (use of public transportation to private cars). The government adopts and implements denser patterns for urban settlements; reserves future public transportation rights of way; restores the image of public transportation by restructuring the taxi, bus, and commuter rail sectors; and manages the demand for private car travel.

Well-planned bids, regulations, and enforcement enhance system performance. Under the new structure, trains and existing rail infrastructure supply passenger demand on the densest routes, buses serve shorter and less dense routes, and minibus jitneys provide feeder and local services. Road-based public transit infrastructure, such as busways to facilitate express transit bus services, are provided in dense corridors where rail infrastructure does not exist. This results in more efficient deployment of public transit modes to meet passenger needs. The government's efforts to formalize the minibus jitney industry and restructure the transit sector result in the recapitalization of the minibus jitney industry, improved vehicle maintenance, and an improved level of service. Bus operators invest in newer and more advanced bus technologies.

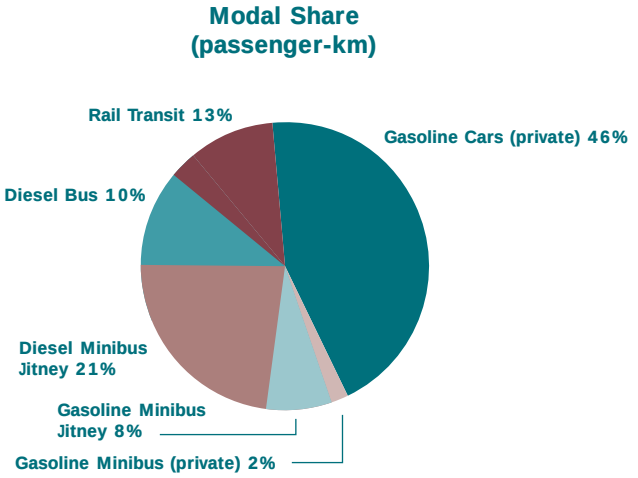
To sustain the public transit system, the government finds a stable and consistent funding source: user charges imposed on private car use. Drawing upon recommendations from *Moving South Africa,* some form of travel demand management is also imposed, either in the form of regulations (e.g., parking and access controls), or pricing and incentives (e.g., High Occupancy Vehicle lanes to promote car-pooling).

To support the government's transit policy, the role of the auto industry is refocused. Domestic auto manufacturers receive incentives to manufacture buses and minibuses for the local market. This use of "carrots" and "sticks" encourages a shift to public transportation.

The international community, increasingly concerned about the effects of GHG emissions, exerts pressure on export industries to comply with stricter international environmental standards. Sasol determines that it is economically advantageous to replace coal with imported natural gas as feedstock for its synthetic fuel production. By doing so, it avoids the high costs of impending capital investments in coal mining, while realizing GHG emissions benefits.

Figure 7

Low Greenhouse Gas Scenario (2020)



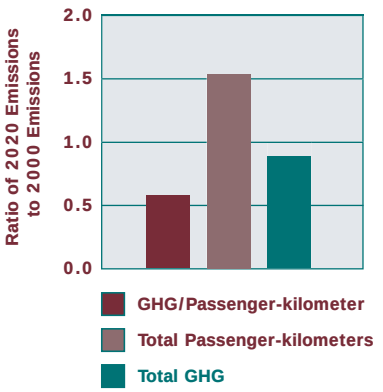
Even with restrictions on the use of private cars, private car ownership increases

by 2.1 percent per annum — similar to the growth in ownership between 1995 and 2000. The total seating capacity of the minibus jitney fleet remains constant into the future, but recapitalization of the minibus jitney industry results in a different composition of the vehicle fleet. Bus passenger-kilometers increase 1.5 percent per year, and rail passenger-kilometers increase 6.3 percent annually.

This scenario has highly positive outcomes for urban land management, resource use, quality of life, energy consumption, and GHG emissions. The modal share of private vehicles and public transit remains about constant at 48 and 52 percent, respectively. In the public transit sector, the minibus jitney share decreases from 65 percent in 2000 to 56 percent in 2020. Bus and rail transportation account for the remaining public share at 19 and 25 percent, respectively.

Figure 8

GHG Emissions from Passenger Transportation in South Africa (2020, Low Scenario)



The net result is a 12-percent decrease in GHG emissions between 2000 and 2020. Passenger-kilometers traveled increase about 54 percent, but use of public transportation increases and 20 percent of the coal used in synthetic transportation fuels production is replaced with natural gas.

The key difference between the high and low GHG scenarios are the shift toward fuels with lower carbon content and the increased use of less energy-intensive transportation modes. Given the large sunk investment in coal, coal mining, and fuel processing technology, a dramatic shift would be untenable, but a gradual shift to natural gas-based synthetic fuels (using advanced techniques developed for coal) and petroleum imports is economically tenable and environmentally desirable. Another difference is the shift in travel toward bus and rail.

V. Conclusion

South Africa faces difficult challenges in the coming years. Transportation and the environment are among those challenges, but are not high on the priority list. Past land use policies forced large numbers of poor people to commute long distances to jobs, creating a problem that remains today. This problem is exacerbated by land use practices that locate new low-cost housing on cheap land at the periphery of cities, far from urban centers. There is no indication of attempts to contain or even slow urban sprawl.

South Africa, in line with other developing countries, is also experiencing increased use of cars and trucks. It is widely anticipated that car usage will continue to increase over the next 20 years due to social aspirations, an expanding black middle class, reduced car prices, a belief that the auto industry is a major contributor to economic development, incentives to use cars, and not least, the lack of an attractive public transportation system. More cars mean more demand for expensive road infrastructure and energy use, and aggravated safety and GHG emissions concerns.

South Africa's public transportation system is neither well organized nor well managed. Fare recovery is poor on bus and rail, necessitating large government subsidies. At the same time, the oversaturated informal minibus jitney industry provides inefficient and unsafe service. The very survival of the public transport system is at stake if the national government does not begin to address these problems.

Nevertheless, many low-cost improvements are at hand. Initiatives aimed at urban sprawl, vehicle use, public transportation, and fuel production could provide huge economic, social, and environmental benefits. GHG reduction would be a side benefit of many of these initiatives.

South Africa is already a high emitter of greenhouse gases compared to other developing countries. The country has an opportunity to reverse this situation — or see it worsen. A higher GHG scenario, based on current trends, reflects a continued lack of concern with the transportation sector and associated GHG emissions. In this scenario, land use policies continue to aggravate transportation concerns. The automotive industry remains a pillar of economic development, and the shift towards personal car use

continues. Cars increase their share of total passenger-kilometers traveled from 48 percent in 2000 to 57 percent in 2020. Public transit's share decreases from 49 to 41 percent, while minibus jitneys retain 60 percent of the public transit modal share. The result is an 82-percent increase in GHG emissions from 2000 to 2020. In the lower GHG scenario, the government plays an active role in enhancing public transportation. New housing and urban development is encouraged to locate nearer city centers. Government restructures the minibus jitney, commuter rail, and urban bus services to be complementary. User taxes are imposed on cars and the revenue is used to support public transportation. Auto manufacturers are provided with incentives to manufacture buses and minibus jitneys for the local market. The effect is no increase in private vehicle use relative to public transportation. Minibus jitneys suffer large declines in public transit modal share, from 65 percent in 2000 to 56 percent in 2020. Bus and rail transportation account for the remaining public share at 19 and 25 percent, respectively. The net result is a 12-percent reduction in GHG emissions despite an almost 54-percent increase in passenger-kilometers traveled.

The lesson is that GHG emissions can be restrained without harming economic growth, even when GHG reduction is not the goal. The strategies considered in this paper to achieve the lower GHG scenario were identified or are in line with two Department of Transport publications, the *White Paper on National Transport Policy* and *Moving South Africa.* The following strategic actions would redirect behavior and investments to create a more economical and socially beneficial transportation system:

- *Promote more efficient urban land use structures through land use and housing policies.* Reverse current trends towards urban sprawl and dispersal by locating settlements and commercial activities along transportation corridors. This requires the use of aggressive development controls and incentives, such as lower land prices in such corridors.

- *Complement strategies to combat urban sprawl*. This can be done through investments in transportation infrastructure.

- *Manage peak-hour car use through controls and pricing to promote public transportation over private car travel*. Charging options include parking fees and taxes, fuel levies, area pricing, and electronic road pricing. Controls include dedicating road space to public transit and walking or cycling, and parking limits.

• *Restructure the public transportation system*. The objective should be to ensure integration of rail and bus and the optimal deployment of such modes of transportation based on level of demand and distance.

• *Use well-planned bids, active regulation, and strict enforcement of regulations to improve the performance of the public transit system*. Enforcement measures include permit enforcement, contract monitoring, safety enforcement, and security enforcement.

• *Use innovative public-private partnerships for commuter rail and competitive tendering for bus and taxi operators*. This would ensure the sustainability of public transit.

• *Provide stable funding for public transit*. Potential funding sources are higher allocations from national and provincial budgets, earmarked user charges imposed on private car users, and differential public transit charges.

Although the government lacks the funds to make significant investments in public transit, several of these strategies are low-cost means to encourage public transit usage, while others can potentially generate the revenues to fund such investments. In addition, changing technologies — such as switching from coal to natural gas as a feedstock in the production of synthetic fuel and incentives for domestic auto manufacturers to produce buses and minibuses — would reduce GHG emissions. These actions are not necessarily costly, but they require strong political will and commitment. If such will is demonstrated, South Africa will soon be on the way to repairing its public transit system, with benefits for society, the economy, and the environment.

Glossary

Busway: One or more lanes dedicated to the use of buses

Clean Development Mechanism (CDM): One of the market-based flexibility mechanisms of the Kyoto Protocol, CDM encourages investment in greenhouse gas reduction projects in developing countries by allowing industrialized countries to apply the resulting emission reductions toward their Kyoto Protocol targets.

Coloreds: Usually refers to South Africans of "mixed" race — usually a mix of black and white.

Homelands: Land reserved for blacks following the report of the Tomlinson Commission (1955). Ten homelands were created to which each black South African was assigned with the intention that the homelands would become independent states and form the basis for ethnic government in South Africa. All political rights, including voting, held by blacks were restricted to the individual's designated homeland. From 1976 to 1981, the South African parliament granted independence to four of these homelands. In 1994, the ten homelands were re-incorporated into South Africa.

Indians: Usually refers to South Africans whose ancestors came from the Indian subcontinent to work on railway construction projects and sugar plantations.

Kyoto Protocol: An agreement negotiated in Kyoto, Japan, in 1997 to strengthen commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The Protocol sets binding emission targets for industrialized countries averaging a 5.2 percent reduction from 1990 levels by 2008-2012, and establishes market-based mechanisms that allow parties to meet their targets in part by trading emission allowances or sponsoring emission reduction projects in developing countries. The Protocol will enter into force when ratified by 55 countries, including countries accounting for 55 percent of carbon dioxide emissions from industrialized countries in 1990.

Minibus: A van-type vehicle with a carrying capacity of nine people, including the driver, and luggage space. Minibuses are used by individuals for personal transportation needs, as hotel vehicles, and by schools.

Minibus jitney: A minibus used for public transit services, also called a combi taxi. The vehicles are modified by replacing luggage space with an extra row of seats. Carrying capacity is between nine and 16 people, including the driver. Services are provided with no prescribed timetable or fares on a specific route, network of routes or within a specific radius. The minibus jitney sector has organized itself into a large number of associations that decide who operates on which routes or areas. Enforcement of these agreements are carried out by the sector itself.

Modal split: The share of total passenger or freight travel on different kinds of transportation, usually measured as a percent or fraction.

Passenger-Kilometer: One passenger moving one kilometer.

Sasol: The large industrial company in South Africa that produces synthetic oil from coal.

Townships: Designated black residential areas on the outskirts of white employment and residential areas.

United Nations Framework Convention on Climate Change (UNFCCC): One of three international agreements negotiated at the 1992 UN Conference on Environment and Development, the UNFCCC set a long-term objective of stabilizing atmospheric concentrations of greenhouse gases at a level that would "prevent dangerous anthropogenic interference with the climate system." The Convention called for industrialized countries to voluntarily return their greenhouse gas emissions to 1990 levels by 2000.

Appendix

A. Brief overview of South Africa's history[80]

The first known European expeditions to parts of the area now known as South Africa were led by Portuguese explorers, who started in 1488 in their search for a route around the Cape of Good Hope to facilitate trading with the Far East. The colonial period and early part of South Africa's history were marked by conflicts among the colonial powers — Dutch, Portuguese, and British — as well as conflicts between the colonial powers and the native tribes in South Africa.

The Dutch established the first European settlement at Table Bay (now Cape Town) in 1652. As the Dutch pioneers (Boer Afrikaans farmers) spread eastward, increasing conflict culminated in a battle in 1779 between the native Xhosas and the Dutch near the Great Fish River. Britain formally received the Cape territory in 1814 under provisions made by the Congress of Vienna. Around this time, the dominant Zulu chief, Shaka, embarked on an aggressive military initiative to expand his territory and unite a large number of the Nguni tribes into the Zulu nation. He succeeded in evicting several African tribes (such as the Basotho, Ndebele, Ngoni, and the Kololo) from their land. This development caused large-scale migrations and ultimately resulted in the formation of several new kingdoms.

Because of the general resentment felt by the Dutch farmers (Afrikaner Boers) towards British rule, a large group, known as the Voortrekkers, began a mass migration into the northern interior in 1835-1836. This resulted in a number of clashes between the native tribes and the Voortrekkers before two independent Boer Republics in 1838. At the same time conflict arose between the British and the Zulus in Natal, largely due to British imperialism in Africa. Several violent clashes took place between the Zulus and the British. In 1879 the Zulu kingdom was finally defeated at Ulundi.

In 1867 and 1886, South Africa's history changed dramatically with the discovery of diamonds and then gold in the two independent Boer Republics of the Orange Free State and the Transvaal. Conflict over these riches eventually culminated in the Anglo Boer War between 1899 and 1902. The Union of

South Africa was formally established on May 31, 1910, and South Africa was proclaimed a self-governing dominion within the British Empire.

As a full member of the British Empire, the Union of South Africa played a vital role in upholding the interests of the Crown. South African volunteers (white and black) participated in World War I, in campaigns in German West Africa (now Namibia), East Africa (now Kenya) and Europe. The Great Depression of the 1930s, however, created considerable poverty and large numbers of disaffected people. Many black Africans and white Afrikaner Boers were forced into the cities to compete for unskilled jobs. As a result, both African and Afrikaner nationalism emerged.

At the same time, the government of James Barry Hertzog (1924-39) adopted a segregationist policy to preserve South Africa as a white country in which black Africans would be restricted largely to homelands. A rigid system of territorial, social, and political segregation was introduced. In 1948, the National Party came to power and apartheid was legalized. The National Party began to institute apartheid laws, which included establishing homelands for all non-whites and instituting strict laws that governed all non-white movement in and out of white territory.

During subsequent years, black opposition to white rule hardened and support for groups such as the African National Congress (ANC) (dating back to 1912), and the South African Communist Party (SACP) grew. The enforcement of apartheid was met with increasing black resistance and hostility. During the 1960s, the ANC formed an armed wing known as Umkhonto we Sizwe. Many freedom fighters, including Nelson Mandela, then leader of the ANC, were arrested. By the 1970s, worker opposition, international sanctions, and the growing economic interdependence of blacks and whites brought the apartheid system into question.

From 1990 onwards, more liberal elements within the National Party emerged, which eventually led to the reinstatement of the ANC and the SACP. Nelson Mandela was released from prison and negotiations over a new political order for the country ensued. Finally in April 1994, all South Africans went to the polls for the first time. The ANC won the election by a wide margin and on May 10, 1994, Nelson Mandela became the country's first black president.

B. Research Approach

This report was a collaboration between researchers at the University of California, Davis, Cambridge Systematics in Oakland, California and the Division of Roads and Transport Technology of the Council for Scientific and Industrial Research (CSIR) in South Africa. The report is based on an extensive review of the literature, a series of interviews in 1999 with experts and leaders in South Africa, further review of reports and other materials identified during interviews, and data analysis conducted by Ms. Prozzi and Dr. Delucchi. The final set of parameters for the GHG emissions scenarios was specified after extensive consultation among the authors and with others. Numeric measures were converted by Dr. Delucchi into quantitative GHG emissions estimates for the two scenarios.

C. Interviewees

Mr. E. Schnackenberg, CSIR, Transportek
Dr. G.L. Dehlen, Consultant
Professor J. Walters, Rand Afrikaans University
Mr. V. Baloyi, Pretoria Metro, Metropolitan Public Passenger Transport Division
Mr. B. Cameron, Transportation Research & Consultancy Africa
Mr. R. Scholz and Ms. P. Kruger, Automobile Association of South Africa (AA)
Ms. P. Drodskie, South African Chamber of Business (SACOB)
Mr. D. Sekgobela, South African Commuters Organization
Ms. E. du Toit, Department of Minerals & Energy, Restructuring and Policy
Mr. N. Vermeulen, National Association of Automobile Manufacturers of South Africa (NAAMSA)
Mr. B. Stanway, Stanway Edwards Ngomane and Associates (SENA)
Ms. E. Koch and Mr. H. Benkenstein, Department of Environment Affairs & Tourism (DEAT)
Mr. A. Shaw, Department of Transport (DOT)
Ms. A Sugrue, Midrand City Council
Dr. P.N.W. Freeman, CSIR, Transportek
Dr. T. Surridge and Mr. H. Baak, Department of Minerals and Energy (DME)
Mr. C. Pereides, Road Freight Association
Ms. M. Costanza, International Institute of Energy Conservation
Mr. T. Burger, Department of Minerals & Energy, Liquid Fuels

D. Overview of the Lifecycle Energy Use and Emissions Model (LEM)

There are many ways to produce and use energy, and many sources of emissions in an energy-production-and-use pathway. Several kinds of greenhouse gases are also emitted at each source. An evaluation of GHG emissions associated with transportation activities must be broad, detailed, and systematic. It must encompass the full "lifecycle" emissions of a particular technology or policy, and include all of the relevant pollutants and their effects. To this end, Dr. Mark Delucchi of the Institute of Transportation Studies at the University of California, Davis has developed a detailed, comprehensive model of lifecycle emissions of urban air pollutants and greenhouse gases from various transportation modes. Many governments and companies use this model. Dr. Delucchi updated and adapted the model for this report.

The Lifecycle Energy Use and Emissions Model (LEM) considers motorized two-wheelers, cars, buses, and trucks operating on a range of fuel types and propulsion technologies; heavy-rail and light-rail transit; ships; and freight railroads. The LEM estimates energy use, GHG emissions, and urban air pollutants for the transportation modes listed above. The model includes lifecycles for fuels and electricity (end use, fuel dispensing, fuel distribution, fuel production, feedstock transportation, and feedstock production), vehicles (materials production, vehicle assembly, operation and maintenance, and indirect support infrastructure), and infrastructure (materials for infrastructure, and construction of infrastructure). GHG results in this report include only emissions associated with fuels and electricity since accurate data are unavailable in South Africa for materials, manufacturing, and construction.

The LEM characterizes GHG emissions and criteria pollutants from several sources: fuel combustion, evaporation and leakage of liquid fuels, venting or flaring of gas mixtures, chemical transformations, and changes in the carbon content of solid or biomass. The model estimates emissions of CO_2, methane, nitrous oxide, carbon monoxide, oxides of nitrogen, nonmethane organic compounds, sulfur dioxide, particulate matter, CFC-12, and HFC-134a. The LEM estimates emissions of each pollutant individually, and also converts the GHG emissions into CO_2-equivalent GHG emissions. To calculate total CO_2-equivalent emissions, the model uses CO_2-equivalency factors (CEFs) that convert mass emissions of all non-CO_2 gases into an equivalent mass amount of CO_2. Delucchi derived these CEFs using various sources and methods, including but not limited to research by others on Global Warming Potentials (GWPs) and Economic Damage Indices (EDIs). GWPs relate different gases to CO_2 in terms of their relative effects on

global warming. EDIs relate the gases to CO_2 in terms of their relative warming-induced economic damages. As a sensitivity analysis, the LEM model was also run accounting only for those gases for which the Intergovernmental Panel on Climate Change (IPCC) has published global warming potentials relative to CO_2, and using those GWPs instead of the CEFs. This made about a 1 to 10-percent difference in the GHG emission estimates and did not affect the relative difference between the scenarios.

Travel

Data specific to South Africa used for this report come from multiple sources. Primary among these are Schutte and Pienaar (1996), who reported fuel consumption, estimated annual vehicle-kilometers traveled, and vehicle operating costs by mode; and *Moving South Africa* (1998), which reported on urban passenger mode share and vehicle-kilometers traveled by mode. Ms. Prozzi and Dr. Clifford Naudé of CSIR also collected unpublished data from various researchers and stakeholders in South Africa. Delucchi and the other co-authors of this report used their professional judgement, other data (e.g., South Africa's Department of Transport, 1997), and unpublished information solicited from South African experts to make small adjustments in these data.

In the LEM, fuel-cycle emissions from minibuses are calculated by scaling emissions according to the fuel economy of minibuses relative to that of full-size buses.

Synthetic fuels

South Africa is the world's largest producer of coal-based synthetic liquid fuels. South Africa's coal-to-liquid plants consume almost 20 percent of the country's coal output, and produce more than 25 percent of the total liquid fuel output (EIA, *International Energy Outlook 1999,* 1999).

The South Africa Department of Minerals and Energy (2001) reports energy balances for the liquefaction energy sector as 624.7 exajoules (EJ) of coal and 71.8 EJ of natural gas producing 309.3 EJ of synthetic crude oil. This gives an output to input energy ratio of 44.4 percent. Dr. Delucchi assumes a slightly higher value of 46 percent.

This low production efficiency results in very high CO_2-equivalent emissions from the fuel-production stage; in fact, the production of a synthetic fuel from coal produces roughly as much CO_2 equivalent as does the end use of the synthetic fuel itself. This can be compared with the production of

the same sort of fuel from crude oil via conventional oil refining, which is approximately 85-95 percent efficient and results in production-stage emissions on the order of 5-20 percent of those from end use.

Regarding diesel-like fuels made from natural gas (by the Fischer-Tropsch process), the EIA's *International Energy Outlook 1999* reports that Chevron and Sasol are working to develop a gas-to-liquids facility that would convert natural gas to middle distillates such as diesel fuel and jet fuel. According to the EIA, Chevron and Sasol estimate that it will take 238 standard cubic feet (SCF) to produce a gallon of middle distillates. A detailed analysis by Argonne National Laboratory (ANL) (Stork, 1997) results in an estimate of 224 SCF per gallon of diesel fuel. Delucchi uses the ANL estimates.

According to the EIA's (2000) *South Africa Country Analysis Brief,* in early 2000 Sasol launched a feasibility study of replacing coal with natural gas because of high costs of complying with environmental regulations applicable to coal, and high impending capital investments in coal mining. Sasol estimates that the switch to natural gas could be completed within three years. Construction on the pipeline that will supply the natural gas is expected to begin in June 2001 (EIA, South Africa, 2000).

Electricity

The South African electric utility, Eskom, provided fuel-use shares for electricity generation in 2000. The Institute for Energy Studies at the Rand Afrikaans University in Johannesburg provided an input-output table on primary energy supply and final consumption. Additionally, the EIA's International Energy Annual 1999 (1999) and International Energy Annual 2001 (2001) reported on the current and projected electricity generation for South Africa.

Based on these data sources and projections, Dr. Delucchi assumed that the South African generation mix is 91 percent coal, 8 percent nuclear, and 1 percent hydro. He also assumed that the United States provides 10 percent of the enrichment work for the uranium fuel used by South African nuclear power plants, and that France, other European countries, and Russia provide 30 percent each.

The EIA's "Country Energy Data Report" (available at www.eia.doe.gov/emeu/world/country/cntry_SF.html) reports that electricity losses are 7 percent of generation. Dr. Delucchi therefore assumed a distribution efficiency of 93 percent.

In terms of generation efficiency, the Department of Minerals and Energy (DME) (2001) energy

balances show that 1,752,999 terajoules (TJ)[81] of coal were used to produce 179,551 gWh of electricity. This gives an efficiency of almost 37 percent, which seems rather high. However, in the LEM, electric generating efficiency is defined as the ratio of net electricity output (net of electricity used within the power plant) to the higher heating values of fuel input.[82] Also, the DME data page does not state whether the TJ of coal input is in higher or lower heating value, or whether the electricity output is gross or net. If the DME data are lower heating value fuel input and gross electricity output, then the efficiency on a higher heating value/net-electricity basis would be about 33 percent. Dr. Delucchi assumed 34 percent efficiency in 1995, and increases in efficiency of 0.2 percent per year subsequently.

Considering the statements of Spalding-Fletcher et al., (2000) and the EIA document, "South Africa: Environmental Issues" (2000) Dr. Delucchi assumed that coal in South Africa has 25 percent more sulfur than coal in the United States. He also assumed that South African coal-fired plants have 10 percent higher NO_X emissions, 100 percent higher SO_X emissions, and 50 percent higher particulate matter emissions than plants in the United States. Dr. Delucchi used U.S. values to determine the heat content of coal in South Africa, which the EIA reports is virtually the same as that of the United States.

Oil and Gas

Data on oil and gas were obtained from the Department of Minerals and Energy's Digest of South African Energy Statistics (1998) and from Sasol.

The EIA's International Energy Annual 1999 (2001) reports that in 1998, South Africa produced 18,000 barrels per day (b/d) of crude oil, 11,000 b/d of natural gas plant liquids, zero refinery processing gain, and 170,000 b/d of synthetic oil made from coal (classified as "other liquids" by the EIA).

The EIA also reports that in 1998, South Africa imported 321,000 b/d of crude oil, and exported (net) 48,000 b/d of all petroleum products. However, South Africa imported 6 percent of its total consumption of motor-vehicle gasoline. According to the EIA's (2000) *Country Analysis Brief, South Africa,* the country imports crude oil primarily from Saudi Arabia and Iran, but is trying to reduce its dependence on oil from Iran.

The South African Petroleum Association (2000) provides data on sources of crude oil by country

of origin (excluding South African production of synthetic oil). Although South Africa did import less oil from Iran in 2000 than it did in 1995, South Africa imported more in 2000 than it did in 1999. Considering this, and noting the continued but gradual reintegration of Iran with the international community, Dr. Delucchi assumed that South Africa would import crude oil in the future from sources similar to those it used in 2000. In 2000, South Africa produced 4 percent of its crude oil, and imported 35 percent from Iran, 40 percent from Saudi Arabia, 10 percent from other Middle Eastern countries, 4 percent from Nigeria, and 7 percent from other sources.

The DME (2001) reports that South African oil refineries consume 0.05 kilojoules (KJ)[83] of electricity and a tiny amount of natural gas for every kJ of petroleum product produced. The rest of the process energy presumably is provided by refinery gas, which is produced from crude oil feedstock. Surprisingly, according to the DME energy balance, South African refineries do not use coal. The use of process energy derived from crude oil can produce significant amounts of sulfur pollution. As a result, at least one refinery (Engen) has begun to use more gas to process fuel.

The LEM specifies refinery energy use by major refining country or region of the world. South Africa is not a separate category, but is included in the category "target country (LDC)" refining region. For this category, Dr. Delucchi assumed that the fuel mix used by petroleum refineries is 60 percent refinery gas, 10 percent residual fuel oil, 10 percent petroleum coke, 10 percent coal, 5 percent natural gas, and 5 percent electricity. These assumptions are reasonably consistent with the DME energy balance data for South African refineries.

The EIA's *International Energy Outlook 1999* (1999) reports that Chevron and Sasol are working to develop a gas-to-liquids facility that would convert natural gas to middle distillates such as diesel fuel and jet fuel. According to the EIA, Chevron and Sasol estimate that it will take 238 standard cubic feet (SCF) to produce one gallon of middle distillates. A detailed analysis by Argonne National Laboratory (ANL) (Stork, 1997) results in an estimate of 224 SCF per gallon of diesel fuel. Dr. Delucchi used the ANL estimates.

The DME (2001) reports the following energy balances for the liquefaction energy sector: 624.7 exajoules (EJ)[84] of coal and 71.8 EJ of natural gas produced 309.3 EJ of synthetic crude oil. This gives an output/input energy ratio of 44.4 percent, but Dr. Delucchi assumed a slightly higher value of 46 percent.

Data References for LEM

South Africa Department of Minerals and Energy. 1998. RSA 1997. Prepared by the Institute for Energy Studies. July 30. www.dme.gov.az/publications/energy_projects/spreadsheet97.htm, viewed June 2001.

South Africa Department of Environmental Affairs and Tourism. 1999. Greenhouse Gas Emissions Inventory. Pretoria.

U.S. Department of Energy. Energy Information Administration. 2001. *International Energy Annual 1999.* Washington, D.C. February. DOE/EIA-0219(99). See also EIA. Country Energy Data Report. www.eia.doe.gov/emeu/world/country/cntry_SF.html.

U.S. Department of Energy. Energy Information Administration. 1999. *International Energy Outlook 1999.* Washington, D.C. March. DOE/EIA-0484(99).

U.S. Department of Energy. Energy Information Administration. 2000. *South Africa: Environmental Issues.* Washington, D.C. January. www.eia.doe.gov/emeu/cabs/safrenv.html.

U.S. Department of Energy. Energy Information Administration. 2000. *South Africa: Country Analysis Brief.* Washington, D.C. December. www.eia.doe.gov/emeu/cabs/safrica.html.

U.S. Department of Energy. Energy Information Administration. 2001. *International Energy Outlook 2001.* Washington, D.C. March. DOE/EIA-0484.

Eskom webpage. See www.eskom.co.za/main.

National Association of Automobile Manufacturers of South Africa (NAAMSA). 2001. *Industry Vehicle Sales, Export and Import Data: 1995-2001.* www.naamsa.co.za/naamsa/matters/matters_2000_05_19.htm.

South African Petroleum Industry Association (SAPIA). 2000. *SAPIA Facts and Figures.* February. www.mbendi.co.za/sapia/arep99a4.htm.

R. Spalding-Fletcher, A. Williams, and C. van Haven. 2000. "Energy and Environment in South Africa: Charting a Course to Sustainability." *Energy for Sustainable Development* IV (4): 8-17. December.

K. Stork, Center for Transportation Research, Argonne National Laboratory, Argonne, Illinois. Fax transmittal communication May 5, 1997. Data analyzed is in Choi et al. (1997).

References for LEM Documentation

The 1997 version of the model is documented in several reports, shown below. Complete, up-to-date working documentation is available from the author. (Please note that Dr. Delucchi changed the spelling of his name from DeLuchi in the mid-1990s.)

DeLuchi, M.A. 1991. *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity 1.* Center for Transportation Research, Argonne National Laboratory, Argonne, IL. ANL/ESD/TM-22. November.

DeLuchi, M.A. 1993. *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity 2.* Appendices A-S. Center for Transportation Research, Argonne National Laboratory, Argonne, IL. ANL/ESD/TM-22. November.

Delucchi, M.A. 1996. *Emissions of Criteria Pollutants, Toxic Air Pollutants, and Greenhouse Gases, from the Use of Alternative Transportation Modes and Fuels.* Institute of Transportation Studies, University of California, Davis. UCD-ITS-RR-96-12. January.

Delucchi, M.A., and T.E. Lipman. 1997. *Emissions of Non-CO_2 Greenhouse Gases from the Production and Use of Transportation Fuels and Electricity.* Institute of Transportation Studies, University of California, Davis. UCD-ITS-RR-97-5. February.

Delucchi, M.A. 1997. *A Revised Model of Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity.* Institute of Transportation Studies, University of California, Davis. UCD-ITS-RR-97-22. November.

Endnotes

1. Of this figure, 33.9 million are South Africans of African descent, 3.8 million are Coloreds, 1.1 million are Indian or of Asian descent, and 4.5 million are White South Africans. Statistics South Africa. 2001. *Bulletin of Statistics* 35(1). March.

2. Annual percentage growth rate of GDP at market prices are based on constant local currency. World Bank. 2001. *World Development Indicators Database.* www.worldbank.org.

3. The exchange rate in South African Rands (R) per U.S. dollar from 1995 to 2000 increased from 3.63 to 6.94.

4. Naudé, C., R. Mirrilees, G. Dehlen, J. Pretorius, M. Mangera, C. Moleno, A. Meyer, D. Sperling, L. S. Redmond, 2000. *Global Climate Change: Developing Countries and Transport Sector Options in South Africa.* Institute of Transportation Studies. University of California, Davis. UCD-ITS-RR-00-12.

5. South African Reserve Bank. 2000. *Quarterly Bulletin Time Series.*

6. Usually refers to South Africans of "mixed" race — usually a mix of black and white.

7. The term "Indians" usually refers to South Africans whose ancestors came from the Indian subcontinent to work on railway construction projects and sugar plantations.

8. *Poverty and Inequality in South Africa.* 1998. Report prepared for the Office of the Executive Deputy President and the Inter-Ministerial Committee for Poverty and Inequality. Summary Report. May 13.

9. Statistics South Africa, 2001.

10. Lawrie Schlemmer (independent consultant to the South African Institute for Race Relations). 1996. *CDE Debates No. 4: Unemployment — The Numbers and Implications for South Africa.* September 30.

11. Presentation by William Stacey Rhodes (USAID South Africa Director) entitled *"Furthering the Southern Africa Housing Renaissance"* at the Institute of Housing Conference in Durban, South Africa, on October 13, 2000.

12. In terms of the World Bank's definition of literacy, South Africa has a very high literacy rate. Approximately 85 percent of its population older than 15 years of age is able to understand, read, and write a short simple statement about their everyday life. World Bank. 2001. *World Development Indicators Database.* www.worldbank.org. Most South Africans, however, lack mathematical, numerical, science, business, and computer skills.

13. Medical Research Council of South Africa. 2001. *The Impact of HIV/AIDS on Adult Mortality in South Africa: Technical Report.* Burden of Disease Research Unit. Tygerberg.

14. Apartheid was more than the separation of people in a residential context — it was a complete transformation of the urban community. The Group Areas Act became the cornerstone of separate education, health and other social services and amenities, as well as local administration and financing.

15. Townships are previously designated black residential areas on the outskirts of white employment and residential areas.

16. Homelands – Land reserved for blacks following the report of the Tomlinson Commission (1955). Ten homelands were created to which each black South African was assigned with the intention that the homelands would

become independent states and form the basis for ethnic government in South Africa. All political rights, including voting, held by blacks were restricted to the individual's designated homeland. From 1976 to 1981, the South African parliament granted independence to four of these homelands. In 1994, the 10 homelands were re-incorporated into South Africa.

17. Most of the residents of these homelands were young children, the elderly, women, and unemployed men.

18. Since blacks in most of the homelands had little or no means of finding employment in these areas, the government attempted to create employment there by facilitating the establishment of border industries. These industries were to form the base for large-scale development, and to help the people in the homelands increase their earning potential. Subsidies were to provide incentives for such industrial development. The policy was not effective, however, and urban development within the homelands retained dormitory characteristics – people only resided there but worked elsewhere. See Voges, E.M. 1983. *Accessibility, Transport and the Spatial Structure of South African Cities: An Historic Perspective.* NITRR Technical Report RT/9/83. Pretoria.

19. Smith, D.M. 1985. *Update: Apartheid in South Africa.* London: Cambridge University Press.

20. The National Department of Transport concluded the *Moving South Africa* project in August 1998. The project resulted in the National Transport Policy White Paper and the development of a long-term strategy for transportation to the year 2020. The *Moving South Africa* Action Agenda is the final summary of that process and its outcomes. South Africa Department of Transport. 1999. *Moving South Africa: Action Agenda.* Pretoria.

21. For a brief history of Sasol, see D. Sperling. 1988. *New Transportation Fuels.* University of California Press: 98-100.

22. Sasol had an annual turnover of almost R26 billion during the 2000 fiscal year. In addition, Sasol claims that the group's multibillion-Rand operations and growing exports save the South African economy more than R18 billion annually. Sasol. 2000. *Annual Report.* www.sasol.com

23. According to 2000 estimates released by Phumzile Mlambo-Ngcuka, Minister of Mineral and Energy Affairs, South Africa consumes approximately 471,000 barrels of oil per day, of which about 184,000 barrels per day is synthetic. U.S. Department of Energy. Energy Information Administration. 2000. Washington, D.C. www.eia.doe.gov/emeu/cabs/safrica.html.

24. Sasol. 2000. *Annual Report.* www.sasol.com.

25. Based on analysis conducted for this study by Dr. M.A. Delucchi. The efficiency of converting coal to crude oil is only 50 percent. This crude oil then has to be converted to gasoline and diesel fuel. Compared with the natural crude-to-products-cycle, there is an additional step at only 50 percent efficiency. This results in roughly a doubling of emissions.

26. Pretorius, J., M. Shahia, A. Smuts, R.I. Mirrilees, and G.L. Dehlen. 1994. *Competitiveness of South African Industries as Affected by Transport Costs.* Division of Roads and Transport Technology. Pretoria.

27. The Gross Domestic Product is the value of all goods and services produced in the country.

28. National Association of Automobile Manufacturers of South Africa (NAAMSA). 2001. *Industry Vehicle Sales, Export and Import Data: 1995 – 2001.* www.naamsa.co.za.

29. NAAMSA. 1999. *Economic Review of Business Conditions in the New Motor Vehicle Manufacturing Industry during 1998 and Prospects for 1999.*

30. South Africa participates in the World Trade Organization (WTO) and WTO multilateral trade agreements.

31. Company cars are defined as company-owned or government-owned cars that are also available for personal use.

32. When an individual receives a travel or car allowance, the South African Income Tax Law requires the individual to pay tax on the portion of the allowance that was not used for business travel. Individuals receiving car allowances have to keep accurate data of the distances traveled for business purposes. The first 8,000 kilometers are, however, exempted from tax, whether traveled for business or personal purposes. If an individual claims business travel of more than 8,000 kilometers, the tax-deductible expenditure is calculated by applying a rate per kilometer prescribed by the Minister of Finance for the category of vehicle used to the distance traveled during the year for business purposes. The individual has to pay tax on the difference between the allowance and the calculated tax-deductible expenditure.

33. *Minibus jitney* — A minibus used for public transit services, also called a minibus or combi taxi. The vehicles are modified by replacing luggage space with an extra row of seats. Carrying capacity is between nine and 16 people, including the driver. Services are provided with no prescribed timetable or fares on a specific route, network of routes or within a specific radius. The minibus jitney sector has organized itself into a large number of associations that decide who operates on which routes. Enforcement of these agreements is carried out by the sector itself.

34. The Republic of South Africa is divided into nine administrative divisions, called provinces.

35. *South African Year Book. 1999.* www.usaembassy.southafrica.net.

36. South Africa Department of Transport. 1998. *Moving South Africa: A Transport Strategy for 2020.* Pretoria.

37. Statistics South Africa, *Statistics in Brief, 2000*. Available at *www.statssa.gov.za/stats_in_brief_2000/transport.htm*

38. South Africa Department of Transport. Chief Directorate Land Transport. 1998. *Annual Report 1997-1998.*

39. Based on information contained in Naudé et al. 2000. *Global Climate Change: Developing Countries and Transport Sector Options in South Africa.* Institute of Transportation Studies. University of California, Davis. UCD-ITS-RR-00-12. Southern African Bus Operators Association, Personal Communication, 2001.

40. About R1.14 for an average trip of 22 kilometers (equivalent to 20 U.S. cents at 1999 exchange rates).

41. de Saint-Laurent, B. 1998. *Overview of Urban Transport in South Africa.* Paper presented at the 8th CODATU (Cooperation for the Continuing Development of Urban and Suburban Transportation) Conference, Cape Town. September.

42. South Africa Department of Transport, 1998.

43. Provincial bus services are subsidized by these authorities.

44. de Saint-Laurent, 1998.

45. Ibid.

46. Department of Transport. 1993. *Transport Statistics.* Pretoria; and *Moving South Africa: Action Agenda,* 1999.

47. During 1996/97, 69 contracts were entered into with previously subsidized operators. South Africa Department of Transport: Chief Directorate Land Transport. 1998. *Annual Report 1997-1998.*

48. Minister of Transport Dullah Omar. 2001. *The Last Window of Opportunity for Illegal Taxis To Be Legal.* Media Release. March 14.

49. Department of Transport. 1993. *Transport Statistics. Pretoria;* and *Moving South Africa: Action Agenda,* 1999.

50. Even though minibus jitney vehicles account for only 8 percent of the total road vehicles involved in traffic collisions in South Africa, the share of fatalities and serious injuries resulting from minibus collisions are believed to be disproportionately higher because of the severity of the accidents and the number of passengers involved. However, no data are collected to substantiate this general belief.

51. The present minibus jitneys are gasoline-powered and the proposed new 18- and 35-seater vehicles will be diesel-powered. This is to help South Africa's oil refineries balance their petrol/diesel production ratio.

52. These estimates are higher than the *Moving South Africa* estimates of 8.7 million for South Africa's total motor vehicle population fleet in 2020.

53. Mirrilees, R.I., J. Pretorius, H.A. Mare, C.M. Naudé and M. de Haan, 1996. *South Africa's Expanding Motor Vehicle Usage: Its Implications for the Environment and Possible Options for Restraining It*. Department of Transport Contract Report (CR-96/022). Pretoria.

54. Department of Transport, *Transport Statistics, 1993; Moving South Africa: Action Agenda, 1999.*

55. Statistics South Africa, *Statistics in Brief, 2000*. Available at *www.statssa.gov.za/stats_in_brief_2000/transport.htm*

56. Bose, R. et al. 2001. *Transportation in Developing Countries: Greenhouse Gas Scenarios for Delhi, India*. Pew Center on Global Climate Change.

57. Statistics South Africa, *Statistics in Brief, 2000*. Available at *www.statssa.gov.za/stats_in_brief_2000/transport.htm*

58. Estimated by Afribike, a non-profit organization in South Africa. White, P.S. *A Brief History of Cycling in South Africa.* Institute for Transportation and Development Policy. www.re-cycle.org/Afribike/SA_Rides_Again/sa_rides_again.html.

59. The rail company did have two success stories: the Mpumalanga-Richards Bay export coal line and the Sishen-Saldanha ore export rail line. Both are considered world-class operations. Bulk freight operations, which trucks do not easily serve, are generally profitable, but general freight services are not.

60. Phumzile Mlambo-Ngcuka, 2000.

61. Rand Afrikaans University. Institute for Energy Studies. 1998.

62. South Africa invested heavily in fuel infrastructure to ensure adequate supplies during the sanctions era (1977 to pre-1994). In 1995, coal production totaled about 212 million tons, of which 152 million tons (about 72 percent) were used domestically. About 57 percent of the domestic coal consumption was used to generate electricity and 30 percent for liquid fuels production. By 1998, South Africa's coal production was estimated at 247 million tons, of which 177 million tons (about 72 percent) were used domestically. Domestic electricity generation and the synthetic fuel industry combined consumed a similar fraction in 1995 — about 85 percent of domestic coal production. It can thus be assumed that the shares of domestic coal consumption used for electricity generation and liquid fuel production remained similar to the shares in 1995 — approximately 55 percent to generate electricity and 30 percent to produce liquid fuels. The remainder of South Africa's domestic coal production is consumed by its large industries, especially steel, while South Africa's poorer households use a small percentage for heating and cooking purposes. Based on 1998 estimates released by Phumzile Mlambo-Ngcuka, Minister of Mineral and Energy Affairs. U.S. Department of Energy. Energy Information Administration. Washington, D.C. www.eia.doe.gov/emeu/cabs/safrica.html.

63. U.S. Department of Energy. Energy Information Administration. 2000. *South Africa: Country Analysis Brief.* Washington, D.C.

64. Therefore, private cars in South Africa travel 20,000 kilometers per year on average, which is substantially higher than the 10,000 miles (or 16,000 kilometers) per year often quoted for private vehicles in the United States.

65. Sasol. 2000. *Annual Report.* Available at *www.sasol.com*.

66. Private corporations and state-owned enterprises, such as Eskom, collect substantial data on sulphur dioxide, ozone, and nitric oxide levels nationally. It is usually impossible to gain access to this data, partly because there is not a

culture of sharing data in the interest of public information. Department of Environmental Affairs and Tourism. 1998. *Results from Testing of Commission for Sustainable Development Indicators of Sustainable Development in South Africa.* Pretoria.

67. Ibid.

68. National Committee on Climate Change. 1998. *Discussion Document on Climate Change.* Available from the UN Framework Convention on Climate Change Secretariat, Department of Environmental Affairs and Tourism, Private Bag X097, Pretoria, 0001.

69. International Energy Agency, 2000. *CO_2 Emissions from Fuel Combustion: 1971-1998.*

70. Department of Environmental Affairs and Tourism. 1999. *Greenhouse Gas Emissions Inventory.* Pretoria.

71. South Africa Department of Transport. 1998. *Moving South Africa: A Transport Strategy for 2020.* Pretoria.

72. Fee imposed on car users for entering or driving in a specific area, usually a congested city center.

73. Fee imposed on the users of a congested road. The user is billed electronically when the car crosses a specific point.

74. Mirrilees, R.I., J. Pretorius, E. Snackenberg, and A.H. Shaw. 1997. *Preparation for the Possible Introduction of Travel Demand Management (TDM) Measures in South Africa.* CSIR Division of Roads and Transport Technology. Pretoria.

75. This estimate accounted for both the direct and indirect costs associated with traffic accidents. Direct costs include hospitalization and treatment of the injured, property damage costs, and lost income through deaths and disabilities. Indirect costs are primarily incurred when major accidents result in delays and reduced productivity. Pretorius, J., C. Naudé, P. Lombard, G. Maasdorp, and A. Taylor. 2000. *A Quantitative Analysis of the Full Costs Associated with Motor Vehicle Use in South Africa.* Funded by the U.S. Agency for International Development under the SEGA Program (Support for Economic Growth Analysis) for South Africa.

76. South African Reserve Bank's projected estimates. Department of Minerals and Energy. 1999. *SARB Quarterly Bulletin.* Pretoria.

77. The country economist for South Africa at the World Bank, Jeffrey D. Lewis, views this growth assumption as reasonable.

78. The government formulated the Growth, Employment and Redistribution (GEAR) strategy to identify structural weaknesses inhibiting economic growth and employment, and to focus attention on market-based policies to address them.

79. Mirrilees, RI., J. Pretorius, H.A. Mare, C.M. Naudé, and M. de Haan, 1996. *South Africa's Expanding Motor Vehicle Usage: Its Implications for the Environment and Possible Options for Restraining It*. Department of Transport Contract Report (CR-96/022). Pretoria.

80. Based on information contained in Naudé et al. 2000. *Global Climate Change: Developing Countries and Transport Sector Options in South Africa.* Institute of Transportation Studies. University of California, Davis. UCD-ITS-RR-00-12.

81. A terajoule is equivalent to 10^{12} Joules.

82. The "higher" heating value (HHV) of a fuel includes the energy available from the condensation of the water vapor that results from fossil fuel combustion. Water vapor is released initially at a high temperature; when the vapor cools and condenses to a liquid, a bit more energy is released. The "lower" heating value (LHV) does not include the energy available from the condensation of the water vapor.

83. A kilojoule is equivalent to 1000 Joules.

84. An exajoule is is equivalent to 10^{18} Joules.

notes

notes

notes