DEDICATED TO MAKING A DIFFERENCE

Mobility for development

São Paulo | Brazil

TTC Engenharia de Tráfego e de Transportes Ltda.

CEBDS Conselho Empresarial Brasileiro para o Desenvolvimento Sustentável

World Business Council for Sustainable Development

Acknowledgement

We would like to thank Mr. Elmir Germani and the team from Engenharia de Tráfego e de Transportes S/C Ltda (TTC) for preparing this report. We would also like to thank Brisa Auto-Estradas de Portugal, S.A., General Motors Corporation, Michelin, Petrobras – Petroleo Brasiliero S.A. and Business Council for Sustainable Development Brazil (BCSD Brazil) for their support in preparing this case study and for their invaluable contribution in organizing the stakeholder dialogue in São Paulo. We also deeply appreciate the valuable input we received from the participants who took part in the stakeholder dialogue in São Paulo.

Mobility for development

São Paulo | Brazil

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

This case study was prepared by Engenharia de Tráfego e de Transportes S/C Ltda (TTC):

Ing. Elmir Germani, Project Leader

Ing. Eduardo Alcantara de Vasconcellos, MSc, Ph.D

Ing. Gabriel Murgel Branco

Ing. Bernardo Guatimosim Alvim, MSc, Ph.D

Ing. Vernon Richard Kohl

Acknowledgements

The authors acknowledge the input and assistance of Shona Grant, George Eads and Mihoko Kimura in the production of this report.

1 Introduction

1. INTRODUCTION

This report was prepared for the World Business Council for Sustainable Development (WBCSD) as part of the Mobility for Development (M4D) project. This project builds on the WBCSD Sustainable Mobility report – Mobility 2030[1] – which defined sustainable mobility as "the ability to meet the needs of a society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values today or in the future". The M4D project aims to further investigate the challenges and opportunities associated with achieving sustainable mobility in the developing world through the conduct of four case studies in cities and associated regions at various stages of economic development, namely: Dar-es-Salaam in Tanzania, Bangalore in India, Shanghai in China, and São Paulo in Brazil. In particular, the study is designed to raise awareness and understanding of:

1. The importance of mobility as a driver of economic development
2. The opportunities to narrow the "mobility divide"[2]
3. The need for sustainable mobility solutions for rapidly growing cities such as Sao Paulo.

The WBCSD has also defined a set of seven goals that it believes will improve the outlook for sustainable mobility. These seven goals are:

1. Ensure that emissions of transport-related conventional pollutants do not constitute a significant public health concern
2. Limit transport-related greenhouse gas (GHG) emissions to sustainable levels
3. Significantly reduce the total number of road vehicle-related deaths and serious injuries from current levels in both the developed and the developing worlds
4. Reduce transport-related noise
5. Mitigate congestion
6. Narrow the "mobility opportunity divides" that inhibit the inhabitants of the poorest countries and members of economically and socially disadvantaged groups within nearly all countries from achieving better lives for themselves and their families
7. Preserve and enhance mobility opportunities for the general population of both developed and developing world countries.

The objectives of the São Paulo case study are to assess the status and outlook for sustainable mobility in light of the seven goals, based on experience to date as well as future plans for the São Paulo Metropolitan Region (SPMR)[3].

---

[1] WBCSD, 2004. Mobility 2030: Meeting the challenges of sustainability.

[2] As defined in the final report of the WBCSD's Sustainable Mobility project, the "mobility divide" (or "mobility opportunity divide") reflects the wide disparity in mobility opportunities between those available to the average citizen in the poorest developing nations and regions and the mobility opportunities experienced today by the average citizen in the developed world. The Sustainable Mobility project emphasizes that closing this divide does not require that people in any region travel a given number of kilometers per year. Rather, "the mobility opportunity divide" will cease to exist when people everywhere have comparable opportunities to "move freely, gain access, communicate, trade, and establish relationships." (Mobility 2030, p. 131).

[3] The Sao Paulo Metropolitan Region is composed of 39 municipal areas; the state capital, São Paulo, is the main city.

Table 1.1 shows a profile of the SPMR, and its relation to the state of São Paulo and the city of Sao Paulo. Its population of 19.6 million inhabitants is almost half that of the state population, while GDP is approximately 57% of that of the state and 19% of GNP (R$ 2,245 billion in 2005). GDP per capita (2005 values) is R$ 21,500 or around US$ 9,000. The economy is dominated by the service sector which represents 72% of activities in the region, in terms of added value.

Table 1.1 – Profile of the region

	YEAR	SÃO PAULO		
		City	Metropolitan Region	State
Area (km^2)	2005	1,509	8,051	248,600
Population (million inhab)	2007	10.8	19,6	41.0
Annual growth rate (% a.a.)	2007	0.55%	1.33%	1.50%
% from state exportation	2007	13%	34%	100%
% of services over total added value	2005	76%	72%	67%
GDP (billion R$)	2005	263	417	727
% from state GDP	2005	36%	57%	100%
GDP per capita (R$ / year)	2005	24,100	21,500	18,000

Source: SEADE

In 2000 (the date of the last census), poor people[4] accounted for about 14% of the population, the figure was similar for the state of São Paulo, while in Brazil as a whole it was 33%.

Most of the assessment presented in this report is based on existing information from various municipal, state and/or federal government agencies. However the report also includes feedback from a dialogue involving multiple stakeholders that was held in Sao Paulo on May 15, 2008. This dialogue offered a unique opportunity to discuss some of the interim findings of the case study with a diverse group of stakeholders from business and civil society as well as with representatives from federal, state and municipal level government bodies and institutions. The summary of the dialogue is included in Appendix 2; a list of participants is included in Appendix 3. The outcome of the dialogue has been used to finalize this case study report and, where appropriate, key observations/findings from the dialogue have been used to supplement the research done by Engenharia de Tráfego e de Transportes S/C Lt (TTC), WBCSD's main partner in the São Paulo case study.

[4] Defined as people who earn less than half the minimum wage.

In order to gain a better understanding of the SPMR (a primarily urban area) mobility context, it was necessary to examine some of the mobility-related issues from a state of São Paulo-wide and even a country-wide perspective. This was the case, for instance, of freight transport and biofuels. In the case of freight transport, there is considerable trade and exchange of goods between the SPMR and its hinterland. As a result, many of the roads, railroads, maritime ports and airport facilities upon which the region depends are located outside its formal boundaries. In the case of biofuels, SPMR is a major consumer; while production, legislation, agricultural and environmental questions are primarily national issues.

Figure 1.1 - Geographical location of São Paulo Metropolitan Region (SPMR)

2

Executive Summary

2. EXECUTIVE SUMMARY

2.1. THE SPMR AND THE STATE OF SAO PAULO

The state of São Paulo is the wealthiest in the country with the majority of wealth concentrated in the São Paulo Metropolitan Region (SPMR). The city of São Paulo is the state capital and one of 39 municipal areas in the SPMR; it dominates economically and is often referred to as the business hub of Latin America.

The SPMR is the largest population centre in the country, with 20 million inhabitants. Its annual rate of population increase was very high in the 1960-1980 period (5.0%), but has gradually decreased in the intervening years to 2.1% (1980-1991), 1.7% (1991-2000) and 1.3% (2001-2007). Most households have access to public services: electricity (100%), garbage collection (100%), water (99%), telephone (90%) and sewage collection (82%).

In economic terms, in 2004 the state of São Paulo and the SPMR, respectively, accounted for 30.9% (US$ 187 billion) and 15.6% (US$ 94 billion) of Brazilian GDP (US$ 604 billion). The GDP of the SPMR is about half of that of the state of São Paulo.

In 2007, the SPMR had 8,116,904 registered vehicles, including 6,069,000 automobiles and 876,000 motorcycles. Motorization rates for automobiles and motorcycles were, respectively, 314 and 45 per thousand inhabitants.

Although high by Brazilian standards, average income remains relatively low with 58% of the population earning less than US$ 350 a month. This pattern is highly skewed in favor of the upper strata: while the poorest 10% earn 1.39% of the total income, the wealthier 10% earn 40.19%.

Access to private transport is unevenly distributed among social groups and classes, resulting in increased transportation problems. There has been a sharp increase in the use of private transportation and a corresponding decrease in the use of public transportation. This has resulted in severe congestion, high levels of atmospheric pollution and high numbers of traffic fatalities.

2.2. CHANGES IN MOBILITY FROM 1967 TO 2002

Quantitative data obtained through four origin-destination surveys (OD) carried out every ten years between 1967 and 1997 (with an extra one conducted in 2002) reveal that overall mobility (trips per person, per day) remained static between 1977 and 1987; it then decreased by about 10%, to increase again in the final survey period. Motorized mobility increased by 50% between 1967 and 1977, and then decreased to 1.33% by 2002. Average travel times remained more or less constant (44 minutes). Journeys to and from places of work decreased from 50% in 1967 to 39% in 2002, while school journeys rose from 12.3% to 29% in the same period.

Walking has always been a very important means of transport – accounting for one-third of all journeys – while the use of bicycles has always been very limited, accounting for about 1% of all journeys in 1997. Private transport increased from 26% in 1967 to 53% in 2002. During the same period, bus use decreased from 64% to 47%. The subway, which opened in 1974, has attracted an increasingly high share of users. The train system, which has suffered decreasing levels of investment and offers poor service, continued to serve only a small part of demand.

There has been a dramatic increase in the number of private cars, with a corresponding increase in the number of car journeys. An analysis of changes in levels of mobility by income level for the 1987-2002 period revealed that use of public transport decreased across all income levels with the exception of the highest income level which remained at the 1987 level. An analysis of automobile use showed that mobility increased among the lower income bands and decreased among the high-income sector.

The complex changes that have taken place and that have led to changes in patterns of mobility are summarized below.

(a) The mobility “gap”: there is still a large difference in average mobility within social classes and groups. The overall mobility ratio (trips/person/day) between the low-income and high-income extremes in 2002 was 1:2.2; while the ratio for motorized mobility was 1:3.5 – fairly typical of developing country conditions. The low-income sector faces severe travel restrictions, while the wealthier sector, with access to cars, enjoys levels of mobility similar to those of European countries.

(b) New patterns of mobility: there has been a shift in mobility patterns towards more women users and more car users. The ratio of female:male mobility increased from 076:1 in 1987 to 0.82:1 in 2002; 75% of the increase in the number of journeys between 1987 and 1997 was in car journeys. This would seem to indicate that SPMR is moving towards greater levels of private vehicle ownership and travel (rather than collective ownership and travel), with serious implications for long-term sustainability.

c) Urban changes: changes in mobility may be the result of changed urban land-use patterns, including changes in the physical location and distribution of services and commercial activities, and the creation of new suburbs.

d) Car-ownership: first-time acquisition of a car has a tremendous impact on family mobility with an estimated 40% of journeys being undertaken by car. As income increases, so car use increases. Car-ownership allows for multiple, inter-connected trips, which account for about 35% of all car journeys undertaken in the region.

2.3. CURRENT CONDITIONS

Institutional conflicts

The SPMR faces several institutional challenges in transport planning and operation. At the regional level there has been a gap between metropolitan-wide transport action and local transport policies. The State Department of Metropolitan Transportation is responsible for the subway system, the suburban railway and all intercity bus services within the metropolitan area. However, there have been occasions when local mayors have sought to protect their local legal decision-making power which has resulted in conflicts surrounding attempts to create regional transportation infrastructure or services that impact on local affairs. In the capital, and largest city, (São Paulo) urban and transport affairs are managed by three different departments: Urban Planning (SEMPLA), Transportation (SMT) and Roadways (SVP). All have tended to work in silos. Within SMT, public transportation and traffic are split and separate agencies deal with practical issues (SPTrans deals with public transport while Traffic Engineering Company (CET) is responsible for traffic). Given that power is skewed in favor of car owners (the middle classes), CET's priority has been traffic flow, which in practice means supporting automobile traffic. Bus priority schemes have been scarce. As far as roads are concerned, planning and construction of expressways and arterial roads have been dealt with independently of urban planning and traffic agencies; they have tended to ignore objectives and suggestions of traffic agencies.

Limited supply of integrated public transportation

In 2002, there were just 101 km of bus lanes or corridors in the SPMR: a mere 3% of the main arterial system. Public transport infrastructure per million inhabitants has decreased from 38 km in 1967 to 23 km in 2002.

Conditions on the large suburban railway system have deteriorated resulting in a considerable and permanent drop in demand for its services. Despite offering a high quality service, development of the subway has been slow. In addition to offering very different levels of service, these two systems are still poorly integrated with each other and with private transport systems. At present, only 10% of subway journeys are integrated with the rail network, because there are only a few points of interconnection between them. There is practically no integration between suburban trains and bus services. Integration between bus services and the subway is better, given that 50% of users make combined trips. Different fare structures and corporate practices have also hindered the organization of a large integrated system. However, the introduction in 2004 of the “bilhete único” (single ticket) which can be used on all three systems, has helped to increase integration.

The bus network covers the entire territory and serves almost 100% of residential areas. There are three main bus systems. The largest one operates in the city of São Paulo; in 2002 it included about 14,000 buses and minibuses. The second network links the cities and has about 3,000 buses. The third system consists of local bus systems in cities other than São Paulo, and has about 3,000 buses. Demand for bus services in the 1967-2002 period closely matched demand for railway services; demand increased to 1987 and subsequently dropped off. During the same period, public transport services were also provided by the informal sector operating small vehicles. This illegal competition was at its height in the early 1990s, following a period of national deregulation and privatization of economic activities. However, after five years of conflict between the authorities and the illegal providers, most were brought into the formal sector; many now serve as feeder lines for the main trunk lines.

For the majority of the population living on the outskirts of the cities and relying on buses, average distances have increased. Moreover, tight fare controls and high inflation have led private operators to place profit before supply, often at the expense of service frequency and high-density areas. Therefore, although the bus network is almost universal, the system is irregular, unreliable, uncomfortable and limited in its connectivity. There are huge differences between the private and public transport systems. Furthermore, many buses have to travel on narrow, often unpaved, streets where they compete for space with other vehicles. User information is limited.

Travel times

In the city of São Paulo, automobile speeds in the main arterial system increased from 25 km/hr in the late 1970s to 27-28 km/hr in the 1980-1984 period; they then dropped to less than 20 km/h in the 1990s. Traffic congestion during peak afternoon hours tripled between 1992 and 1996 – from 39 km to 122 km – while the proportion of congested roads in the main system peaked at 80% in 1998. In 1998, the average speed in the main arterial system during the afternoon peak traffic hour was 17 km/hr and the bus speed was 12 km/hr. In 1998, it was estimated that to relieve traffic congestion 3,000 of the 10,000 buses in operation would need to be taken out of service.

Costs of transport

The cost of public transport increased dramatically, especially in the 1987-1997 period. Inflation notwithstanding, fares for buses – the most important means of transport –doubled between 1977 and 1997. Train fares, the primary means of transport among very poor people, increased by a factor of 3.5. Between 1997 and 2002, the cost of public transport increased by 14% before inflation. The increase in activities in the informal sector has further served to exclude a large portion of the population from the system given that only those employed in the formal job market are entitled to low-cost travel passes. They have also been excluded from integrated journeys, or trips using multiple means of transport, since the cost of fares for such transport also remain beyond the purchasing power of the very poor. The most important change came in 2002, when the “bilhete único” was introduced which enabled travelers to travel on up to four buses in a two-hour period using a single ticket.

Car-ownership taxes have always been very low, around US$ 100 a year. The cost of parking has not had a serious impact given that there is an abundance free parking available in the streets.

Congestion

The growing number of vehicles and the lack of investment in integrated public transport systems have resulted in congestion. Although infrastructure development has been dominated by road-building at several points in the city's history, congestion levels have remained high and continue to increase, with peak afternoon congestion levels on the main arterial roads doubling between the end of the 1980s and 2007.

Several policies have facilitated private car purchase including, availability of long-term and low-interest funding for car purchases, free roadside parking, relatively cheap fuel prices, lax enforcement of traffic laws and operations aimed at easing traffic flow. Buses have not benefited from similar conditions.

Accidents

The development of road networks to cope with the increasing numbers of cars has created a dangerous environment for pedestrians and those using non-motorized means of transport, resulting in large numbers of severe traffic accidents. Although the annual number of fatalities in the city of Sao Paulo dropped from 2,300 in 1980 to 1,400 in 2005, figures nonetheless remain very high in comparison to those for developed countries; they match those found in other large cities of the developing world such as Bogotá, New Delhi and Bangkok (with, respectively, 1,139, 1,114 and 977 fatalities per year). Currently, the increasing number of motorcycle-related accidents is causing concern: as the number of motorcycles in the city of São Paulo increased from 140,000 to 455,000 between 1997 and 2006, so the number of deaths increased from 221 to 380 (72%), reaching a peak of 406 in 2001.

Mobility

The most recent origin-destination survey carried out in 2002 revealed that the modal split has continued with increasing use of private transport means (automobile) and decreasing use of public transport means. For the first time in the history of the city, private vehicle usage (34.2%) overtook public transport (28.1%).

Cargo transport

Within the SPMR cargo is primarily transported by road, with about 90,000 daily truck haulage journeys, carrying about 600,000 tons of cargo. Transport of goods to and from factories is carried out by vehicles with a large number of axles, of which 31% are trucks with four axles or more.

Air pollution

The level of pollutants emitted by vehicles in the SPMR has decreased over the years, thanks to the National Program for Motor Vehicle Pollution Control (PROCONVE). It has set increasingly strict emissions standards, and as cleaner vehicles have entered the fleet, pollution per vehicle has declined. As a result, environmental monitoring carried out by the São Paulo State Environment Agency (CETESB) has pointed toward continuous improvements in air quality standards in the Metropolitan Region, especially in carbon monoxide (CO) and particulate matter (PM) levels. The number of days of emissions exceeding CETESB rates has been reduced. Although the number of vehicles in the SPMR nearly doubled between 1996 and 2005, ozone (O3) levels have remained stable, albeit high, exceeding admissible levels on several days. This indicates a need for stricter emissions control standards.

Based on the findings of different air quality monitoring exercises (see chapter 5.6.4) the following conclusions can be drawn with regards to emissions control:

a) Motorcycles are the main focus of efforts to control CO; for other vehicles the emphasis is on the development of technology;

b) Control of VOC emitted by type of vehicle depends essentially on significant restrictions applied to motorcycles, as well as on the continuity of control requirements for automobiles;
c) NOx limits for heavy-duty vehicles should be reduced, whereas for the remaining types of vehicles maintaining the already established strategies should be sufficient;
d) As of 2015, control strategies for PM emissions will have to be extended to light-duty vehicles and motorcycles, and it is essential to maintain the already established requirements for heavy-duty vehicles;
e) State-of-the-art technologies aimed at significant improvements in energy efficiency in light duty-vehicles might stabilize CO_2 emissions for this category of vehicle; research is still needed into options for heavy-duty diesel-powered vehicles. Therefore, a review of the emissions levels resulting from different types of transport is necessary to slow energy consumption and, consequently, CO_2 emissions.

The adoption of such strategies should help to reduce local pollutant emissions to sustainable levels. This could contribute towards mitigating vehicle-related air pollution problems.

2.4. THE SPMR AND NATIONAL AND REGIONAL CONSTRAINTS

National relations and constraints

Although the SPMR has its own sources of funds and strong public agencies, it nonetheless relies on the support of the state and federal governments, as well as international funding. However, the adoption of the new Brazilian Constitution in 1988 and with it, a policy of decentralization, has created difficulties, with several federal authorities interpreting decentralization as freeing the federal government from any formal commitment to support local or regional transport policies. This has been made further complicated by the fact that regional transport policies and investments are sometimes subject to federal laws (concession rules, vehicle technology, fuel prices, labor relations). Although the Ministry of the Cities was created in 2002 to deal with national urban transport issues, few resources were put at its disposal. Similarly, the National Bank for Social Development (BNDES) has reduced its urban transport investments.

Regional relations

The SPMR is situated in a wealthy state. Thanks to a network of 33,000 km of paved highways, 5,100 km of cargo railways, two international airports, two maritime ports, and 6,500 km of pipelines, the state generates considerable economic wealth.

Many vehicles – cars and trucks – enter the SPMR on a daily basis with significant impacts on traffic conditions and air quality.

In 2000 it was estimated that roughly 700 million tons of cargo were transported to or from the state of São Paulo. About 76% was traffic to or from the “macrometropolis” (São Paulo and the surrounding cities of Santos, Campinas, Sorocaba and São José dos Campos).

Most of the cargo included industrial products, consumer goods, and food – fresh produce grown round the major cities as well as dairy and refrigerated animal produce. Secondary oil and ethanol derivatives accounted for approximately 10% of total transport demand and were shipped by road, rail and pipeline.

2.5. CHARACTERISTICS AND IMPACTS OF PROPOSED PROJECTS

Several actions could be implemented to assist the SPMR to improve overall mobility conditions and achieve WBCSD mobility objectives. They vary widely in scope, cost and implementation time and require different political agreements, some difficult to reach in the short term.

Reducing GHG emissions will require the development of renewable fuels, especially ethanol, whose production and use may increase substantially.

Similarly, the most effective way to reduce local emissions could be through a continuation of the PROCONVE program, which integrates diesel vehicles and motorcycles, and foresees the implementation of a vehicle inspection program, the creation of links between the southern and eastern metropolitan ring roads (Rodoanel) and the reorganization of truck transport operations within the SPMR, especially in São Paulo city center.

Bridging the mobility divide will require modernization of the railway network (to increase daily use from 1.5 to 3.3 million people), expansion of the subway system (to increase capacity from 2.6 to 4.4 million people), reorganization of the local and intercity bus systems, implementation of bus rapid transit (BRT) systems and introduction of the “single ticket” in other cities of the SPMR.

Reducing the number of traffic accidents will require the implementation of massive and coordinated education and traffic safety programs by local authorities and, to a lesser extent, the use of traffic safety Intelligent Transportation System (ITS) equipment.

Finally, the key to relieving traffic congestion may rest in the introduction of fees for road use; however, reaching political agreement surrounding this seems to be difficult in the short term.

3

The Brazilian Transportation System

3. THE BRAZILIAN TRANSPORTATION SYSTEM

3.1. THE BRAZILIAN TRANSPORTATION SYSTEM

Brazil is a federal state and as such the three levels of government – federal, state and city – have their own areas of responsibility as defined in the Brazilian Constitution. That said, state and city authorities still depend significantly on the federal government. This is reflected in several ways in the transport sector. The federal government has exclusive responsibility for defining traffic regulations and fuel quality; it is also responsible for establishing service contracts and for approving technological innovations to vehicles, as well as the use of new types of fuel. This document therefore looks at mobility issues in the context of the role of the federal government in the Brazilian transport sector; a role which is possibly more important in Brazil than in other countries.

3.2. GENERAL DATA

Studies conducted by Castro, N.R. in 1999 revealed that in Brazil, most goods – measured in useful-tons (TKU) – are transported by truck (82%), with railways (9.1%), pipelines (2.1%), marine vessels (6.5%) and air (0.1%) accounting for much smaller proportions of goods transport. Similarly, it is estimated that 96% of passengers travel by road, 2% by rail and subway trains, while the remainder use waterways and airways (Geipot, 1997). Consequently, road transport consumes the lion's share of energy in the transport sector, with diesel accounting for the greatest fuel use.

Since 1990 efforts have been implemented to modify Brazilian transport patterns, including restructuring of the ports, and granting of private concessions for the operation of the main railway network and key federal and state highways. This remains a work in progress and highway concessions continue to attract significant private domestic and international investments.

Brazil currently has 14,000 km of privately-operated highway networks; toll collection has increased the cost of highway transport and made other means of transport more competitive. It is believed that this will lead to changes in transport patterns. Such changes have already been observed. For instance, according to research conducted by the Institute for Economic Research Foundation (FIPE) as part of its Transport Economic Performance Index (IDET) system, in 2007 the rail network transported 239 billion TKU, an increase of 70% over 1999 figures. Similarly, according to the National Petroleum Agency (ANP), diesel consumption increased at a slower pace (20%) during the same period.

The expansion of the privately-operated highway network, and growing use of other means of transport, has resulted in the growth of rail transport. Similarly, there has been a growth in water-based transport. In 2006 cabotage navigation accounted for 26% of water transport, while long-distance navigation accounted for 73% of the total 692 million tons transported through waterway ports and terminals. Cabotage navigation grew by 9% and long-distance navigation grew by 6.3% during the same period. Container transportation also grew significantly (15% p.a.), thereby adding momentum to intermodal practices and the rationalization of the existing transportation matrix.

In urban areas, diesel-powered buses remain the predominant means of transport. It is estimated that 110,000 buses are currently in operation, transporting 50 million passengers a day. There are 12 railway and subway systems in operation in Brazil, most of which are located in large cities or metropolitan regions, providing transport services to nearly 5 million passengers a day. In cities with a high average income, such as those in the Brazilian southeast, private cars account for the majority of journeys undertaken (52% in the São Paulo Metropolitan Region) (CMSP, 2002).

The Brazilian automotive industry comprises several multinational companies which together produced about 2.6 million automobiles, buses and trucks in 2006 (Anfavea, 2007). The motorcycle industry produced a further 1.26 million vehicles (Abraciclo, 2007) resulting in a total production of 3.8 million vehicles. Automobiles accounted for 61% of total production, followed by motorcycles (33%), trucks (4.5%) and buses (1.5%). Currently, 86% of all new automobiles are of the flex-fuel type (powered by either gasoline and ethanol or a mixture of both – gasohol – in any proportion), 10% are imported and only 4% are diesel-powered light commercial vehicles. Strictly ethanol-powered vehicles are no longer manufactured. Heavy duty vehicles, however, are almost entirely diesel-powered. The breakdown of the current Brazilian fleet is shown in Table 3.1.

Table 3.1 - Brazil – registered vehicle fleet, September 2007

VEHICLE	QUANTITY	%
Automobiles	29,273,941	60.5
Light commercial	4,580,121	9.5
Buses and microbuses	580,024	1.2
Trucks and tow trucks	3,171,278	6.6
Motorcycles and mopeds	10,658,091	22.0
Others	134,234	0.3
TOTAL	**48,397,689**	**100**

Source: National Traffic Department (Denatran), 2007 (www.denatran.gov.br/estatisticas).

Table 3.2 - Brazil – domestic vehicle sales 1990-2006

YEAR	Automobile and light commercial vehicles	All vehicles	GROWTH FACTOR (Total)
1990	532,906	712,741	1.0
2000	1,176,774	1,489,481	2.1
2005	1,369,182	1,714,644	2.4
2006	1,556,220	1,927,738	2.7

Source: National Association of Automotive Vehicles Manufacturers (Anfavea), domestic vehicle sales statistics (www.anfavea.com.br).

3.3. URBAN MOBILITY IN BRAZIL

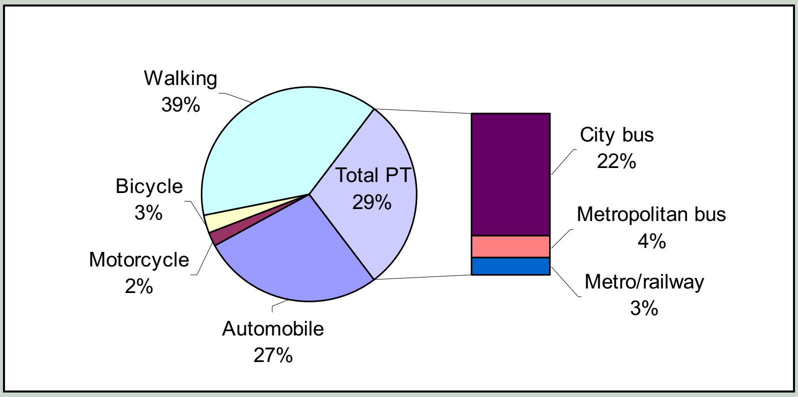
The following data refers to transport of people in Brazilian cities with more than 60 thousand inhabitants in 2005 (www.antp.org.br). As can be observed in Table 3.3 residents in these cities made 50 billion journeys in the year (about 150 million per business day). Most of these journeys were on foot (39%), with the remainder equally divided between public and private motorized vehicles (30% each). Figure 3.2 demonstrates how modal distribution differs according to the size of the city, with more motorized transport in the larger cities.

Table 3.3 - Trips per year by major mode of transport (millions of trips/year), 2005, cities with 60,000 inhabitants or more

SYSTEM	TRIPS (millions of trips/year),	TRIPS (%)
City bus	11,283	22.3
Intercity bus	2,047	4.0
Tracks	1,501	3.0
Collective transport –Total[1]	**14,831**	***29.3***
Automobile	13,762	27.2
Motorcycle	995	2.0
Individual transport – Total	**14,757**	***29.2***
Bicycle	1,363	2.7
On foot	19,667	38.9
Non-motorized – Total	**21,030**	***41.5***
TOTAL	**50,618**	**100.0**

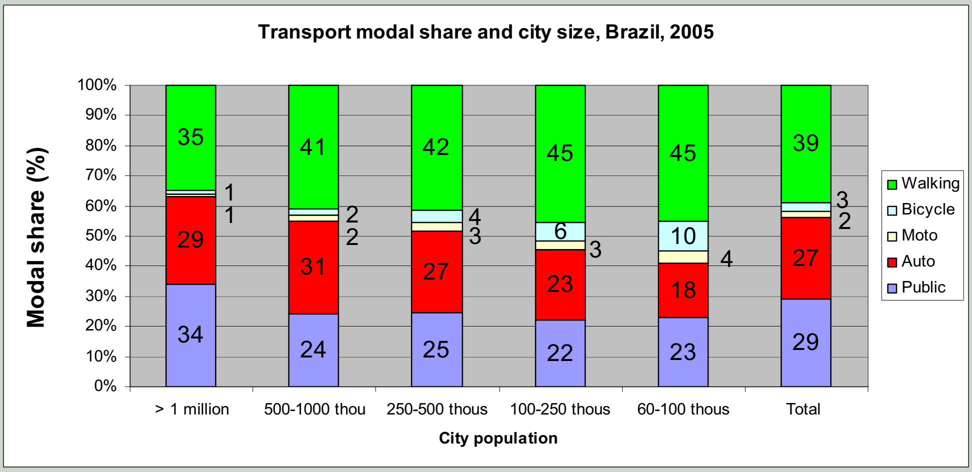
1 – Does not include informal-sector public transport in small buses.
Source: ANTP (2005)

Figure 3.1 - Transport mode distribution, 2005, cities with 60,000 inhabitants or more



Source: ANTP (2005)

Figure 3.2 - Transport mode distribution by population range, 2005, cities with 60,000 inhabitants or more



Source: ANTP (2005)

3.4. INSTITUTIONAL ISSUES

3.4.1. Power-sharing within the federation

Institutional responsibility for transport in Brazil is spread across the three levels of government – federal, state and city – depending on infrastructure and transport modes. The federal government is responsible for airports and ports, the federal railway system and the federal highway system (although part of these systems has been or will be transferred to the state government); it also controls the bus and interstate train system. State governments are responsible for state highways and railways, intercity and long-distance bus systems, and for intercity transport. City governments are in charge of public transport and traffic within the cities' geographical limits.

Transport issues are handled by technical departments, usually state or city transport departments. Urban traffic comes under the responsibility of state governments (vehicle licenses and driver's licenses) and local authorities (planning, signaling and operation). This distribution of responsibilities was defined by the Brazilian Traffic Code, which took effect in January 1998. Prior to that date, the state government had been responsible for all transport issues.

Environmental issues are under the responsibility of the Ministry of the Environment and the State Departments of the Environment, whenever these are available (São Paulo State Environment Agency, for example). The main federal government environment regulatory agency is the National Council for the Environment (CONAMA). Few cities have their own environmental departments.

3.4.2. Management of urban affairs

The Brazilian Federal Constitution requires that all cities with more than 20,000 inhabitants define an urban master plan. In practice, however, urban policy initiatives in the transport and traffic areas are seldom coordinated.

Most cities feature a transport, traffic or public roads department, but seldom an urban planning department. Urban development in Brazilian cities is determined by market laws, land-values and accessibility and tends to be devoid of regulation and control mechanisms. In medium-sized cities, public transport is usually managed directly by city mayors and their technical staff. However, these activities tend to be separated from traffic concerns and dealt with as part of wider transport-related concerns. In large cities, transport and traffic issues tend to be better coordinated although they still suffer from a lack of integration with road and urban planning departments.

Community engagement with transport issues is still weak although the last decade has seen improvements in the relationship between government and civil society in this area. This can be explained in part by the deterioration of the urban environment – generating society concerns – and the strengthening of Brazilian democracy, which has resulted in the inclusion of new social groups in formal discussions surrounding policy decisions. Currently, a large number of government agencies are committed to engaging with civil society, notably in projects with significant environmental impacts, which usually require environmental impact studies to be conducted prior to project approval.

3.4.3. Scope of federal government action on urban transport and transit

Political and administrative changes operated in the second half of the 1980s saw responsibility for urban transport transferred from the Brazilian Ministry of Transport to the Ministry of Urban Development and subsequently to the Ministry of Housing and Urban Planning before once again coming under the remit of the Ministry of Transport. As a result, the federal government became increasingly detached from urban transport questions. The 1988 Constitution empowered the federal government to draft the guidelines for a National Policy for Urban Development – including city transportation (Article 21, clause 20); define principles and guidelines for the National Transportation System (Article 21, clause 21); receive private proposals for the National Transportation Policy (Art. 21, clause 9); and legislate for traffic and transport (Article 21, clause 11). However, this had the effect of increasing federal government disinterest in urban issues, something that had been observed for some time. This had the effect of strengthening the interpretation by the federal transport and economic authorities, that urban development and transport were the responsibility of the municipal authorities with the result that the federal government further distanced itself from formulating urban transport guidelines. This resulted in a setback for the transport sector and a return to a situation witnessed decades previously: a lack of public policies, a lack of articulation and transparency between the different levels of government, and a lack of coordinated and consistent mechanisms for providing funds and support to the transport sector.

In light of the deterioration in urban transport, civil society organizations, including the National Mayors Front, the Brazilian Association of Public Transport (ANTP), and the National Forum of Urban Transport and Traffic Secretaries, sought to engage with the federal government to address those issues whose scope went beyond the local management of urban transport systems. As a result, in 2002 the Ministry of the Cities was created to bring together all activities connected with public transport, transit, housing and urban development. The newly formed Ministry created the National Secretariat for Mobility and Urban Transport and transferred the National Traffic Department (DENATRAN) from the Ministry of Justice to the Ministry of the Cities.

3.4.4. Scope of state government action on urban transport

Under the Brazilian Constitution, state government involvement with urban transport in metropolitan areas is limited to intercity public transport. Attempts to develop and manage urban transport networks in metropolitan regions in Brazil have met with few successes.

Following the promulgation of the 1988 Constitution, responsibility for public transport was devolved to the municipal authorities. Conflicts began to emerge between metropolitan and local agencies over issues such as intercity bus line regulations. The persistence of such conflicts has resulted in serious problems in metropolitan regions, made all the more acute by the fact that these regions are home to the largest concentration of populations and the most extensive vehicle fleets in Brazil.

Regulation of intercity bus lines is the responsibility of the Highway Departments (DER). For the most part these agencies lack the human and material resources required for the discharge of their duties, and face severe deficiencies in planning and service inspection.

Prior to the publication of the new Brazilian Traffic Code (CTB) in 1998, state governments were entirely responsible for all traffic-related initiatives, which were carried out by their State Traffic Departments (DETRAN), most of which came under State Public Security Departments. Under the new CTB, vehicle and driver licensing remained the responsibility of the state, while DETRAN was responsible for planning, operating and inspecting traffic activities in all cities in each Brazilian state. These duties have now been devolved to city authorities, with the exception of policing, which remains under the responsibility of the state Military Police, along with vehicle safety inspection.

Failures by the state government to adequately inspect drivers' licenses and verify status of road tax payments have had negative impacts on the general public with huge numbers of drivers and cars circulating without the necessary paperwork. Furthermore, the poor performance of statewide traffic agencies is also reflected in the lack of reliable data on traffic conditions in Brazil, particularly inaccurate reporting on the number of traffic accidents.

3.4.5. Scope of municipal government action on urban transport

For decades, Brazilian cities have been responsible for public transport. However, until recently they were not responsible for traffic-related issues, which rested with the State Traffic Departments (DETRAN). Following the publication of the new Brazilian Traffic Code in January 1998, cities joined the National Traffic System and local mayors became legitimate authorities with the power to conduct traffic planning, operations and inspections, including administrative policing regulations. For this reason, the following section will be limited to municipal government actions in public transport management.

Most municipal authorities have contracted private operators to manage the bus system and provide what is essentially a public service. Unlike other Latin American countries – where public transport tends to be loosely regulated – public transport in Brazil is highly regulated. Tender agreements tend to contain very detailed instructions governing services to be provided, definition of bus lines, timetables, vehicles, tariffs and overall operational conditions. Few cities have mechanisms in place to assess feedback from the users of the public transport system.

This unique relationship between government authorities and private operators has given the Brazilian collective transport system certain unique features. Given the size of the Brazilian population and the inadequacy of the railway system, the country's bus system became one of the largest in the world. As a result, a large bus-manufacturing industry was born; it remains one of the most important in the world with 18,000 buses produced in 2007 alone. This has resulted in large-scale job creation and the development of innovative technologies. For example, the industry produced the first Brazilian urban bus – the PADRON – in the 1980s and developed articulated and bi-articulated buses in the 1990s. No other Latin American country is yet as advanced despite the existence of several adapted vehicles. However, the environmental impacts of this have been considerable and Brazilian environmental agencies struggle to align themselves with European and North American emissions standards.

Brazil was one of the first countries to implement exclusive bus corridors and integrated systems in several large and medium-sized cities such as Curitiba, São Paulo, Porto Alegre, Belo Horizonte, Goiânia, Recife, Campinas and Manaus. The São Paulo subway, inaugurated in 1975, is acknowledged as one of the best in the world

3.5. ECONOMIC AND FINANCIAL ISSUES

One of the drivers of positive change in the Brazilian urban transport sector may rest in the reorganization of financing sources. However, four main obstacles remain.

First, as a result of the process of decentralization resulting from the promulgation of the new Brazilian Constitution in 1988, galloping inflation and the financial crisis of the 1990s, municipal governments reduced their investment in urban transport, particularly high capacity systems. At the federal level, investment in urban transport over the last few years has been reduced. Resources usually come from three major sources: General Budget of the Union (OGU), Brazilian Development Bank and the Special Agency for Industrial Financing (FINAME).

Second, the high level of dependence among cities upon external funding constitutes another obstacle. On average, only 32% of Brazilian cities' funds are self-generated (Kahir, 1999).

Third, restrictions imposed by the federal government's financial authorities on loans to the public sector present further problems. BNDES, the principal funding agency, has had severe restrictions imposed upon it thereby limiting its ability to finance public sector transport projects. As recently as the period after 2002, restrictive fiscal policies prevented available funding resources from being utilized for investments. These funds were locked away and used to ensure a fiscal surplus for the federal government.

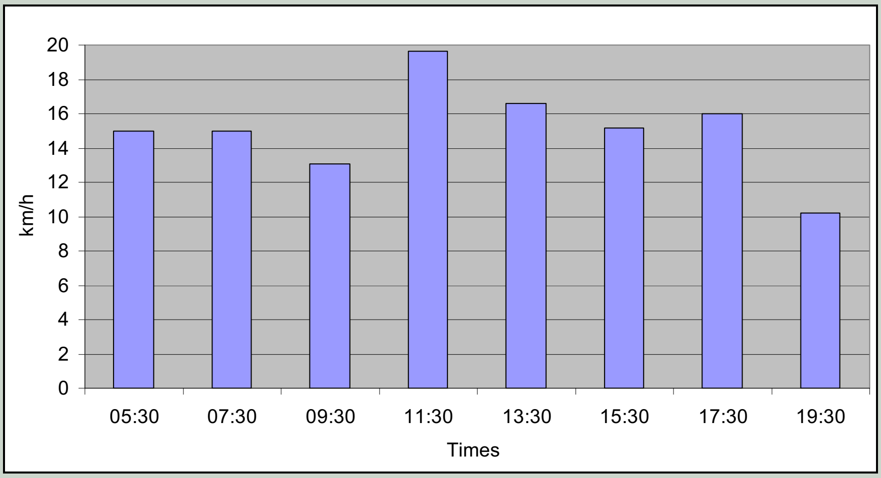
Finally, even private investors are reluctant to finance urban transport projects. New urban transport projects – bus corridors, terminals, subway and railway systems – often fail to secure private funding. This, combined with the financial crisis and loan restrictions in the public sector, renders such projects economically unfeasible.

3.6. URBAN TRANSPORTATION QUALITY ISSUE

In the last few decades, major Brazilian cities, like other large cities in the developing world, have developed to accommodate the automobile. This development has taken place hand-in-hand with the growth in the number of cars. Cars seem to appeal to the high-income sector as the only efficient means of transportation available; although such efficiency is now being jeopardized by massive traffic jams and gridlock. Concurrently, public transport systems, in spite of a few important investors in specific areas, remain unable to provide adequate services to fulfill growing demand. The problem has been compounded by financial crises as well as management and operational shortcomings. Furthermore, the public image of the transport system has suffered on account of declining importance, quality, efficiency and reliability and it is today perceived as a “necessary evil” by those who cannot afford to buy cars.

The growing number of cars on the roads is affecting the performance of city buses; the disproportionate share of road space taken up by cars has served to reduce bus speeds. This has a direct impact on operational costs, system reliability and attractiveness, and on the costs to users. In many Brazilian cities, average bus speeds are now well below 20 km/hour (in São Paulo speeds ranges from 11 to 19 km/hour with an average of 14.5 km/hour – according to a survey conducted by the São Paulo Environmental Company and the International Sustainable Systems Research Center (ISSRC) in 2004). With adequate management, optimum bus speeds should average about 25 km/hour. In large cities commute times tend to be very long, i.e., about 50 minutes in each direction, once access on foot and waiting times at bus stops and terminals are taken into account. The need to change buses results in discomfort, cost increases and longer journey times. It is estimated that traffic jams, caused by a rise in the number of cars, increase the costs of buses by up to 16% in São Paulo and 10% in Rio de Janeiro (IPEA/ANTP, 1998).

Figure 3.3 - Average bus speeds in São Paulo



Source: CET (2006)

The growing gap between the quality of public and individual private transport encourages the use of cars and motorcycles. This situation is compounded by the ready availability of vehicle financing and relatively inexpensive maintenance costs. A 7 km journey during peak time afternoon traffic in a large Brazilian city can take twice as long by public transport as by car or motorcycle; it can also cost twice the amount of a journey by motorcycle and only 33% less than a similar journey by car (in direct operational costs: fares for public transport; fuel expenses for motorcycles; fuel expenses and parking expenses for 5% of automobile trips) (ANTP, 2005).

Furthermore, regular public transport has been facing growing competition from informal sector providers, who have secured part of the custom, thereby aggravating the economic woes of the public transport system.

The key problems identified include:

- *Emergence of chronic traffic congestion*, with a lengthening of travel times and a reduction in productivity of urban activities. Previously restricted to big cities, traffic congestion now affects medium-sized cities where the number of cars has also been on the rise. The impact of restricted mobility and accessibility on the economy as a whole is enormous. In a study conducted by the ANTP in 10 Brazilian metropolises (2007) it was estimated that 1.5 billion hours are wasted each year in traffic jams.
- *Increasing loss of urban bus performance*, chiefly on account of a slow-down brought about by increasing congestion, inadequate road maintenance (bad pavements, drainage ditches), and irregular parking by car and truck drivers. This has a direct impact on operation costs, reliability and attractiveness of the system, and the price of fares paid by users.
- *Decrease in use of public transport:* in Brazil's large and medium-sized cities, the number of passengers using public transport has decreased (Table 3.4). The railway system in particular has been grossly underused. Part of the explanation for this lies in the lack of sorely needed investment, growing competition from the informal sector, and super-inflationary price increases.

Table 3.4 - Decline in the use of public transport (buses) in Brazil from 1992 to 2003 in selected Brazilian capital cities[1] and medium-sized[2] cities

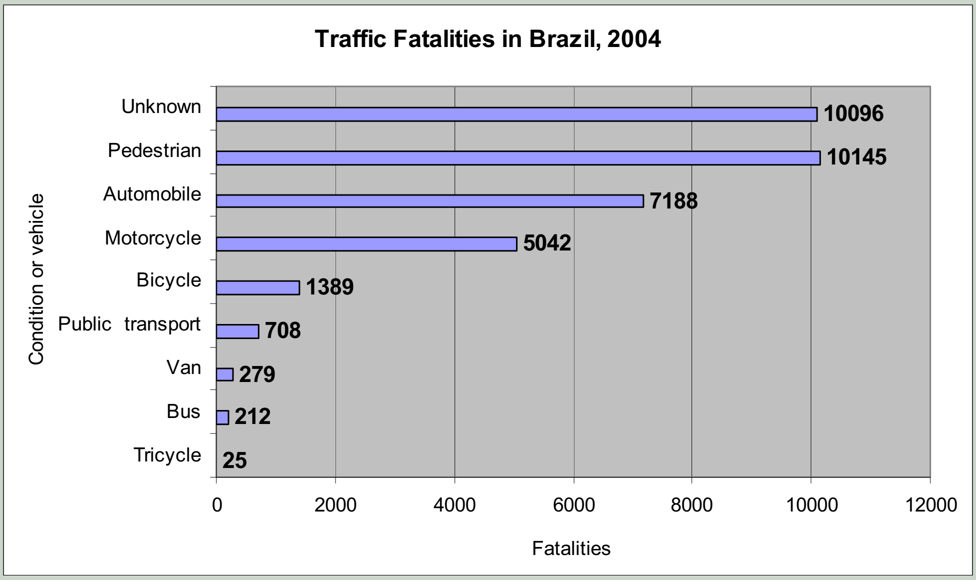
YEAR	ACTUAL DEMAND billion pass/year	IDEAL DEMAND[3] billion pass/year	DECREASE (%)
1992	11,9	-	-
2003	10,6	14,3	20,2

(1) 11 capitals were selected. (2) 15 medium-sized cities were selected. (3) The number of trips per inhabitant should remain constant during the period.

Source: ANTP/BNDES (2006)

- *Increase in number, severity and distribution of traffic accidents:* Brazil has one of the highest rates of traffic accidents in the world, due to poor quality roads, driver behavior, large numbers of pedestrians, and inadequate road-safety education and inspection. In 2004, the National Traffic Department recorded more than 30,000 deaths due to traffic accidents and more than 260,000 casualties (Figure 3.4). These figures should be taken as conservative in view of the underreporting of accidents highlighted in section 3.4.4, and the number of deaths that take place *after* accidents have occurred. A study conducted in 2001-2002 by IPEA and ANTP estimated the annual cost of traffic accidents in Brazilian urban areas to be R$ 5.3 billion (Table 3.5). In large capitals, the largest number of deaths recorded was among pedestrians – 80% in Belo Horizonte and 60% in São Paulo – which is evidence of the poor traffic conditions endemic to Brazil. Traffic accident rates in large Brazilian cities can be up to 15 times greater than those in cities in industrialized countries (Vasconcellos, 2001).

Figure 3.4 - Traffic fatalities in Brazil, 2004



Source: Brazilian Ministry of Health.

Figure 3.5 - Traffic fatalities in Brazil, 2004 – percentage by mode

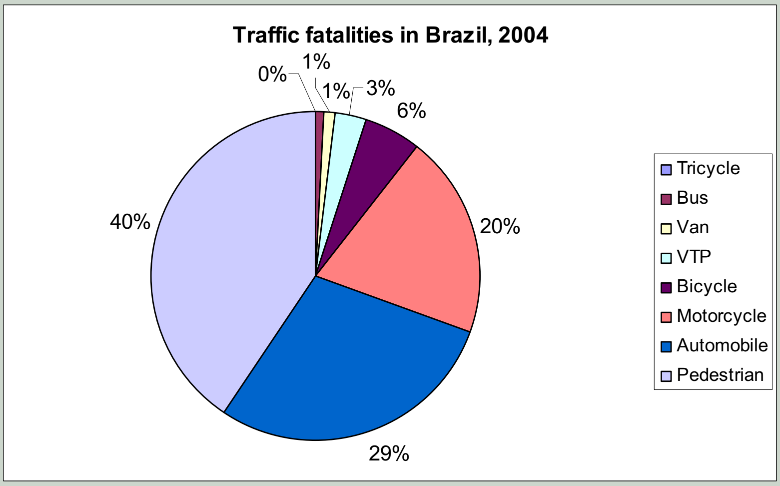


Table 3.5 - Specific costs of traffic accidents in Brazil, 2002

TYPE	COST/YEAR (R$billion)
With casualties	3,65
Without casualties	1,65
TOTAL	**5,30**

Source: IPEA/ANTP (2003)

Part of the explanation for the increase in the number and costs associated with traffic accidents rests in the growth in the number and use of motorcycles, previously viewed as a secondary means of transportation (Table 3.6). This resulted in an increase in the number of fatalities from 500 motorcyclists in the 1990s to 8,000 in 2006 (Brazilian Ministry of Health, 2007).

Table 3.6 - Sales of motorcycles in the Brazilian domestic market, 1990-2007

YEAR	MOTORCYCLES	GROWTH FACTOR (1990=1)
2007	1,600,157	13.0
2006	1,268,041	10.3
2005	1,024,000	8.3
2004	912,000	7.4
2003	848,377	6.9
2002	792,424	6.4
2001	692,096	5.6
2000	574,149	4.7
1999	441,536	3.6
1997	407,430	3.3
1995	200,592	1.6
1990	123,169	1

Source: Brazilian Motorcycle Manufacturers Association (Abraciclo) (www.abraciclo.com).

- *The need for increased investment in the transport system:* in order to meet demand generated by growing automobile use, the road network is constantly being adapted and expanded, often at huge cost; although the benefits are rapidly neutralized by increases in the number of vehicles.

- *Violation of residential and collective use areas and destruction of historic and architectural landmarks:* the construction of new roads, the reorganization of traffic to improve vehicle flow and the abusive use of the city streets and avenues as traffic corridors has led to destruction of city landmarks and publicly-owned lands.

- *Production of large urban diseconomies of scale:* as a result of uncontrolled growth and the lack of organization of urban transport systems, large diseconomies have been generated for Brazilian society; these are reflected in traffic congestion, pollution, fuel consumption and overuse of the city's road network.

4

Passenger and Cargo Transportation in the State of São Paulo

4. PASSENGER AND CARGO TRANSPORTATION IN THE STATE OF SÃO PAULO

This chapter describes the situation in the area surrounding the SPMR – the Macrometropolis and the state of São Paulo. The Macrometropolis of São Paulo includes three metropolitan regions of São Paulo, Santos Region or Baixada Santista (south of SPMR) and Campinas (north of SPMR), and the urban agglomerations of Sorocaba (to the west) and São José dos Campos (to the east). It is often referred to in regional studies as a non-official division within the state of São Paulo. The Macrometropolis is the area which has absorbed the urban and economic sprawl associated with the SPMR over the last three decades (see Figure 4.1).

Figure 4.1 - Macrometropolis of São Paulo

4.1. OVERVIEW OF PASSENGER AND CARGO TRANSPORTATION ON STATE HIGHWAYS

According to data provided by the origin-destination survey conducted in São Paulo state in 2005, there are 900,000 daily car and truck journeys undertaken on the state's highway network.

Table 4.1 - Characteristics of inbound and outbound journeys in São Paulo state

Total daily journeys

VEHICLE TYPE	TRIP TYPE			TOTAL	%
	Internal	External	Passing		
Automobiles	593,086	52,059	2,955	648,099	73.1
Trucks	185,234	46,564	6,444	238,242	26.9
TOTAL	**778,320**	**98,623**	**9,399**	**886,341**	**100**
%	88	11	1		100

Total daily truck journeys

TRIP TYPE	LOADED	EMPTY	TOTAL	%
Internal	93,832	91,402	185,234	78
External	28,917	17,647	46,564	19
Thoroughfare	4,885	1,559	6,444	3
TOTAL	**127,634**	**110,608**	**238,242**	**100**
%	54	46	100	

Note: Internal trips: refers to origin and destination within São Paulo State area.
External trips: refers to either origin or destination outside São Paulo State area.
Passing trips: refers to both origin and destination outside São Paulo State area.

Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo, Secretaria de Transporte do Estado de São Paulo, 2006

Some 88% of journeys are internal journeys, i.e., trips that originate or end in the state. Some 92% of car journeys are internal, while 78% of truck journeys are internal.

Some 21% of truck journeys are external (journeys that either originate or end outside the Sâo Paulo state area) or passing trips (journeys that originate *and* end outside the São Paulo state area), a figure that is more than twice that of external automobile trips (9%), highlighting the importance of truck transport on interstate exchanges.

Journeys originating or whose destination is outside the state make up 11% of the total number of journeys, while passing trips to or from outside the state account for only 1% of the journeys undertaken.

Of the total number of truck journeys, 46% travelled empty or with no load. Furthermore, the number of trucks as a proportion of all vehicle traffic was high: one cargo truck for every 2.7

automobiles. This shows the heavy bias towards use roads for freight transport, a consequence of the inequalities described in section 3.2.

4.2. PASSENGER TRANSPORT

There are three means of passenger transport available in São Paulo state: individual or private (automobile), collective or public (intercity and suburban buses), and air. Regional intercity passenger rail transport within the state has been discontinued; however, a metropolitan train continues to service urban demand and is described in chapter 5.

4.2.1. Individual or private transport

Most car journeys take place at the intersection of the three metropolitan regions of the state, or Macrometropolis. Car journeys account for about 80% of all travel to and from this region.

Journeys originating or ending outside São Paulo state, along with passing trips (whose origin and destination are outside the state), represent 4.2% of all journeys outside and 4.0% of journeys into the state, with the highest concentration of traffic found on the borders with Minas Gerais and Paraná states.

Travel to and from work accounts for more than 40% of daily journeys undertaken in the state and 53% of journeys undertaken in the Macrometropolis. Overall, the high-income sector is the most mobile with 53% of all journeys undertaken by people whose individual income is above R$1,500, and only 8% of journeys undertaken by people whose income is below R$600.

Most car journeys to the São Paulo Macrometropolis, and in particular the metropolitan region, are undertaken by high-income people. Most vehicles have two occupants; while two-thirds of all journeys have one or two occupants per vehicle.

According to the origin-destination survey for the state of São Paulo, if all reasons for travel are taken into account, rate of vehicle occupation decreases as incomes increase; but vehicle occupation is highest when journeys are undertaken for leisure purposes. Vehicle occupation rates were found to be higher in the interior of the state, regardless of the reason for the journey. Standard and utility cars represent 43% and 25% of the fleet, respectively. Nearly 80% of the vehicle fleet in circulation is less than 10 years old.

4.2.2. Intercity bus transport

Intercity passenger transport in São Paulo state is provided by private companies. These companies are granted permits to operate subject to fulfilling stringent conditions. The regular intercity bus system is operated by 138 registered companies, while 509 companies operate a charter bus service. The total fleet consists of 13,730 buses – 5,052 regular and 8,678 chartered – that serve more than 1,550 routes. The regular service alone covers a distance of some 450 million kilometers per year.

The regular bus service provides frequent daily transport between the cities and carries more than 60 million passengers annually on long-distance regional lines and nearly 100 million passengers on short-distance intercity lines. Van transport services only carry a negligible 10,000 passengers a year. The (Table 4.1) number of passengers transported every year declined by about 15% between 2000 and 2005.

The state is responsible for inspecting and overseeing the bus companies operating regular and chartered intercity lines, as well as for regulating tariffs, itineraries, timetables, security related issues, and analyzing users' demands.

Table 4.1 - Intercity passenger road transport in the state of São Paulo

Passengers transported — passengers

TRANSPORT	2000	2001	2002	2003	2004
Intercity bus	67,475,220	68,820,859	67,829,131	66,634,919	64,614,844
Suburban bus	122,909,430	127,243,046	101,656,991	99,286,687	99,034,694
Jitney van	18,557	15,372	14,422	13,905	11,996
TOTAL	**190,403,207**	**196,079,277**	**169,500,544**	**165,935,511**	**163,661,534**

Distance covered in kilometers — km

TRANSPORT	2000	2001	2002	2003	2004
Intercity bus	374,206,663	370,135,061	352,390,696	342,329,291	338,605,092
Suburban bus	124,909,416	131,952,048	109,612,681	110,663,520	114,616,955
Jitney van	843,965	712,470	715,700	647,700	554,965
TOTAL	**499,960,044**	**502,799,579**	**462,719,077**	**453,640,511**	**453,777,012**

Source: ARTESP

Note: In January 2002, the Campinas Metropolitan Region lines were transferred to STM/EMTU.

4.2.3. Highway accidents

There were 31,000 accidents on São Paulo state highways in 2004, 2,300 of which were fatalities (Table 4.2). Most of the 111,000 vehicles involved in these accidents were automobiles (70,000), followed by trucks (24,000). These figures have remained steady in the last few years.

Table 4.2 - Accidents on state highways in São Paulo state

Number of casualties — unit

INJURY SEVERITY	2000	2001	2002	2003	2004
Light	23,741	23,825	24,947	25,338	22,279
Severe	7,781	7,170	7,511	7,355	7,321
Fatal	2,422	2,319	2,504	2,230	2,329
TOTAL	**33,944**	**33,314**	**34,962**	**34,923**	**31,929**

Fatal victims per public or private operators — unit

OPERATORS	2000	2001	2002	2003	2004
DER (public)	NA	NA	1,538	1,314	1,411
Dersa (public)	NA	NA	85	135	118
Concessionaires (private)	NA	NA	881	781	800
TOTAL	**2,422**	**2,319**	**2,504**	**2,230**	**2,329**

Note: NA = not available.

Number of vehicles involved — unit

TYPE OF VEHICLE	2000	2001	2002	2003	2004
Intercity bus	68,570	64,045	66,096	65,971	70,024
Trucks	20,632	19,612	20,461	20,209	23,692
Suburban buses	3,036	3,400	3,208	2,945	3,520
Motorcycles	4,691	5,560	6,297	6,598	10,163
Bicycles	1,258	1,464	1,622	1,876	1,683
Tractors	283	401	187	146	268
Other	6,331	7,685	3,203	1,298	1,821
TOTAL	**104,801**	**102,167**	**101,074**	**99,043**	**111,171**

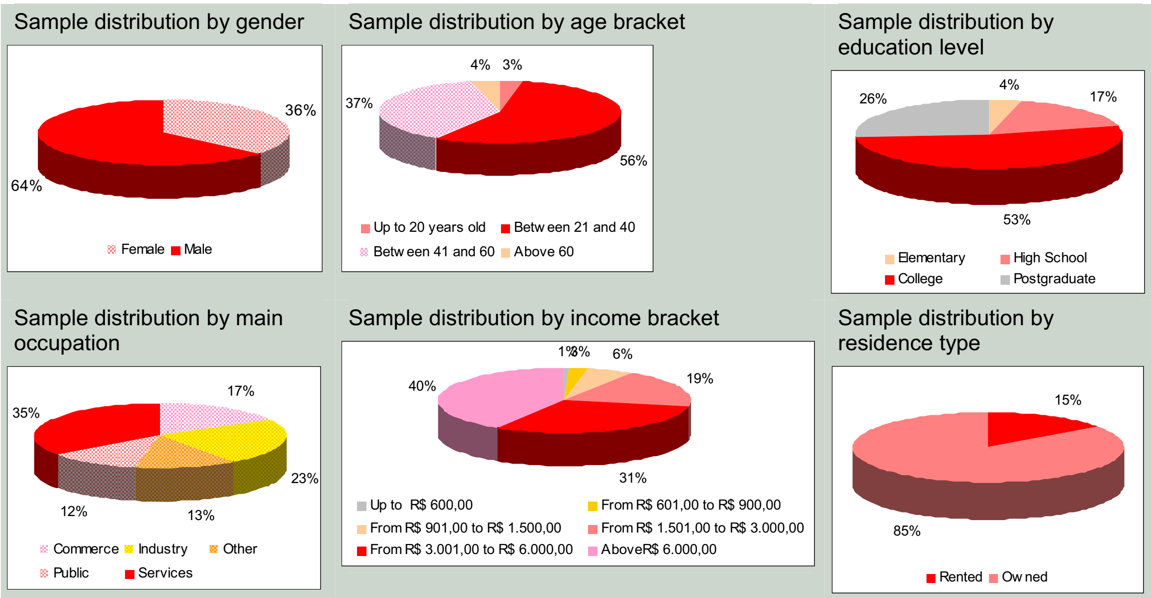
Source: Boletim Estatístico da Secretaria de Transportes do Estado de São Paulo (2005).

4.2.4. Air passenger transport

According to Infraero (Brazilian Airports Agency), 83 million passengers travel by air each year in Brazil. São Paulo state accounts for 34% of these passengers. The airports within the state of São Paulo are managed by Infraero or DAESP (São Paulo State Airport Agency).

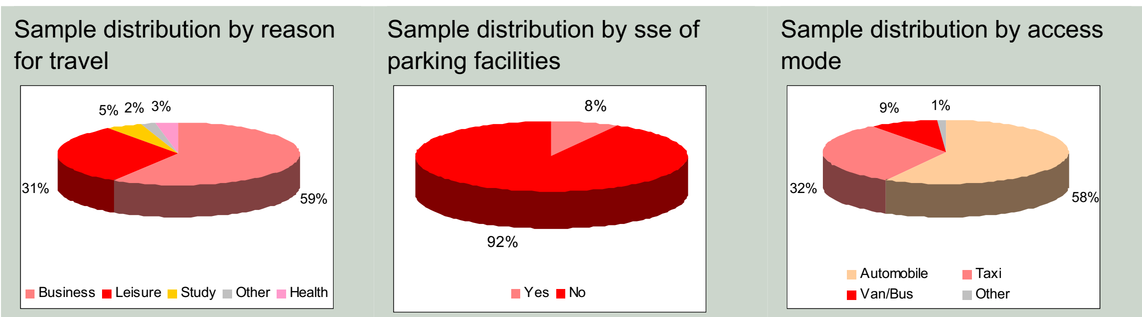
A survey conducted in 12 airports across São Paulo state offering scheduled passenger transportation services showed that demand comes predominantly from passengers aged 21-40 (over 50%), university graduates with relatively high incomes, and most are homeowners. Most of these passengers are employed in the service sector, followed by the industrial and commercial sectors. Most of the fares are paid for by companies, indicating that most travel is business-related (59%), followed by leisure (31%).

Figure 4.2 - Passenger socio-economic profile



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

Figure 4.3 - Travel habits

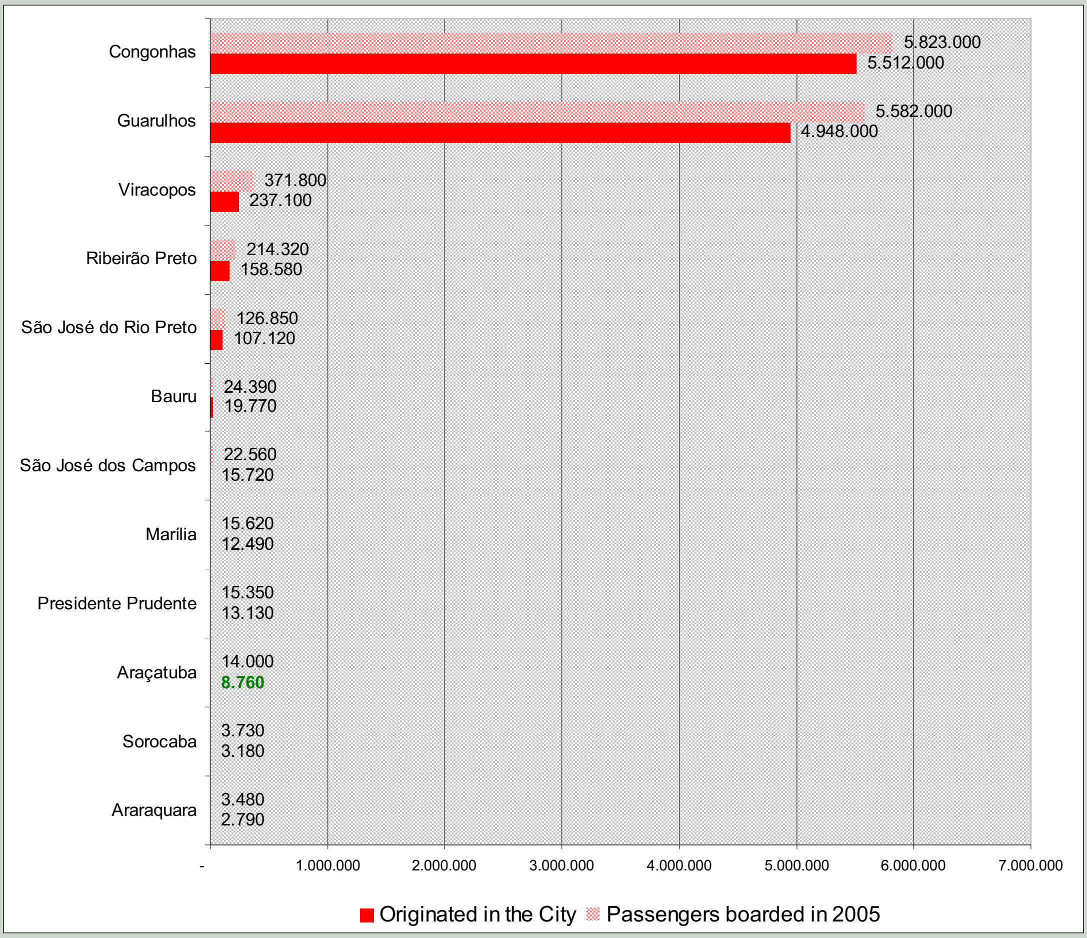


Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

Time of arrival at the airport in advance of travel depends on access times and flight type (domestic or international). As a general rule, the greater the travel distance and difficulties of access, the earlier the arrival at the airport in advance of a flight. Most travelers travel to the airport by car, although most do not make use of the parking facilities.

Figure 4.4 - Demands, pick-up areas and passenger destinations

Passengers who boarded at surveyed airports and passengers who originated their travel in cities



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

In 2005, according to data provided by Infraero, the major São Paulo airports handled 34 million passengers, taking into account boarding, deplaning and connections. The city of São Paulo, with its two airport hubs, Congonhas and Guarulhos, is responsible of 80% of demand generated by the whole of São Paulo state. These airports provide a wide range of flights, both domestic and international, and together share 93% of boarded passengers, most of whom originate in the cities or neighborhoods of the cities where the airports are located.

4.3. CARGO HAULAGE SYSTEMS

4.3.1. State highway network

São Paulo’s highway network spans approximately 200,000 km, 33,000 km of which are paved roads; one-third are rural feeder roads. The road network under state jurisdiction extends nearly 21,500 km, including ring roads and slip roads, while the federal highway network crossing the state spans about 1,000 km. The greatest portion of the network (80%) is operated by the state government. The remaining 20% of the network (4,200 km) is operated by twelve private concessionaires who are responsible for nearly 50% of the volume of state traffic (in terms of vehicles per km). Relations between public agencies and concessionaires are governed by agreements, while inspections are the responsibility of the São Paulo Regulatory Agency for Delegated Public Services (ARTESP).

Table 4.3 - São Paulo state highway network, 2004

HIGHWAYS		STATE	FEDERAL	MUNICIPAL	TOTAL
Non-paved roads		1,257	-	164,158	165.415
Paved Roads	Single lane	14,617	442	11,649	26.708
	Double lane	3,760	610	-	4.370
	Local access and ramps	1,899	NA	NA	1.899
TOTAL		**21.533**	**1,052**	**175,808**	**198,393**

Source: DER

Figure 4.5 - São Paulo state highway network, 2004

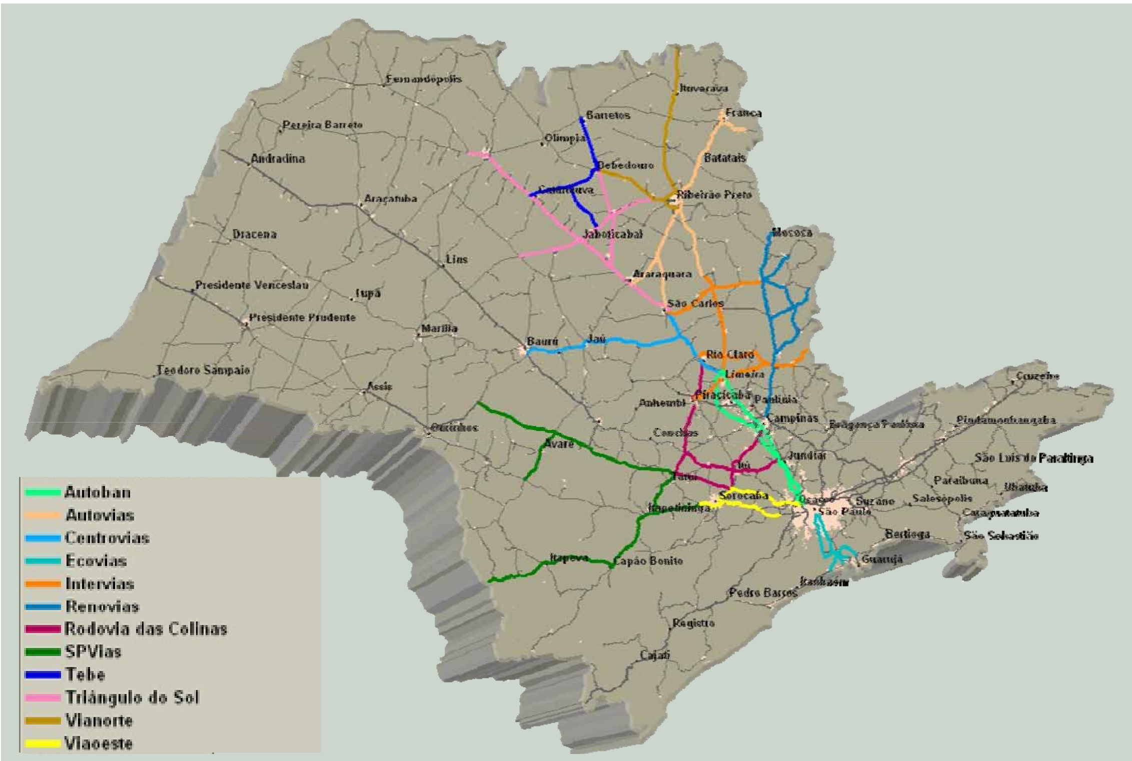
Source: DER

Table 4.4 - São Paulo state highway network concessionaires, 2004

CONCESSIONAIRES	CONCESSION START DATE (30-year contract period)	SINGLE LANE	DOUBLE LANE	TOTAL
AutoBan	1/5/1998	-	316	316
Tebe	2/3/1998	110	46	156
Vianorte	6/3/1998	35	202	237
Intervias	17/2/2000	249	122	371
Controvias	18/6/1998	80	138	218
Triâgulo do Sol	18/6/1998	157	285	442
Autovias	31/5/1998	91	226	317
Renavias	14/4/1998	148	197	345
Viaoeste	30/3/1998	47	115	162
Colinas	2/3/2000	133	166	299
SPVias	10/2/2000	209	297	506
Ecovias	27/5/1998	3	173	176
TOTAL		**1.262**	**2.283**	**3.545**

Source: DER

Figure 4.6 - São Paulo state highway network concessionaires, 2004



Source: ARTESP

The concession-run state highway network is well-maintained, provides an optimal service to users and is in full compliance with environment conservation requirements. Table 4.5 below shows a steady pattern of environmental investment by the private sector, while publicly run DERSA restarted investing in 2003.

Table 4.5 - State of São Paulo environmental investments

EMPRESAS	2000	2001	2002	2003	2004
Private concessions	**2.719,40**	**888,5**	**4.990,00**	**1.531,50**	**1.507,40**
AutoBAn	-	563,9	1.791,7	-	-
Autovias	-	-	-	-	-
Centrovias	-	100,0	222,0	-	-
Ecovias	2.719,4	-	2.756,1	1.507,4	1.507,4
Intervias	-	-	77,7	19,4	-
Renovias	-	-	-	-	-
Colinas	-	-	-	-	-
SPVias	-	-	-	-	-
Tebe	-	-	-	-	-
Triângulo do Sol	-	-	-	-	-
Vianorte	-	24,6	142,5	4,7	-
Viaoeste	-	200,0	-	-	-
Dersa – Public concession	**0,0**	**56,6**	**0,0**	**3.773,3**	**4.619,1**

Source: ARTESP / Dersa / DAESP
Note: Resource applied in Environmental Mitigation and Adjustment.

One stretch of the federal network is still under private administration. The Presidente Dutra BRa 116 highway, a 232 km stretch of road that links the city of São Paulo to the Rio de Janeiro state border, has been leased to a private concessionaire for a 25-year period starting March 1, 1996.

Nearly 36% of the 238,000 daily truck journeys across the state either originate in or are bound for the metropolitan regions of Campinas, São Paulo and Santos. Approximately 20% of all daily truck journeys either start or end in the São Paulo Metropolitan Region.

The primary destinations of the trucks, both empty and loaded, are factories and warehouses, followed by stores, supermarkets and distribution centers. Most truck fleets are owned and operated by private transport companies. Nearly 46% of all vehicles in circulation are empty.

According to the survey, the port of Santos is the destination of nearly 25% of trucks carrying agro industrial products. Interstate thoroughfare journeys account for just 2.7% of all truck journeys.

Table 4.6 - Truck journey origin by cargo type in the São Paulo State Metropolitan Region (journeys/day)

Metropolitan region of origin	Empty	Non-food industrial products	Minerals	Foodstuffs	Chemicals and petrochemicals	Agricultural	Not stated	Agroindustrial products	Steel and metallurgical products	TOTAL
São Paulo	24,708	7,646	2,879	4,135	2,655	2,067	1,349	1,168	226	46,833
Campinas	12,914	3,965	3,882	1,802	1,561	1,561	747	1,003	192	27,627
Baixada Santista	6,839	726	1,677	930	534	659	326	179	340	12,211
MR subtotal	**44,461**	**12,337**	**8,438**	**6,867**	**4,750**	**4,287**	**2,422**	**2,350**	**758**	**86,671**
% MR	40,2	38,5	31,8	44,0	27,7	26,2	30,4	28,7	19,7	36,4
Other regions	66,146	19,684	18,104	8,739	12,372	12,053	5,535	5,844	3,094	151,571
TOTAL	**110,607**	**32,021**	**26,542**	**15,606**	**17,122**	**16,340**	**7,957**	**8,194**	**3,852**	**238,242**

Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

Table 4.7 - Truck journey destination by cargo type in São Paulo State Metropolitan Region (journeys/day)

Metropolitan region of destination	Empty	Non-food Industrial products	Minerals	Foodstuffs	Chemicals and petrochemicals	Agricultural	Not stated	Agroindustrial products	Steel and metallurgical products	TOTAL
São Paulo	18,143	8,597	6,993	3,392	2,800	3,035	2,454	1,086	1,290	47,790
Campinas	13,784	3,422	2,274	2,004	2,640	823	1,012	219	651	26,829
Baixada Santista	2,996	749	1,019	611	526	776	257	1,888	182	9,003
MR sub-total	**34,923**	**12,768**	**10,286**	**6,007**	**5,966**	**4,634**	**3,723**	**3,193**	**2,123**	**83,622**
% MR	31,6	39,9	41,2	35,1	34,7	32,2	37,9	48,4	38,5	35,1
Other Regions	75,685	19,253	14,685	11,115	11,211	9,769	6,099	3,409	3,393	154,620
TOTAL	**110,608**	**32,021**	**24,971**	**17,122**	**17,177**	**14,403**	**9,822**	**6,602**	**5,516**	**238,242**

Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

A large proportion of cargo is transported by road on a daily basis, much of it at peak traffic times. Nearly 64% of cargo transport journeys take place five times a week or more.

Some 48% of cargo is transported by company-owned vehicles while 52% is transported by private haulage companies and self-employed operators.

Haulage companies tend on average to have a better rate of occupation with 1.3 loaded vehicles for every empty vehicle in circulation. For vehicles driven by independent operators, the rate is 1.12, while for those companies that transport their own cargo the rate is 1.11 loaded vehicles for every empty vehicle. This would seem to indicate that outsourcing transport guarantees greater efficiency.

Some 46% of cargo of 10 tons or more and 67% of all cargo is transported in 2 or 3-axle vehicles. Most independent truck drivers operate 2 or 3-axle vehicles, although on average their cargo is lighter than that transported by company-owned vehicles. There are a few larger 4-axle vehicles in circulation; they tend to belong to the manufacturing companies or to haulage companies. In the metropolitan regions, smaller vehicles are more common.

Data for São Paulo state indicate that the age of the vehicles in circulation varies widely. Some vehicles on the roads are 55 years old! However, 80% of the truck fleet is less than 20 years old and 60% less than 10 years old. The newest vehicles tend to belong to manufacturing and haulage companies, while the oldest tend to be operated by independent drivers.

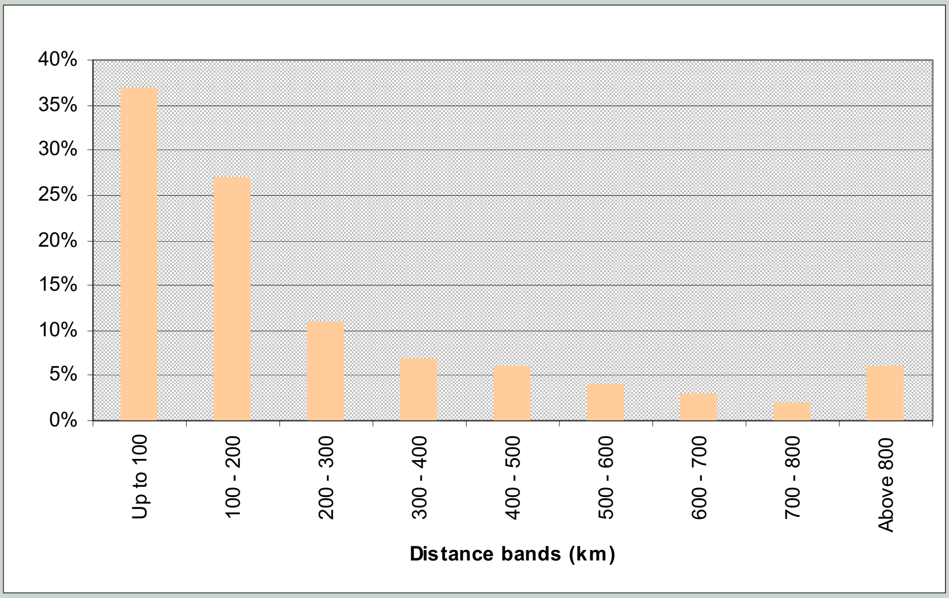
Two-thirds of all journeys undertaken are less than 200 km; only 6% of journeys cover distances over 800 km. The longest journeys are undertaken by larger vehicles. The longest distances are for the transport of agro industrial products.

Table 4.8 - Truck journeys – average journey distances by cargo type

CARGO CLASS	AVERAGE DISTANCE (km)
Agro industrial	389
Not stated	319
Non-food industrial products	315
Agricultural	313
Steel and metallurgical products	303
Foodstuffs	282
Minerals	264
Chemicals and petrochemicals	251
LOADED TRUCKS	**295**
Empty	199
GLOBAL	**251**

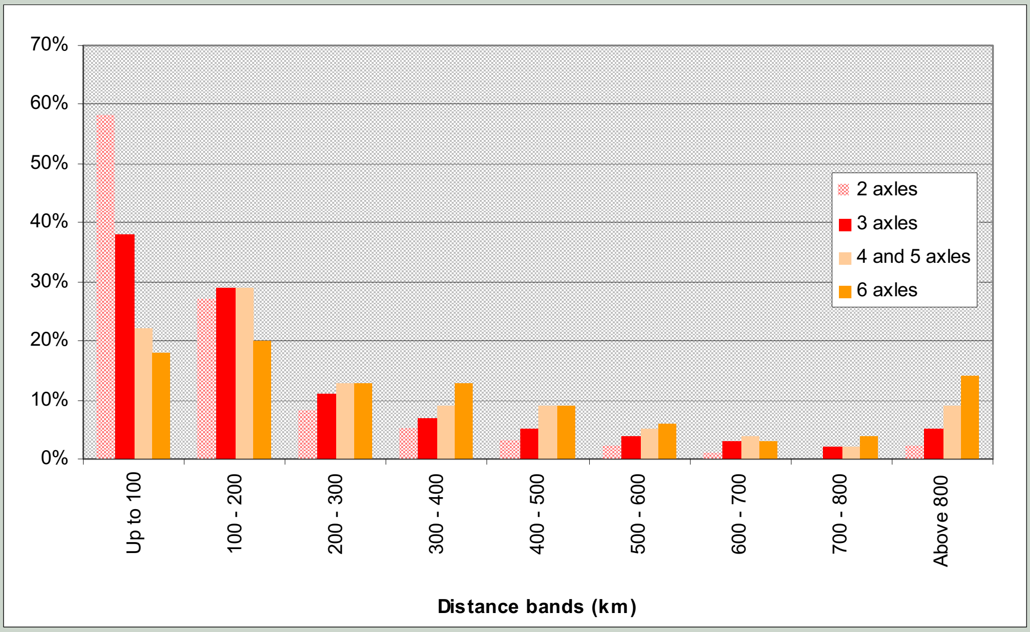
Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo

Figure 4.7 - Truck journeys – average journey distances distribution



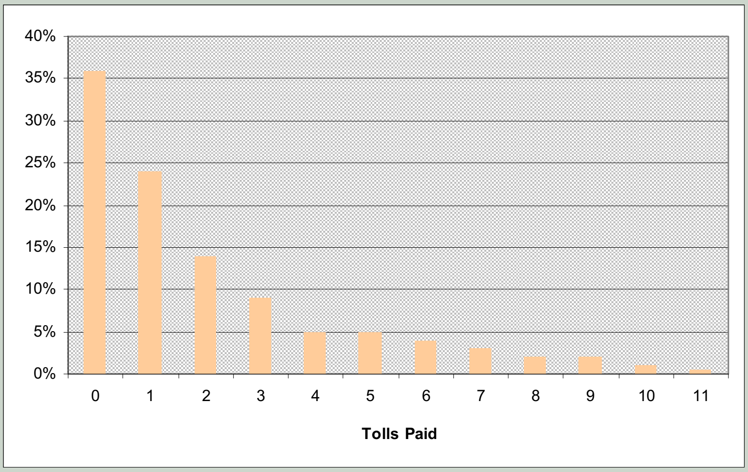
Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

Figure 4.8 - Truck journeys – average journeys distances by cargo type



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

Figure 4.9 - Truck journeys – number of tolls paid



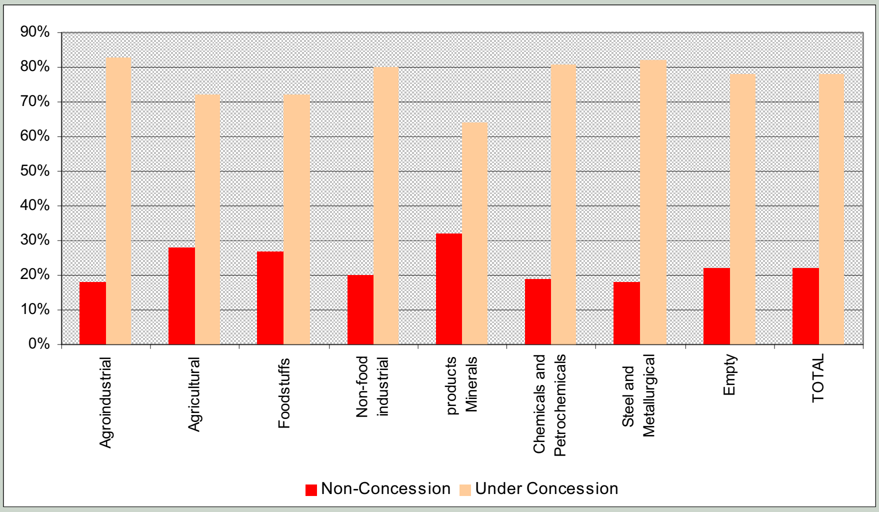
Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

4.3.2. Truck journey distribution by road network and cargo type

Nearly 36% of all journeys undertaken by truck on São Paulo state highways are toll-free. The privately-operated highway network is used mainly for the transport of high value-added products while low value products, such as minerals (10% of daily journeys in the state) tend to be transported on the public network.

It is worth noting that 80% of vehicles transporting agro industrial goods use at least one stretch of privately-operated road network; the figure for the transport of mineral products is 65%.

Figure 4.10 - Truck journey distribution by road network and cargo type



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

Some 82% of truck journeys that start in the São Paulo Macrometropolis use the privately-operated highway network. Of the 114,622 daily truck journeys that begin in the Macrometropolis, nearly 82% use stretches of privately-operated road networks, while 76% of journeys that begin in the São Paulo Metropolitan Region use the privately-operated road network.

Table 4.9 - Truck journeys – origin by network type in São Paulo State Metropolitan Region

METROPOLITAN REGION OF DESTINATION	ROADWAY NETWORK TYPE				TOTAL	
	Non-concession		Under concession			
	Trips	%	Trips	%	Trips	%
Baixada Santista	1,221	10,0	10,991	90,0	12,211	5.1
Campinas	3,340	12,1	24,288	87,9	27,628	11.6
São Paulo	11,474	24,5	35,358	75,5	46,832	19.7
Outside Metropolitan Region	4,312	15,4	23,640	84,6	27,951	11.7
Macrometropolis sub-total	**20,347**	**17,8**	**94,277**	**82,2**	**114,622**	**48.1**
Outside the Macrometropolis	36,479	29,5	87,140	70,5	123,619	51.9
TOTAL	**56,826**	**23,9**	**181,417**	**76,1**	**238,241**	**100.0**

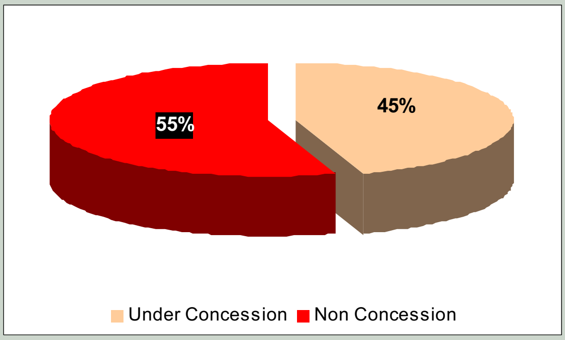
Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

It is estimated that the daily volume of cargo traffic in São Paulo state is about 60 million vehicles kilometers. Even though the privately-operated portion of the network accounts for no more than 20% of the state's entire paved network, cargo transport accounts for a significant volume of the traffic utilizing the network (about 45% of the total).

This can be explained by the fact that the highways able to absorb the largest volume of traffic are privately operated. Shorter and more frequent trip interchanges tend to happen in the macrometropolitan area, which is mostly served by concession roads, on the other side longer and less frequent trips cover the whole state area where public ownership of road prevails.

Table 4.10 - Truck journeys – system type – transport distribution in vehicles.km

SYSTEM	Performance (vehicle.km)	%
Under concession	26,619,896	45.0
Non-concession	33,071,025	55.0
TOTAL	**59,690,921**	**100.0**



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

4.3.3. Airport network

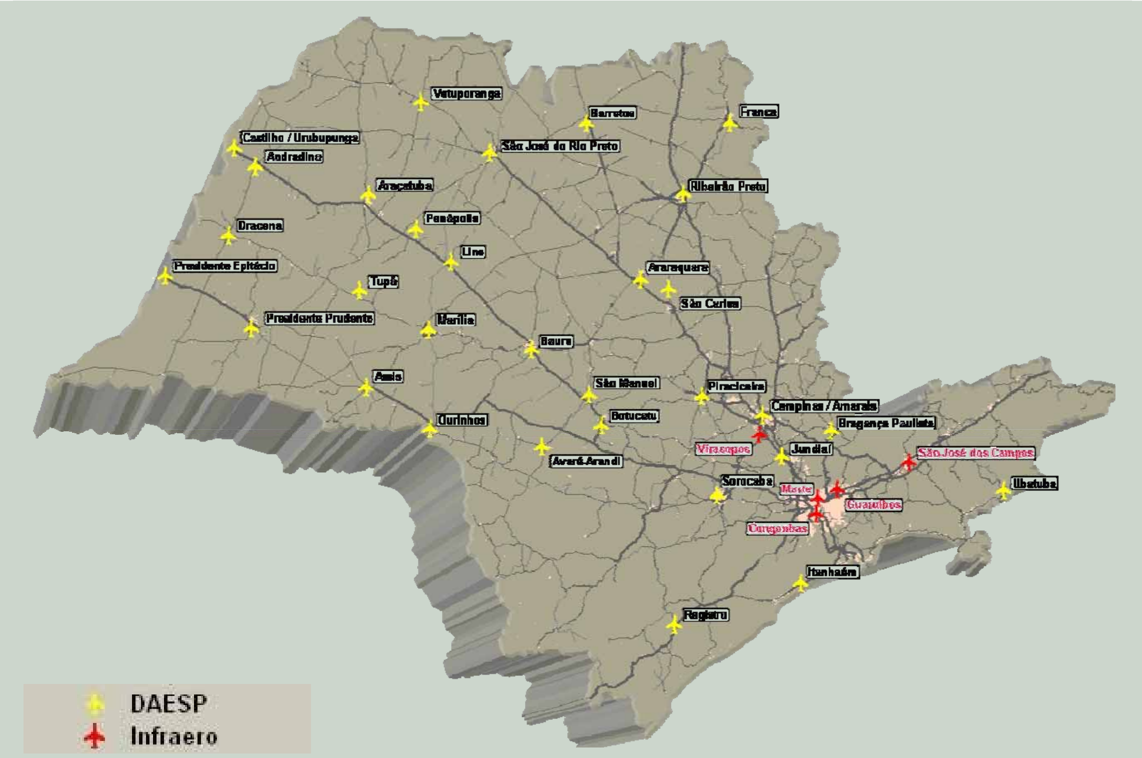
The São Paulo state airport network includes 31 airports managed by the state government and five airports managed by Infraero. Major airport hubs include São Paulo International Airport, in Guarulhos and Viracopos Airport, in Campinas which, in addition to passenger transport plays a key role in transporting cargo to domestic and international markets.

Table 4.11 - São Paulo state airports, 2004 unit

AIRPORT MANAGEMENT	TOTAL
São Paulo State Government (DAESP)	31
Infraero	5
TOTAL	**36**

Source: DAESP – Airport Department of the State of São Paulo.

Figure 4.11 - São Paulo state airports, 2004



Source: DAESP – Airport Department of the State of São Paulo.

As illustrated in Table 4.12 and Table 4.13, in 2004 airports managed by the São Paulo State Airport Department handled 763,000 passengers while the airports managed by Infraero (Federal Government) served 27.3 million passengers.

Passenger and cargo traffic transiting through DAESP-administered airports has decreased because of the closure of several less profitable regional routes and their transfer to routes served by Infraero Airports.

Table 4.12 - São Paulo airport network – circulation in the DAESP airports

MANAGEMENT	UNIT	2000	2001	2002	2003	2004
Boarded/deplaned passengers	pax	1,077,885	1,123,866	1,001,490	709,984	768,179
Landings and takeoffs	units	358,110	370,613	338,839	276,440	262,402
Loaded/offloaded cargo	kg	5,463,189	4,912,929	3,850,322	2,646,480	3,212,223
Loaded/offloaded post office cargo	kg	6,609,755	6,981,813	4,785,317	1,842,665	1,222,706

Source: DAESP – Airport Department of the State of São Paulo

Table 4.13 - São Paulo airport network – circulation in Infraero airports

MANAGEMENT	UNIT	2000	2001	2002	2003	2004
Domestic						
Boarded/deplaned passengers	pax	18,172,900	19,707,500	19,470,726	17,555,577	20,091,229
Landings and takeoffs	units	516,654	547,388	511,500	411,249	411,894
Loaded/offloaded cargo	kg	231,990,091	215,601,407	206,748,985	205,573,344	233,327,313
Loaded/offloaded post office cargo	kg	40,956,209	20,166,949	13,074,896	28,602,643	30,515,780
International						
Boarded/deplaned passengers	pax	6,467,207	6,153,037	5,906,897	6,928,709	7,358,581
Landings and takeoffs	units	73,454	72,994	66,052	67,162	70,523
Loaded/offloaded cargo	kg	435,985,824	415,061,104	395,632,877	419,104,855	476,206,165
Loaded/offloaded post office cargo	kg	6,516,861	5,687,660	6,102,915	10,110,575	9,936,694

Source: DAESP – Airport Department of the State of São Paulo.

Note: Data supplied by Infraero.

Table 4.14 and Graph 4.1 show that in 2005, 425 tons of cargo were handled, 64% by the São Paulo International Airport in Guarulhos.

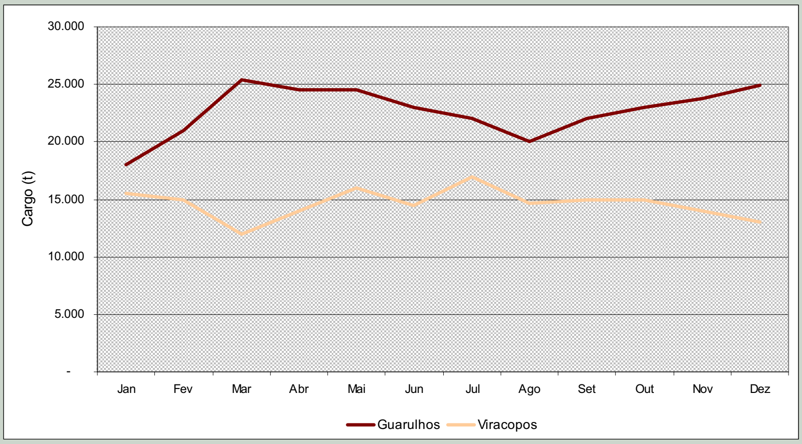
Table 4.14 - São Paulo state – international cargo traffic airports, 2004

AIRPORTS	CARGO (t)
Guarulhos	270,885
Viracopos	175,183

Source: Infraero

Graph 4.1 - Guarulhos and Viracopos airports

Monthly international cargo traffic (2005)



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

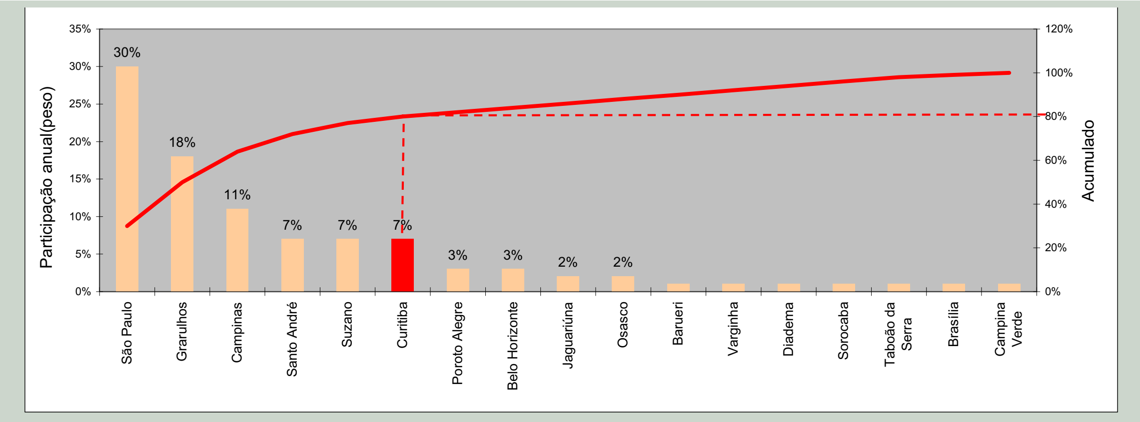
Table 4.15 shows that the primary points of origin and destination for air cargo were companies, customs warehouses and transport haulage companies.

Figure 4.12 and Figure 4.13 show that the destination of most of the goods imported through Guarulhos and Viracopos airports are customs warehouses – 22% and 19% respectively. Company exports account for the lion's share of export cargo handled by Guarulhos (31%) and Viracopos (26%) airports.

Table 4.15 - Origin and destination of cargo handled by Guarulhos and Viracopos airports

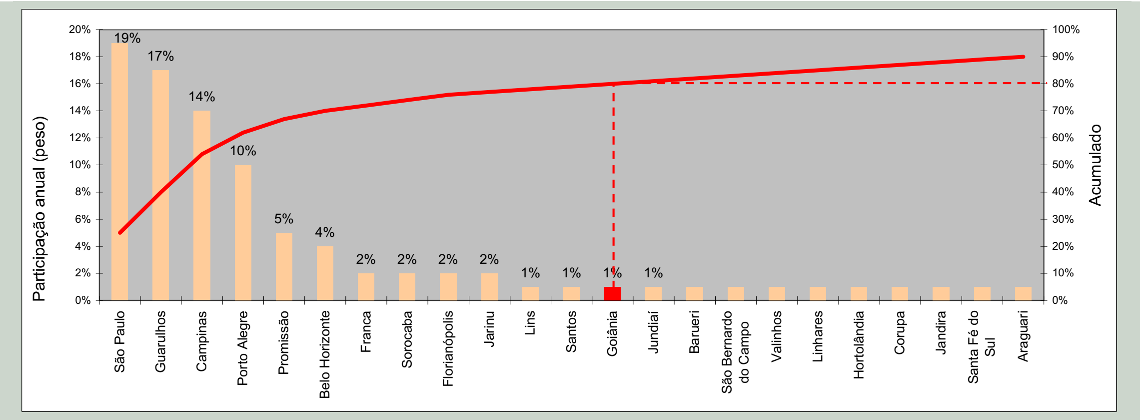
ORIGIN / DESTINATION	GUARULHOS		VIRACOPOS	
	Exports (%)	Imports (%)	Exports (%)	Imports (%)
Distribution center	2	9	2	15
Company	31	4	26	9
Customs warehouse	8	22	5	19
Factory	3	0	1	7
Transport haulage company	14	6	5	5
Other	0	3	1	6
TOTAL	**58**	**44**	**40**	**61**

Figure 4.12 - Destination of cargo imported through Guarulhos Airport



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

Figure 4.13 - Origin of cargo exported through Guarulhos airport



Source: Pesquisa Origem e Destino do Transporte Rodoviário e Aeroviário do Estado de São Paulo.

4.3.4. Maritime port terminals

São Paulo's maritime port infrastructure includes the ports of Santos and São Sebastião.

Santos is a key port for São Paulo and Brazil since it handles nearly one-quarter of Brazil's foreign trade. It is managed by the São Paulo State Docks Company (CODESP), a jointly-owned government and private company that comes under the jurisdiction of the federal government. As part of attempts to modernize the port (Law 8,630/93), most of the areas and facilities at Santos have been put out to public tender and operations transferred to the private sector. As a result, there have been significant investments in equipment and warehousing facilities resulting in greater efficiency, especially in the container transport sector where costs have been substantially reduced. In 1997, the cost of shipping one container through the Port of Santos was US$ 313, by 2001 this had gone down to US$ 171. This saving was made possible by a reduction in costs of R$ 228 million in 1998 to R$ 131 million in 2001 (Revistas Problemas Brasileiros N 353 _ SESC-SP).

Figure 4.14 - São Paulo state port terminals, 2004

Source: Boletim Estatístico da Secretaria de Transportes do Estado de São Paulo (2005).

Currently, there are 87 certified port operators working in the port of Santos. Container transport has continued to expand. The growth rate of 25% p.a. in the period from 2000 to 2004 far exceeds the 11.6% per annum rate of increase observed overall for cargo.

Santos is the primary commercial port. It handles 67 million tons of cargo per year. The port of São Sebastião manages imports of crude oil. In 2004 it handled 53 million tons of crude oil destined for the state's refineries (Table 4.16). Exports grew significantly during the 2000-2004 period on account of the devaluation of the Real *vis-a-vis* foreign currencies including the US Dollar and the Euro. At the same time, strong external demand for agricultural commodities, food and similar products helped to expand exports. Imports did not increase significantly on account of high interest rates which reduced levels of investment in machinery and related capital assets.

Table 4.16 - São Paulo maritime port terminals

Circulation tons

	2000	2001	2002	2003	2004
São Sebastião	**45,695,191**	**46,937,494**	**52,774,257**	**52,050,718**	**53,135,933**
Commercial docks	468,026	423,394	372,781	448,049	368,212
Almirante Barroso private terminal	45,227,165	46,514,100	52,401,476	51,602,669	52,767,721
Santos	**43,084,383**	**48,161,593**	**53,474,268**	**60,077,073**	**67,609,753**
Long distance	35,464,767	40,884,414	45,681,764	50,343,295	58,005,326
Coastal navigation	7,619,616	7,277,179	7,792,504	9,733,778	9,604,427
	2000	**2001**	**2002**	**2003**	**2004**
São Sebastião - commercial docks	**468,026**	**423,394**	**372,781**	**448,049**	**368,212**
General cargo	23,474	16,541	43,374	28,529	37,225
Vehicles	143	1,294	-	-	12,447
Bulk vegetable	134,890	148,187	88,854	103,769	79,003
Bulk mineral	309,506	256,004	240,341	315,751	237,699
Containers, bulk liquids and animals	13	1,368	212	-	1,838
Santos	**43,084,383**	**48,161,593**	**53,474,268**	**60,077,073**	**67,609,753**
General cargo	**13,216,385**	**14,775,074**	**18,159,264**	**20,801,647**	**26,193,786**
Bulk solids	**19,204,220**	**22,248,446**	**23,979,655**	**26,299,235**	**27,898,592**
Sugar	2,947,152	4,529,966	5,368,616	6,279,971	7,846,257
Fertilizers	2,573,170	2,103,541	2,395,107	2,943,769	3,067,253
Coal	2,768,138	2,733,548	2,827,092	2,242,281	2,867,122
Soybean – in grains and pellets	4,297,028	6,163,519	7,712,756	8,291,105	9,471,998
Others	6,618,732	6,717,872	5,676,084	6,542,109	4,645,962
Bulk liquids	**10,663,778**	**11,138,073**	**11,335,349**	**12,976,191**	**13,517,375**
Fuel oil	2,043,738	2,946,470	1,092,957	4,776,784	4,679,174
Diesel oil	1,396,292	1,101,014	1,083,256	1,662,016	1,496,190
Citric juices	907,885	1,042,674	1,103,456	1,244,655	1,281,385
Alcohol	622,508	579,209	913,071	730,271	984,401
Others	106,321	-	-	-	859,252
TOTAL	**43,552,409**	**48,584,987**	**53,847,049**	**60,525,122**	**67,977,965**
	2000	**2001**	**2002**	**2003**	**2004**
São Sebastião	**468,026**	**423,394**	**372,781**	**448,049**	**368,212**
Imports	459,690	415,397	354,145	443,389	348,285
Exports	8,336	7,997	18,636	4,660	19,927
Santos	**43,084,383**	**48,161,593**	**53,474,268**	**60,077,073**	**67,609,753**
Imports	20,730,572	20,131,123	19,651,784	20,950,407	21,799,925
Exports	22,353,811	28,030,470	33,822,484	39,126,666	45,809,828
TOTAL	**43,552,409**	**48,584,987**	**53,847,049**	**60,525,122**	**67,977,965**

Source: Dersa / CODESP.

4.3.5. Railway network

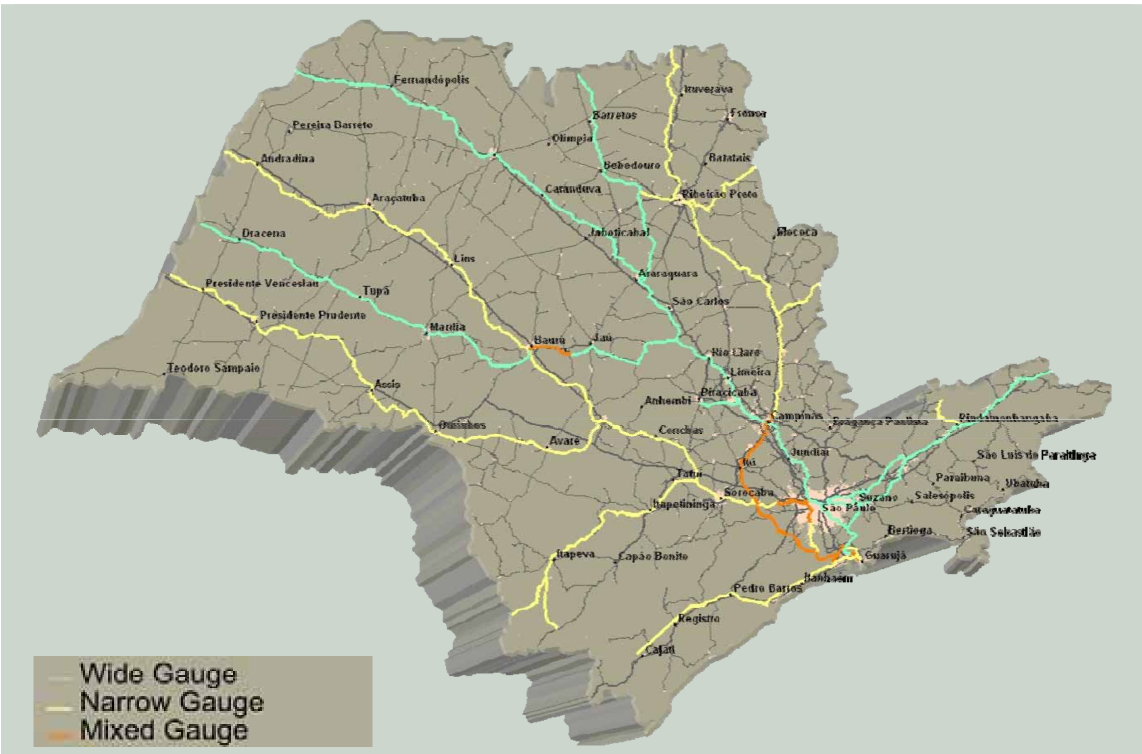
São Paulo state is served by a 5,104 km railway network which includes metric, wide and mixed gauge tracks. The railway network, originally managed by São Paulo state, was incorporated into the federal network in 1998 and then transferred to private operators the following year. Following privatization, management of the state network was restructured and finally incorporated by Latin American Logistics (ALL), whose primary task is to provide support for the growing volume of agricultural cargo shipped from Mato Grosso and other Brazilian states to the port of Santos.

Table 4.17 - São Paulo state railway network, 2004

TRACK GAUGE	LENGTH (km)
Metric (1.00m)	2,694
Wide (1.60)	2,014
Mixed (1.00 / 1.60m)	396
TOTAL	**5,104**

Source: Secretaria dos Transportes.

Figure 4.15 - São Paulo state railway network, 2004



Source: Secretaria dos Transportes.

The section of the railway network originally managed by the Federal Railway Network has now been transferred to MRS Logistics S.A. whose primary task is to connect the states of Rio de Janeiro and Minas Gerais to the port of Santos and the São Paulo and Campinas metropolitan areas.

Privatization of the railway cargo service has yielded several benefits. It has enabled the rail network to recover some of the traffic that had migrated to the road network. In 2004 the railway system transported nearly 60 million tons of cargo over nearly 20 billion ton kilometers (Table 4.18).

Table 4.18 - São Paulo railways transport operators **Million TKU**

VEHICLE TYPE		2000	2001	2002	2003	2004
Generation(1)		**2,708**	**3,226**	**3,520**	**3,191**	**3,580**
Brasil Railways	Ferroban (*)	1,720	2,273	1,689	1,463	1,486
	Novoeste (*)	-	16	239	298	358
	Portofer	47	36	90	84	130
Latin America Logistics		231	213	227	132	144
MRS		454	417	629	494	619
FCA		257	271	686	721	844
Traction(2)		**10,662**	**13,321**	**15,657**	**16,353**	**17,076**
Brasil Railways	Ferroban (*)	2,530	3,160	1,880	1,573	1,603
	Novoeste(*)	1,241	2,865	4,211	4,958	4,973
	Portofer (*)	356	312	394	392	394
Latin America Logistics		423	397	387	349	346
MRS		4,267	4,915	6,430	6,520	7,124
FCA		1,846	1,672	2,345	2,561	2,636

(*) Presently owned by Latin America Logistics.
(1) Generation refers to cargo that originated within the specific concession network.
(2) Traction refers to cargo that originated outside the specific concession network.
Source: ALL / Brasil Ferrovias / MRS / FCA.

Table 4.19 - São Paulo railways cargo transportation Thousand TU

VEHICLE TYPE		2000	2001	2002	2003	2004
Generation (1)		**13,391**	**15,248**	**15,427**	**13,931**	**14,969**
Brasil Railways	Ferroban (*)	5,157	6,406	5,159	4,146	3,876
	Novoeste(*)	-	23	367	457	550
	Portofer	112	86	115	154	231
Latin America Logistics		2,321	2,264	2,378	1,623	1,749
MRS		5,176	5,852	6,100	6,261	7,108
FCA		625	618	1,308	1,289	1,455
Traction (2)		**31,929**	**39,595**	**42,938**	**42,260**	**44,083**
Brasil Railways	Ferroban (*)	7,114	8,417	6,276	5,023	4,906
	Novoeste (*)	1,406	3,175	4,756	5,609	5,659
	Portofer	718	643	717	559	599
Latin America Logistics		3,432	3,468	3,619	3,009	3,012
MRS		14,985	18,806	22,341	22,511	24,567
FCA		4,274	5,086	5,230	5,590	5,341

(*) Presently owned by Latin America Logistics.

(1) Generation refers to cargo that originated within the specific concession network.

(2) Traction refers to cargo that originated outside the specific concession network.

Source: ALL / Brasil Ferrovias / MRS / FCA.

4.3.6. Railway accidents

There have been about 750 accidents involving cargo trains.

Table 4.20 - São Paulo railways network accidents unit

VEHICLE TYPE		2000	2001	2002	2003	2004
Brasil Railways	Ferroban (**)	377	355	360	242	297
	Novoeste (**)	272	222	234	248	317
	Portofer	17	20	20	21	27
MRS		134	97	80	74	59
FCA		NA	NA	38	27	45

Source: ALL / Brasil Ferrovias / MRS / FCA.

Note: NA = not available/ (*) Data provided by Portofer – monthly averages.

(**) Presently owned by Latin America Logistics.
The data provided by Ferroban and Novoeste cover the whole industrial network within São Paulo State.

4.3.7. Pipelines

The pipeline network both in São Paulo state and Brazil is used for the transport of hydrocarbons. Most of the pipeline network is today operated by Petrobras. The earliest pipelines were built by Comgás in the early 20th century; and later by Petrobras in the 1950s. During the 1990s, these companies expanded their respective networks.

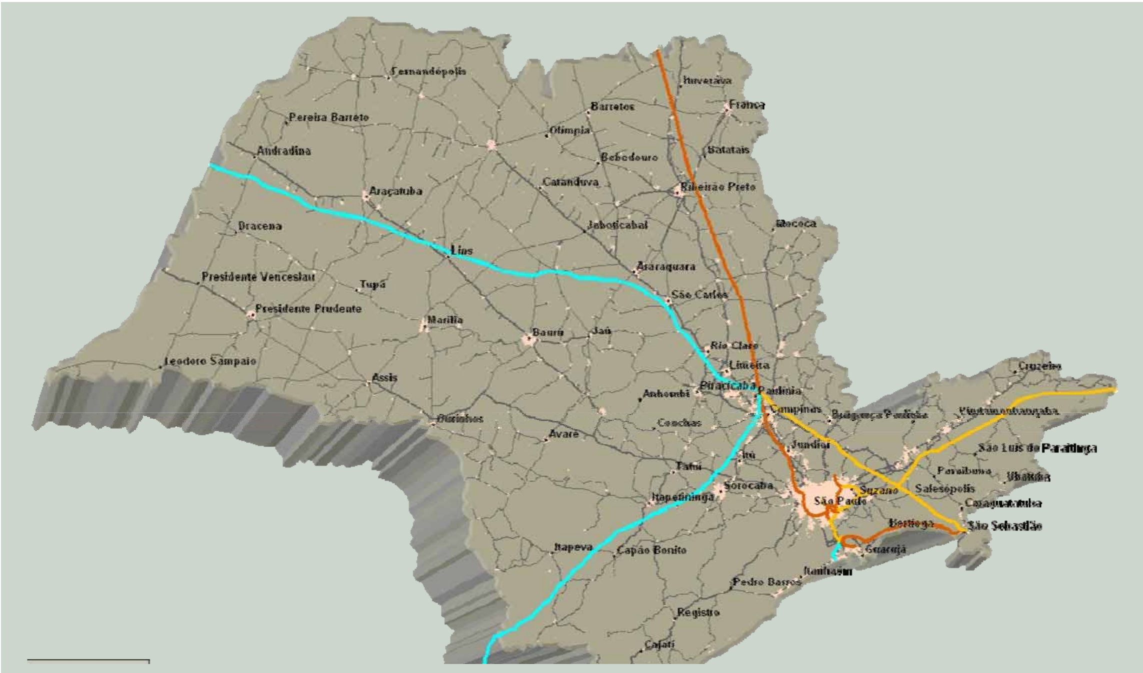
Table 4.21 - São Paulo State pipeline network, 2004

TIPO	TOTAL (km)
Gas pipeline	4,723
Oil pipeline	1,856
TOTAL	**6,579**

Source: Transpetro / CSPE.

In São Paulo state, pipelines pump petroleum and crude oil from the São Sebastião Sea Port to refineries located in Cubatão, Paulínia and São José dos Campos. The state's pipeline network also distributes gasoline, diesel, naphtha and fuel oil, through Petrobras' bases and the bases of other companies involved in the storage and distribution of derivatives.

Figure 4.16 - São Paulo State pipeline network, 2004



Source: Secretaria dos Transportes.

The Brazil-Bolivia pipeline extends approximately 3,150 km, 1,042 km of which cross São Paulo state. It connects the neighboring country's oil wells to major Brazilian consumer markets, thereby enabling investments in the thermo-electric and industrial segments, particularly in São Paulo state.

5

Passenger Transportation in the São Paulo Metropolitan Region

5. PASSENGER TRANSPORTATION IN THE SÃO PAULO METROPOLITAN REGION

This chapter examines passenger transport within the São Paulo Metropolitan Region. Section 5.1 provides some historical and economic context, sections 5.2 to 5.5 describe historical developments and trends related to the provision of mobility within SPMR using origin-destination surveys conducted at 10 yearly intervals; sections 5.6 and 5.7 consider the most recent data in more detail.

5.1. OVERVIEW AND OBJECTIVES

The state of São Paulo is the wealthiest state in the country; the bulk of the state's wealth is concentrated in the São Paulo Metropolitan Region. The city of São Paulo is one of 39 municipal areas in the SPMR, although it dominates economically and is often referred to as the business hub of Latin America.

The first human settlement was established in 1554, 20 km south of the current historical city center. It remained a small commercial center until the middle of the 19th century, when it began to experience economic prosperity, dominated by coffee production and export through the nearby port of Santos. At the beginning of the 20th century a sharp decline in international coffee prices caused a slump in both production and economic prosperity. As a result, local entrepreneurs turned to industry as the future of São Paulo; this resulted in a major influx of overseas immigrants to the city. By the middle of the 20th century the region was the main industrial center in the country; in the late 20th century it transitioned progressively towards a service-based economy. In 2003, 56.5% of all jobs were service-related compared to 19.2% industry-related jobs (SEADE).

The SPMR is the largest population center in the country, with 20 million inhabitants, 72% more than the second largest metropolitan area – Rio de Janeiro. Annual population growth was very high in the 1960-1980 period (5.0%) but eventually decreased to 2.1% (1980-1991), then to 1.7% (1991-2000) before leveling off at 1.3% (2001-2007). In the same period, average population density more than doubled, from 1,024 inhabitants/km^2 in 1970 to 2,465 inhabitants/km^2 in 2007 (Emplasa, 2008).

The last decades have seen an aging population: the proportion of people aged between 16 and 64 years increased from 63.5% in 1980 to 68.8% in 2006, while the proportion of people aged 65 years or more increased from 3.6% to 6% (Emplasa, 2008).

Most households have access to public services: electricity (100%), garbage collection (100%), water (99%), telephone (90%) and sewage collection (82%) (Emplasa, 2008).

In economic terms, in 2004 the state of São Paulo and the SPMR were responsible, respectively, for 30.9% (US$ 187 billion) and 15.6% (US$ 94 billion) of Brazilian GDP (US$ 604 billion). This means that the GDP of the SPMR is about half that of the state of São Paulo.

In 2007 there were 8,116,904 motorized vehicles registered in the SPMR, including 6,069,000 automobiles and 876,000 motorcycles. There were approximately 314 and 45 cars and motorcycles respectively per thousand inhabitants.

The region has become the most important economic and political region in the country. Average incomes, although high by Brazilian standards, remain relatively low, with 58% of people earning less than US$ 350 a month. This pattern is highly skewed in favor of the upper income strata: while the poorer 10% of workers earn 1.39% of the total income, the wealthier 10% earn 40.19% (Matos, 2005).

The region has also faced increasing transport problems, with access to private transport unevenly distributed among social groups and classes. Most of the transport-related problems are the result of a sharp increase in the use of private transport and a corresponding decrease in the use of public transport. Among the consequences are severe congestion, high levels of atmospheric pollution and high numbers of traffic fatalities.

5.2. MOBILITY CHANGES FROM 1967 TO 2002

Quantitative data relating to mobility come from four origin-destination surveys performed at ten-year intervals between 1967 and 1997, and a complementary survey conducted in 2002. The main variations in social and economic data are summarized in Table 5.1. They show that during this period the population multiplied by a factor of 2.6, school enrollments rose by a factor of 5, the number of jobs increased by a factor of 2.9, and the number of motorized journeys grew by a factor of 3.4.

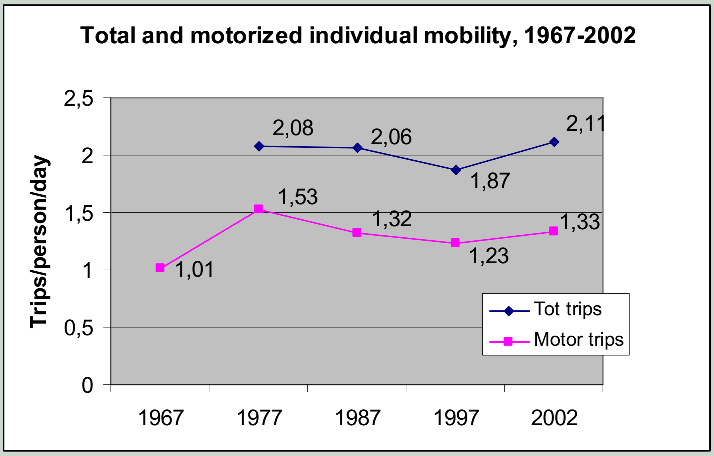
Thus, the school enrollment rate per inhabitant experienced a huge increase, while the number of jobs per person remained nearly constant. Overall mobility (journeys per person per day) in the SPMR remained constant between 1977 and 1987; it decreased by about 10% in the following decade, to increase once again in the final period. Motorized mobility increased by 50% between 1967 and 1977 and then decreased to 1.33 in 2002 (Figure 5.1). Although no detailed survey was carried out, it is likely that the explanation for this lies with the tremendous economic development experienced during the first decade of the survey, which was followed by a period of economic crisis during the second decade (high inflation, lower average salaries). Average travel times by motorized modes of transport remained constant (44 minutes).

Table 5.1 - Social and economic changes in the SPMR, 1967-1997

YEAR	POP (000'S)	EDUCATION		JOBS		WALKING TRIPS (000´S)	MOTORIZED TRIPS (000´S)	MOBILITY (TRIPS/PER/DAY)		
		students (000's)	enroll/ inhab	(000's)	jobs/ inhab			All trips	Walk trips	Motor trips
1967	7,097	1,088	0.15	2,736[1]	0.39	---[2]	7,163	----	----	1.01
1977	10,273	2,523	0.25	3,960	0.39	5,641	15,758	2,08	0,55	1.53
1987	14,248	3,676	0.26	5,647	0.40	10,658	18,749	2,06	0,75	1.32
1997	16,792	5,011	0.30	6,959	0.41	10,812	20,620	1,87	0,64	1.23
2002	18,345	5,448	0,30	7,983	0,44	14,194	24,466	2,11	0,77	1,33

1- estimated. 2- not included in the 1967 survey.
Source: CMSP (1998 and 2002).

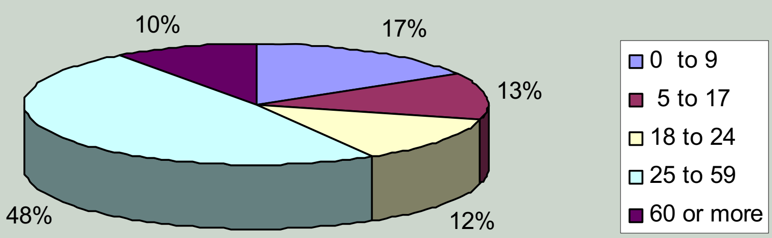
Figure 5.1 - Mobility in the SPMR, 1967-2002



Source: CMSP (1998 and 2002)

There have been other important changes in patterns of mobility that are also worth highlighting. First, gender differences have narrowed with female mobility approaching that of males. Second, age distribution among the population changed significantly in recent decades as the population aged. Third, the tertiary sector (commerce, services) is now the dominant employer. Its share has grown from 68.7% in 1987 to 77.4% in 1997, while industry has declined from 28.7% to 16.3%. Such changes are directly attributable to changes in mobility given the different mobility rates attached to each economic activity. In addition, spatial distribution of employment has also changed. Between 1987 and 1997, new employment opportunities were offered in sub-centers, especially in the tertiary sector, allowing for shorter home-to-work distances and hence to the replacement of motorized journeys with pedestrian ones. Such opportunities include both formal activities and informal or temporary ones, all of which have different mobility requirements.

Figure 5.2 - SPMR population age distribution, 2004



Source: Emplasa (2008)

Journey purposes too have changed: the number of journeys to and from places of employment decreased from 50% in 1967 to 39% in 2002, while the number of journeys to and from schools rose from 12.3% to 29% in the same period. It is worth noting that in 1997 a large proportion of the workforce (18% – 1.2 million) worked from home, a possible indication of a growing informal sector (CMSP, 1998).

5.3. MOBILITY FACTORS AND CHANGES

The complex changes that have taken place have also resulted in changes in mobility that remain difficult to explain. Some of these are described below.

(a) The mobility "gap": there remains a large difference in average mobility within social classes and groups. The overall mobility ratio (trips/person/day) between low-income and high-income extremes in 2002 was 1:2.2, while the ratio for motorized mobility was 1:3.5, typical of developing country conditions. Low-income people face severe restrictions to travel, while the wealthy, with access to cars, enjoy mobility levels similar to those of European countries.

(b) A new mobility pattern: there has been a shift in mobility towards more women users and more car users. The female to male mobility ratio increased from 0.76:1 in 1987 to 0.82:1 in 2002; 75% of the increase in the number of journeys between 1987 to 1997 were made by car. This would seem to indicate that the SPMR is moving towards greater levels of private car ownership and travel (rather than collective ownership and travel), with serious implications for long-term sustainability. .

(c) Urban changes: changes in mobility could be related to changes in urban land-use patterns, including changes in the physical distribution of services and commercial activities and the creation of new suburbs.

(d) The impact of the automobile: first-time acquisition of a car has a huge impact on family mobility with 40% of journeys being made in the new car (CMSP, 1998). Private car use increases as income increases. Car-ownership also allows for multiple, inter-connected journeys which account for about 35% of all car journeys in the region.

5.4. THE USE OF TRANSPORT MODES

Walking has always been a very important means of travel – accounting for one-third of all trips – while the use of bicycles has always been very small, around 1% of all journeys undertaken in 1997. The use of private transport increased from 26% in 1967 to 53% in 2002. Accordingly, bus use decreased from 64% to 47% in the same period. The subway, which was opened in 1974, has attracted an increasing number of passengers. The train system, dogged by lack of investment and poor levels of service, has continued to meet only a small share of demand (Table 5.2).

There has been a dramatic increase in the number of private cars, with a corresponding increase in the number of automobile journeys (Table 5.3; Figure 5.3 and Figure 5.4). When changes in mobility are analyzed by income level for the 1987-2002 period, the use of public transport decreased for all income levels except the highest, which remained at previous (1987) levels. Car mobility increased among the lower-income segment and decreased among the high income segment.

Table 5.2 - Changes in the use of motorized transport modes in the SPMR, 1967-2002

TRANSPORT MODE	PERSON - TRIPS/DAY (%), MAIN MODE				
	1967	1977	1987	1997	2002
Public	63.5	60.7	54.8	50.8	47.0
Train	4.4	3.2	4.4	3.2	3,3
Subway	--	3.4	7.6	8.3	7,8
Bus	59.1	54.1	42.8	39.3[1]	36,1
Private (auto and taxi)	25.9	34.8	41.9	47.3	53.0
Other[2]	10.6	4.4	3.3	0.9	0.0
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

1 Includes 1% of declared trips on illegal minivans.

2 Bicycle and truck; became negligible in 2002.

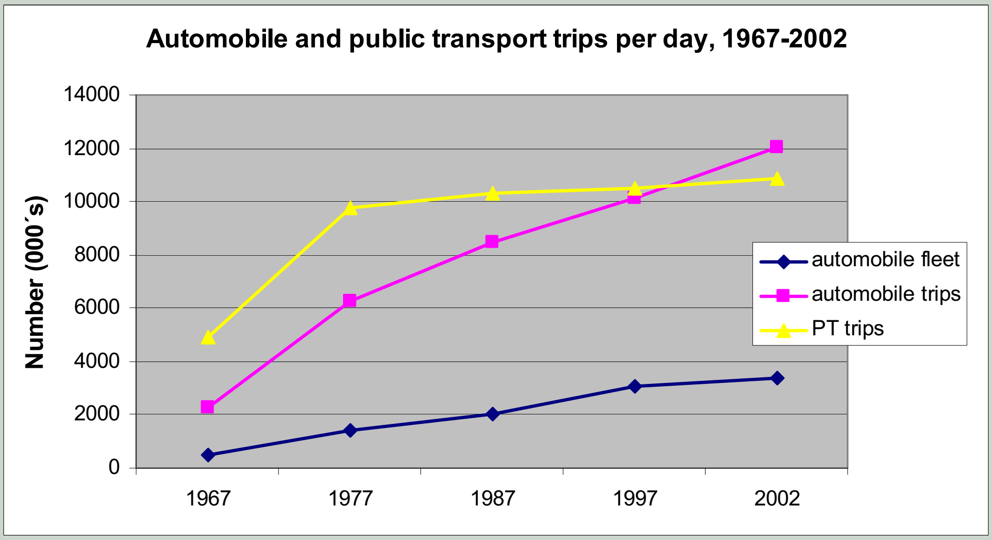
Source: CMSP (1998 and 2002)

Table 5.3 - Changes in car fleets and in motorized trips in the SPMR, 1967-2002

YEAR	AUTOS (000'S)	AUTOS/ '000 PEOPLE	AUTO TRIPS (000'S)	PUBLIC TRANSPORT TRIPS (000'S)	AUTO TRIPS/ PERSON	PUBLIC TRANSPORT TRIPS/ PERSON	MODAL SPLIT PUBLIC-PRIVATE (%)
1967	493	70	2,293	4,894	0.32	0.69	68-32
1977	1.384	135	6,240	9,759	0.61	0.95	61-39
1987	2.014	141	8,473	10,343	0.59	0.73	55-45
1997	3.095	184	10,147	10,473	0.60	0.62	51-49
2002	3.378	169	12,049	10,878	0,66	0,59	47-53

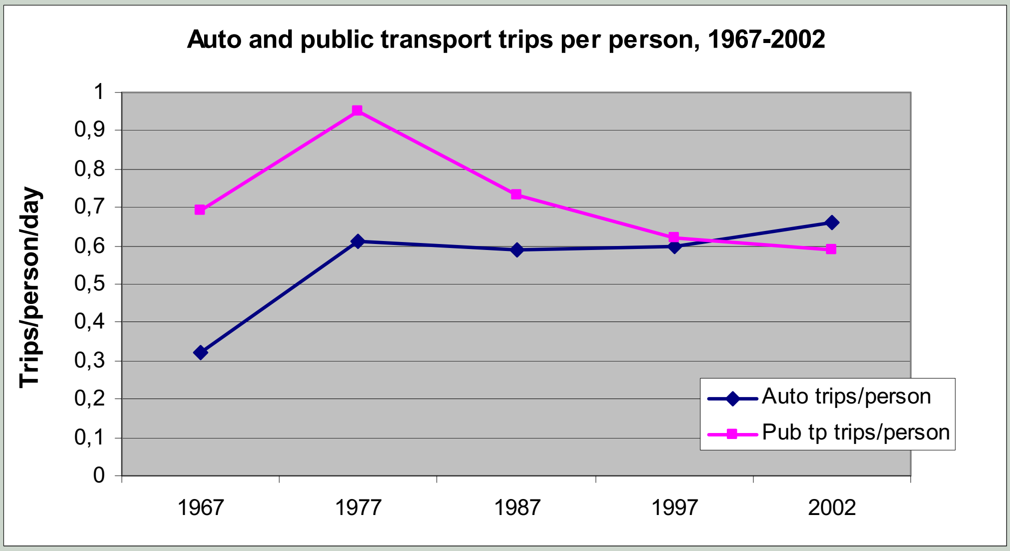
Source: CMSP (1998 and 2002)

Figure 5.3 - Changes in car and public transport journeys, 1967-2002



Source: CMSP (1998 and 2002)

Figure 5.4 - SPMR car and public transport journeys per person, 1967-1997

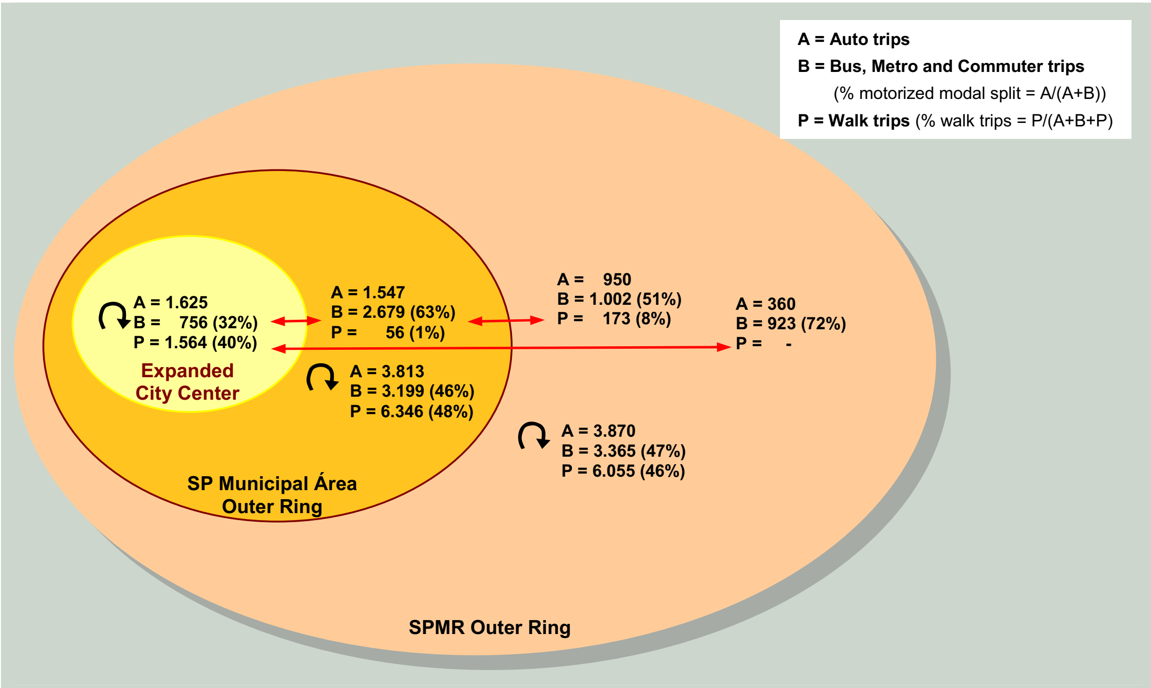


Source: CMSP (1998 and 2002)

There are significant differences in transport modes between the city center and the suburbs. Figure 5.5 - Trips per Metropolitan Ring (2002), was produced with OD-2002 data, and shows that the motorized modal split varies from 32% (public transport/total) in the inner area (expanded city center), to 46% in the outer municipal area, and 47% in the outer metropolitan area (municipalities other than the city of São Paulo). When interactions between the rings are factored in, the modal split is bigger for a journey that takes in the expanded city center (63% with the second ring and 72% with the third one), while it remains at about 51% between the second and the third rings. The same figure shows that the number of journeys undertaken on foot, which represent 40% of total number of journeys in the expanded center, stands at 48% in the rest of the São Paulo municipal area, and 46% in the rest of SPMR.

Figure 5.5 - Trips per metropolitan ring (2002)

(1000 trips/day)



Source: Metrô – OD Survey 2002.

As far as two-wheel transport is concerned, a study carried out for the SPMR[5], based on the origin-destination surveys of 1987, 1997 and 2002 showed high growth in the numbers of bicycle trips (as the main mode) between 1997 and 2002, a number that reached about one and a half million journeys per day in the São Paulo Metropolitan Region in 2007. A 2002 analysis of the reasons for journeys undertaken showed that the biggest growth area was in industry, about 200% (3 x) more than 1997 and 1987. Travel for educational purposes (i.e., to or from schools) showed a 300% (4 x) increase over 1997 and 1987. Table 5.4 and Figure 5.6 show these figures.

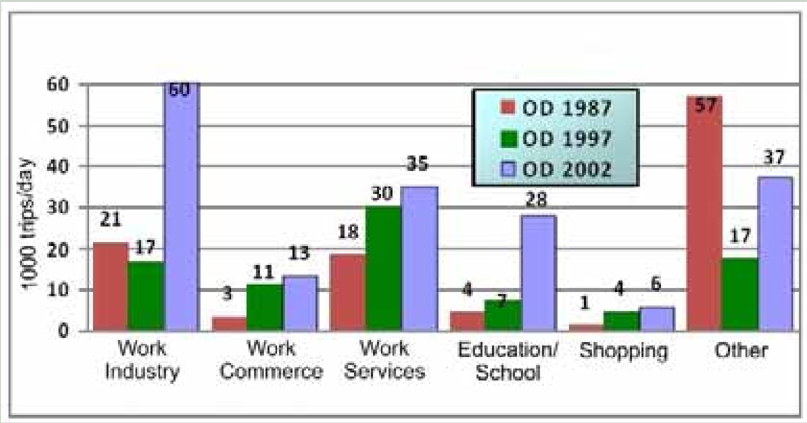
[5] ANÁLISE DO NÚMERO DE VIAGENS DE BICICLETA NA REGIÃO METROPOLITANA DE SÃO PAULO, Carlos Eduardo de Paiva Cardoso,CET/SP,2008.

Table 5.4 - Evolution of bicycle trips

ANO	SÃO PAULO		SPMR	
	Trips/day	% over 1987	Trips/day	% over 1987
1987	45,778	-	108,803	-
1997	54,438	19%	162,855	50%
2002	130,431	140%	336,195	106%

Source: Metrô O-D surveys.

Figure 5.6 - Bicycle trips by purpose in the SPMR



Source: Metrô O-D surveys.

5.5. UNDERSTANDING CHANGES: TRANSPORT AND TRAFFIC POLICIES

A trawl through the history of the Sao Paulo Metropolitan Region reveals a remarkable set of policies that have ultimately proved unsustainable. Some of the historical conditions and policy decisions are described below in an attempt to make sense of some of the complexities surrounding mobility in the region.

5.5.1. Institutional conflicts

Decisions relating to land use, transport and traffic are highly interdependent and the agencies responsible for them need to coordinate their policies and actions. In many large cities and regions in developing countries, such as the Sao Paulo Metropolitan Region, this coordination is lacking. The current conditions – at federal, regional and city (São Paulo) levels – are described below.

Federal level: until 1993, a large portion of the suburban railway system (70%) was managed by the federal railway company, which also managed similar systems in other major Brazilian towns. Differing objectives and goals, combined with political and corporate conflicts, have prevented coordination of the federal and state railway systems. Very low service levels have resulted in permanent chaos which has slowly undermined public confidence and contributed to rejection of suburban trains as a means of transport.

Regional level: historically, there has been a gap between metropolitan-scale transport activities and local transport policies. The State Department of Metropolitan Transportation is responsible for the subway system, the suburban railway and all intercity bus services within the metropolitan area. However, it has been observed that local mayors have often sought to protect their legal decision-making power with the result that conflicts arise when attempts are made to create regional transport infrastructure or services that have a local impact.

Local level: in the city of São Paulo, urban and transport issues are handled by three different departments: Urban Planning (SEMPLA), Transportation (SMT) and Roadways (SVP). For the most part these agencies have worked independently. Within SMT, public transport and traffic are divided, and there are special agencies with responsibility for practical issues (SPTrans for public transportation and CET for traffic). In addition, since power is highly skewed in favor of car owners (middle classes), the CET has made traffic flow, particularly car traffic, its priority. Priority bus schemes have been scarce. As far as the road network is concerned, planning and construction of expressways and arterial roads have been separated from both urban planning and traffic agencies; the needs and objectives of the traffic agencies have tended to be largely ignored.

5.5.2. Limited supply of integrated public transport

In 2002 there were just 101 km of bus lanes or corridors in the SPMR, equating to merely 3% of the main arterial system. The supply of public transport infrastructure per million inhabitants has decreased from 38 km in 1967 to 23 km in 2002.

The large suburban railway system has deteriorated and consequently lost a significant part of its customer share. The result has been a decrease in the number of journeys. Despite offering a very high quality service, development of the subway has been very slow. Thus, in addition to offering very different levels of service, these two systems are poorly integrated with each other and with private transport systems. At present, only 10% of subway journeys are integrated with the rail system and there are very few points where the two systems connect. Integration between the suburban train and bus services is almost entirely absent. Integration between the bus and subway systems has improved with 50% of users now making combined journeys (CMSP, 2000). Differing fare structures and corporate practices have also prevented the creation of a large integrated system. The introduction in 2004 of the “bilhete único” (single ticket) that can be used on all three systems has, however, helped to increase integration.

5.5.3. Poor bus services

The bus network covers the entire region and serves almost 100% of residential areas. Only a few households in very remote areas lack access to a bus service. There are three main bus systems. The largest operates in the city of São Paulo; in 2002 it had about 14,000 buses and microbuses. The second, with about 3,000 buses, links the region's cities to one another. The third system includes all the local bus systems in cities other than São Paulo, with about 3,000 buses. Demand for bus transport over the 1967-2002 period mirrored demand for railway services: demand rose until 1987 after which it decreased. Overall demand for public transport increased up to 1987 and then decreased by about 10% (Table 5.5). Throughout the 1967-2002 period transport was also provided by drivers operating in the informal sector. Competition from the informal sector was acute in the early 1990s, following the deregulation and privatization of economic activities. After five years of conflict between the authorities and informal sector operators, the latter were incorporated into the formal sector and today they frequently serve the routes feeding into the trunk lines.

For the majority of people living on the outskirts of the region and relying on buses, average travel distances have increased. Furthermore, tight fare controls and high inflation have resulted in private operators increasing profitability at the expense of supply, particularly in low-density areas. Thus, although there is near universal network coverage, the service is irregular, unreliable, and uncomfortable with often limited connections. This is in sharp contrast to private transport. In addition to sporadic bus services, the bus system is often dogged by traffic problems. Most of the recently-built main roads do not have specially designated bus lanes and no schemes have been implemented to improve bus circulation. As a result, buses travel on narrow streets – often unpaved in some remoter areas – and compete for road space with other vehicles. User information is limited.

Table 5.5 - Public transport demand in the SPMR, 1967-2002

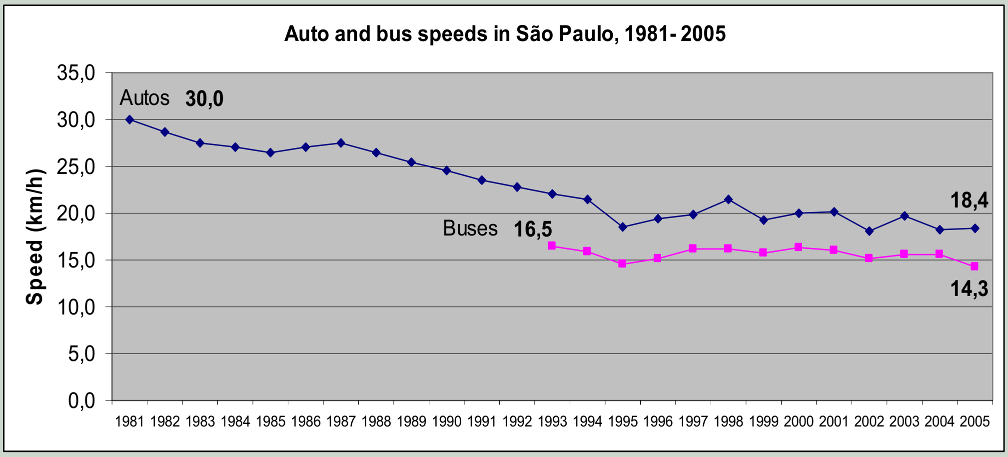
YEAR	DEMAND (MILLION PASS/YEAR)			
	Buses	Train	Subway	Total
1967	1,557	122	0	1,679
1977	2,390	146	176	2,712
1987	2,904	316	540	3,760
1997	2,362	272	690	3,324
2002	2,493	230	541	3,263

Source: CMSP (1998 and 2002)

5.5.4. Travel times

In the city of São Paulo, average car speeds on the main road network increased from 25 km/hr in the late 1970s to 27-28 km/hr in the 1980-1984 period and then fell to less than 20 km/h in the 1990s (CET, 1997) (Figure 5.7). Congestion levels during peak afternoon traffic increased threefold between 1992 and 1996 – from 39 km to 122 km – (CET, 1998a) and the proportion of congested roads in the main system reached 80% in 1998. In 1998, car speeds during peak afternoon traffic averaged 17 km/hr and bus speeds averaged 12 km/hr. In 1998, it was estimated that removing from circulation some 3,000 of the 10,000 buses in operation would help to eliminate severe congestion; furthermore, maintaining all these buses in circulation added an extra 16% to the cost of bus fares. In 1998, it was estimated that congestion resulted in the loss of 316 million passenger-hours per year in the city in 1998, for bus and car journey (ANTP/IPEA, 1998).

Figure 5.7 - Traffic speeds on main arteries in the city of São Paulo



Source: CET (2006)

5.5.5. Access to transport

In the SPMR, average times required to access different modes of transport vary significantly. It takes on average one minute to walk to a private vehicle. Most members of the population are within 6 or 7 minutes of a bus or metro station, and within about 11 minutes of a train station (CMSP, 1998). Overall average travel times also vary: the average car journey lasts 27 minutes, while the average bus journey lasts 57 minutes; average journey times for combined bus-rail and bus-metro trips range from 77 to 93 minutes.

5.5.6. Costs of transport

Public transport has become increasingly more expensive, especially in the 1987-1997 period. Inflation notwithstanding, fares for buses – the most common form of transport – doubled between 1977 and 1997. Train fares (the most common form of transport among the low-income segment) increased by a factor of 3.5. Between 1997 and 2002, the cost of public transport increased by 14%, not including inflation. An increase in the size of the informal sector has served to exclude a large portion of the population from public transport: travel passes are only issued to those working in the formal sector[5]. Similarly, many members of the low-income segment are unable to use multiple means of transport because the cost of an integrated fare remains beyond their reach. The most important change to the transport system occurred in 2002, when the introduction of the “bilhete único” started enabling people to travel on multiple (four) buses for a two-hour period using the same ticket.

Car taxes have always been very low, around US$ 100 a year. Furthermore, the cost of parking does not discourage private car-ownership since there is free roadside parking available in most areas.

5.5.7. Support for the car

Car-friendly policies have added to congestion problems. Road-building has been a central feature of infrastructure development at regular times in the city's history. Between 1967 and 1977, 27% of the city's budget was used for road building. The greatest level of investment was made in the period between 1960 and 1980, although there was also substantial investment during the 1990-1997 period (Vasconcellos, 1996).

As congestion increased between 1996 and 1999, the city invested about US$ 3 billion in the construction of a tunnel and a few links to the expressways; there was little investment in public transport. However, road congestion during peak afternoon traffic increased from 60 km at the end of the 1980s to more than 100 km during the 1990s. Recently (2007), congestion has increased to more than 120 km (CET, 2007).

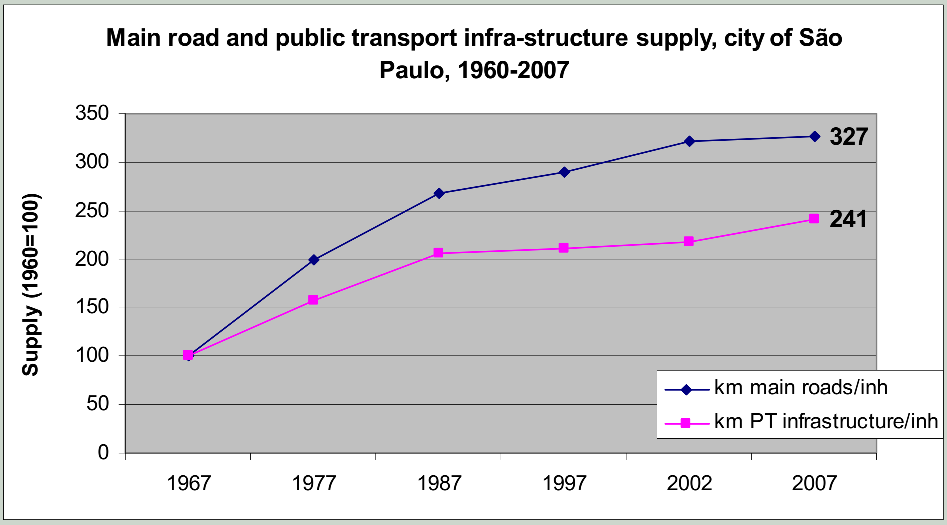
In addition to free parking and relatively cheap gasoline, private car acquisition has been further facilitated by two other instruments – car consortia enabling group monthly repayments, and bank loans. Furthermore, lax traffic law enforcement and a lack of penalties for traffic offenses – e.g., speeding, illegal parking, lack of respect for pedestrian crossings – do little to deter use of private cars. The situation has been further exacerbated by the fact that efforts to ease traffic flow have often been implemented at the expense of safety and quality of life in residential areas. For instance, the introduction of one-way streets in many neighborhoods has increased the speed and flow of traffic, but with negative social and environmental impacts[6].

Figure 5.8 illustrates the different levels of investment in private and public transport infrastructure in the city of São Paulo. Public transport infrastructure (metro, railway and bus routes) per inhabitant has developed far more slowly than the road network (expressways, major arteries).

[5] Travel passes are given by employers to employees at a very low price.

[6] These traffic changes prompted a series of reactions from local communities, which in some cases included blocking the streets to force public authorities to reconsider their proposals (Vasconcellos, 1984-1985).

Figure 5.8 - Supply of roads and public transport infrastructure in the SPMR



Source: CMSP (1998 and 2002) and Vasconcellos (1996).

5.5.8. Accidents

The development of the road network to cope with the number of private cars has created a very dangerous environment for pedestrians and users of non-motorized transport, resulting in high numbers of severe traffic accidents. Since 1980, the number of fatalities – mainly pedestrians – has remained fairly constant at about 2,300 a year (with a decrease observed in the 1990s) (Table 5.6). In 1995, there were about 60,000 road accident victims. Of this number, approximately 9,000 people sustained serious injuries and of those, 6,000 sustained permanent injuries (CET, 1996). More recently car-related fatalities have decreased to around the 1,400 mark, thanks to the introduction of a series of traffic and safety measures including compulsory seat belt (cars) and helmet (motorcycles) use, extensive new road designs, use of warning signs at high-incident spots, and speed control devices (such as radars). However, the city of São Paulo still has one of the highest accident rates observed among large cities in the developing world (by way of comparison, annual traffic-related fatalities in Bogota, New Delhi and Bangkok were 1139, 1,114 and 977 respectively in the 1990s – Vasconcellos, 2001).

Table 5.6 - Traffic fatalities in the city of São Paulo, 1980-2005

YEAR	VEHICLE OCCUPANTS	PEDESTRIANS	TOTAL	FATALITIES/ 10^5 POP
1980	750	1,580	2,330	27.4
1985	1,044	1,515	2,559	27.8
1995	846	1,432	2,278	23.0
1997	933	1,109	2,042	20.4

2002[1]	801	559	1,360	13.0
2005	731	774	1,505	14.1

1 Data not verified by the medical system; reported figures may be lower than actual ones.

Source: Cia de Engenharia de Tráfego – CET (1996 and 2005).

No efforts have been made to introduce road safety education programs in most cities of the SPMR. Finally, a lack of enforcement has resulted in a culture of impunity, with serious implications for road-safety.

5.6. DETAILED INFORMATION FOR MOST RECENT DATA

The 2002 origin-destination survey reveals some interesting information about mobility. This is briefly discussed below.

5.6.1. Mobility

Use of private transport has continued to increase with a corresponding decrease in the use of public transport. For the first time in the history of the city, the share of private vehicles (34.2%) overtook that of public means (28.1%).

Table 5.7 - Modal split in the SPMR, 2002

MODE	THOUSAND TRIPS/DAY	%
Subway	1,803	4.7
Trains	765	2.0
Buses	8,310	21.5
Subtotal public	10,878	28.1
Auto	12,049	31.2
Taxi	115	0.3
Collective taxi	630	1.6
Motorcycle	415	1.1
Sub tot private	13,209	34.2
Walking	14,194	36.7
Other	379	1.0
TOTAL	**38,660**	**100.0**

Source: CMSP (2002)

The main reasons for undertaking journeys continued to be for travel to and from places of work (39.4%) and places of education (29.3%), a pattern similar to that observed in most global cities.

Table 5.8 - Journeys by purpose in the SPMR, 2002

PURPOSE	%
Work	39.4
Education	29.3
Shopping	5.4
Health	4.2
Leisure	8.8
Other	12.9
TOTAL	**100.0**

Source: CMSP (2002)

Table 5.9 shows that average mobility per person increases as incomes increase; with a range from 1.53 trips/person/day to 3.33 trips/person/day. Average travel times show little variation among income levels, although they decrease with rising incomes.

Table 5.9 - Mobility and travel time per income level in the SPMR, 2002

FAMILY MONTHLY INCOME (R$)	TRIPS/PER/DAY	MINUTES/TRIP/PERSON
< 400	1.53	31
400 to 800	1.77	35
800 to 1600	2.11	36
1600 to 3000	2.52	33
3000 to 6000	2.79	30
> 6000	3.33	27
TOTAL	**2.11**	**33**

Source: CMSP (2002)

Level of education also has an impact on levels of mobility with the number of journeys undertaken rising with increased levels of education (Table 5.10).

Table 5.10 - Mobility and level of education in the SPMR, 2002

Level of education	Trips/ person/day
Basic	1.62
Intermediate, incomplete	2.43
Intermediate, complete	2.72
College	3.38

Source: CMSP (2002)

Individual mobility is highest among the 15 to 49 age group, which corresponds to the better-educated actively employed segment of the population (Table 5.11).

Table 5.11 - Mobility and age in the SPMR, 2002

Age	Trips/ person/day
< 3	0.69
4 to 6	1.37
7 to 10	1.8
11 to14	2.02
15 to 17	2.36
18 to 22	2.39
23 to 29	2.63
30 to 39	2.68
40 to 49	2.46
50 to 59	2.04
> 60	1.27
Overall	2.11

Source: CMSP (2002)

There is greater mobility among men than among women (about 21% more); however, this gap has begun to narrow.

Table 5.12 - Mobility and gender in the SPMR, 2002

Gender	Trips/ person/day
Female	1.91
Male	2.32

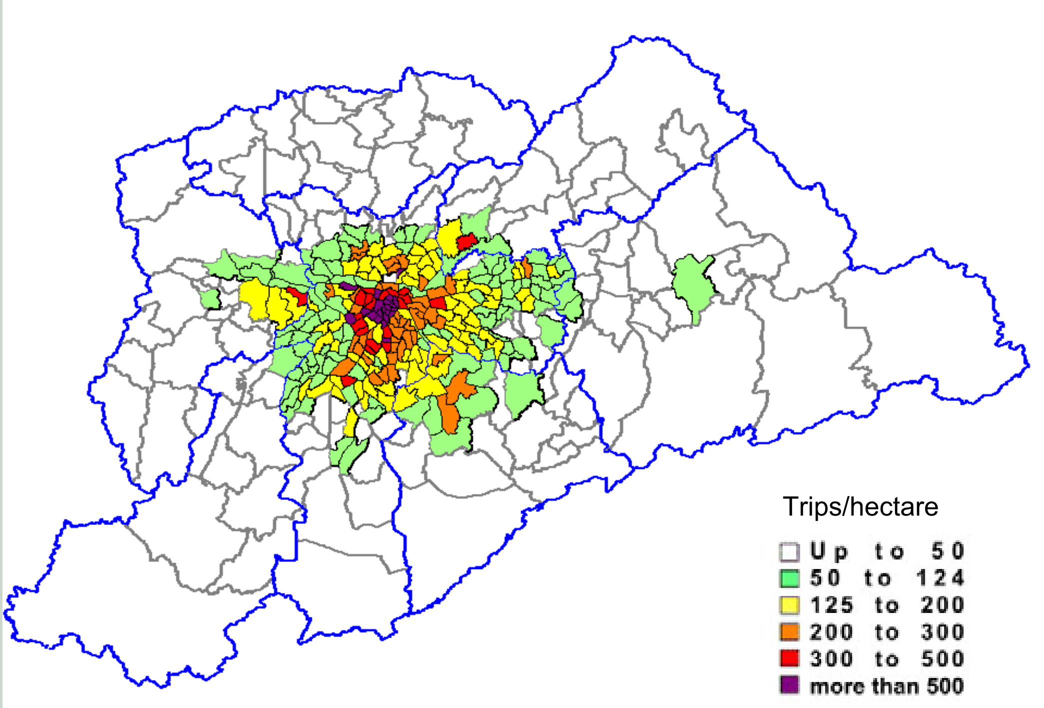
Source: CMSP (2002)

5.6.2. Geographical distribution of journeys

Most personal journeys in the SPMR remain concentrated in the region's "core" area, where the greatest number of employment opportunities is found (

Figure 5.9).

Figure 5.9 - Geographical concentration of journeys in SPMR



Source: CMSP (2002)

5.6.3. Traffic safety

Given the lack of detailed information on traffic accidents in most cities of the SPMR, the data below reflect the situation in the city of São Paulo.

In 2005, there were 1,505 recorded traffic-related fatalities in the city of São Paulo (Table 5.13); 78% were male. Most of the fatalities were among pedestrians (49.5%), followed by motorcyclists (22.1%) and occupants of motor vehicles (20.3%).

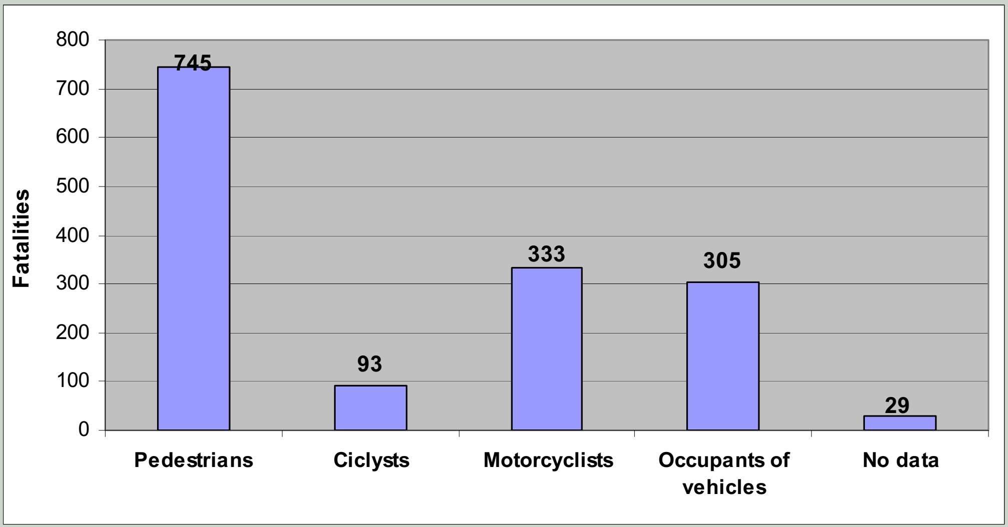
Table 5.13 - Traffic fatalities in the city of São Paulo, 2005

TYPE OF USER	MALE	FEMALE	TOTAL	% TOTAL
Pedestrians	518	227	745	49.5
Cyclists	90	3	93	6.2
Motorcyclists	310	23	333	22.1
Occupants of vehicles	239	66	305	20.3
No data available	23	6	29	1.9

TOTAL	1180	325	1505	100.0
Total (%)	78.4	21.6	100.0	

Source: CET (2007)

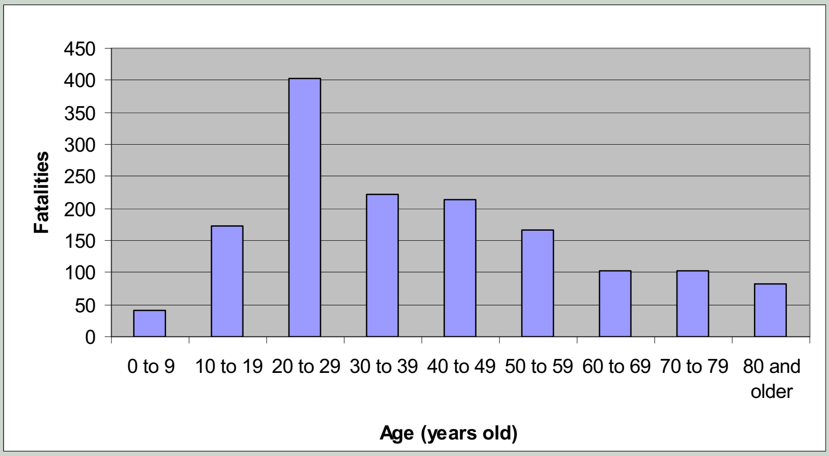
Figure 5.10 - Traffic fatalities in the city of São Paulo, 2005



Source: CET (2007)

Figure 5.11 shows that most of the fatalities were among the 20 to 29-year age bracket; the most physically active segment.

Figure 5.11 - Traffic fatalities in the city of São Paulo by age, 2005



Source: CET (2007)

Table 5.14 illustrates that most accidents (66.9%) occur between intersections, while Table 5.15 shows that the share of motorcycles, buses and trucks involved in fatal accidents is proportionally higher than their share of the traffic. They have a much greater chance of being involved in serious accidents.

Table 5.14 - Traffic accident location in São Paulo, 2005

PLACE OF ACCIDENT	NO. OF ACCIDENTS	%
Intersections	227	15.8
Between intersections	963	66.9
Highways	89	6.2
Expressways	79	5.5
No data	82	5.7
TOTAL	**1,440**	**100**

Source: CET (2007)

Table 5.15 - Share of vehicles in traffic flow and fatal accidents in São Paulo, 2005

VEHICLE	SHARE (%)	
	Traffic Flow	Fatal Accidents
Automobile	78.6	41.2
Motorcycle	10.6	28.9
Bus	7.6	18.5
Truck	3.2	11.3

Source: CET (2007)

The increasing number of motorcycle-related accidents is currently a cause for concern. The number of accidents involving motorcycles in Brazil generally and the city of São Paulo in particular has increased dramatically since 1990. Table 5.16 shows that between 1997 and 2006, the city's motorcycle fleet went from 140,000 to 455,000, while the number of deaths increased from 221 to 380 (72%) during that period, peaking at 406 in 2001. This is even more worrying given that motorcycle accidents tend to be much more serious than accidents involving other vehicles and the number of casualties with severe injuries and permanent disabilities tends to be much higher: in the city of São Paulo, there are 56 serious injuries for every one hundred motorcycle accidents, compared to an average of 14 for all accidents (CET, 2000).

Table 5.16 - Evolution of the motorcycle fleet and the number of fatal accidents involving motorcyclists in the city of São Paulo

YEAR	FLEET	DEATHS
1997	140,000	221
1998	160,000[a]	212
1999	180,000[a]	245

2000	215,000[a]	347
2001	268,949	406
2002	301,311	374
2003	319,850	405
2004	353,481	318
2005	392,629	333
2006	455,562	380

Source: CET (2005 and 2007)
a – estimated fleet

5.6.4. Air pollution

Current situation

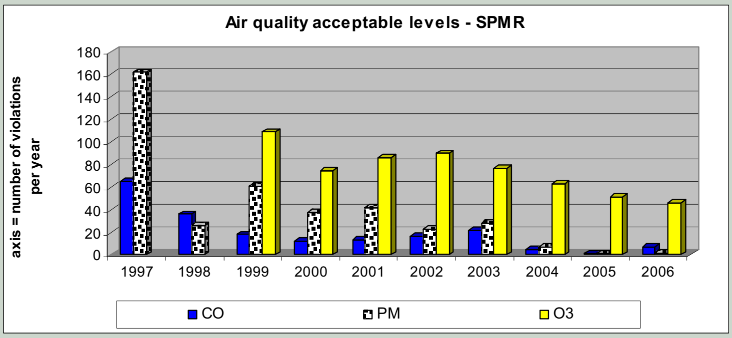
The level of pollutants emitted by vehicles in the SPMR has decreased over the years, thanks to the National Program for Motor Vehicle Pollution Control (PROCONVE). It has set increasingly strict emissions standards, and as cleaner vehicles have entered the fleet, pollution per vehicle has declined. Ethanol was introduced to facilitate the elimination of lead in gasoline (which then allowed for the faster introduction of catalytic converters) and the reduction of carbon monoxide (CO) and hydrocarbon (HC) emissions, which were high at that time. Thanks to the efforts of Petrobras, Brazil was one of the first countries in the world to use unleaded gasoline.

With the introduction of PROCONVE, CO and HC emissions from gasoline-powered vehicles were gradually reduced to alcohol-typical emission levels.

Motorcycle use has increased dramatically. In 2002, the National Environment Council (CONAMA) started a new program called PROMOT (National Program for Motorcycle Pollution Control) to control motorcycle emissions. It followed the same three-step strategy adopted for cars, with the third step completed in 2009. The effects of PROMOT are included in the emissions inventory below. Projections point to a need for further stringent control of CO and HC to respond to the growing number of motorcycles on the roads.

The findings of the environmental monitoring exercise carried out by the São Paulo State Environment Agency (CETESB), which are illustrated in Figure 5.12 below, point to continuous improvements in air quality in the Metropolitan Region, especially CO and particulate matter (PM) levels. The number of days of emissions exceeding CETESB rates has been reduced. Although the number of vehicles in the SPMR nearly doubled between 1996 and 2005, ozone (O3) levels have remained stable, albeit high, exceeding admissible levels on several days. This indicates a need for stricter emission control standards. Despite a high number of days in which emission levels have exceeded authorized levels, since 2004, annual average concentrations of particulate matter in the air have been lower than Brazilian averages. Figure 5.10 below shows the number of days in which the volume of emissions exceeded authorized levels, for each pollutant.

Figure 5.12 – CETESB's air quality monitoring



Source: Environ Mentality[7]; CETESB[8]

Emission inventory trends

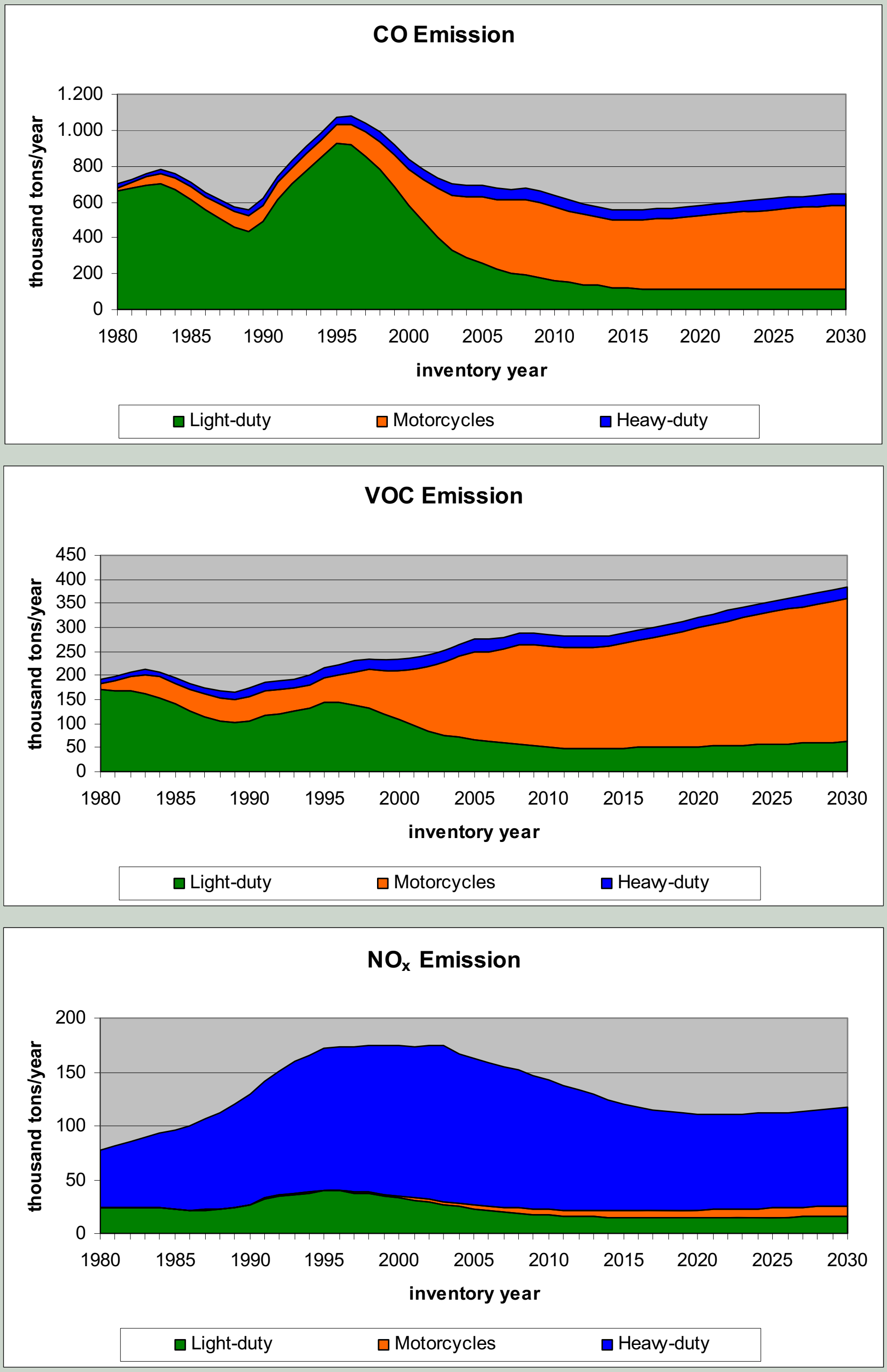
The emission scenarios (1980-2030) shown in Figure 5.13 below take account of current environmental regulations and the current vehicle fleet, whereby flex fuel vehicles account for 95% of sales as of 2009, without the introduction of new emission standards. The emission inventory was calculated taking into account average wear and tear factors, and considering normal vehicle deterioration (80%) and vehicles using adulterated fuel (20%). The data for the year 2000 were obtained by remote sensing. All vehicles were presumed to be in accordance with the PROCONVE requirements already approved and extended to 2030.

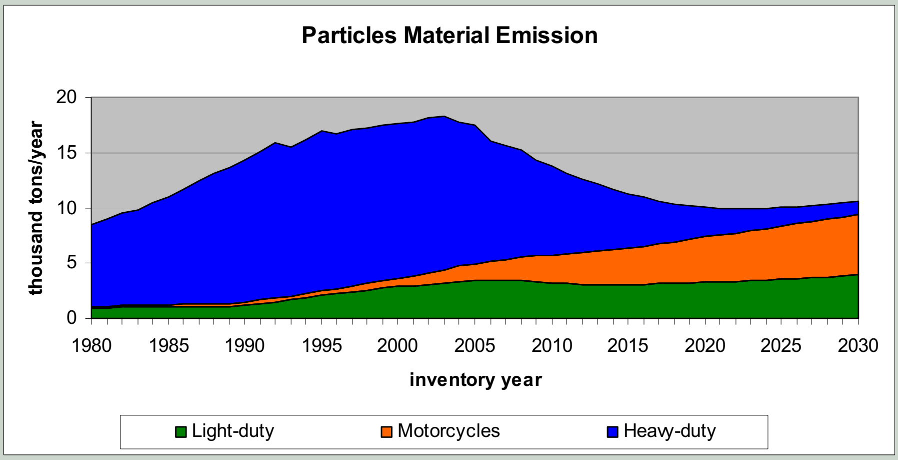
The figures below show emission levels for each type of vehicle assuming that 80% of the SPMR flex fuel fleet is expected to use ethanol by 2010; after that date it is assumed that only 50% would utilize this type of fuel owing to other fuels available on the market. Obviously, specific pricing policies might produce different behavior.

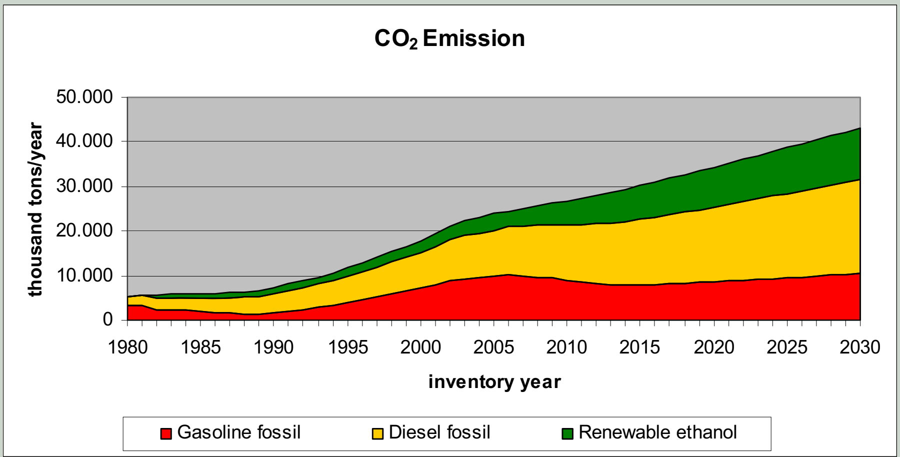
---

[7] Walsh, M.P.; Branco, G.M.; Ryan, J.; Romano,J.; Linke, R.R.A.; Martins, M.A.R.B. – Clean Diesels: the key to clean air in São Paulo_SAE 2005-01-2215 – Fuels and Lubricants Meeting and Exibition – SAE BRASIL – Rio de Janeiro – 2005.
[8].CETESB – Air Quality in São Paulo State – Annual Report – 2006.

Figure 5.13 – Vehicle Annual Emission Inventory in SPMR (actual data is provided up to 2006, forecasts apply from 2007 onwards)







Source: EnvironMentality[9]

In the early 1980s, blending alcohol with gasoline helped reduce CO and HC emissions in the existing light vehicle fleet by 40%. The use of vehicles powered by gasohol fuel led to significant additional emissions reductions until 1989, when PROCONVE was implemented.

The decline of the Brazilian Ethanol Program (PROÁLCOOL) and the return of gasoline-only fueled vehicles in 1990 resulted in increased levels of air pollution. In 1995, the effects of PROCONVE began to be felt and CO and HC emissions began to decrease.

Starting in 2000, growth in the market for motorcycles in the SPMR resulted in these vehicles becoming the primary sources of CO and HC emissions, thereby creating a need for stricter environmental standards than those already established by CONAMA, especially for HC emissions which are likely to increase again by 2012, as illustrated in the emission inventory above.

[9] Branco, Gabriel Murgel and Branco, Fábio Cardinale - INVENTORY OF MOVABLE SOURCES: Prospective and retrospective analysis of the PROCONVE program benefits for air quality from 1980 to 2030 – This report was prepared with the support of the Hewlett Foundation for the Brazilian Ministry of the Environment – March 2007.

The introduction of flex fuel vehicles in the Brazilian market has not increased the level of emissions from vehicle exhaust pipes, since the maximum emission limit provided for by the country's environment laws is the same for gasohol, natural gas and gasoline-powered vehicles. The impact of heavy duty vehicles on CO and HC pollutants is less significant and is currently under control.

Fuel evaporation emissions, which naturally decreased with the introduction of gasohol-powered vehicles (due to lower vapor pressure generated by this type of fuel), were drastically reduced with the introduction of the PROCONVE program in 1990. The introduction of vapor collecting devices with activated charcoal, and improvements made to fuel system connections and gaskets also helped to ameliorate the situation. No similar controls have yet been put in place for motorcycles and fuel evaporation may become a major hydrocarbon source if the fleet continues to grow in the future.

If all emissions of volatile organic compounds (VOCs), i.e., exhaust pipe hydrocarbons[10] added to evaporative and crankcase emissions for each type of vehicle are taken into account, VOC emissions continue to increase. New strategies are needed to limit exhaust pipe and evaporative HC emissions from motorcycles, as well as crankcase emissions from heavy duty engines, since all the signs indicate that these are likely to increase.

NOx emissions originate predominantly from heavy-duty diesel engines. NOx emissions from light-duty vehicles are now reasonably under control and emissions from diesel-fueled vehicles are gradually being reduced, albeit unsatisfactorily since diesel emissions are expected to grow after 2020. In an effort to reverse this trend, in December 2008 CONAMA published new stricter emission limits for heavy-duty vehicles, with EURO V (CONAMA P7) standards scheduled to enter into force from 2012. New stricter emission limits for light-duty vehicles are also being negotiated with CONAMA and are expected to enter into force in 2013.

The increase in VOC emissions, and the difficulties encountered in efforts to reduce overall NOx emissions, point to a potential increase in ozone formation caused by pollutants from vehicles. This indicates a need for stricter control of these pollutants. However, the air quality data shown in Figure 5.12 presents an ozone reduction tendency, which needs to be studied better.[11]

PM emissions from diesel-fueled vehicles have decreased. However, since particulates are not regulated for Otto cycle engines, including motorcycles, these vehicles are expected to have a major impact on PM emissions. However, it needs to be borne in mind that this estimate has not been confirmed by reliable PM emissions data for light duty vehicles and motorcycles in Brazil, since this calculation was based on values taken from bibliographical sources.

As far as the impacts of pollution on human health are concerned, research studies undertaken by the University of São Paulo's Medical School suggest that air pollution may still contribute to as many as 3,000 premature deaths per year in the São Paulo Metropolitan Region.[12] On the

(10) Aldehydes are generally accounted for in HC emissions through vehicle exhaust pipes. However, they were underestimated by the method used to measure. For this reason and for the selective toxicity of the other organic compounds, aldehydes are measured separately using a more accurate method.

11 It may be explained by the lower reactivity of ethanol emissions, thus reducing the potential of ozone formation (this mechanism needs to be better studied in the Brazilian case). On the other hand, ethanol has a higher aldehydes-content in not burned ethanol than gasoline. Aldehydes are a strong factor for ozone formation. Some papers (Argonne Laboratories) present worse emissions results for ethanol, mainly in the cold start.

12 These studies point out a strong correlation of diesel PM emissions to epidemiologic and mortality data, but not a link of the gasoline and ethanol vehicle PM emissions to those diseases.

other hand, according to the World Health Organization (WHO), air pollution “increases the *risk* of deaths”, but the causal link between particulate material and deaths is still being studied.[13]

Finally, CO_2 emissions were calculated separately according to their fossil origin (gasoline and diesel) and renewable origin (ethanol). These calculations were done on a tail-pipe basis and do not take into account well/field to tank analysis of CO_2 emissions. Biodiesel was not taken into account in this estimate, since its role is still incipient and the biodiesel program is in its infancy. On average, biodiesel accounts for no more than 5% of total diesel production representing a small contribution within the scope of this report.

It is possible to draw the following conclusions from this inventory:

f) Motorcycles are the main focus of efforts to control CO; for other vehicles the emphasis is on the development of technology;
g) Control of VOC emitted by type of vehicle depends essentially on significant restrictions applied to motorcycles, as well as on the continuity of control requirements for automobiles;
h) NOx limits for heavy-duty vehicles should be reduced, whereas for the remaining types of vehicles maintaining the already established strategies should be sufficient;
i) As of 2015, control strategies for PM emissions will have to be extended to light-duty vehicles and motorcycles, and it is essential to maintain the already established requirements for heavy-duty vehicles;
j) State-of-the-art technologies aimed at significant improvements in energy efficiency in light duty-vehicles might stabilize CO_2 emissions for this category of vehicle; research is still needed into options for heavy-duty diesel-powered vehicles. Therefore, a review of the emissions levels resulting from different types of transport is necessary to slow energy consumption and, consequently, CO_2 emissions.

Once these strategies are implemented, this inventory should show that an overall reduction in local pollutant emissions to stable levels is feasible. This could contribute to mitigating vehicle-related air pollution problems. Such a strategy could also be extended to aldehydes, and could result in a return to the levels observed at the onset of the PROÁLCOOL program in 1982.

Action to control CO_2 emissions is not simply regarded as a local environmental issue, but as part of Brazil’s wider strategy to combat the global greenhouse effect. Furthermore, a significant part of Brazil’s CO_2 emissions come from renewable energy sources due to the use of ethanol as fuel, which is derived from sugar cane, and large scale hydroelectric power, which are the primary sources of energy in Brazil (Appendix 4).

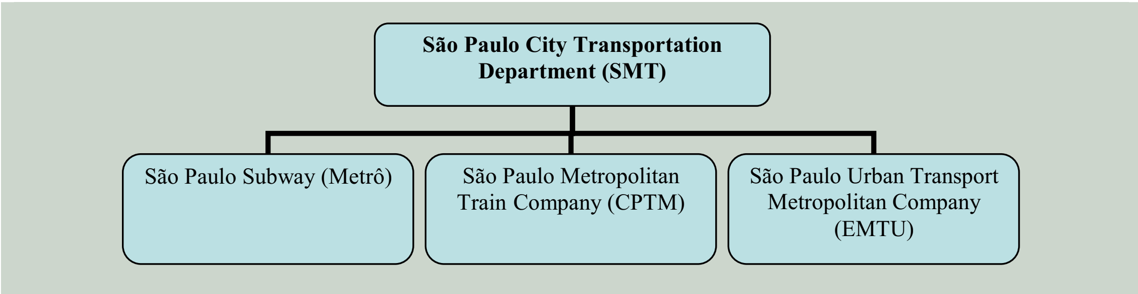
5.7. AVAILABILITY OF PUBLIC TRANSPORT

Public transport services in the SPMR are provided by the 39 municipalities that make up the Metropolitan Region and by the São Paulo state government.

[13] A recent revision of statistics models has resulted in a revision of the data and conclusions of “National Morbidity, Mortality and Air Pollution Study – NMAPS”, at the Special Report – Revised Analyses of Time-Series Studies of Air Pollution and Health, pg. “i” (fls. 1.058-1.060) and it is referred to in the WHO document “Air Quality Guidelines – Global Update 2005”, pg. 94.

At the state level, the departments and agencies responsible for providing public transport services are divided into separate sectors. Metropolitan transportation services come under the remit of the São Paulo Metropolitan Transportation Department (SMT) and its three agencies: São Paulo Subway (Metrô), São Paulo Metropolitan Train Company (CPTM) and São Paulo Urban Transport Metropolitan Company (EMTU); the latter is responsible for intercity bus systems (Figure 5.14).

Figure 5.14 - Metropolitan transportation services



Other state agencies connected to the São Paulo State Transportation Department (SET) also handle transport-related issues. State highways passing through the SPMR are under the jurisdiction of the São Paulo State Department of Highways (DERSA), which is responsible for the busiest highways, and the Highway Department, which is responsible for other state highways and roads.

Planning functions in general are undertaken by both STM and SET and are consolidated in a single plan named PITU (Urban Transport Integrated Plan), which was recently updated to include projections up to 2025 (see item 8 – Programs and Actions). All projects proposed by these public agencies are compiled and consolidated into Action Plans and submitted for approval by the São Paulo State Planning Department, which may include these plans in its Pluriannual Plan (PPA). The day-to-day operation of public transport services and highways is carried out by the responsible agencies or by private contracted agencies, in the same way as bus services and highway concessions.

Municipalities in general have their own local bus transport systems that are regulated by the public authorities. Through the Metropolitan Transportation Department (STM), the state provides train, subway, bus and intercity bus services within the SPMR area (Table 5.17).

Table 5.17 - Public transport services offered by the São Paulo state government in the SPMR, 2007

TRANSPORT SYSTEM	EXTENSION (km)	No. OF LINES	FLEET	PASSENGERS/DAY
Train	262	6	248[1]	1,600,000
Subway	61	4	101[2]	3,000,000
Bus	NA	573	3.500	1,100,000
TOTAL				**5,700,000**

1 Trains with 6 to 9 carriages.
2 Trains with 6 carriages each.
Source: ANTP (2007)

The Metropolitan Transportation Department, through the São Paulo Urban Transport Metropolitan Company, operates one of the largest bus corridors in Brazil. Named “ABD”, this corridor was built in the 1980s; it is 33 km long and runs through four cities in the SPMR area – São Paulo, Santo André, São Bernardo and Diadema. It transports 210,000 passengers every day on approximately 200 buses.

Table 5.18 summarizes the data related to bus services provided by the main SPMR cities.

Table 5.18 - Bus network system in the main SPMR cities, 2006

CITY	POP (million)	BUS FLEET	PASSENGERS/DAY[1]
São Paulo	10,927,985	14,017	5,400,000
Guarulhos	1,251,159	572	213,000
S Bernardo	788,560	344	231,500
S André	669,592	346	183,400

1 Assuming that the average daily demand is equal to the annual demand divided by 300.
Source: ANTP (2007) – Information System (www.antp.org.br/sistemadeinformações/maiorescidades)

Table 5.19 - Summary of daily public transport demand in the SPMR, 2006

TRANSPORT SYSTEM	FLEET	PASSENGERS/DAY[1]
Trains	248[1]	1,600,000
Subway	101[2]	3,000,000
Intercity Buses	3,500	1,100,000
São Paulo Buses	14,017	5,400,000
Buses in other municipalities	6,000	4,200,000
TOTAL		**15,300,000**

1 Trains with 6 to 9 carriages. 2 Trains with 6 carriages.
Source: ANTP (2007)

6

Cargo Transportation in the São Paulo Metropolitan Region

6. CARGO TRANSPORTATION IN THE SPMR

6.1. SÃO PAULO STATE TRANSPORTATION MATRIX

According to data in the 2000-2020 Transport Development Master Plan (PDDT), in 2000 the total volume of cargo transported within São Paulo state was estimated at roughly 700 million tons/year for regional flows into/from the state.

Among the goods regarded as "general cargo", there was a predominance of industrial products and consumables as well as natural foodstuffs i.e., fresh produce grown in the vicinity of major cities, as well as dairy and refrigerated products of animal origin. Transport of secondary oil products and ethanol derivatives accounted for approximately 10% of total demand and included transport by road, rail and pipeline.

Table 6.1 - Current demand, 2000

GOODS	VOLUME (10^6 t)	%
General cargo	530	82.3
Mineral products	35	5.4
Agricultural products	32	5.0
Oil and ethanol derivatives	28	4.3
Agroindustrial products	19	3.0
TOTAL	**644**	**100.0**

Source: Transport Development Master Plan for 2000/2020 – São Paulo State Transportation Department (2000)

Cargo flows within São Paulo state are significantly more important than inter-regional and international flows and can be broken down as follows:

- 12% = inter-regional trade flow between São Paulo state and other Brazilian states;
- 76% = volume of cargo to/from São Paulo state, of which:
  - 2/3 originated from and was bound for the macrometropolis;
  - 1/3 was to/from São Paulo state countryside.
- 6% = cargo passing through São Paulo state;
- 6% = cargo for international trade.

The lion's share of cargo transport takes place in the region known as Macrometropolis, which is made up of the São Paulo Metropolitan Region and the surrounding cities of Sorocaba, Campinas, São José dos Campos and Santos (see also Chapter 4).

In the state of São Paulo, industrial activities are responsible for 31.7% of the GDP, services for 65.5% and agriculture for only 1.8%. In the SPMR corresponding values are similar: 28.3%, 71.6% and 0.1% respectively.

The value of exports transiting through the port of Santos in 2007 was US$ 43.48 billion, while imports were valued at US$ 28.03 billion.

6.2. CARGO TRANSPORTATION IN THE SÃO PAULO METROPOLITAN REGION

Cargo transport is predominantly carried out by road in the São Paulo Metropolitan Region SPMR. A total of 46,832 daily truck journeys carrying 234,000 tons of cargo begin in the SPMR.

Table 6.2 - Freight journeys originating in the São Paulo Metropolitan Region

ORIGIN	DESTINATION	TRIPS	TONS	%
SPMR	Distribution centers	8,417	40,029	17%
	Factories or warehouses	24,016	130,779	56%
	Farms	505	2,350	1%
	Stores/supermarkets	2,955	6,731	3%
	Not stated	7	0	0%
	Other	7,739	41,644	18%
	Port	121	525	0%
	Silos or plants	76,237	4,208	2%
	Cargo terminal	2,299	7,569	3%
	Rail terminal	6	31	0%
TOTAL		**46,832**	**233,866**	

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

Table 6.2 shows that 46,832 truck journeys transporting 2,234 tons of cargo are made daily from the SPMR. Most journeys begin at industries/factories (56%), distribution centers (17%) and "other" (18%).

Table 6.3 - Freight journeys ending in the São Paulo Metropolitan Region

DESTINATION	ORIGIN	TRIPS	TONS	%
SPMR	Distribution centers	6,926	67,327	18%
	Factories or warehouses	24,788	195,499	52%
	Farms	331	1,571	0%
	Stores/supermarkets	4,567	36,393	10%
	Not stated	7	0	0%
	Other	8,177	56,133	15%
	Port	126	3,783	1%
	Silos or plants	589	10,082	3%
	Cargo terminal	2,266	7,364	2%
	Rail terminal	13	21	0%
TOTAL		**47,790**	**378,175**	

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

A total of 47,790 daily truck journeys carrying 378,000 tons of cargo ended in the SPMR, as shown in Table 6.3.

The main destination points are factories and warehouses (55%), distribution centers (18%), stores (10%) and other destinations (15%).

Journeys starting at factories are undertaken in vehicles with a large number of axles, of which 31% are trucks with four axles or more.

Table 6.4 - Journey origins by number of axles

ORIGIN	PLACE OF ORIGIN	2 AXLES	3 AXLES	4 OR 5 AXLES	6 OR MORE AXLES	TOTAL GERAL
SPMR	Distribution centers	2,360	3,981	1,666	411	8.418
	Factories or warehouses	6,513	10,091	5,518	1,894	24.017
	Other	2,578	3,335	1,583	244	7.739
TOTAL		14.199	20,227	9,440	2,967	4,6832

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

ORIGIN	PLACE OF ORIGIN	2 AXLES	3 AXLES	4 OR 5 AXLES	6 OR MORE AXLES
SPMR	Distribution centers	28%	47%	20%	5%
	Factories or warehouses	27%	42%	23%	8%
	Other	33%	43%	20%	3%
TOTAL		30%	43%	20%	6%

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

Journeys ending at stores are undertaken in smaller-sized vehicles, 53% of which are 2-axle vehicles. Large-sized vehicles tend to serve factories and warehouses.

Journeys originating from distribution centers tend to carry the following types of cargo: non-food industrial products (13%), chemicals and petrochemicals (8%), foodstuffs (6%) and agricultural products (6%).

Table 6.5 - Journeys originating from distribution centers

PLACE OF ORIGIN	CARGO	TRIPS	%
Distribution Center	Agroindustrial products	11	0%
	Agricultural products	484	6%
	Foodstuffs	477	6%
	Non-food industrial products	1,054	13%
	Mineral products	382	5%
	Not stated	510	6%
	Chemicals and petrochemicals	686	8%
	Steel and metallurgical products	249	3%
	Empty	4,567	54%
TOTAL		8,418	

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

Journeys bound for distribution centers tend to carry mainly the following types of cargo: non-food industrial products (18%), agricultural products (16%), foodstuffs (10%), and mineral products (10%).

Table 6.6 - Journeys bound for distribution centers

PLACE OF DESTINATION	CARGO	TRIPS	%
Distribution Center	Agroindustrial products	211	3%
	Agricultural products	1,104	16%
	Foodstuffs	676	10%
	Non-food industrial products	1,214	18%
	Mineral products	726	10%
	Not stated	353	5%
	Chemicals and petrochemicals	535	8%
	Steel and metallurgical products	223	3%
	Empty	1,883	27%
TOTAL		6.926	

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

Journeys originating from factories carry mainly foodstuffs (20%) followed by mineral products (10%).

Table 6.7 - Journeys originating from factories

PLACE OF ORIGIN	CARGO	TRIPS	%
Factory or Warehouse	Agroindustrial products	172	1%
	Agricultural products	271	1%
	Foodstuffs	1,408	6%
	Non-food industrial products	4,860	20%
	Mineral products	2,302	10%
	Not stated	909	4%
	Chemicals and petrochemicals	1,747	7%
	Steel and metallurgical products	905	4%
	Empty	11,442	48%
TOTAL		24.017	

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

Similarly, there is approximately the same breakdown in the cargo bound for the various destinations with 17% of non-food industrial products and 16% for minerals.

Table 6.8 - Journeys bound for factories

PLACE OF DESTINATION	CARGO	TRIPS	%
Factory or Warehouse	Agroindustrial products	579	2%
	Agricultural products	655	3%
	Foodstuffs	1,376	6%
	Non-food industrial products	4,328	17%
	Mineral products	3,864	16%
	Not stated	1,309	5%
	Chemicals and petrochemicals	1,297	5%
	Steel and metallurgical products	790	3%
	Empty	10,589	43%
	TOTAL	24.788	

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

The breakdown of goods bound for stores and supermarkets is 48% non-food industrial products and mineral products combined and 38% agricultural products and foodstuffs.

Table 6.9 - Goods bound for stores and supermarkets

PLACE OF DESTINATION	CARGO	TRIPS	%
Store/Supermarket	Agroindustrial products	90	2%
	Agricultural products	598	15%
	Foodstuffs	872	23%
	Non-food industrial products	1,076	28%
	Mineral products	773	20%
	Not stated	269	7%
	Chemicals and petrochemicals	181	5%
	Steel and metallurgical products	1	0%
	Empty	6	0%
TOTAL		3.865	

Source: Road and Airport Transportation Origin/Destination Survey, 2005 – São Paulo State Transportation Department.

7
Virtual Mobility

7. VIRTUAL MOBILITY

There has been no comprehensive research undertaken in Brazil to assess the impact of telecommunications on human mobility. One of the indirect attempts at estimating this impact has been through the analysis of the availability of mobile phones and personal computers, as well as Internet access by users.

The data displayed in Table 7.1 shows that 45% of the population within the SPMR aged 10 years and older had a cell phone for personal use in 2005. Ownership of cell phones is higher among the higher-income segment of the population. In 2006 in Brazil, according to a survey conducted by NIC, 85% of households with a monthly family income higher than R$1,800 (US$1,100) owned a cell phone in comparison to only 9% of households with a monthly family income up to R$300 (US$170).

Internet access is more restricted and concentrated than cell phone ownership and tends to follow income patterns. In the SPMR, the proportion of the population with Internet access in the three months prior to the start of the National Household Sample Survey (PNAD) (2005), organized by the Brazilian Institute of Geography and Statistics (IBGE), was 34% (Table 7.2). According to the NIC survey data for Brazil as a whole (2006), 50% of households with a monthly family income higher than R$1,800 had Internet access compared to less than 1% of households with a monthly family income up to R$300.

Table 7.1 - Cell phone ownership and Internet use in Brazil, 2005

AREA	CELL PHONE OWNERSHIP		INTERNET USE[1]	
	No. of people	% total	No. of people	% total
Brazil	56,104,605	36.7	32,109,939	21
São Paulo state	13,979,859	40.7	10,245,783	29.9
SPMR	7,325,515	44.5	5,578,159	33.9

1 In the three months prior to the National Household Sample Survey (PNAD).
Source: IBGE

Table 7.2 - Internet use by reason, 2005

LOCATION	PERCENTAGE OF USE BY REASON					
	Education	Communicating with people	Leisure	Reading	Shopping	Interaction with the public sector
Brazil	71.7	68.6	54.3	46.9	25.2	43
São Paulo state	70.4	72	53.3	44.3	28.5	44
SPMR	68.4	72.6	52.2	43.9	31	50.6

Source: IBGE

The main impediment to Internet access in the SPMR (as well as in São Paulo state and in Brazil) is the lack of a computer, according to 38% of respondents in a 2005 survey conducted by the PNAD. This was followed by “I don’t need it/I don’t want it” (24%) and “Don’t know” (18%).

Virtually all companies in Brazil have computers and Internet access (99%) and 47% of employees make use of them. Only 15% of companies offer their employees remote access to their computers, according to the NIC survey (2006). The proportion is higher among large companies with more than 1,000 employees (61%) than among small companies with 10 to 19 employees (9%).

As far as online banking is concerned, according to data provided by the Brazilian Federation of Banks (FEBRABAN), there were 2,885 thousand online bank transactions conducted by companies in 2006, while individual online transactions totaled 3,278 thousand. Transactions conducted over-the-counter through retail bank branches totaled 3,799 thousand in 2006. Online transactions outnumbered over-the-counter transactions by 60%. The FEBRABAN data also suggests that, in Brazil, online transactions have been growing more quickly than over-the-counter transactions (average annual growth in the 2004-2006 period is 25.6% for online banking compared to 2.6% through bank branches).

It is also worth noting that individuals and legal entities are able pay their taxes and other services directly to the federal, state and city governments by Internet. The electronic voting system in Brazil also deserves a mention. The voting system is totally automated with electronic ballots. Results of elections can be published within hours of the polls closing (however, voters are still required to cast their votes at the polling station).

The table below illustrates the relatively widespread broad availability and use of information & communications technology (ICT) in the SPMR area and throughout Brazil. The greatest restriction impeding the expansion of ICT is lack of financial means to buy ICT equipment among a considerable section of the population. Despite the increasing use of ICT, it has not yet been possible to evaluate its impact on the physical mobility of the population. It should be noted that most of the journeys undertaken within the SPMR area are for work and educational purposes (based on origin-destination surveys conducted periodically by the São Paulo Subway). These journeys have probably not been reduced significantly as a result of the widespread utilization of ICT.

Summarized below are the data related to the availability of ICT equipment obtained through sample surveys conducted by private Brazilian companies.

Table 7.3 - Brazil – Percentage distribution of households owning ICT equipment by region and family income range, 2006

Percentage over total households[1]

		Landline telephones	Mobile telephones[2]	Internet access mobile phones (Basis: owns a cell phone)[3]	Desktop computer	Portable computer (laptop, etc.)
Total		**49.69**	**67.64**	**17.78**	**19.3**	**0.61**
BRAZILIAN REGION	SOUTHEAST	**58.59**	**70.33**	**18.04**	**23.83**	**0.56**
	NORTHEAST	31.21	53.9	13.06	8.38	0.23
	SOUTH	53.91	75.2	21.48	24.24	0.94
	NORTH	34.62	61.66	14.66	9.97	0.6
	CENTRAL-WEST	51.76	81.36	22.37	18.35	0.93
MONTHLY FAMILY INCOME (In Brazilian Reais)	UP TO R$300	8.89	26.59	4.33	1.57	0
	R$301-R$500	23.31	46.98	9.3	2.36	0.08
	R$501-R$1000	50.51	69.47	16.24	13.73	0.07
	R$1001-R$1800	71.67	85.23	25.96	36.27	1.14
	R$1801 OR HIGHER	85.17	95.11	36.83	59	4.2

[1] Basis: 10,510 households surveyed. Multiple responses.
[1] Household projection: 53.1 million households, according to estimates based on the 2005 PNAD.
[2] Considering that at least one member of the household owns a mobile phone.
[3] The calculation basis for this indicator is the column “Mobile Telephones” in this Table.
Source: NIC.br - Jul/Aug 2006 (in www.cetic.br)

Table 7.4 - Brazil – Percentage distribution of households with internet access[1] by region and family income range, 2006

Percentage over total households[2]

Percentage (%)		YES	NO	DK/DR [3]
TOTAL		**14.49**	**85.35**	**0.15**
BRAZILIAN REGION	SOUTHEAST	18.74	81.00	0.26
	NORTHEAST	5.54	94.37	0.09
	SOUTH	16.90	83.07	0.03
	NORTH	6.15	93.79	0.06
	CENTRAL-WEST	13.05	86.88	0.06
FAMILY INCOME (In Brazilian Reais)	UP TO R$300	0.46	99.42	0.13
	R$301-R$500	1.22	98.76	0.03
	R$501-R$1000	8.90	91.07	0.03
	R$1001-R$1800	27.33	72.39	0.28
	R$1801 OR HIGHER	50.53	48.51	0.96

[1] Considering only Internet access via desktop computers or portable computers (laptop and notebook).
[2] Basis: 10,510 surveyed households.
[2] Household projections: 53.1 million households, according to estimates based on the 2005 PNAD.
[3] DK/DR: Doesn't Know or Didn't Answer.¨
[4] The criterion used for classification takes into account the educational level of the household head and ownership of a number of household appliances, listing them according to a score point system. The sum total of the points reached per household is associated with a specific Socio-Economic class categorized as A, B, C, D, E.
Source: NIC.br - Jul/Aug 2006 (in www.cetic.br)

Table 7.5 - Internet-related activities – financial services

Percentage over total Internet users[1]

Percentage (%)		Consulted banking account	Pay-ments	Credit card consult-ation	Consulted savings account	Mobile phone rech-arge	Bank transfers	Investments (financial transactions, social security, etc)	Other financial services
TOTAL		12.09	5.92	5.48	5.60	3.76	3.48	1.98	0.77
BRAZILIAN REGION	NORTH/ NORTHEAST	7.80	4.08	4.51	4.55	2.35	1.74	1.24	0.84
	SOUTHEAST	12.88	6.41	6.25	5.67	4.40	3.52	2.28	0.43
	SOUTH	12.70	6.46	3.47	6.16	3.33	3.96	1.38	0.84
	CENTRAL-WEST	12.62	4.20	5.09	4.54	2.61	4.01	1.60	1.14
SEX	Male	12.72	5.87	6.10	6.55	3.56	3.28	2.09	1.19
	Female	11.41	5.98	4.81	4.58	3.97	3.71	1.87	0.32
SOCIAL ECONOMIC CLASS[3]	AB	17.97	8.53	7.90	7.63	5.05	5.44	2.89	1.05
	C	9.48	5.00	4.59	4.80	3.38	2.50	1.41	0.51
	DE	3.04	1.12	1.09	2.10	1.12	0.85	1.15	0.78

[1] Basis: 2,924 respondents who used the Internet in the last three months. Multiple responses.
[1] Population projection: 42.6 million people, aged 10 years and older, according to estimates based on the 2005 PNAD.
[2] The category "is not part of the economically active population" includes students, retirees and housewives.
[3] The criterion used for classification takes into account the educational level of the household head and ownership of a number of household appliances, listing them according to a score point system. The sum total of the points reached per household is associated with a specific Socio-Economic class categorized as A, B, C, D, E.
Source: NIC.br - Jul/Aug 2006 (in www.cetic.br)

It is worth noting that mobile-phone ownership and Internet use in the SPMR have grown over time. Data provided by ANATEL, the Brazilian Telecommunications Agency, point to an increase in the number of cell phones in the SPMR area (dialing code 11) from 13.7 million in December 2006 to 16.7 million in December 2007 (a 21.4% variation over a one-year period, considerably higher than the area's population growth). In respect to Internet use, no data was found specifically for the SPMR area. The following data is based on a survey conducted by the Brazilian Institute of Public Opinion and Statistics (IBOPE – a private survey company) and shows the evolution of the proportion of Brazilian households with Internet access on a quarterly basis between 2005 and 2007 – in the case of the SPMR, the evolution is believed to have been similar.

Table 7.6 - Internet penetration among households *

Percentage of households with Internet access through a domestic computer

	2005			2006				2007		
TOTAL HOUSEHOLDS	2º Q 2005	3º Q 2005	4º Q 2005	1º Q 2006	2º Q 2006	3º Q 2006	4º Q 2006	1º Q 2007	2º Q 2007	3º Q 2007
Percentage	11%	11%	12%	12%	12%	12%	13%	14%	15%	17%

Source: IBOPE (in www.cetic.br - IBOPE/NetRatings)

8
Programs and Actions

8. PROGRAMS AND ACTIONS

This chapter outlines the programs and actions undertaken at federal, state and municipal levels to improve the outlook for sustainable mobility in São Paulo. It examines measures to improve pollution control, traffic safety, congestion, the mobility divide and travel security.

8.1 RENEWABLE FUELS AND AIR POLLUTION CONTROL

8.1.1 History of programs and action

Programs and action

Both the alternative fuel and the emission control programs were motivated by the same concerns; however, they were developed at different times. The use of ethanol started with PROÁLCOOL in 1977, while the vehicle emission program only began in 1986. The emission control program benefited from the existence of the ethanol program. However, with the ethanol crisis in 1990 car manufacturing shifted once again to the production of gasoline-powered cars. However, emission standards for new cars remained at the same levels. The technology had improved to make this possible.

The use of natural gas to power taxis and cars was introduced later; however conversion of engines to natural gas actually increased emissions. Thus, natural gas has in reality not been an effective tool for pollution mitigation.

Minor smoke controls were introduced for diesel-powered vehicles (heavy duty engines and SUVs) in 1989. Since 1996 there have been some improvements in fuel quality to bring it in line with European standards.

Finally, emissions restrictions were only extended to motorcycles in 2003, when sales increased dramatically.

The introduction of pollution control programs can be summarized as follows:

- Ethanol was blended with gasoline in 1977, reaching 20% in 1980 in São Paulo;
- Ethanol cars were produced between 1980 and 1990 (over 90% of production was Brazilian);
- Phase I of the light duty vehicles' (LDV) emission control (gasohol and ethanol engines) began in 1989, phase II in 1992, phase III in 1997, phase IV in 2005 and phase V in 2009;
- Lead-free gasoline was introduced in 100% volume sales by PETROBRAS. Brazil was the first country in the world to introduce lead-free gasoline nationwide. This and the use of ethanol (also a lead-free fuel) made it possible to install catalysts in light-duty vehicles;
- Flex fuel vehicles were introduced in the market in 2003, under the same LDV emission standards;

- Smoke control programs for heavy-duty engines (HDE are 100% diesel) were introduced in 1987/89;
- Gas emissions controls for HDE started in 1994; EURO I started in 1996; EURO II in 1998/2000; EURO III in 2004/5 and EURO V is planned to start in 2012 (substituting the failed phase EURO IV, which was scheduled for 2009);
- Reduced sulfur diesel with 5,000 parts per million (ppm) was introduced in the metropolitan market in the 1990s; the sulfur content was subsequently reduced to 3,500, 2,000, and eventually to 500 ppm in 2005;
- In 2002, CONAMA introduced legislation 315, with new emissions limits for diesel vehicles equivalent to EURO IV standards to be implemented from 2009. This required diesel sulfur to be limited to 50 ppm in new vehicles.[14]
- In November 2008, CONAMA introduced legislation no. 403/2008, with new stricter emission limits for heavy-duty vehicles; this CONAMA phase 7 was based on EURO V standards, to be enforced by 2012. This legislation requires reducing the diesel sulfur content to 10 ppm by 2013.

The PROÁLCOOL Program

Brazil has been using renewable energy from hydroelectric power plants for a considerable period of time. As a result of the 1975 oil crisis, the Brazilian government set up the PROÁLCOOL ethanol fuel program, which became a key biomass energy program for the production of automotive fuel. At that time, Brazil used to import gas, so ethanol production was intended mainly to replace and reduce reliance on imports.

The development of ethanol-fueled engines led to a substantial evolution in the domestic automotive and auto parts industries, boosting the country's technological independence and making it a world leader in this sector. Brazil successfully tackled and resolved several technical problems surrounding the development of ethanol and amassed considerable experience during the 22 years of the PROÁLCOOL ethanol fuel program. Currently, the country is a major exporter of flex-fuel vehicles, including to newcomers in ethanol use. Today Brazil has a vast nation-wide ethanol distribution network: a remarkable strategic achievement for this sort of program. The Brazilian program was the first successful large-scale program for the replacement of gasoline with ethanol worldwide.

In keeping with the technological developments of the PROÁLCOOL program, CONAMA created the nation-wide PROCONVE Program. The program establishes environment targets and emission limits based on US and European legislation. This is the only federally legislated vehicle manufacturing air pollution control program with environmental requirements in the country.

[14] The Resolution 315/02 of the National Environmental Council (CONAMA) – related to the Brazilian Environmental Ministry – determined the level of emissions of vehicles, to be implemented as of January 2009. However, the regulation on fuel composition is under the jurisdiction of the regulatory National Agency for Oil, Natural Gas and Biofuels (ANP). ANP did not, at first, provide the necessary time to industry for investment and product development. The ANP Resolution no. 32, dated October 16, 2007, provides the fuel specification in accordance with CONAMA Resolution 315/02. The automotive industry has, by the National Law 8723/93 article 7, 3 years to design the engines suitable to the fuel regulation.

Unlike PROCONVE, other programs for the development of alternative fuels have set intermediate targets for their implementation and market development, but have otherwise been flexible about their maintenance and continuity, since they are not subject to strict legal requirements.

The PROÁLCOOL is a typical example of a regulated Brazilian program that suffered when the country moved towards the free market economy. However, soaring oil prices in the international market served to boost it and today it is becoming firmly established in Brazil's ethanol-producing states; while the advent of flex fuel engines has made ethanol an everyday choice for consumers who are no longer at the mercy of ethanol supply shortages.

Unfortunately, several alternative energy programs have begun to market themselves as "clean energy" solutions, but without including provisions for emissions reductions. Ideally, whenever a new clean fuel program is established, it should include environmental targets otherwise the products may not provide any *a priori* environmental advantage and the new fuel may lose credibility.

For example, the implementation of ethanol fueled cars in Brazil produced, at the time, an immediate reduction in emissions as a result of the physical and chemical properties of alcohol. However, emissions reduction was not a primary requirement of the PROÁLCOOL program. The same occurred to the Brazilian program of automotive natural gas. There is a widely held belief that natural gas is less polluting; however, despite being a clean fuel, in Brazil light-duty natural gas-powered vehicles emit more pollutants (approx. twice as many) when converted to natural gas than with the original fuel. This can be explained by the poor quality engine conversion services provided in Brazil. In addition, from the start of the natural gas program no serious environmental targets were set to ensure that engine conversion for alternative fuels would result in cleaner engines. Steps have now been taken by CONAMA to require emission performance certification of conversion kits. Manufacturers of conversion kits are finding it difficult to achieve the emissions requirements set by the new phases of PROCONVE.

In 2006, a "Tetra Fuel" vehicle was launched on the market by a car manufacturer, as an alternative to engine conversion. This vehicle can run with ethanol-free gasoline, gasoline with ethanol, hydrated ethanol and Compressed Natural Gas (CNG). It complies with PROCONVE standards[15] and sales have been increasing, with many users choosing natural gas, until a recent supply crisis occurred in 2008.

Currently, Brazil is in the throes of a natural gas shortage. And no incentives are in place to encourage continued use of natural-gas powered light vehicles, especially since they do not at present offer any environmental advantages to justify the level of investment needed to sustain the program.

A Brazilian biodiesel program (the third in 20 years) is currently in development motivated by the claim (as yet unproven) that it is a cleaner fuel. This program has no environmental requirements and environmental targets are not a major component of this program.

[15] Legislation CONAMA no. 291 on certification of natural gas converted vehicles.

Brazil's alternative fuels program is based chiefly on political good will. These government-backed programs have fulfilled their basic role of developing alternative fuels up to their implementation, while the strategy has provided opportunities that have made Brazil a leader in renewable energies.

Air pollution control and the PROCONVE experience

Starting in 1980 in Brazil, the practice of blending ethanol with gasoline resulted in a significant shift in annual vehicle emissions levels. Immediately prior to the inception of the PROÁLCOOL program, annual CO and HC vehicle emissions were 60% higher than the values estimated by the mobile sources emission inventory, while the NOx level was 15% lower. This indicates that the program – originally conceived as an oil-saving program – had a positive impact on emissions.

In the period between 1983 and 1989, the introduction of ethanol-fueled vehicles resulted in significant changes in the emissions inventory, since emission factors were inherently different before the application of emission control technologies. The gaps between them narrowed considerably with the establishment of PROCONVE. This was because environmental requirements meant that all light-duty vehicles required the same technology.

With the implementation of the PROCONVE program in 1986, engine designs were reformulated and engine emissions were reduced both for gasoline-fueled and ethanol-fueled engines. The second phase of this program was started in 1992, and led to the use of oxidation catalyst converters and/or electronic fuel injection. From then on, ethanol and gasohol (gasoline with 22% ethanol added) engines achieved an 80% emissions reduction. Ethanol-fueled engines achieved more important CO and HC emission reductions than their gasohol counterparts because of the greater durability of their catalysts. Furthermore aldehydes emissions, one of the weak points of ethanol-fueled engines from an environmental standpoint, were regulated and reduced.

In January 1997, Brazilian automotive technology complied with the restrictive requirements set forth at the time, achieving emissions reductions of more than 95% in new cars through the use of three-way catalysts and electronic fuel injection. In 2003, following the development of microprocessors, the first flex fuel vehicles were launched on the Brazilian market. Flex fuel engines run both on ethanol and gasoline in any proportion and currently make up 85% of Brazil's automotive market. This technology was introduced to solve technology diversity problems and fuel supply and cost issues, including:

- Manufacturers began to produce one single type of engine to meet demands for pure gasoline (exports), ethanol and gasohol (both employed in Brazil);
- Users can use ethanol without fear of sugar cane harvest interruptions and the devaluation of vehicles caused by fluctuations in the sugar market, and they can choose the cheapest fuel depending on which area of the country they live in;

- The Brazilian fuel market has matured thanks to competition between ethanol and gasoline fueled engines;
- Since ethanol is a cleaner fuel, the quality of gasoline sold in the country has improved keeping it competitive without compromising the durability of vehicle catalysts.

It is worth noting that ethanol use in Brazil has brought about a significant reduction in CO_2 emissions. This is a particularly important aspect since environmental problems have reached alarming levels in many of those Brazilian considered being “good” models of economic development.

8.1.2 Fuel for light vehicles

Basis of PROÁLCOOL (ethanol fuel program)

In the 1970s, the most coveted characteristics in Brazilian vehicles were high performance, and maximum speed and power output. The introduction of the PROÁLCOOL program in 1977 resulted in 20% ethanol in Brazilian gasoline by 1980.

The mixture of ethanol and gasoline leads to a more complete fuel burn-out, since the volume of air required to burn ethanol is lower than that required for gasoline i.e., 1 kg ethanol requires 9 kg air for a complete burn-out, while 1 kg gasoline requires 14 kg air. Provided the engine maintains its original calibration, the new ethanol-based mixture requires less air. When gasoline and ethanol are mixed, fuel burn-out becomes more thorough, CO and HC emissions decrease and consumption tends to be lower in engines calibrated for maximum power to reach maximum engine yield – with 12% ethanol in engines produced in Brazil in 1975, the addition of 20% ethanol to gasoline reproduced the same specific fuel consumption pattern of the original fuel (pure gasoline). The government’s strategy was to adopt the 20% ratio as a nominal value for the new Brazilian gas, since users couldn’t identify the variation in consumption and Brazil could enjoy a 20% reduction in the country’s demand for gas. This was the basic premise of the PROÁLCOOL program.

In the early 1980s, automotive manufacturers began producing engines for the 20% ethanol-gasoline mixture but aimed at energy efficiency so that users could enjoy a better and more economical vehicle. Concurrently, the first full pure ethanol engines started being produced using an altogether different calibration specifically for this type of engine. From then on, Brazilian manufacturers produced two different engines: a gasohol engine with 20% ethanol content, later increased to 22%, and another engine with pure hydrated ethanol. Both types of engine were manufactured without any environmental control, but nonetheless reduced the CO and HC emissions, albeit in insufficient levels to solve the air pollution problems in large Brazilian cities.

Brazil has managed to strike a balance between demand for ethanol and gasoline demands, while demand for diesel oil is much greater. This creates problems for the refining process and has made it difficult to improve the quality of diesel oil. Such refining imbalances led the oil industry to modify the refining bands, aggregating both light and heavy hydrocarbons to keep the desired average diesel conditions.

Newer refining technologies have been introduced by Petrobras in the last few years with a view to solving these difficulties and providing diesel fuel with sulfur content below 50 ppm, starting in 2009.

Biofuel production estimates

Production estimates supplied by the Brazilian sugar-ethanol sector show a current ethanol production of roughly 13 million m³ within the São Paulo state catchment area, where a pipeline is being planned. Some 75% of the production volume comes from the state's catchment area and by 2012 total production in this area is expected to reach 20 million m³ under favorable market expansion scenarios (Table 8.1).

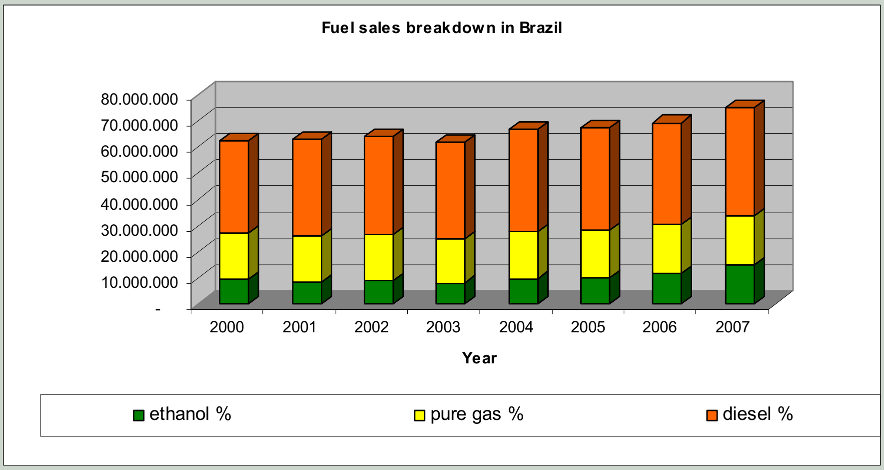
Table 8.1 - Projection scenario of expected growth in ethanol consumption

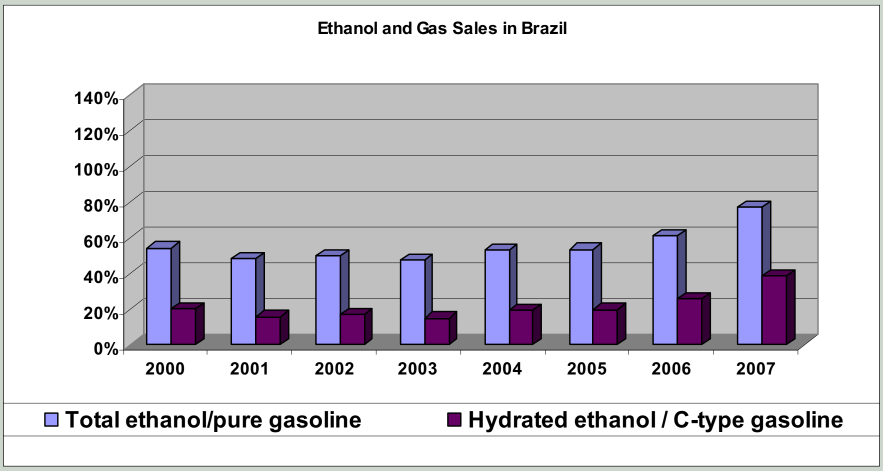
DESTINATION	HARVEST					(million of m³)	
	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Brazilian market		7,3	7,4	7,6	7,6	7,6	7,6
Export via pipeline		5,0	6,0	7,0	8,0	9,0	10,0
Total export	4,0	7,0	8,0	9,0	10,0	11,0	12,0

Source: Guidelines and Pre-Feasibility Analysis of the Conchas – Paulínia – Porto Ethanol Pipeline, Synthesis Report, São Paulo State Transportation Department, 2006

Figure 8.1 and
Figure 8.2 below show that domestic sales of hydrated ethanol have been growing exponentially since 2005, and in 2007 reached 38% of C-type gasoline (refinery gasoline with 24% ethanol added) in Brazil and 77% in São Paulo state, indicating a high uptake of ethanol-fueled vehicles. With regard to the replacement of industrial inputs, ethanol consumption has reached 77% of pure gasoline consumption in Brazil and 127% in São Paulo state.

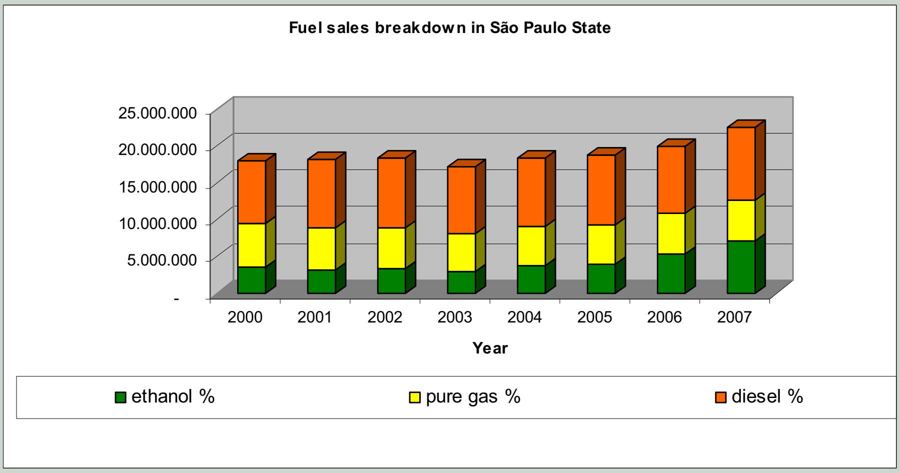
Figure 8.1 - Brazilian data

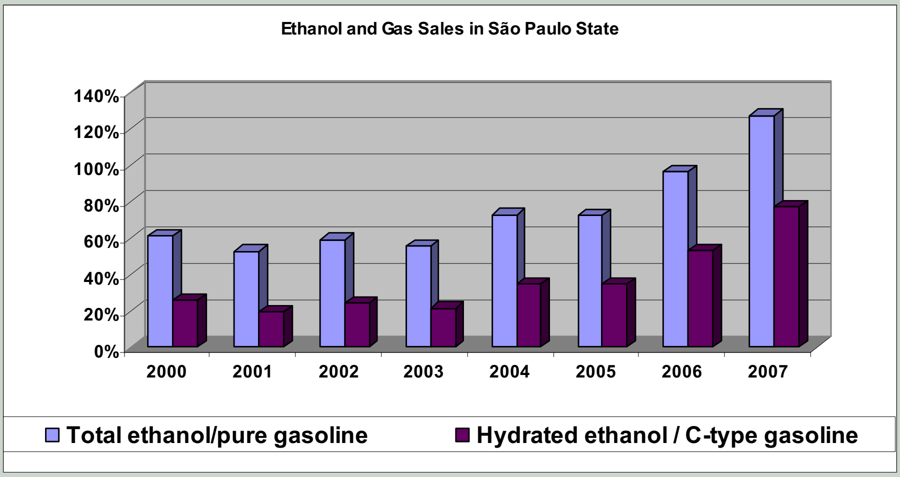




Source: ANP

Figure 8.2 - São Paulo state data





Source: ANP

8.1.3 Heavy duty vehicle fuel alternatives

Imbalances in the Brazilian fuel matrix

Diesel-powered engines are still regarded as the most energy-efficient alternative among the present fuel options for heavy duty vehicles. However, oil refining processes do not produce diesel oil alone, and because of the characteristics of crude oil and refining processes, the diesel/gasoline ratio has a limited span. In Europe, demand for diesel oil is slightly higher than gasoline production, so some European countries have to import diesel oil. A different picture is observed in the US, where gasoline consumption is considerably higher than demand for diesel oil, and the country has to import gasoline. Therefore, depending on local use, fuel industry demand can be substantially different.

In the Brazilian case, demand for gasoline is half the demand for diesel oil, because only gasoline was substituted by ethanol. This imbalance has distorted the refining process. To keep diesel prices from rising, gasoline prices were set artificially high to cross-subsidize diesel prices. Over time, this cross-subsidy was gradually reduced and finally eliminated. Currently, the government has instruments to regulate prices and to keep the cost of diesel below that applied in most countries. High consumption has resulted in high diesel oil import costs, although prices in the internal market have been kept low to avoid increases in the cost of transport. The importance of diesel use in Brazil is the result of a focus on road transport over the last 50 years.

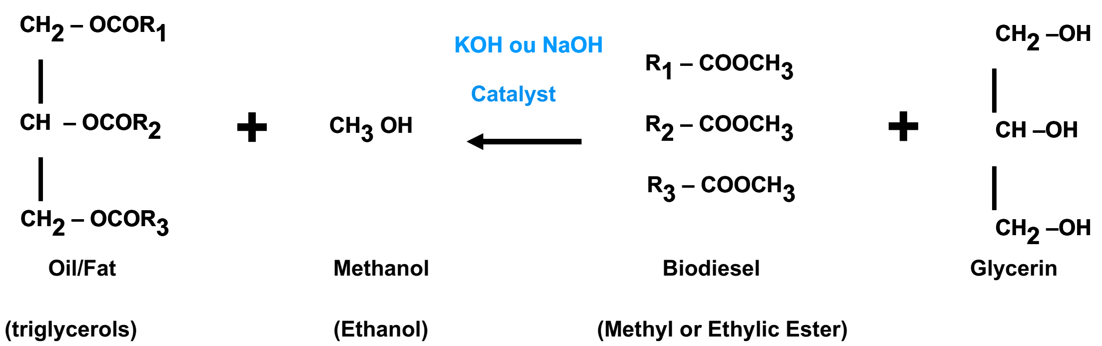
Brazil's fuel matrix has been one of the major stumbling blocks for the PROÁLCOOL program. Over the course of a single decade, the country's automotive fuel matrix went from high demand for gasoline to intense diesel oil consumption, which was followed by a significant growth in the fleet of diesel-powered heavy-duty vehicles.

Another means for increasing renewable energy sources is through the partial replacement of diesel-powered engines with alternatives, such as ethanol-fueled diesel-cycle engines, hybrid vehicles, biodiesel, natural gas, and the hydrogen fuel cell. In addition, more efficient transportation systems, such as trains, trolleybuses, waterway systems, may play a significant role in improving energy-efficiency in transport and in reducing demand for diesel fuel in Brazil.

Ethanol-powered engines for heavy duty vehicles were being considered in the 1980s, but the idea was soon abandoned because of the substantial difference observed in performance and consumption between diesel and ethanol engines. More recently, with oil prices soaring, despite its lower performance and higher consumption, ethanol-fueled engines for heavy duty vehicles are again being considered. In addition, they are much cleaner than the current diesel-powered engines. An OEM manufacturer is planning to bring to Brazil a diesel-cycle engine that runs on unleaded ethanol and meets the European requirements for Extra Environment Compatible Vehicles (EEV) vehicles. Also, an advanced natural gas-powered bus made by many different automotive makers has low emissions and is being used in different cities worldwide. These could be interesting strategies for use in bus corridors and captive fleets of large Brazilian cities, as they mean that heavy duty vehicles can start meeting emission requirements at once

Biodiesel

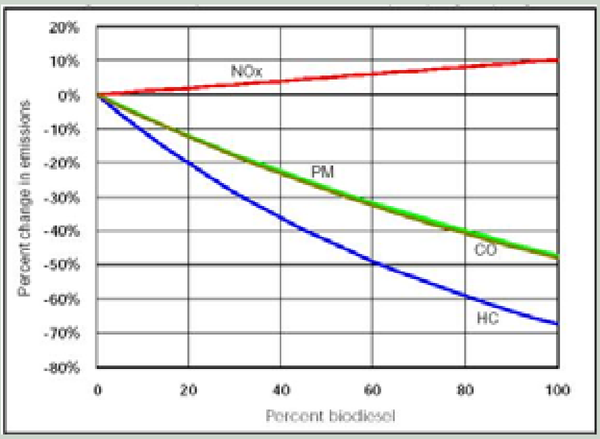
Biodiesel is a product obtained from the chemical reaction of alcohol with an organic ester i.e., vegetable oil or animal fat that breaks the ester molecular triple chain to form another ester of a simpler and more linear molecular configuration. The characteristics of this new product are much closer to oil diesel properties than natural vegetable oils. In addition to reducing frying odors typical of vegetable oils, biodiesel's greatest advantage is to reduce significantly the build-up of gum resins in the engine resulting from the polymerization of vegetable oil under high temperature. This reaction produces glycerin, which corresponds approximately to 10% of the processed mass, and must be removed. Large-scale biodiesel programs may generate an excess supply of this product, which has to be absorbed in the marketplace.



Source: FATEC[16]

However, diesel-powered engines running on 2% or 5% vegetable oil ester or a biodiesel blend produce the same amount of emissions, and depending on the origin of the biodiesel or the seed from which oil is extracted, there may be an increase in toxic aldehyde emissions. Figure 8.3 shows the average influence of biodiesel on emissions whereby the smoke level decreases and the NOx emission increases. Depending on how the crop is grown (fertilizers, type of biomass, etc.), harvested and processed there may be very little CO_2 benefit – this is particularly true for example of corn-based programs in the US for ethanol production – when replacing fossil-based diesel, it can effectively reduce CO_2 levels in nearly the same proportion as its mixture.

Figure 8.3 - Influence of biodiesel additions on emissions



Source: US Environmental Protection Agency[17].

[16] Celso Fernandes Joaquim Junior - TECHNOLOGICAL ASPECTS OF BIODIESEL PRODUCTION – TECHNOLOGY UNIVERSITY (FATEC) AT – BOTUCATÚ - 04/2007.
[17] Report EPA420-P-02-001 - October 2002 - A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions Branco, Gabriel Murgel – Fuel Consumption Survey – 2007.

Put simply, the Brazilian biodiesel program is in its infancy and it is too early to estimate the practical advantages or disadvantages in relation to emissions since only 3% to 5% of biodiesel is currently added to diesel oil. This mixture does not produce any significant effect, however if this ratio is increased to 20, 30, 50 and 100% levels, it might pose some operational difficulties that are not as yet known. Therefore the biodiesel program should include an in-depth study to find out the effective differences between biodiesel and common diesel oil and their impact on emissions.

In addition, a key biodiesel issue relates to the quality of its production, which demands complex industrial facilities. The Brazilian biodiesel program targets the creation of jobs through small-scale production by independent farmers. However, poor production control poses a risk that may greatly jeopardize the biodiesel program as the volume of reagent substances and the separation of by-products in the production process could vary, leading to an end product with excess alcohol, vegetable oil or glycerin. Any of these excesses may contain harmful substances that might damage or destroy the engine. Therefore, the biodiesel program should rely primarily on large-scale industrial production processes with total quality control, although the raw materials can be sourced from independent farmers.

Figure 8.4 - The targets established for the Brazilian biodiesel program as defined by the Brazilian Petroleum Agency (ANP)

BIODIESEL APPLICATION	% OF ADDITION	VOLUNTARY	MANDATORY
Lubricant additive - B2	2%	2006	2008
Additive - B5	5%	2008	2013
Mixtures – B20	20%	2013	
Mixtures – B20 to B30		Experimental only	
Pure – B100	100%		

Source: FATEC – Technology University.

Depending on the Brazilian region where biodiesel is to be produced, its vegetable origin may vary and, therefore, careful attention should be paid to its specification.

Source: FATEC – Technology University.

Taking into account legal requirements, as well as Brazilian diesel oil consumption which reached 18.7 million m^3 (ANP) in 2007, production of B100 would need to reach 374,000 m^3 to meet the 2% demand legally required for B2 and 936,000 m^3 to meet the 5% demand legally required for B5. Brazilian diesel oil production in 2007 amounted to 402,000 m^3, enough to comply with B2 targets, but still insufficient to comply with B5 targets. In order to meet B20 targets, B100 production would need to reach 3.75 million m^3 annually.

A variation in this process – H-BIO technology – was recently announced by Petrobras, the Brazilian oil company. This process involves blending vegetable oils with mineral diesel during the refining process, i.e., blending crude oil with extra natural vegetable oil. Under this scenario, the oil cracking process is extremely efficient and results in true diesel oil (not biodiesel because it is no longer an ester) that yields outstanding performance and physical properties (including lower sulfur and density). Furthermore, the utilization rate of vegetable oil in the end product is raised to 98%, it is glycerin free; in the biodiesel transterification process only 90% of vegetable oil is converted to fuel. Petrobras estimates that processing 256 million liters of soybean oil in these units will result in a 10% saving in diesel imports. Other raw materials are also being tested for their suitability as biodiesel.

This process could solve some of the problems surrounding biodiesel production. It also has the advantage over conventional refining processes of ensuring economies of scale. To date, this process is being carried out in three Petrobras refineries.

8.1.4 Natural gas vehicles

The use of natural gas to power cars in Brazil was encouraged because of the observed efficiency of the conversion of Otto cycle gasoline engines to natural gas. However, for the last decade such conversions have been carried out in facilities that lack the appropriate technology which has resulted in sub-standard natural gas-powered engines with higher emissions! Although some of these conversions are certified by environmental agencies, the environmental gain has been minimal. In 2006, when the first Tetra Fuel car was produced, requiring no conversion, the natural gas-powered vehicles started to comply with PROCONVE standards and there was a greater shift toward the use of natural gas. The Tetra Fuel car can also run on pure gasoline, ethanol or any blend of these fuels; as a result, market demand for this vehicle was far greater than originally anticipated.

More recently, efforts to produce a heavy-duty Otto cycle natural gas engine have resulted in the introduction of new technology but so far these have not demonstrated any advantages over diesel-powered vehicles. Today, manufacturers are developing diesel injection systems that can be used in natural gas-powered cars. This is a slightly different technology which has a similar performance to the diesel engine, but the process is in its infancy and remains at the certification phase. Some car manufacturers are hoping to import natural gas-powered buses with low emissions (in compliance with EURO V), however, these are more expensive than the vehicles currently in use and reusing them for use in rural areas after urban use remains a challenge.

8.1.5 Hybrid and hydrogen vehicles

While diversifying the Brazilian fuel matrix could offer one possible solution to the country’s mobility-related challenges, another option rests in the development of new vehicle technologies. An electric vehicle powered by hydrogen-producing electrolytic cells could be a future option. The technology, which is very recent and has not yet been commercialized, uses pure hydrogen and an electrolytic cell to produce electrical energy through a cooling process; this process has a higher thermal efficiency than internal combustion engines.

The first vehicles that will use this technology will be electric trolleybuses powered by an onboard generator consisting of a fuel cell and state-of-the-art electronic control system. A variation of this concept involves replacing the hydrogen electrolytic cell with a generator group also installed on board the vehicle – this so-called hybrid vehicle is already available on the international market but not in Brazil. Hybrid vehicles could provide the interim technology between today’s vehicles with their internal combustion engines and mechanical transmission, and future electric vehicles powered by hydrogen cells.

The main challenge presented by modern hybrid vehicles is when to switch to the internal combustion engine to ensure the greatest fuel economy, this is particularly important in urban areas where speeds can vary significantly. Modern hybrid engines offer energy efficiency improvements of approximately 30% when used in heavy-duty vehicles, like buses, and reductions in fuel consumption of up to 50% when used in cars. As far as emissions are concerned, it is important to emphasize that hybrid vehicles will only be clean if their combustion engines are built using clean technologies and include exhaust treatment devices. The advantage of the hybrid vehicle design is that the engines operate at a constant level and it uses cleaner technologies than traditional vehicles.

However, without clean technologies, the introduction of hybrids will not result in significant reductions in emissions. That said, current hybrids available in the market place are the cleanest vehicles worldwide. They are marketed in the US and Japan as having emission levels 90% lower than current US standards require – as noted on the EPA website – and offering the user a higher level of performance.

All these technologies will benefit from the use of clean fuels. A clean vehicle powered by a flex engine running on ethanol, for instance, might offer the same advantages as a hybrid vehicle i.e., use of renewable fuels and fuel flexibility. This should be the way forward for the Brazilian automotive industry.[18]

8.1.6 Vehicle inspection

Vehicle inspection and maintenance (I&M) procedures were established by the same CONAMA legislation that created the PROCONVE. A few cities in Brazil implemented them; the city of Rio de Janeiro was the first to do so about 10 years ago. Rio inspects light-duty vehicles for compliance with emissions standards, but only has a smoke/opacity inspection program for heavy-duty vehicles. The city of São Paulo only began implementing an I&M program in 2008. This program includes monitoring and screening high-emission vehicles using remote sensing devices. However, it is too soon to talk about environmental benefits.

Based on the PROCONVE program, Brazilian authorities plan to implement vehicle inspection and maintenance programs at the municipal level in the most polluted cities in order to reduce air pollution caused by vehicles in circulation. Since the São Paulo I&M Program is in its infancy, there is little data available. However, a Brazilian company has published some statistics relating to São Paulo, Brasilia and Rio de Janeiro, based on remote sensing measurements which show that 20% of vehicles in major Brazilian cities have been tampered with (loss of catalysts, engine modification and very poor maintenance) and are responsible for 70% of the emissions from the total vehicle fleet.[19] This lack of compliance has been observed in vehicles of all ages though it exceeds 30% in vehicles over 20 years old.

[18] A great advantage of the hybrid vehicle is the possibility of using a conventional generator while investing in the development of electrical power transmission and management system for the vehicle, which is quite similar to the forthcoming hydrogen powered vehicles. While hydrogen cells are not commercially available, this transition may allow Brazil to prepare itself industrially for the production of vehicles with the most advanced electrical traction technology.
[19] Source: Environmentality private report

8.1.7 Future strategies

Rationale for an environment-friendly fuel matrix

The primary rationale for introducing alternative fuels is to reduce polluting emissions, and particularly greenhouse gas emissions. Carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_X) and sulfur dioxide (SO_2) generally create local problems, while other emissions such as carbon dioxide (CO_2) and methane (CH_4) contribute to global warming and climate change. According to a report published by the Intergovernmental Panel on Climate Change (IPCC), “The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual carbon dioxide concentration growth rate was larger during the last 10 years (1995-2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960-2005 average: 1.4 ppm per year), although there are variations in the growth rate from one year to the other. The main source of the increase in atmospheric concentration of carbon dioxide since the pre-industrial period is the continuous use of fossil fuels, with the change in land use contributing in a small but significant way”. The latter is particularly true in countries like Brazil with a high forest cover.

With regard to CO_2, stricter emission reduction targets have been set for some industrialized countries. For emerging countries like Brazil no specific targets have been established. Brazil could reduce CO_2 emissions through the introduction of new technologies, conservation of trees and forests, reforestation and other viable alternatives. Brazil also has the opportunity to trade CO_2 credits for projects and initiatives that lead to a reduction in carbon dioxide emissions globally. For example Brazil currently accounts for 13% of the registered projects worldwide under the Clean Development Mechanism (CDM) hosted by the United Nations Framework Convention on Climate Change (UNFCCC). Traditionally, Brazil produces much of its energy from hydroelectric power plants and could become one of the largest global centers for CO_2 abatement, contributing not only to combating the greenhouse effect but also benefiting economically from the sale of environmental carbon credits.

Technology is the most important parameter. For transport, the move towards cleaner renewable fuels is not a definitive solution on its own, but rather the beginning of a process. Traditional fuels are sensitive to impurities; it is this sensitivity which led to improvements in fuel quality. Clean technologies are also sensitive to impurities and may provide solutions to some of the quality adjustments required by traditional fuels. For example, ethanol is a good substitute for lead in gasoline; fuels must be lead-free to prevent catalyst damage. Ethanol and natural gas have low sulfur content, which can increase the durability of catalysts and other electronic sensors in internal combustion engines using new electronic fuel injection technology.

Strategies based on different modal systems

By looking at the data gathered by the emission inventory discussed above, it is possible to predict the relative importance that each type of vehicle might have in future annual emission scenarios (as of 2020). Table 8.2 below, provides an overview of the impact of the main pollutants, rated on a scale from 0 (lowest importance on annual emissions) to 5 (highest), thereby highlighting the items that require most attention.

Table 8.2 - Weight of the main pollutants (0 = requires least attention, 5 = greatest attention)

	LIGHT VEHICLES		MOTORCYCLE	BUS	TRUCK
	Flex	Gas			
Local effect pollutants					
CO	**1**		**3**	**0**	**1**
$HC_{escapamento}$	2		3	0	1
Aldehydes	1		1	1	3
Evaporative	0		5	0	0
Crank case	0		2	1	2
VOC_{total}	**2**		**3**	**0**	**1**
NOx	**0**		**0**	**1**	**4**
Particulates	**1**		**1**	**1**	**2**
Greenhouse effect gases					
$CO_{2(fóssil)}$	**1**		**0**	**1**	**3**
$CO_{2(renewable)}$	5		0	0	0
$CO_{2(total)}$	2		0	1	3

Source: EnvironMentality

This table shows the emissions produced by each type of vehicle in Brazil, and shows where greatest action is needed to curb pollution. It can also help to define strategies for behavioral change and modal shift.

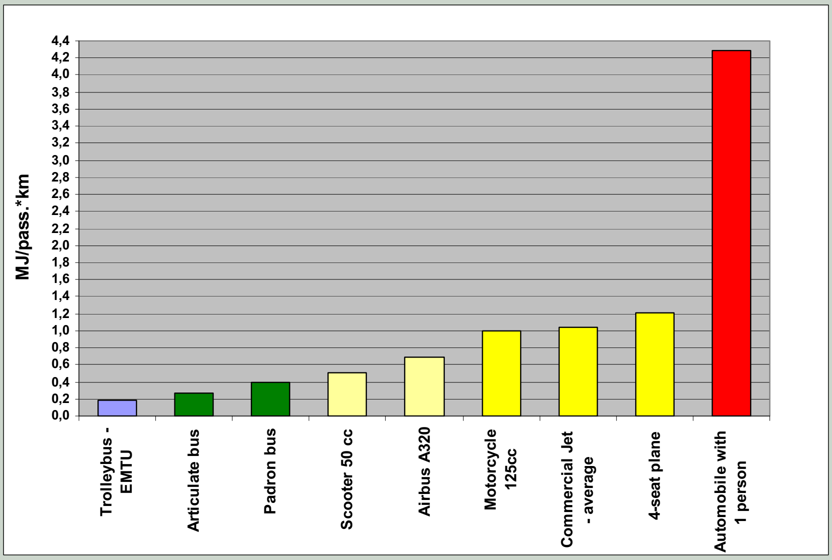
Pollutant and CO_2 emissions can be reduced through the introduction of new vehicle and engine technologies, but these alone will not suffice. It will also be necessary to tackle energy consumption.

Figure 8.5 below shows the energy consumption of various types of vehicles, measured in MJ/km* passenger; trolleybuses are much more efficient than buses with internal combustion engines. This figure is based on average numbers of passengers per vehicle, observed in the SPMR transport system. This figure shows that motorcycles are not the energy-efficient means of transport they are usually perceived to be but rank, in terms of consumption, alongside commercial jets and cars carrying four people. However, single-occupant cars remain the least energy-efficient option.

Figure 8.5 shows that collective transport is much more efficient than individual transport. Furthermore, in the absence of private vehicle inspection policies, public transport may turn out to be more reliable, e.g., vehicles could suffer fewer breakdowns. This could help to make public transport more efficient and reliable by reducing vehicle failures, thereby impacting positively on traffic. Public transport could also help to reduce overall emissions. Furthermore, buses take up less road area per passenger, provided that seven to 10 bus passengers occupy the equivalent area required by one car user in the same road network.

The improved efficiency of trolleybuses in relation diesel buses lies in the use of electric traction, which is far more efficient than the internal combustion engine.

Figure 8.5 - Energy consumption by various vehicle types



Source: EnvironMentality[20]

The public transport system also includes trains and subways, which are a much more efficient means of transport than smaller vehicles. In a statistical survey conducted in São Paulo's transport network, energy consumption per passenger per realized trip is lowest in the subway system, a little higher in the São Paulo train network, higher in trolleybuses, and higher still in buses, with an even wider gap separating it from automobiles.

The differences in energy consumption between the São Paulo subway and train networks can be explained by the organization of both systems; occasional idleness of the system or a longer trip may raise the consumption rate per train trip or per ticket paid.

Table 8.3 - Energy consumption per transported passenger in São Paulo (kWh/trip)

Passenger transported on subway	0.5
Passenger transported on metropolitan trains	0.9
Passenger transported on trolleybuses	1.2
Passenger transported on buses	2.0
Car passenger in the São Paulo Metropolitan Area	13.1

Source: EnvironMentality and AMBranco [21]

These figures are indicative only and obviously vary according to the efficiency of the transport system as a whole, their IPK (index per passenger per km), length of trip and average speed.

[20] Branco, Gabriel Murgel – Fuel Consumption Survey – 2007.
[21] Branco, Adriano M.; Branco, Gabriel M. - THE ALTERNATIVE OF HYDROGEN POWERED BUSES IN THE SÃO PAULO METROPOLITAN REGION - PNUD/GEF - 1998.

More precise values should take into account the density of passengers per kilometer, and in the case of gasoline consumption it would be necessary to calculate more accurately the consumption on long distance trips.

In 1998, the São Paulo State Environment Department recommended the creation of an emissions-related program entitled “For a Sustainable Transport”, which encompassed all technological aspects of fuel quality, traffic, transport and policing, but the program was never implemented.

8.2. IMPROVING TRAFFIC SAFETY

Both local and state authorities are responsible for implementing traffic safety measures. Cities act inside their territory while state authorities usually implement actions on state roads.

8.2.1. Traffic operations and law-enforcement

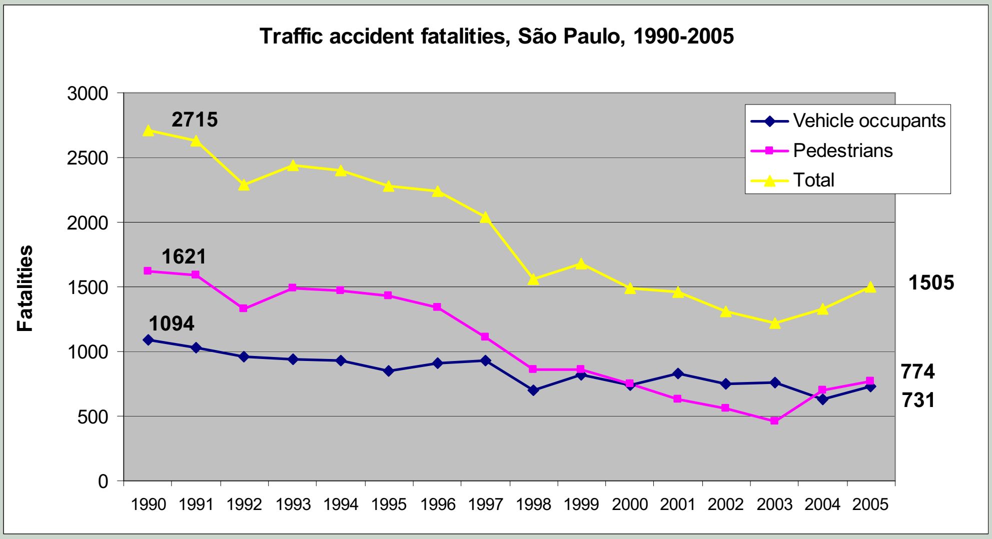
The most important efforts have been undertaken by the city of São Paulo. The city Traffic Engineering Company (CET) divided the city into six different areas, each equipped with traffic management, human resources and materials to perform regional traffic surveillance operations. There are specialized technicians, operational support vehicles, tow trucks, motorcycles and radio and laptop communication. Also available are an extensive television camera network and technicians positioned in high-density traffic areas who send information to a control center, thereby allowing the continuous monitoring of the city's traffic conditions. More recently, after the publication of the Brazilian Traffic Code in 1998, a city body of civilian traffic inspectors was organized and electronic traffic safety equipment was installed, such as radars, cameras next to traffic lights and electronic speed bumps.

SPMR

Some cities in the SPMR implement traffic education programs geared to audiences of different age brackets (students, youth, and elderly) and professionals such as cab drivers and motorcyclists.

Figure 8.6 shows the successes of these actions in the city of São Paulo during the last two decades. Despite a decrease in fatalities, however, the figures are nevertheless quite high.

Figure 8.6 - Traffic accident casualties in São Paulo, 1990-2005



8.2.2. Traffic education

São Paulo state highways

Several traffic safety initiatives are currently being implemented on the São Paulo state highways. There are greater levels of investment on privately-operated highways where special accident prevention programs and assistance services have been put in place. Table 8.4 shows some of the services provided by concessionaires and the results achieved.

Table 8.4 - Traffic safety services on São Paulo state highways

Assistance on state highways

unit

INCIDENTS and OCCURRENCES	2000	2001	2002	2003	2004
Ambulances and accidents	39,333	62,135	57,058	59,575	61,189
On-site intervention, roadside assistance and broken-down vehicles	388,164	780,578	784,099	902,237	957,302
Traffic inspection	494,803	907,154	383,526	363,680	402,706
TOTAL	**922,300**	**1,749,867**	**1,224,683**	**1,325,492**	**1,421,197**

Source: ARTESP/DER/Dersa
Note: In 2000, three new highway concessions were granted, raising the current total to 12.

8.2.3. Weigh stations

Weigh stations have been introduced on the highway network to inspect the weight of the trucks using the network. The idea is to assess wear and tear on the road network, protect public property and ensure the highways are adequately maintained thereby improving overall traffic safety conditions.

There are 33 stationary scales and 146 sites for dynamic weighing on the state's highway network (Table 8.5). In 2004, this equipment performed about 17 million weighing operations (

Table 8.6).

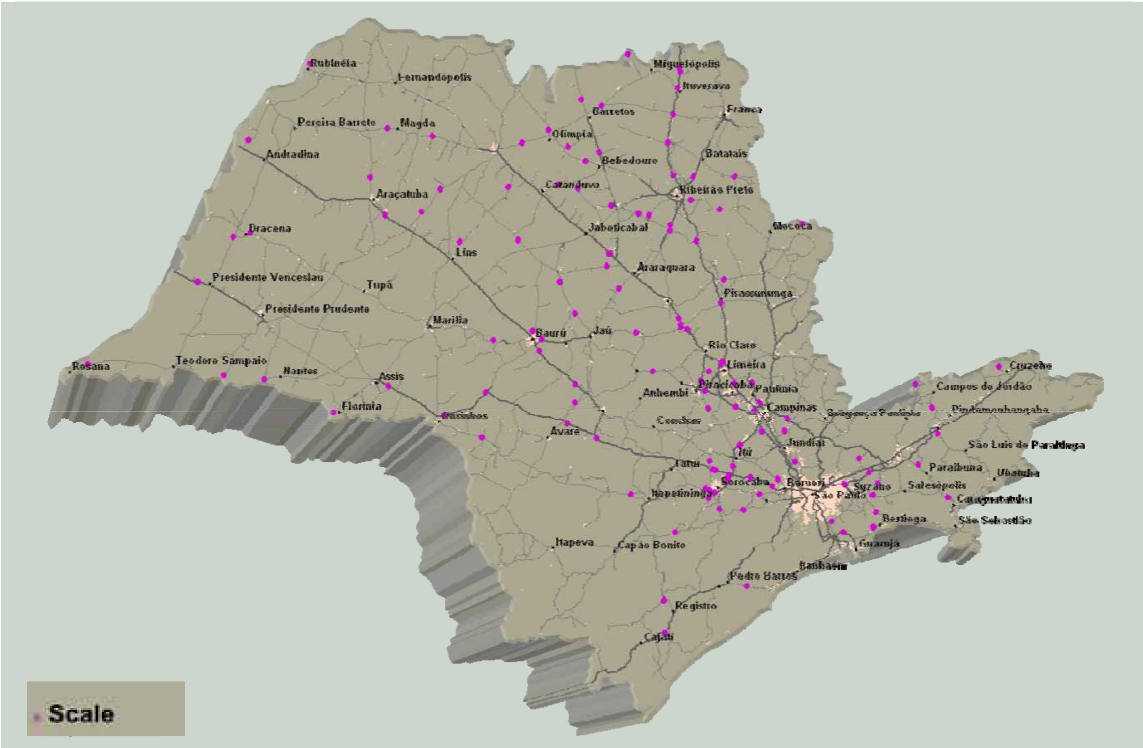
Table 8.5 - Truck weigh stations – São Paulo state highway network, 2004

unit

OPERATORS	STATIONARY	MOBILE
State concessionaires	26	54
DER	2	82
Dersa	3	10
Novadutra	2	NA
TOTAL	**33**	**146**

Source: ARTESP / DER / Dersa
Note: NA = not available

Figure 8.7 - Truck weigh stations – São Paulo state highway network, 2004



Source: ARTESP / DER / Dersa

Table 8.6 - Scale operation: highway network, transport secretariat

unit

SCALE OPERATION	2000	2001	2002	2003	2004
Heavy vehicles	1,756,683	7,675,268	12,516,996	14,645,519	17,576,816
Violation tickets issued	22,926	32,670	57,792	57,862	62,279
Special permits granted	32,326	37,793	45,307	42,577	42,999

Source: DER/Dersa

8.3. RELIEVING CONGESTION

For decades traffic congestion has been a major concern for road users and governments alike. In the SPMR, congestion is particularly concentrated in the so-called Expanded Center located within the city of São Paulo. Congestion is also commonplace, though to a lesser degree, in central areas of other SPMR cities. The main cause of congestion is the number of private cars on the road, which reached a staggering 4.5 million units in the city of São Paulo alone.

Efforts to relieve congestion have focused on the following:

- Investments in infrastructure
- Improved use of the roadway system
- Improvements and incentives to encourage the use of collective transport
- Actions to decongest and organize the flow of cargo and goods
- Changes in land use through urban renewal projects.

8.3.1. Investment in infrastructure

a) Roadway infrastructure

Brazilian federal government

The main federal government projects dealing with infrastructure development, including transport and other economic and social projects, are grouped under the Growth Acceleration Plan (PAC). Launched in 2007, PAC provides for investment in infrastructure totaling R$504 billion from 2007 to 2010, R$ 58 billion of which will be for logistics, including land transport (including urban transport), airports and ports[22]. Total PAC investments projected for 2007 were R$112 billion. However, according to data provided by the federal government[23], the actual investment made in PAC projects in 2007 reached R$ 16 billion, only 14% of the estimated total.

---

[22] Cf. pdf file "070123_PAC_Infra-estrutura", available on the Brazilian Ministry of Planning website http://www.planejamento.gov.br/noticias/conteudo/noticias_2007/070122_pac.htm.

[23] Cf. pdf file "Balanço PAC_2_Execução do PAC" available on the Brazilian government website http://www.brasil.gov.br/pac/arquivo.

Below are some of the key transport-related projects provided for under PAC in the SPMR:

- Rodoanel ring road, a state government project, discussed in greater detail below.
- Ferroanel/Tramo Norte railroad ring, a cargo railway bypass through SPMR involving railways which currently share the rail network with the São Paulo Metropolitan Train Company trains. This project is still in its preliminary phase with technical studies and private sector participation modeling currently underway.
- Enhancement and expansion of Congonhas city airport. The passenger terminal and roadway access are being rebuilt. Emergency renovation of the runway was undertaken following an accident in July 2007 when a commercial jet crashed into a busy avenue and neighboring buildings causing the deaths of 198 people. A third passenger terminal is also planned for Guarulhos international airport, along with further enhancements to flight infrastructure.
- High speed train between the cities of São Paulo and Rio de Janeiro. This project was recently included in PAC (November 2007); plans for private sector participation in modeling are currently (March 2009) being formulated by the Federal Government.

Another initiative undertaken by the federal government for the development of transport infrastructure projects comes by way of BNDES financing. BNDES loans are predominantly aimed at the private sector – including public service providers and concessionaires (highways, railways, city buses and others) – although the bank has the potential to finance the public sector[24] as well. Most long term loans for the public sector, however, are provided by international development banks, especially the Inter-American Development Bank (IDB/BID) and the World Bank.

Also worthy of note are the federal highway and railway privatization programs which, as far as SPMR is concerned, have resulted in private concessions for the expansion, operation and maintenance of the highway (via Dutra) linking São Paulo and Rio de Janeiro in 1996; Fernão Dias highway (linking São Paulo and Belo Horizonte, in Minas Gerais state) in 2007; and the regional railway networks (Fepasa and RFFSA), which were transferred to private operators Ferroban and MRS in 1996.

The Brazilian government has made investments using PAC and other project resources for the development of renewable fuels (ethanol, biodiesel and Hbio), discussed in section 8.10.

São Paulo state government

The São Paulo state government is currently building the Rodoanel – a ring road in the SPMR, linking the major regional highways out of São Paulo. Its western stretch has been in operation

[24] Cf. Performance Bulletin published by BNDES for the month January 2008 (http://www.bndes.gov.br/empresa/download/bol.pdf), in the 12 months between February 2007 and January 2008 the bank disbursed R$ 64,6 billion, R$ 2.1 billion of which were disbursed for “social” projects (health, urban environment, sanitation and other).

since late 2002, while the southern stretch is under construction and slated to start operating in 2010. Northern and eastern stretches are also planned, although no start or finish dates have been scheduled. Rodoanel's western stretch was privatized in mid 2008 with toll collection beginning in December of that year. The concessionaire is expected to pay the state R$2 billion which will be used to construct the southern stretch, currently budgeted at R$3.8 billion.

City governments

The chief responsibilities of city governments, insofar as mobility of people and cargo are concerned, are the implementation, operation and maintenance of the São Paulo roadway system – as well as country roads in the immediate vicinity – and the public transport system (city buses, taxis and others). It should be underscored that city governments are also responsible for defining urban occupancy and land-use standards. More recently, responsibility for vehicle carbon emissions has also been devolved to them, although responsibility for issuing vehicle licenses remains with the state government.

The main traffic and transport-related projects, either underway or scheduled by SPMR city governments, include:

- Restructuring of the São Paulo city bus system: between 2002 and 2004 structural corridors were built, bus lines were reorganized based on a feeder-trunk system, a new fare policy, the "bilhete único" (single ticket) was introduced (see section 8.4);

- Under the umbrella of Urban Operations (regulated by the City Statute introduced in 2001), new roads were built, along with overpasses and tunnels to improve urban land-use; in São Paulo, this resulted in the linking of Roberto Marinho Avenue to Pinheiros marginal road (referred to as Águas Espraiadas Urban Operation), as well as underground tunnels built at the intersection of two major São Paulo thoroughfares: Faria Lima Avenue and Rebouças Avenue and Faria Lima Avenue and Cidade Jardim Avenue (referred to as Faria Lima Urban Operation). Other urban projects are scheduled for São Paulo and other SPMR cities, i.e., Downtown Urban Operation in São Paulo and Eixo Tamanduateí in Santo André.

Private sector

Large supermarkets, retail networks and consumer goods manufacturers (beverages, in particular) have built distribution centers and rearranged cargo distribution systems in urban areas. Several distribution centers have been built alongside major regional highways around the Rodoanel ring road. The Rodoanel was originally conceived as an integral part of the road network, rather than to relieve congestion (a claim occasionally refuted by the state government). It provides access to major regional highways only and, exceptionally, two city avenues. There have been no additional facilities built to serve as an interface for intra and inter-regional cargo transport. As a result, it is only used by large private companies seeking to improve their logistics within the SPMR. Smaller companies are unable to take advantage of the ring road resulting in poor and inefficient logistics. As a result, cargo transport and storage are poorly rationalized in the urban landscape.

b) Collective transport infrastructure

PITU 2025 project

The Urban Transport Integrated Plan (PITU) 2025 project is a set of public transport and road infrastructure proposals aimed at improving traffic conditions in the SPMR. Since its inception in 2002, the project has undergone two reviews, one in 2004 and a second in 2006-2007. Using an evaluation process that included a wide range of economic, social, technical and environmental variables, the PITU project modeled current mobility in the SPMR and after assessing the impact of transport investments sifted out the best investment alternatives.

The following PITU 2025 proposals deserve a mention:

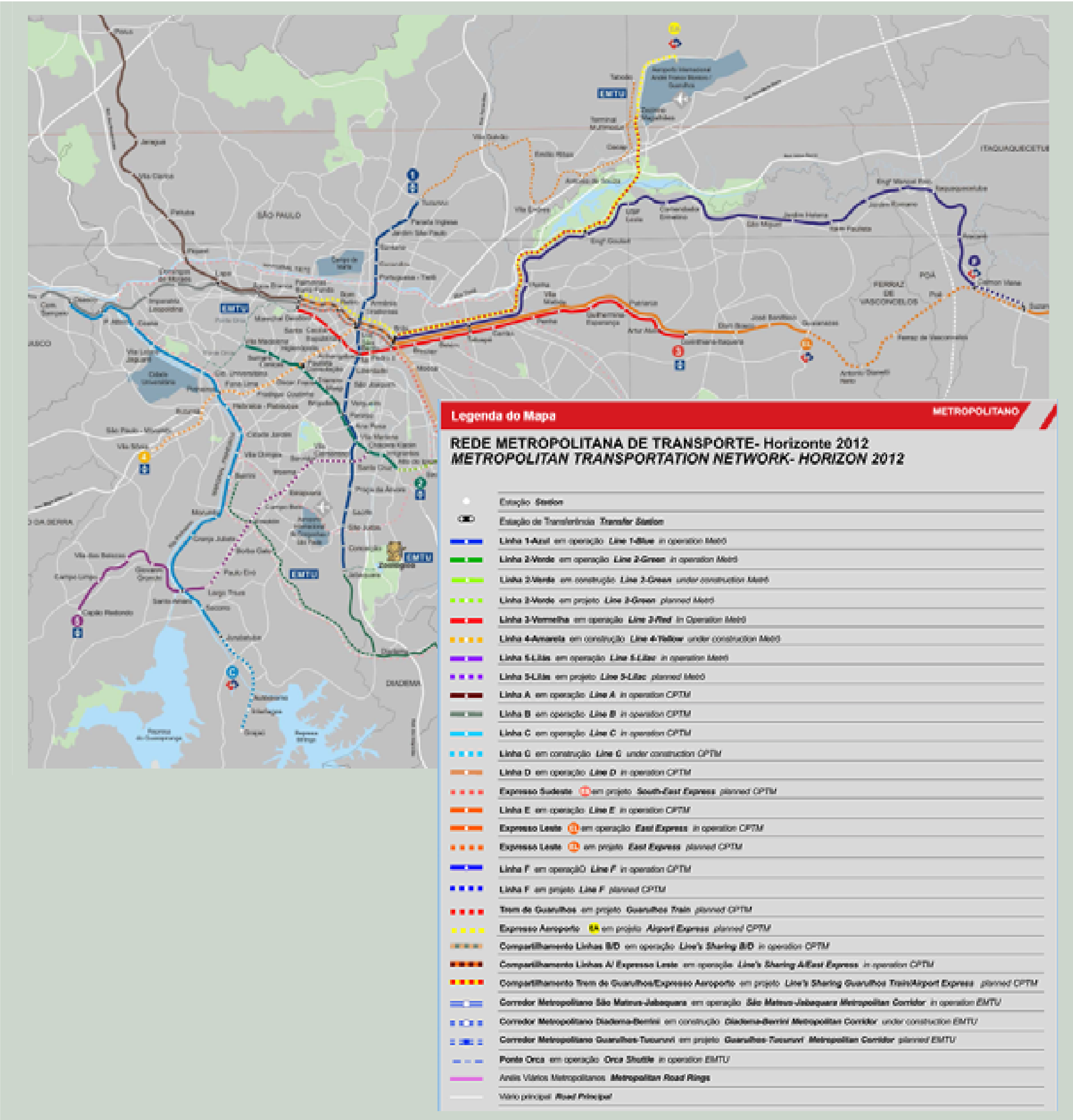
- Subway expansion and upgrade: the subway should be able to upgrade its Line 1 (blue) and Line 3 (red), and complete the construction of Line 2 (green) connecting the districts of Alto do Ipiranga and V. Prudente; Line 4 (yellow) connecting Luz and Vila Sônia; and Line 5 (purple) linking Largo 13 and Chácara Klabin;
- Expansion and upgrade of the metropolitan train network: the metropolitan train system is expected to upgrade lines A, C, B and F and implement the E Line/East Express; an airport train connecting São Paulo and Guarulhos International is also in the pipeline;
- Construction of the metropolitan express bus corridors: in the SPMR, the construction of the Tucuruvi – Guarulhos (TEU Project) and the Diadema – Brooklin corridors is expected as a continuation of the ABD express bus corridor, which is already in operation.

Table 8.7 - Investment forecast for the 2007-2010 period

SYSTEM	R$ BILLION	% TOTAL
Subway	9.1	55.7
CPTM (train)	6.0	36.8
EMTU (buses)[1]	1.2	7.5
TOTAL	**16.3**	**100.0**

1 Includes the three metropolitan regions of São Paulo, Campinas and Baixada Santista.
Source: STM, PITU 2025.

Figure 8.8 - Main projected PITU investments, SPMR



<u>Improved bus services in the city of São Paulo</u>

As part of efforts to improve bus circulation in the city, São Paulo city authorities have implemented two recent projects.

The first, named “Passa-Rápido” (Fast Lane) consists of a set of exclusive bus lanes, 110 km in length, running alongside the median strip. They are electronically monitored. Raised bus stops make it easy for passengers to get on and off the buses (Table 8.8).

Table 8.8 - Express bus corridors alongside median strips in the city of São Paulo, 2007

AVENUES	LENGTH (km)
Paes de Barros	4,3
Raimundo P Guimarães, Fco Matarazzo	15,0
Inajar de Souza, Rio Branco	12,5
Rebouças	11,2
Ibirapuera	9,3
Rio Bonito	26,8
Guarapiranga	8,2
João Dias	8,4
Sto Amaro/9 de Julho	14,5
TOTAL	**110,2**

Source: SPtrans_- São Paulo Transportes.

The second project is the Tiradentes Corridor, whose initial stretch was built in the 1990s under the label “Fura-fila” (Line Jumper). The project was almost abandoned by several administrations because of political disputes, technological questions and high costs. Building on the initial stretch, which only opened in 2007, the corridor will be extended to the end of the eastern area (Tiradentes), covering a total length of 33 km. It is estimated that once it is completed it will carry 300,000 passengers daily.

c) Cargo transport infrastructure

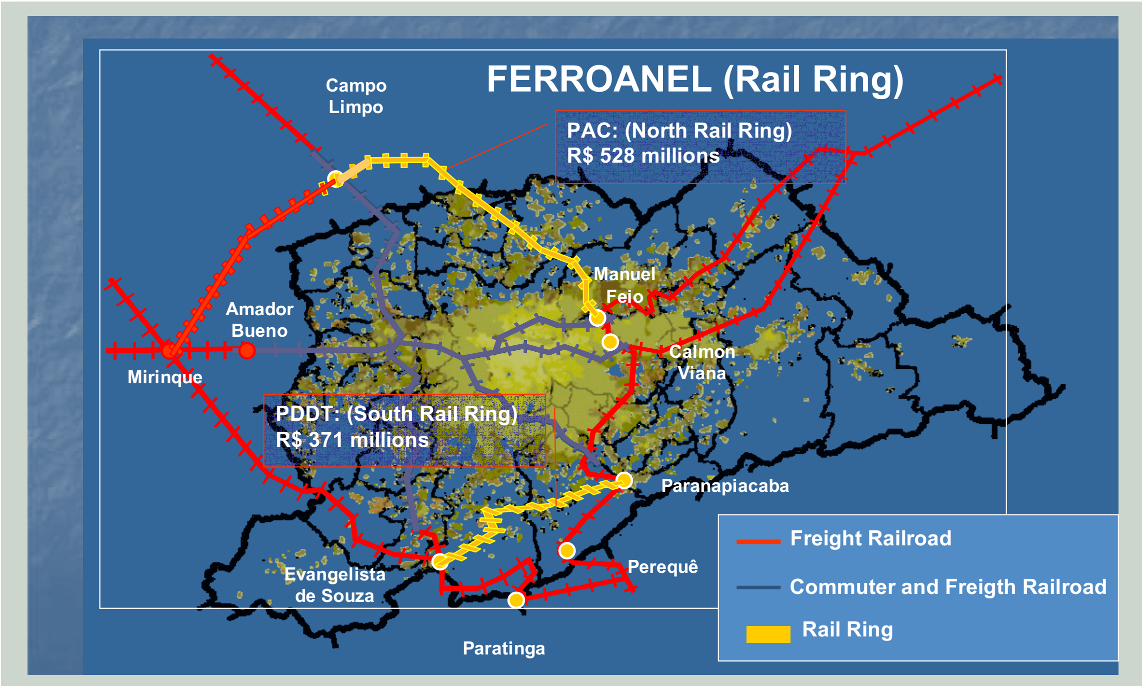
The main large-scale transport projects planned in the short and medium-term which will have an impact on the transport of cargo across the SPMR are the Ferroanel railroad ring and the Conchas-Paulinia-Porto pipeline.

The Ferroanel project is currently being considered by the state government and private companies. These projects are included either in the PAC program or in the PDDT. Both aim to ensure a cargo-share between the private operator MRS and the CPTM passenger train lines to ensure that cargo trains only operate at limited times so as not to interfere with passenger traffic.

Table 8.9 - SPMR railroad ring lay-out

PROJECT	TYPE	AMOUNT IN R$ MILLION	GOVERNMENT PROGRAM
South Rail Ring	Civil works	371.0	PDDT
North Rail Ring	Civil works	529.0	PAC
TOTAL		**900.0**	

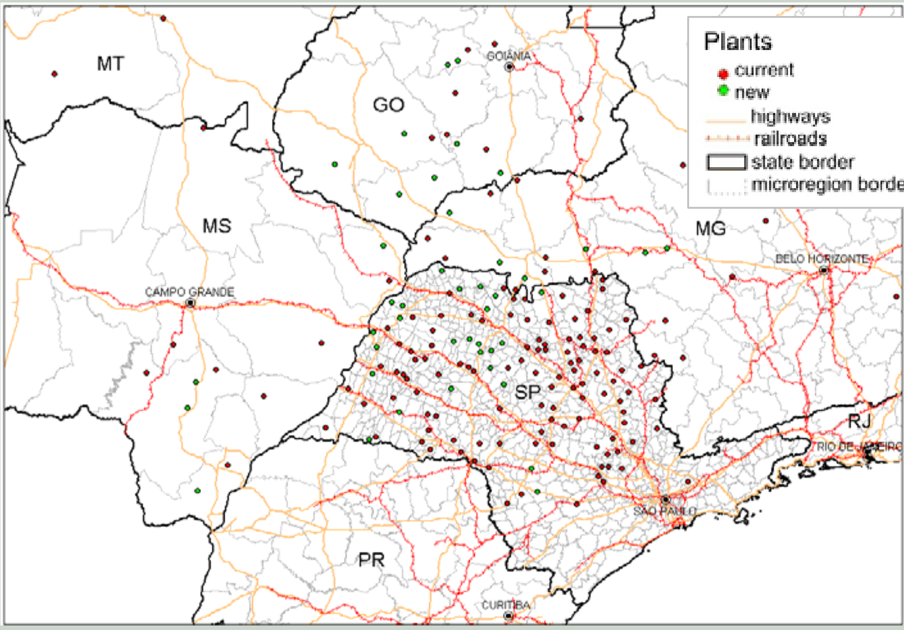
Source: SET Transport Secretariat of the State of São Paulo.



Source: Transportation Development Master Plan of the State of São Paulo 2000-2020 – SET Transport Secretariat of the State of São Paulo.

The Conchas-Paulinia-Porto pipeline will transport ethanol from ethanol-producing regions across the state to the port of Santos on the southern coast; in the absence of the pipeline, ethanol would be transported by trucks. According to a production estimate provided by the sugar-ethanol sector, current production in the potential pipeline collection area is nearly 13 million m³.

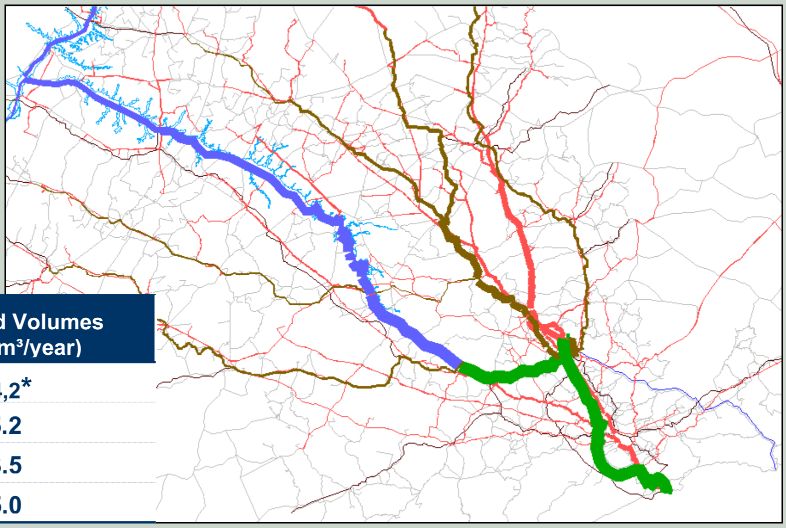
Figure 8.9 - Ethanol-producing center locations



Source: SET Transport Secretariat of the State of São Paulo.

One of the alternatives to a pipeline is to use a waterway to connect the port of Santos with a SPMR distribution base at Cajamar. It is estimated that domestic demand for ethanol is in the region of 7.5 million m³. Investments required by this alternative scenario have been estimated at R$600 million.

Figure 8.10 - Alternative ethanol transportation scenario



Mode	Transported Volumes (millions m³/year)
Roadway	14,2*
Railway	5.2
Waterway	3.5
Pipeline	5.0

Source: Guidelines and Pre-Feasibility Analysis of the Conchas - Paulínia – Porto Ethanol Pipeline, Synthesis Report, São Paulo State Transportation Department, 2006.

8.3.2. Improving the use of the urban street network

a) *Intelligent Transport System (ITS)*

ITS use has increased in the last decade in several SPMR cities and particularly in the city of São Paulo thanks to efforts of the Traffic Engineering Company (CET). It currently uses the following equipment and services with their respective short-term expansion projects:

i. Semaphore devices – 1,200 computer-controlled smart semaphores were installed using real time performance algorithms at a total of 5,200 intersections with traffic lights.

ii. CCTV – 300 cameras have been installed.

iii. Stationary speed control and vehicle identification devices – 40 devices were installed – 25 of which are equipped with Automated License Plate Readers (LAP). These devices are located on the city's expressways and within the limits of the city's expanded center. The devices are equipped with Optical Character Recognition (OCR) and the data are transmitted to a Control Center in real time. These devices are used for:

- Speed control.
- "Rodizio" control: charging of fines ("rodizio" is a traffic control system implemented in the city of São Paulo that restricts the circulation of vehicles on certain days depending on their license plate number – see item b, below).
- Safety control: assistance in locating stolen vehicles.
- Restricted circulation enforcement: provide control when certain vehicles are not allowed to circulate in certain traffic lanes, e.g., trucks in the left-hand lanes of the marginal ring roads.

The number of devices is expected to increase to 175, 150 of which will be equipped with LAP.

iv. Speed control and vehicle identification equipment (speed bumps) – currently, there are 100 such devices installed across São Paulo, 11 equipped with LAPs. Electronic speed bumps, also known as "sleeping policemen", are used in a manner similar to stationary equipment. The only difference is that they display the current vehicle speed. The projected expansion should raise their number to 153 devices with 30 LAPs.

v. Equipment for control of the Maximum Truck Restriction Zone (ZMRC) – this zone restricts truck circulation within the city at different times of the day. Sixty devices are currently being acquired, all equipped with LAP.

vi. Static radars for speed control – 26 devices are available and are generally employed for speed control on exclusive bus lanes/corridors.

Recently, the National Traffic Department (Denatran) approved the implementation of the National Automatic Vehicle Identification System (SINIAV) and distributed free labels to the whole domestic fleet, starting with brand-new vehicles. The use of ITS is likely to increase substantially when vehicles fitted with "electronic identification labels" circulate in the city. Traffic agencies are expected to install aerials in strategic sites to monitor vehicle flow, thus enabling:

- Vehicle license and registration inspection;
- Cargo vehicle inspection and prevention of cargo theft;
- Urban mobility improvement policies;
- Traffic and transportation management;
- Actions geared to increasing public security.

b) Traffic demand management

In 1996, operation "rodizio" was implemented in the city of São Paulo. This strategy sought to limit the number of vehicles in circulation at peak traffic times. Under this system use of some main roads is restricted on certain days. Access rights by drivers are based on the final digit of the license plate (license plates ending 1 and 2 on Mondays, 3 and 4 on Tuesdays, etc.). The idea was to reduce by 20% the volume of cars circulating on each business day. The mechanism is enforced between 7 and 10 am and 5 and 8 pm.

Preliminary studies conducted by CET (Traffic Engineering Company) (1997) showed that this policy had resulted in a 12% reduction in the number of vehicles circulating during restricted traffic times. This reduction is mathematically lower than the anticipated 20% since to circumvent this drivers have begun using spare vehicles (second cars), borrowing cars, and purchasing vehicles with convenient license plate numbers, or simply driving illegally. Over time, and as the number of vehicles on the roads has continued to grow, congestion levels have exceeded pre-1996 levels. However, the situation might have been even more serious without operation "rodizio". That said, the situation might have been improved had the use of public transport been encouraged early and the necessary investments made. The figure below indicates the "rodizio" limit area in the city of São Paulo.

Urban tolls are often proposed as a viable alternative for São Paulo traffic. Some studies and proposals have been advanced but so far the idea has not been embraced by the city's administration. Opinions diverge, even in the technical arena. One main objection is rests in the current inability of the public transport system to absorb the increase in demand that is likely to ensue. There are, however, strong supporters of this alternative who argue in favor of a comprehensive discussion of the issue, since there are foreseeable advantages including reduced travel times for bus and car users, not to mention that tolls from urban revenues could be re-invested to improve public transport systems.

Figure 8.11 - "Rodizio" limit area within the city of São Paulo

Source: CET

c) Cargo flow and urban access

São Paulo City Traffic Engineering Company (CET) introduced the following measures and to control cargo traffic within the city:

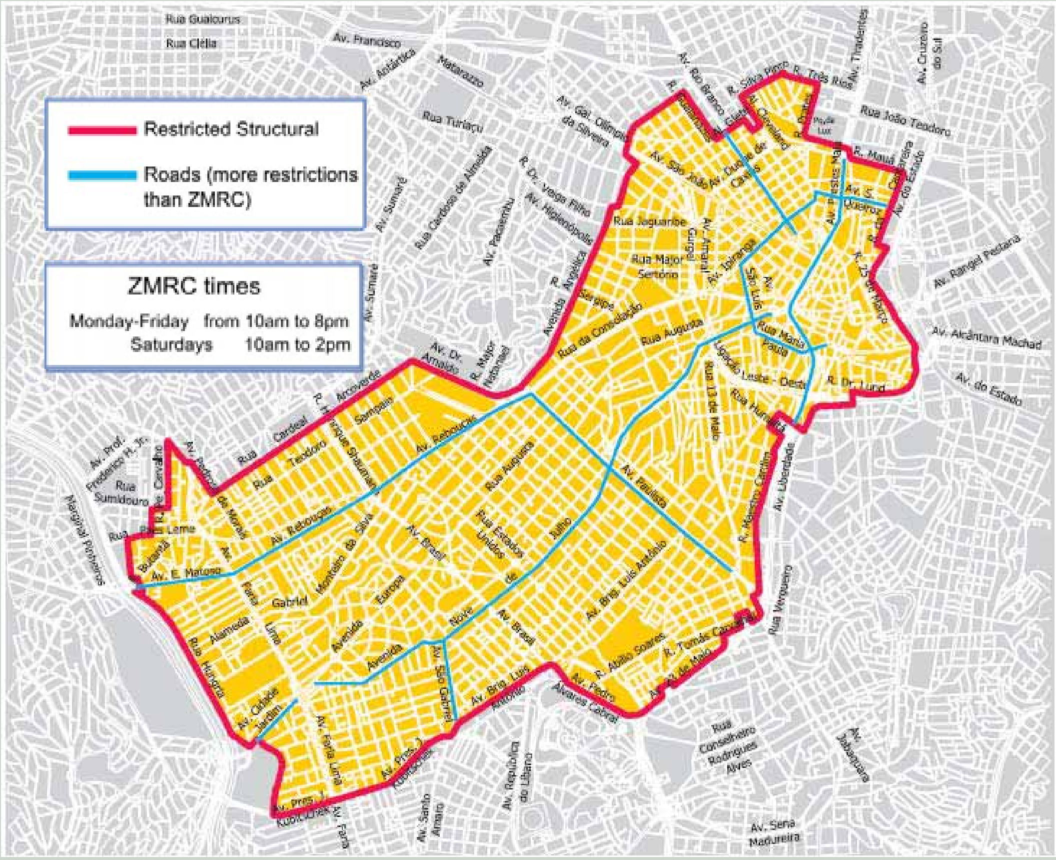
- **VUC – Urban Cargo Vehicles:** they are the only trucks allowed in restricted areas. They must comply with the following specifications: (a) maximum width of 2.20 m; (b) maximum length: 6.30 m; and (c) pollutant emission limits specified by PROCONVE L-4 or P-5, and as of January 1, 2009, PROCONVE L-5 or P-6.

- **ZERC – Special Circulation Restriction Zone:** these are **areas or roads located in Strictly Residential Zones (ZERs)**, as defined by the Strategic Master Plan and Law nº 13,885 of August 25, 2004. They aim to restrict truck traffic in order to foster safety and environmental quality.

- **VER – Restricted Structural Roads:** these are roads and access points where truck traffic is banned at certain times such as peak traffic periods. They include tunnels, overpasses and bridges.

- **ZMRC – Maximum Circulation Restriction Zones:** these are city areas where most business and trade takes place (business centers). Specific restrictions are imposed at certain times. The ZMRC make up a single continuous area in the city of São Paulo. Only VUC vehicles, essential services and emergency vehicles are allowed to enter these restricted zones. All other vehicles require authorization.

Figure 8.12 - ZMRC – Truck restriction area



Source: www.cet.com.br

8.3.3. Improving quality of public transport

In addition to the measures described above, i.e., investments in public transport and traffic demand management, improving the quality of the services available will be key to encouraging greater use of public transport and discouraging further use of private cars. Certain programs are currently being implemented to this effect.

Thanks to the "bilhete único" (single ticket) system (see details under section 7.4), introduced by the São Paulo Public Transportation Agency, users now have access to the whole network for a single fare. Initially, the system applied only to the city bus network (nearly 12,000 buses and microbuses); it was eventually expanded to include the subway and CPTM networks (in the case of the latter, users have to pay an additional, but still conveniently priced, fare). The program's success has resulted in an increase in the use of public transport, including the subway. EMTU introduced a similar fare payment system, the Metropolitan Bus Ticket (BOM), on intercity buses. However, the BOM and the bilhete único systems are not yet integrated.

Programs for greater ITS use are currently being implemented by SPTrans in order to improve the quality of management of the bus system. This program involves primarily monitoring bus terminals and bus corridors. The whole São Paulo fleet is currently being equipped with vehicle position monitoring systems using Global Positioning Systems (GPS) and General Packet Radio Service (GPRS) communication technology. Data is centralized and communicated to users by means of variable message panels (PMV) installed at bus stops. These panels inform users of schedules, timetables and any disruptions to the network. At some sites (transfer stations) television cameras – monitored from a Control Centers – are used to keep an eye on the network

Source: SOCICAM

Terminals are equipped with Terminal Operation Centers (COT), which use CCTV cameras, PMV screens and flat screens to monitor the flow of people on buses and vehicles, and communicate with station platforms. This system is currently (March 2009) fitted in city bus terminals, and comprises 167 TV cameras, 54 flat screens and 354 PMV's.

8.3.4. Urban renewal projects

The metropolitan (EMPLASA) and the city of São Paulo (SEMPLA) land use authorities have been proposing land use changes through urban development master plans and related legal instruments. Such proposals were intended to rebalance urban density, land use and occupation to improve quality of life and overall efficiency of public services in the region (e.g., transport). However, political and social conflicts have meant that few of these proposals have so far been implemented.

Recently (2001) the city of São Paulo approved a new Strategic Development Plan (PDE) that defines new land-use rules for the city. Among other measures it proposes urban "densification" of selected areas, through an increase in available housing and employment opportunities along major transport routes. Such proposals are now being evaluated by SEMPLA using a special transport modeling tool in order to analyze their physical, environmental and social impacts. This analysis will reveal how much “densification” is possible in each area, which in turn will be used to define the formal limits for inclusion in the master plan.

8.4. REDUCING THE MOBILITY DIVIDE

8.4.1. The “single ticket” experience in São Paulo

In 2004, the “single ticket” system was implemented on the city of São Paulo’s bus system. Thanks to the single ticket, users can ride on up to four vehicles during a two-hour period for the cost of a single fare (R$2.00 at the time of implementation). Users can interrupt their trip for some other activity and then re-board the bus without paying any additional fare, provided that the two-hour, three-bus transfer limits are observed. The availability of electronic ticketing across the system was instrumental in the project’s success. The traditional ticketing and payment system was maintained in parallel.

As well as the obvious financial advantages enjoyed by users, the single ticket has radically changed the way bus lines are utilized as it enables people to conveniently reorganize their preferred routes. Thus, considerable changes in bus use patterns were observed immediately following implementation of the single ticket.

The introduction of the single ticket led to a debate about the introduction of a similar system in other existing transport services in the city and Metropolitan Region. Two years after its initial implementation (January 2006) the single ticket was extended to the metropolitan train and subway systems; by late 2006 it had been extended to the entire railway network.

Increased demand

The single ticket altered the pattern of public transport journeys undertaken in the city of São Paulo (Table 8.10).

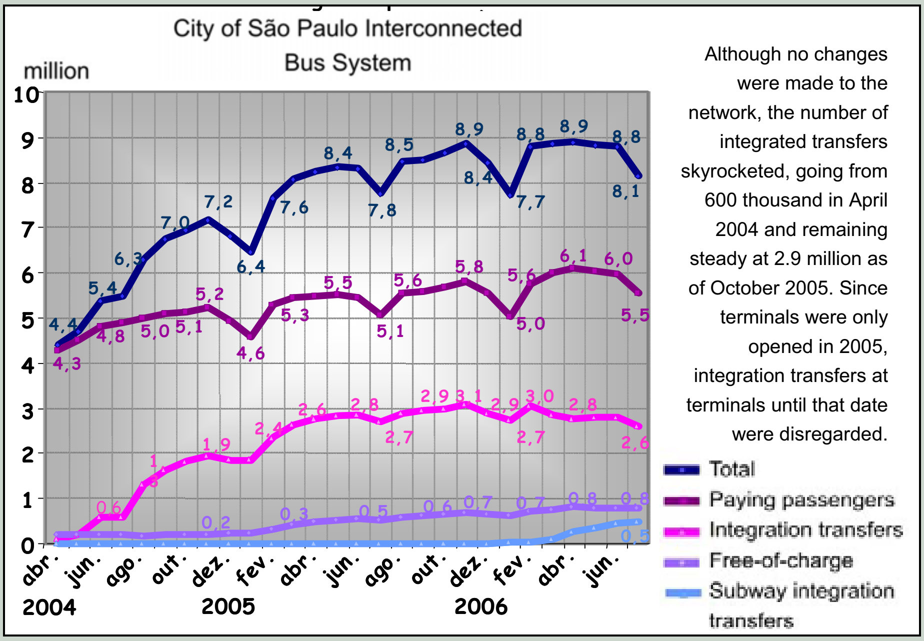
Table 8.10 - Daily pre- and post-single ticket demands, São Paulo.

DATE/STATUR		INTEGRATION INDEX	TRIP[1]	TRIP LINK[2]	TRANSFERS					
					Total		Street		At terminals	
			million	million	Million	(%)	million	(%)	million	(%)
Before	1997	1.15	5.38	6.19	0.81	15	0.25	5	0.56	10
	2002	1.17	5.25	6.16	0.91	17	0.35	7	0.56	10
After	Nov. / 2004	1.52	5.30	8.07	2.77	52	1.97	37	0.80	15
	Mar. / 2005	1.52	5.18	7.87	2.69	52	1.89	37	0.80	15
	May. /2006	1.51	6.06	9.16	3.10	51	2.19	37	0.90	15

1 Between origin and final destination. 2 Considering transfers from the first bus to others during the trip.
Source: Souza (2007), based on origin-destination surveys from 1997 to 2002, survey at SPTrans terminals in 2001 and November 2004, and electronic ticketing data on typical days of November/2004, march/2005 and may/2006.

Table 8.10 shows that after the single ticket was introduced there was an increase in the number of vehicles boarded (from 5.4 million to 6.1 million, a 13% rise) as well as in the number of transfers (from 810,000/day to 3.1 million/day). Most transfers (72%) occurred outside the terminals, i.e., at regular bus stops, thus confirming that users did indeed "reorganize" their journeys. This reorganization also meant that some longer routes previously chosen because of concerns about money (cheaper routes, etc.) were abandoned. The benefits to users were undoubtedly significant.

Figure 8.13 - Passengers per business day



8.4.2. Accessibility for the disabled

a) Brazilian legislation and measures undertaken

In the last 10 years debates have intensified on the social empowerment of physically disabled citizens in Brazilian cities and the public services available. An essential element of such empowerment is ease of access to public transport.

In 2000, two federal laws were passed (#10,048 and #10,098) and regulated through presidential decree # 5,296 of December 2, 2004.

The new legislation calls for the implementation of mechanisms to enable the physically challenged to make use of public transport, including tactile, visual and sound communication, construction of ramps and equipment for access to public transport boarding terminals, as well as priority implementation of vehicles that ensure level boarding (without steps) (Affonso, 2007).

In the specific case of public transport vehicles, this adaptation must be completed throughout the country by 2014. In the SPMR, several cities, along with their metropolitan transport systems (subway, train and bus), already have programs underway aimed at adapting vehicles and stations to the new legal requirements.

The decree determines that the technical standards for the manufacture of vehicles and collective transport equipment be defined by institutions and entities including the National Metrology, Standardization and Quality System. These standards will vary according to the transport mode and the timeframe for standard definition and implementation. All systems are required to be in compliance within 10 years, i.e., by December 2014.

b) Specific programs

A number of Brazilian cities have organized special services for the transport of handicapped passengers. In the particular case of São Paulo, the ATENDE (special door-to-door transportation service for disabled customers) system was created in 1996 to meet the transport needs of physically challenged people with severe mobility limitations. ATENDE is a, free, self-regulated and self-sponsored door-to-door service under SPTrans management. ATENDE's task is to do home pick-ups and take passengers to their place of activity based on a pre-determined schedule and according to pre-defined priorities: rehabilitation, health treatment, education and, car fleet allowing, work, sport, leisure, culture and other daily activities. The fleet includes 268 vans equipped with elevators and enough space for two fixed wheel-chairs and six other seats. It belongs to a bus consortium operating in the city's public transport system. Working hours are 7 am to 8 pm, Monday through Sunday. Every week these vans cover more than one million kilometers on different routes and serve 7.8 million people, including users and their escorts, a population which has grown 43% since June 20, 2005.

8.4.3. Fare discounts for special user groups

The Brazilian Constitution guarantees free urban public transport for senior citizens above 65 years of age. Furthermore, since 1985 employers have been required to provide employees with vouchers for public transport – known as "vale-transporte", or transport vouchers (VT). A maximum of 6% of transport-related costs are deducted from employee salaries. This subsidy helped to relieve difficulties caused by inflationary pressure on bus fares, and is currently used by nearly 45% of workers traveling by public transport. Nevertheless, the cost issue remains for workers in the informal market who have no access to VT. In most Brazilian cities, state and city laws grant students a 50% discount.

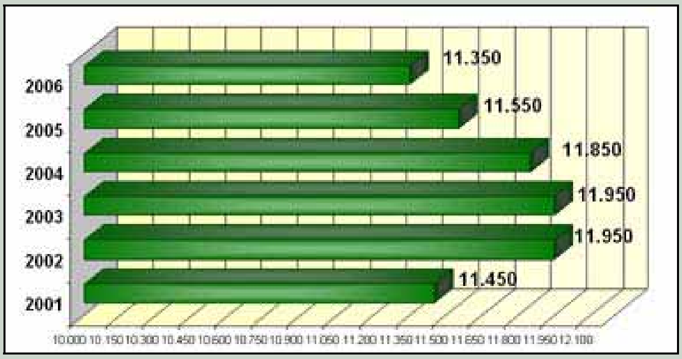
A significant part of the SPMR population faces difficulties in the use of public transport because of their low incomes. Among the families with incomes lower than three minimum wages (US$ 600) (26.7%) average individual mobility was 0.88 trips/day, as compared to the overall average of 2 trips/day (Itrans, 2004; CMSP, 2003). Within this low-income population 40% did not expend any money on public transport in the average week and, among all families, average expenses incurred by public transport were 22% of the monthly family income.

8.5. SECURITY

8.5.1. Security on state highways

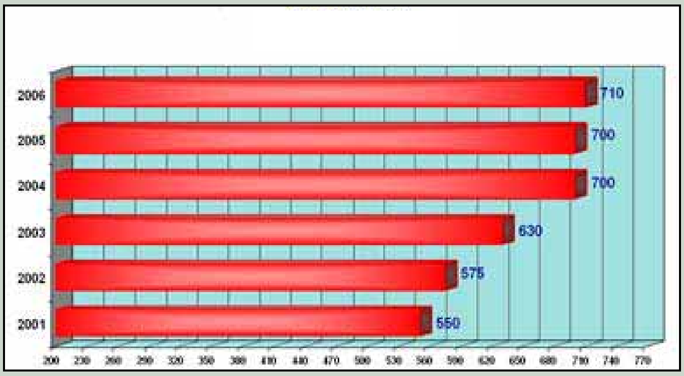
Cargo robberies and thefts are a serious, widespread problem in Brazil. According to the National Association of Cargo Carriers (NTC), the number of thefts in Brazil has remained at a fairly constant 12,000 per year in the last few years, at a cost of R$700 million (Figures 7.15 and 7.16).

Figure 8.14 - Cargo theft in Brazil: annual progression and occurrence



Source: Permanent Security Committee / NTC – (COMPSUR / NTC) – Estimated data – Highways and Urban Areas.

Figure 8.15 - Cargo theft in Brazil: annual progression and occurrence **(in millions of Brazilian Reais (R$))**



Source: Permanent Security Committee / NTC – (COMPSUR / NTC) – Estimated data – Highways and Urban Areas.

Safety on state highways is the responsibility of the Highway Police Command (CPRv), which comes under the administration of the state Public Security Secretariat (PMRv). With 150 operational bases, there is constant police presence across the highway network. The PMRv operation bases are located throughout the highway network.

Police surveillance on highways is aimed at preventing and punishing actions that might pose a threat to public security, thus ensuring safe vehicle circulation. The Public Security Secretariat and the Transportation Department are bound by an agreement. Among its operational functions, the Military Highway Police enforces traffic violation fines and regulates the transport of hazardous goods; applies administrative penalties provided for under the Brazilian Traffic Code; provides accident assistance; and works on crime prevention on the highway network.

8.5.2. Traffic security

In the SPMR the best public security systems are found on trains and subways.

In the trains, the CPTM relies on an Operational Security Corps, which develops and implements strategies to combat violations and crimes committed on the railroad system. These activities are carried out in partnership with the state's security agencies, such as the Civil and Military Police.

Their most effective joint actions are the so-called "blitzes", which are carried out inside trains and stations. In 2006, 250 police blitzes took place with the support of both Police Departments during which 15,582 people were approached for exhibiting suspicious behavior in stations or trains. As a result, 95 people were placed under arrest. By November 2007, the CPTM security teams and the Military Police had carried out 312 operations involving 25,826 people exhibiting suspicious behavior, which led to the arrest of 187 people.

The company's Security Corps surveillance rounds are instrumental in preventing crime committed on the railway system. Both overt and covert surveillance operations are carried out with the purpose of preventing crime and apprehending offenders and criminals in the act of committing felonies. A considerable number of surveillance operations are geared towards preventing the illegal peddling of goods inside trains. By November 2007, 43,136 goods' seizures had been made resulting in the confiscation of 1,275,452 illegal items traded on CPTM trains.

With regard to surveillance technology, CPTM has a monitoring system comprised of 802 cameras scattered around 84 stations and a CCTV system installed at its Station and Security Center facilities, which allows the scanning of images in stations across the system. Among the advantages offered by this equipment it is worth noting the high definition images captured by special software, extended storage time of recorded material and the simultaneous monitoring by 320 cameras at different stations. Moreover, the system can detect simultaneous alarms from different stations while the unit's ground plan appears on the monitor showing the precise location of the incident.

The software also allows for real time access via the Internet, thereby facilitating and expediting contact between the Security Monitoring Center (CMS) and all stations. By using a remote control device, the CMS operator can observe the images of a given unit and simultaneously keep track of images on all cameras of a given station, or whichever cameras have been selected. Since the cameras were implemented, several crimes, such as drug dealing, thefts and robberies have been elucidated and several suspects arrested. This feature plays a fundamental role in solving other problems, such accidental falls, fare evasion, illegal trade, use of counterfeit tickets and even suicides.

Finally, CPTM relies on police dog surveillance in eight stations where these animals help to prevent fare evasion and reduce the number of public security incidents. Users have reported an increased sense of security thanks to the presence of these dogs in stations.

In subway stations, there is a team of law-enforcing inspectors with police power. The overall work is coordinated together with civilian and military police authorities. The system boasts a sophisticated network of TV cameras in all stations and armored ticket booths.

Regarding buses, two types of public security threat are worth mentioning: hold-ups on board buses in order to steal fare cash. In such events, fare collectors are the primary targets. A special study conducted by the Fernand Braudel Institute in the city of São Paulo revealed that 10,407 such hold-ups occurred in 2000; the majority occurred in the eastern zone.

The second problem relates to passenger hold-ups whereby passengers are mugged on route to bus stops or on board. The concerns of the population have been widely publicized through opinion surveys and newspapers. In surveys carried out by ANTP in the SPMR in 2007, which sought to hear users' opinions on public transport, users listed "greater personal security against thefts and muggings" (31%), above "arriving faster at my destination (22%) and "spending less on public transport" (20%).

9

Evaluation of Proposed Projects

9. EVALUATION OF PROPOSED PROJECTS

The following sections evaluate some of the projects proposed to tackle mobility challenges in the SPMR in terms of costs, implementation time, probability of implementation, and private sector participation. It also makes a qualitative evaluation of the impacts of each project in relation to WBCSD objectives and the outlook for sustainable mobility in São Paulo.

9.1. CHARACTERISTICS AND IMPACTS OF PROPOSED PROJECTS

Road expansion

Road expansion in the SPMR is usually very costly given the need to relocate large numbers of people. Such projects require one to two years for completion. While many road expansion projects are implemented, private sector participation tends to be very modest. This situation is exacerbated by the number of political decisions required for private sector participation and the difficulties inherent in introducing toll fees and facilities in most Brazilian urban traffic environments.

New roads would do little to relieve congestion in SPMR. Furthermore, they are likely to result in greater levels of emissions caused by the increased number of vehicles. They are also likely to have negative impacts on traffic safety due to increased speeds particularly through densely populated areas.

Subway expansion

Subway expansion in the city of São Paulo is a costly project (several billion Reais), requiring several years for completion. Daily demand is expected to rise from 2.6 million in 2006 to 4.4 million in 2014. The probability of implementation is high, as there is already a public commitment by transport authorities with the corresponding resources already earmarked in the state budget. The probability of private participation is also high, as line 4 (“yellow line”) has already been out for tender and is approved as a public-private partnership project (PPP) project.

The proposed subway expansion is likely to have positive impacts including reduced emissions of pollutants and GHG. In addition, it will help to bridge the mobility demand. However, the latter will be dependent on the affordability of tickets for the low-income segment. It is believed that it will have positive, albeit minor, given the tendency by car-owners to expand their occupation of free spaces, impacts on congestion, by reducing the demand for private vehicles.

Railway modernization

Railway modernization in the SPMR is also a costly project (several billion Reais), requiring several years for completion. Daily demand is expected to rise from 1.5 million in 2006 to 3.3 million in 2014. The probability of implementation is high, as there is already a public commitment by the transport authorities, with the corresponding resources already earmarked in the state budget. The probability of private participation is not as high as the subway, as it is less financially attractive.

The project is likely to have positive impacts in terms of pollutant and GHG emissions; it is also believed that it will help to bridge the mobility divide by enabling greater access to transport by the low-income segment, particularly those living in the peripheral areas served by the system.

International airport railway link

The proposed international airport railway link is a costly project (several billion Reais), that will require 2 to 3 years for completion. The probability of implementation is high, as there is already a public commitment by transport authorities, with the corresponding resources already earmarked in the state budget. The probability of private participation is not as high as with the subway, as it is not as financially attractive.

The project is unlikely to have much impact in terms of reducing pollutant and GHG emissions. Equally, it will not have much impact on congestion given limited demand and spatial coverage.

São Paulo bus corridors

Some of the proposed bus corridors in the city of São Paulo have already been implemented in the last decade. The largest project under implementation – the Tiradentes corridor targeting 300,000 additional passengers daily – is expensive on account of the investment required during the initial phases. It is expected to be operational in about a year and a half. Private sector participation will be minimal and restricted to provision of buses.

The project will likely lead to a reduction in emissions as new-technology buses will be used. Its impacts on the mobility divide will be minimal given that it only satisfies a small part of the overall demand for mobility.

TEU bus corridor

The TEU (Transporte Expresso Urbano) bus corridor linking the north of the city of Sao Paulo to Cumbica international airport is a R$ 300-million project, targeting 130,000 additional passengers daily. The probability of implementation is high, as there is already a public commitment by transport authorities, with the corresponding resources already earmarked in the state budget. The probability of private participation is not high and will be limited to providing vehicles and controlling financial operations.

If implemented, the project is expected to bring high benefits in relation to air pollution (new vehicles and high average speeds).

City of São Paulo bus reorganization

The reorganization of the bus system in the city of São Paulo began 5 years ago, with the creation of low-cost priority lanes for buses. However it was not accompanied by a reorganization of supply, thereby reducing its beneficial impacts. It is not a costly project for the public sector when compared, for instance, with subway expansion. The probability of private sector participation is low and may be limited to provision of vehicles and ITS equipment and systems.

If completed in the city of São Paulo and implemented in other cities of the SPMR it could help to bridge the mobility divide and reduce levels of pollution. However, its implementation in other Brazilian cities will depend on the political and economic arrangements in each city.

The “bilhete único”

The “bilhete único” has already been implemented in the city of São Paulo. It has helped to bridge the mobility divide given that it serves 100% of demand. The cost of implementing such a system in other cities of the SPMR is thought to be low; it would make a major contribution towards bridging the mobility divide. However the probability of such a system being implemented in other cities will depend on the political and economic arrangements in each city.

Urban operations

Urban renewal projects can be inexpensive or highly costly depending on the type of project implemented. They usually take several years to complete (sometimes over a decade), on account of the large number of legal requirements, and the need to attract new capital.

If the appropriate legal arrangements are in place, such projects can appeal to the private sector (real estate sector) making them attractive to business.

Urban renewal projects can help to reduce both levels of pollution and congestion, provided appropriate transport supply and traffic management schemes are integrated into land-use change planning.

License plate scheme

Operation “rodízio” was implemented in the city of São Paulo more than 10 years ago. It is a low-cost project from the public sector point of view and implementation only takes a few months. The probability of implementation in other cities of the SPMR is not high, given political resistance and enforcement limitations in place in some cities.

In the early phases of implementation, the impacts of the license plate scheme on congestion levels are very positive. However, these are reduced as the vehicle fleet expands. Proposals to increase the number of days are met with opposition from a large section of car owners.

Traffic management and education programs

Traffic management and education programs are mostly low-cost measures. They have been implemented in several cities of the SPMR and completion usually takes a few weeks to a few months. The probability of implementation is high once society is convinced of their benefits. Participation of the private sector is usually limited to providing devices and technology.

Traffic management and education programs can have very positive impacts on safety but their impacts are more limited when it comes to reducing traffic congestion and pollution.

Toll roads

The implementation of toll roads in the SPMR could be done in a relatively short period of time provided that public transport has the capacity to deal with the increased demand. The main items that must be taken into consideration in the definition of such a strategy include coverage and charging schemes. To these must be added the reorganization of public transport to cope with the new demands and political will for implementation.

The necessary technology already exists and such schemes should appeal to the private sector.

A scheme such as this could contribute towards relieving congestion, which is becoming extremely severe in a large portion of the SPMR. It would also yield benefits in terms of air quality and GHG emissions. Revenues from the new system could be used to invest in public transport services that are more environmentally-friendly and take up much less road space.

ITS

Although the use of ITS to manage traffic and public transport implies relatively high costs, it could result in benefits that would more than compensate for such costs, including travel-time savings (signals and bus lanes), accident reduction (electronic enforcement) and security (enforcement in terminals and also inside vehicles). ITS measures could also reduce emissions. ITS systems could be very attractive to the private sector that could benefit from the sales of new technology and products.

Urban cargo logistic rearrangements

The most costly element of projects aimed at controlling access and circulation of trucks rests in the construction of integrated logistics centers. Although they require high levels of investment such programs can be implemented through urban renewal projects or using financial mechanisms which involve the private sector. The ideal time for implementation could be planned to coincide with the completion of the southern section of the Rodoanel and the northern section of the Ferroanel, which are expected to be opened for use in 2010/2011. The probability of implementation is low to medium given that they are dependent on a series of agreements between several public and private agents from the local, state and federal governments, in addition to the metropolitan authorities. High rates of economic return should make the creation of logistics centers an attractive option and drive the necessary decisions, provided the regulatory environment and the role and action of public agencies are well-defined.

Implementation of these projects could help to reduce GHG emissions; however, they would probably not have much of an impact on emissions of local pollutants or on congestion levels, since they would not result in lower volumes of traffic in the central area of the SPMR, simply in smaller vehicles.

9.2. EVALUATION OF INVESTMENTS

The table below shows a concise evaluation of the results so far achieved and/or expected from the aforementioned projects and their effects on passenger and cargo mobility in the SPMR. This evaluation was formulated by the team of consultants involved in this study.

AREA	PROJECTS	ASPECTS EVALUATED / EFFECTS: Local vehicle emission	GHG emission	Fatality / casualty reduction	Congest. reduction	Reduction of the mobility divide	Personal security increase
SPMR macro-infrastructure	Rodoanel ringroad	O (blue)	O (blue)	O (green)	O (blue)	O (green)	O (green)
	Ferroanel railroad ring	O (blue)	O (blue)	O (green)	O (green)	O (blue)	O (green)
Transportation infrastructure and operation	SP subway expansion	OO (blue)	OO (blue)	O (green)	O (blue)	OO (blue)	O (blue)
	CPTM upgrade/modern.	OO (blue)	OO (blue)	O (green)	O (green)	OOO (blue)	O (blue)
	International airport train	O (blue)	O (blue)	O (green)	O (blue)	O (green)	O (green)
	São Paulo bus corridors	O (blue)	OO (blue)	O (red)	O (blue)	OO (blue)	O (green)
	TEU corridor – São Paulo to Cumbica	O (blue)	O (blue)	O (red)	O (blue)	O (blue)	O (blue)
	Bus System Reestruct.	O (blue)	O (green)	O (green)	O (blue)	OOO (blue)	O (blue)
	Single Ticket in São Paulo	O (green)	O (green)	O (green)	O (green)	OOO (blue)	O (green)
	Road expansions	O (red)	O (red)	O (red)	O (blue)	O (green)	O (green)
Environmental actions	PROCONVE	OOO (blue)	O (blue)	O (green)	O (green)	O (green)	O (green)
	Renewable source fuels	O (blue)	OOO (blue)	O (green)	O (green)	O (green)	O (green)
Vehicle inspection		O (blue)	O (blue)	OO (blue)	O (blue)	O (green)	O (green)
Urban structure	Urban operations	O (blue)	O (blue)	O (green)	O (blue)	O (green)	O (green)
Traffic engineering	License plate alternation in traffic	O (blue)	O (blue)	O (green)	O (blue)	O (red)	O (green)
	Traffic safety and education projects	O (blue)	O (green)	OOO (blue)	O (blue)	O (green)	O (green)
	Road charging	OO (blue)	OO (blue)	O (green)	OO (blue)	O (blue)	O (green)
Other	ITS projects	O (blue)	O (blue)	O (blue)	O (blue)	O (green)	O (blue)
	Urban cargo logistic rearrangement	O (blue)	OO (blue)	O (green)	O (blue)	O (green)	O (green)

Scale: O Positive; O No significant effect; O Negative

Appendix 1
Glossary

APPENDIX 1: GLOSSARY

ABRACICLO – Associação Brasileira dos Fabricantes de Motocicletas, Ciclomotores, Motonetas, Bicicletas e Similares / *Brazilian Association of Manufacturers of Motorcycles, Mopeds, Bicycles and Similar*

ATENDE – Serviço especial de atendimento porta a porta (SPTrans) / *Special Door to Door Transportation Service for disabled customers (SPTrans)*

ALL – América Latina Logística S.A / *Latin American Logistic S.A.*

ANATEL – Agência Nacional de Telecomunicações / *National Telecommunication Agency*

ANFAVEA – Associação Nacional de Fabricantes de Veículos Automotores e Empresas Associadas / *National Association of Motor Vehicles Manufacturers and Associated Companies*

ANP – Agência Nacional do Petróleo / *The National Petroleum Agency*

ANTP – Associação Nacional de Transportes Públicos / *National Association of Public Transport*

ARTESP – Agência Reguladora de Serviços Públicos Delegados de Transporte no Estado de São Paulo / *Regulatory Agency for Delegated Transportation in the State of Sao Paulo*

BID – Banco Interamericano de Desenvolvimento / *Interamerican Development Bank*

BNDES – Banco Nacional de Desenvolvimento Econômico e Social / *National Bank of Economic and Social Development*

BOM – Bilhete Ônibus Metropolitano / *Metropolitan Bus Ticket*

CET – Companhia de Engenharia de Tráfego (Município de São Paulo) / *Traffic Engineering Company (City of São Paulo)*

CETESB – Companhia de Tecnologia de Saneamento Ambiental / *Company of Technology of Environmental Sanitation*

CETIC – Centro de Estudos sobre as Tecnologias da Informação e da Comunicação / *Center for Research on Information and Communication Technology*

CFTV – Circuito Fechado de TV / *Closed Circuit TV*

CMS – Central de Monitoramento de Segurança / *Safety Monitoring Center*

CMSP – Companhia do Metropolitano de São Paulo – Metrô / *Company of the Metropolitan of São Paulo – Metrô*

CODESP – Companhia Docas do Estado de São Paulo / *State Docks Company of São Paulo*

COMPSUR – Comissão Permanente de Segurança / *Permanent Safety Commission*

CONAMA – Conselho Nacional do Meio Ambiente / *National Environment Board*

COT – Centro de Operação do Terminal / *Terminal Operation Center*

CPRv – Comando de Policiamento Rodoviário / *Road Police Command*

CPTM – Companhia de Trens Metropolitanos / *Metropolitan Train Company*

CSPE – Comissão de Serviços Públicos de Energia do Estado de São Paulo / *Energy Public Services Commission of the State of São Paulo*

CTB – Código de Trânsito Brasileiro / *Brazilian Traffic Code*

DAESP – Departamento Aeroviário do Estado de São Paulo / *Airport Department of the State of São Paulo*

DENATRAN – Departamento Nacional de Trânsito / *National Department of Traffic*

DER – Departamento de Estradas de Rodagem do Estado de São Paulo / *State Roads Department of São Paulo*

DERSA – Desenvolvimento Rodoviário S.A. / *Roadway Development S.A.*

DETRAN – Departamento Estadual de Trânsito / *State Department of Traffic*

DSV – Departamento de Operação do Sistema Viário (Município de São Paulo) / *Road System Operation Department (Municipal District of São Paulo)*

DTP – Departamento de Transportes Públicos (Município de São Paulo) / *Department of Public Transport (Municipal District of São Paulo)*

EEV – Veículos Excepcionalmente Compatíveis com o Meio Ambiente / *Extra Environment Compatible Vehicles*

EMPLASA – Empresa Paulista de Planejamento Metropolitano S.A. / *São Paulo Company of Metropolitan Planning S.A.*

EMTU – Empresa Metropolitana de Transportes Metropolitanos / *Metropolitan company of Metropolitan Transport*

FATEC – Faculdade de Tecnologia de São Paulo / *Technology School of São Paulo*

FEBRABAN – Federação Brasileira de Bancos / *Brazilian Banks Federation*

FEPASA – Ferrovia Paulista S.A. / *S. Paulo Railway S.A.*

FINAME – Agência Especial de Financiamento Industrial / *Special Agency of Industrial Financing*

FIPE – Fundação Instituto de Pesquisas Econômicas / *Institute of Economic Research Foundation*

GEE – Gases do Efeito Estufa / *Greenhouse Gases*

GEF – Fundo Global para o Meio Ambiente / *Global Environment Fund*

GEIPOT – Grupo Executivo de Integração da Política de Transportes / *Policy Integration Executive Transport Group*

GNC – Gás Natural Comprimido / *Compressed Natural Gas*

IBGE – Instituto Brasileiro de Geografia e Estatística / *Brazilian Institute of Geography and Statistics*

IBOPE – Instituto Brasileiro de Opinião Pública e Estatística / *Brazilian Institute of Public Opinion and Statistics*

IDET – Índice de Desempenho Econômico do Transporte / *Index of Transport Economic Performance*

INFRAERO - Empresa Brasileira de Infraestrutura Aeroportuária / *Brazilian Company of Airport Infrastructure*

IPCC – Painel Intergovernamental de Mudanças Climáticas / *Intergovernmental Panel on Climate Change*

IPEA – Instituto de Pesquisa Econômica Aplicada / *Institute of Applied Economic Research*

IPK – Índice de Passageiros por Quilômetro / *Passengers per Kilometer Index*

IPVA – Imposto sobre a Propriedade de Veículos Automotores / *Tax on the Property of Automotive Vehicles*

ISSRC – Centro Internacional de Pesquisa em Sistemas Sustentáveis / *International Center of Research in Sustainable Systems*

ITS – Sistemas Inteligentes de Transporte / *Intelligent Transportation System*

LAP – Leitura Automática de Placas / *Automatic Reading of Plates*

METRÔ – Companhia do Metropolitano de São Paulo / *São Paulo Metropolitan Company*

MP – Material Particulado / *Particulate Matter*

MS – Ministério da Saúde / *Health Ministry*

MT – Ministério dos Transportes / *Transport Ministry*

NIC - Núcleo de Informação e Coordenação do Ponto br

NTC – Associação Nacional dos Transportadores de Carga / *National Association of Freight Transportation*

OCR - *Optical Character Recognition*

O/D – Origem e Destino / *Origin and Destination*

OGU – Orçamento Geral da União / *General Budget of the Union*

PAC – Plano de Aceleração do Crescimento / *Growth Acceleration Plan*

PDDT – Plano Diretor de Desenvolvimento de Transportes / *Transport Development Master Plan*

PDE – Plano Diretor Estratégico / *Strategic Master Plan*

PIB – Produto Interno Bruto / *Gross Domestic Product*

PITU – Plano Integrado de Transportes Metropolitanos / *Integrated Plan of Metropolitan Transport*

PMR – Polícia Militar Rodoviária / *Military Road Police*

PMV – Painel de Mensagem Variável / *Variable Message Panel*

PNAD – Pesquisa Nacional por Amostra de Domicílios / *National Research of Household Sample*

PNUD – Programa das Nações Unidas para o Desenvolvimento / *United Nations Development Program*

PPA – Plano Estadual de Investimentos / *State Investment Plan*

PPP – Participação Público Privada / *Public-Private Partnership*

PROCONVE – Programa de Controle da Poluição do Ar por Veículos Automotores / *Air Pollution Control Program of Automotive Vehicles*

RFFSA – Rede Ferroviária Federal S.A. / *Federal Railroad S.A.*

RM – Região Metropolitana / *Metropolitan Region*

RMSP – Região Metropolitana de São Paulo / *São Paulo Metropolitan Region*

SEADE – Sistema Estadual de Análise de Dados (Fundação) / *Data Analysis State System (Foundation)*

SEMPLA – Secretaria Municipal de Planejamento / *Municipal Secretariat of Planning*

SESC – Serviço Social do Comércio / *Social Service of the Commerce*

SINIAV – Sistema Nacional de Identificação Automática de Veículos / *National Vehicles Automatic Identification System*

SMT – Secretaria Municipal de Transportes / *Municipal Secretariat of Transport*

SPTrans – São Paulo Transporte S.A. / *São Paulo Transport S.A.*

STM – Secretaria dos Transportes Metropolitanos / *Secretariat of Metropolitan Transport*

SVP – Secretaria de Vias Públicas / *Secretariat of Public Roads*

TEU – Transporte Expresso Urbano / *Urban Express Transport*

TIC – Tecnologia da Informação e Comunicação / *Information and Communication Technology*

TKU – Toneladas.Quilômetros Úteis / *Ton-Kilometers*

VER – Vias Estruturais Restritas / *Restricted Structural Roads*

VOC – Compostos Orgânicos Voláteis / *Organic Volatile Compound*

VT – Vale Transporte / *Transport Voucher*

VUC – Veículo Urbano de Carga / *Urban Freight Vehicle*

ZERC – Zona Especial com Restrição de Circulação / *Special Zone with Circulation Constraint*

ZMRC – Zona de Máxima Restrição de Caminhões / *Maximum Constraint Zone for Trucks*

Appendix 2 Summary of the Stakeholder Dialogue

APPENDIX 2: SUMMARY OF THE STAKEHOLDER DIALOGUE

Sustainable Mobility in São Paulo
Summary of the Stakeholder Dialogue held in Sao Paulo
May 15, 2008

The dialogue was co-hosted by Conselho Empresarial Brasileiro para o Desenvolvimento Sustentável (CEBDS – the WBCSD partner organization in Brazil), Brisa auto-estradas de Portugal, General Motors, Michelin and Petrobras. The morning session began with a welcome address from Fernando Almeida, the Executive President of CEBDS, who explained why the dialogue was important given the mobility challenges São Paulo and other cities in Brazil are facing. This was followed by a keynote address from Mr. José Roberto dos Santos, the Logistics and Infrastructure coordinator, São Paulo State Secretariat of Development. He explained the mobility priorities for the state of São Paulo and outlined some of the actions the state was taking to address these mobility challenges. Shona Grant from the WBCSD gave the vote of thanks.

Session 1: The challenge of Sustainable Mobility in rapidly growing cities

The first plenary session was chaired by Mr. Valdemar Mendes the President, Brisa Participações e Empreendimentos, who explained Brisa's interests in sustainable mobility in Brazil. This was followed by Dr George Eads who summarized the WBCSD's Mobility 2030 report, outlining the challenges of making mobility sustainable. He presented the seven sustainable mobility goals and gave a frank assessment of the current outlook for sustainable mobility globally. This was followed by Mr. Elmir Germani and Mr. Gabriel Murgo Branco from TTC who summarized the findings of the São Paulo case study on sustainable mobility.

The presentations were then followed by three separate roundtable discussions each focusing on a separate issue. The topics were introduced by Shona Grant:

1. Can São Paulo avoid permanent grid-lock?
2. Does mobility in São Paulo adequately address the mobility needs of all citizens?
3. What more can be done to reduce the adverse health and environmental impacts from transportation in São Paulo?

Dr Bernardo Guastimosim Alvim summarized the view of TTC on the extent to which the initiatives currently underway in São Paulo are addressing the sustainable mobility challenges in the city and the associated goals from the WBCSD SMP project.

Session 2: Feedback from roundtable discussions

The second plenary session was chaired by Mr. Jacques Toraille, Sustainable Development Corporate Manager, Michelin. During this session the chairpersons from each table presented the main findings and observations from the morning table discussion groups.

Q1 - Can São Paulo avoid permanent grid-lock?

The general conclusion was that the vehicle fleet will continue to grow and that congestion will get worse so most of the discussion focused on the observation that it was "hard to avoid congestion but could it be less?" A recent survey of São Paulo citizens placed congestion as their number one concern. The economic losses due to traffic congestion are estimated at 4 billion reais per year.

People have also realized that this will not be solved by just adding/widening roads and there is now more focus on improving public transport and reducing the demand for road space by cars. The general view expressed was that current overall investment levels are insufficient to solve the issues and specific financing by public agencies should be increased. However all agreed that there is no one solution and a combination of actions will be required.

Public transport is not always a popular choice. Middle-class residents will use the Metro but generally not buses, while only the poorest use the train service. One group stated that no one at their table uses public transport in São Paulo but that they do use it when traveling to other cities, for example in Europe – "we use public transport abroad but not at home". There was a belief expressed that better marketing of public transport may help. However all agreed that the quality, reliability, and frequency of public transport need to be dramatically increased to attract middle-class users. The bus companies are also monopolies that do not compete with each other so there is little incentive to improve service levels. Vans (big taxis) offer a higher level of service to citizens. One group also called for São Paulo residents to "exercise greater citizenship" such that the users take greater care of public transport and do not tolerate vandalism and littering, for example.

License plate limiting was brought up by all participants as an example of what São Paulo had done to address congestion. At first the reduction in cars was around 12%, now it is estimated at 5 to 7% as people have purchased second cars to deal with the days they cannot use their first car. Road pricing was also brought up by all participants as a possible future measure that may curtail the number of vehicles, especially at peak times – basically changing the mindset that "public road space is regarded a scarce public good". The charges would also create much needed revenues to improve public transport. However it was also recognized that the introduction of restrictions by necessity requires the introduction of alternatives – i.e., "we need both the carrot and stick approach". Cargo transport should also make more use of the ring roads and/or railways while other activities could start earlier and finish later to increase flexibility.

Urban planning was also brought up and a suggestion made that origin-destination surveys could be used to move activities nearer to people in order to reduce journey distances and to enable people to make more use of non-motorized modes (e.g., walking, bicycles) – "reinventing the city to create areas where people are closer to what they need". However several participants pointed out that there are very few bicycle lanes in São Paulo, there is a lack of secure cycle parking and bicycles are not allowed on buses so its use in multi-modal trips is limited – "you have to be brave to ride a bike to work in São Paulo".

People also expressed a concern that the institutions in charge of transport lack motivation: each has its own agenda, and there is not enough cooperation and integration – "different cooks with different spoons in the same pot". However others believed "that the only thing really missing was the political will to make it happen". Political terms of office were also viewed as too short compared to the planning and implementation periods for major projects. As a result there is limited continuity in plans from one political term to the next. The example of France was cited whereby once a plan is approved by law the civil administration implements it, thereby avoiding political cycles.

Q2 - Does mobility in São Paulo adequately address the mobility needs of all citizens?

The general consensus was "no" in that the mobility needs of the low-income segment are not being sufficiently addressed with the poorest citizens often unable to afford public transport – one group noted that in fact "all people are poorly served". They are also disproportionately exposed to the negative impacts of transport (traffic accidents, pollution, etc.). One group stated that "people sleep on the streets downtown in São Paulo Monday to Friday because they have no money to go home".

There was general agreement that service and investment levels in public transport need to improve significantly. However it was also recognized that improving quality will require investment and that this will lead to higher ticket prices – this paradox needs to be solved if São Paulo is to be successful in getting more people onto public transport while still keeping it affordable for all citizens. There was general agreement that public transport garners significantly less investment per head of population than other modes. The spatial coverage of buses is good but they are not reliable. Also, increased congestion leads to more idling time with the result that more buses are required to provide a service. The key issue is to increase the speed of buses by implementing more bus-only lanes and re-engineering concessions.

The single ticket was universally agreed to have brought about major improvements in the affordability and use of public transport. However participants also agreed that current subsidies disproportionately benefit the middle-income sector over the elderly and lower-income groups. Another example was given relative to fuels where the gasoline subsidy benefits cars users (predominantly middle and higher income users) while there is no subsidy for diesel that is used in public transport (predominantly low and middle-income users).

Institutionally at the federal, state and municipal levels, there is no clear policy that prioritizes public transport over other modes. There was general agreement that this needs to change to ensure that public transport becomes a policy priority. An example was given where a federal law was put in place and has successfully promoted easy access for less able people on public transport. Work is ongoing to ensure compliance by all buses in São Paulo. Participants also called for a longer term urban plan for the city that is focused (due to resource restrictions) and specifically addresses the mobility divide.

Q3 - What more can be done to reduce the adverse health and environmental impacts from transportation in São Paulo?

There was general agreement that the environmental and health impacts from transportation are not seen as a priority by São Paulo citizens or the municipal government (perhaps reaching # 4 on the list of priorities). However, it was also noted that cleaner vehicles resulting from the new phases of PROCONVE implementation were reducing pollution, even though levels remain very high. Participants also agreed that the use of cleaner technology in cars will not be enough and there is a clear need for more and cleaner mass transport solutions.

There was general agreement among participants that there was insufficient vehicle inspection and enforcement of existing standards. Participants also felt that not enough was being done to encourage a shift to non-motorized modes – “all bicycle lanes are in the parks not for daily commutes”. A participant gave an example of their daily commute of 3.5 km where the trip would take 40 minutes by car, 10 to 15 minutes by bike, and 30 minutes by foot. There was no public transport available on the route. As a result they cycled as it was the most efficient. It also had the added benefit to the city of removing a car from the road and reducing pollution – some cyclists wear a sign “please respect me, I mean one less car on the roads”. It was pointed out that the federal government does have a “Bicycle for Brazil” policy that is targeting investment in infrastructure for bikes. This is now being rolled out but has not reached São Paulo.

Participants also agreed that very little has been done around heavy goods vehicles which use diesel. For example, the motivation for biodiesel was mainly social (the creation of jobs) and not air quality benefits. There was agreement among key stakeholders as early as 2002 on the new diesel standard, similar to EURO IV, but ANP (Brazilian Oil and renewable Agency) only published it at the end of 2007.

The observation was made that “the regulator does not act as a regulator” due to lack of coherent institutional objectives and plans for implementation and monitoring.

The health costs of pollution are not factored into most of the thinking on emissions standards.

Session 3: The role of biofuels in achieving sustainable mobility in São Paulo

The second plenary session was chaired by Mr. José Carlos Pinheiro Neto, Vice President, General Motors (GM), Brazil. He introduced the session topic. He briefly described the implications of increasing ethanol use for GM in Brazil and globally (GM is the #1 provider of ethanol-based cars in the US with sales of 2 million). He also reiterated the need for vehicle inspection and advocated for the removal of non-compliant vehicles from the roads.

The first presentation was made by Mr. Frederico Kremer, Product Development Manager, Petrobras. He explained that the Brazil energy mix was 54% fossil-based and 46% renewable. He also pointed out that biofuels would solve some of the dependency on fossil fuels but “they would not solve the problem”. According to the Ministry of Energy, 2007 data for the vehicle energy matrix is: 22.1 % ethanol (13.8 % hydrated ethanol and 8.3% anhydrous, to be blended in the gasoline); 23.4% gasoline (without ethanol); 3.4% CNG and 51.2% diesel. One of the biggest problems for natural gas-powered buses is that the buses have such a low resale value that people do not want to buy them in the first place.

Future predictions of the number of flex fuel vehicles are fairly robust at just over 70% of the car fleet. However one of the biggest problems facing Petrobras is predicting the future demand for ethanol as there is enormous uncertainty over the future proportions of gasoline and ethanol in the flex fuel mix – people will decide on the day they fill up their tanks.

He also advised that Petrobras was working on enzyme technology for lingo-cellulose conversion to biofuels that – if successful – would eliminate food vs. fuel competition.

The second presentation was made by Ms Ana Cristina Barros, Representative of The Nature Conservancy (TNC) of Brazil. She explained that one of her organization’s roles in Brazil was to minimize transport impacts – “through biofuels these problems are solvable”. She also explained that TNC believed that Brazil had great legislation on biofuels and that rural communities can make money out of it. However she then went onto say that “we are not doing a very good job to make it all fit in Brazil”, quoting the example of the Atlantic Forest where only 7% remains.

TNC advised that Brazil is the world’s fourth largest carbon emitter with 75% of emissions coming from deforestation and forest fires. However the federal government has very little real say in Amazonian deforestation. Ms Barros then explained that there was very little information and poor control of land use. As an example, there is no data on how many small farmers are being displaced by sugar cane plantations to the south in the Amazon area. TNC is advocating for more legislation to deal with land registration, impact assessments, compliance, licensing and monitoring.

TNC is advocating for a market-based approach to deal with non-compliance with the requirement to have 20% of land under conservation. They are proposing that farmers, who have gone below the 20% level, pay other farmers to make up the difference by maintaining their forests at an equivalent amount above the 20% requirement. They believe this will be much more successful than a command and control approach by government.

Summary of the day

Dr George Eads and Mr. Elmir Germani summarized the main discussion points from the dialogue. Mr. Germani focused on congestion, pointing out that it will be difficult to eliminate but that it should be possible to achieve a better balance between supply and demand. He also stressed the importance of demand management and car pricing to make up the funding shortfalls in public transport.

Dr Eads used the bicycle to compare the four cities that the WBCSD has looked at. In Dar es Salaam citizens aspire to move from walking to owning a bicycle; in Bangalore the role of bicycles is being overtaken by motor scooters and cars; Shanghai was the city of bikes in the 1980s (more bike lanes than roads) but now the city is trying to discourage bicycles as they are seen as disruptive to the traffic; in São Paulo bikes are almost non-existent, public transport is quite good but there are lots of cars and congestion.

Concluding remarks

The WBCSD thanked CEBDS and the sponsor companies for supporting the event and thanked participants for coming along to this dialogue. The WBCSD also thanked TTC for preparing the interim case study report on São Paulo and encouraged the participants to review this and send any comments to the WBCSD or Mr. Germani. The WBCSD’s Mr. Jacques Toraille from Michelin then presented the plans for the upcoming Michelin Challenge Bibendum in Rio de Janeiro in 2009 and encouraged participants to attend. Ms Beatriz Bulhoes, Director of CEBDS ended the session and invited participants to join the organizers for cocktails hosted by Petrobras.

Appendix 3 Dialogue participants

APPENDIX 3: DIALOGUE PARTICIPANTS

(Total 85 excluding journalists and support staff)

Name	Affiliation	Sector
Moacyr Servilha Duarte	Associação Brasileira de Concessionárias de Rodovias (ABCR)	Regulation Organizations
Marcos Bicalho dos Santos	Associação Nacional das Empresas de Transporte Urbano	Regulation Organizations
Ulrich Jagger	Autonomo	Other
Daniela Konrad	Basf S.A	Private Sector
Rita de Cassia Monteiro Marzulho	Basf S.A	Private Sector
Duncan Eggar	BP	Private Sector
Robson Freitas	BP	Private Sector
João Tavares	Brisa	Private Sector
Valdemar Mendes	Brisa	Private Sector
Ana Sheila Rodrigues Fachini	CAIXA ECONOMICA FEDERAL	State-owned company
Arioneide Ferreira Viana da Silva	CAIXA ECONOMICA FEDERAL	State-owned company
Maria da Conceição Bastos Bemerguy	CAIXA ECONOMICA FEDERAL	State-owned company
Sonia Bertoni Bacovski	CAIXA ECONOMICA FEDERAL	State-owned company
Davi Pires	Cápsula	Private Sector
Renato Nadalin	Companhia de Concessoes Rodoviarias (CCR)	Private Sector
Francisco Bulhões	CCR	Private Sector
Harald Peter Zwetkoff	CCR	Private Sector
Hermes Quadros	CCR	Private Sector
Beatriz Bulhões	Conselho Empresarial Brasileiro para o Desenvolvimento Sustentável (CEBDS)	Business Association
Fernando Almeida	CEBDS	Business Association
Mariana Perricelli	CEBDS	Business Association
Marina Grossi	CEBDS	Business Association

Name	Affiliation	Sector
Pablo Barros	CEBDS	Business Association
Adalberto Maluf	Clinton Climate Initiative	NGO
Adriana Almeida	Companhia Brasileira de Petróleo Ipiranga	Private Sector
Joaquim Carlos Mendes Barreto	Companhia de Engenharia de Tráfego (CET)	Government
Edson Renato dos Santos	Desenvolvimento em Comunicação (CONAPUB)	Private Sector
Janine Lemos	Desenvolvimento em Comunicação (CONAPUB)	Private Sector
Antonio Roberto Martins	Conselho Federal de Engenharia, Arquitetura e Agronomia (CONFEA)	Regulation Organizations
Carmem Eleonôra C. Amorim Soares	Conselho Federal de Engenharia, Arquitetura e Agronomia (CONFEA)	Regulation Organizations
Paula Martins	CRIANÇA SEGURA Safe Kids Brasil	NGO
Luis Antonio Lindau	EMBARQ	NGO
Luiz Antônio Carvalho Pacheco	Empresa Metropolitana de Transportes Urbanos de São Paulo S.A.(EMTU/SP)	Government
Luiz Carlos de Alcantara	Empresa Metropolitana de Transportes Urbanos de São Paulo S.A.(EMTU/SP)	Government
Fabio Cardinale Branco	Environmentality	Private Sector
Yanko Guimarães	ERM Brasil Ltda	Private Sector
Ana Beatriz F. Monteiro	Genesis Projetos e Concessões	Private Sector
Terry Cullum	GM	Private Sector
José Carlos S. Pinheiro Neto	GM do Brasil	Private Sector
Milton Fratta	GM do Brasil	Private Sector
Pedro Bentancourt	GM do Brasil	Private Sector
Danilo Movikawa	Holcim Brasil S/A	Private Sector
Giseli Martins	Holcim Brasil S/A	Private Sector
Jonas Hagen	Instituto Intern. de Desenv. de Políticas de Transporte	NGO
Priscila Corrêa Fóglia	Itaú	Private Sector
Victor Mauro Salomoni Dos Reis	Itaú	Private Sector
Leonardo Roggério	IVECO Latin America	Private Sector

Name	Affiliation	Sector
Cacilda Bastos	Metrô São Paulo	State-owned company
Jacques Toraille	Michelin	Private Sector
Karênina Martins Teixeira	NTC & Logística	NGO
Ana de Sá	Perfil Urbano	NGO
Ana Paula Grether	Petrobras	State-owned company
Consuelo Sánchez	Petrobras	State-owned company
Frederico Kremer	Petrobras	State-owned company
Frederico Marinho	Petrobras	State-owned company
Luiza Cristina Sodré Mesquita	Petrobras	State-owned company
Mariana Miranda	Petrobras	State-owned company
Rodrigo C. C. de Oliveira	Petrobras	State-owned company
Tadeu Cordeiro de Melo	Petrobras	State-owned company
Jean Grebert	Renault	Private Sector
Natalia Castanha	Renault	Private Sector
José Roberto dos Santos	Secretaria de Desenvolvimento do Estado de São Paulo	Government
Antonio Galvão Alvares de Abreu	Secretaria de Estado dos Transportes	Government
Fernando Barbosa	Secretaria Nacional de Transportes e da Mobilidade Urbana	Government
Guilherme de Paula	Shell Brasil S/A	Private Sector
Glauce Ferman	Sociedade Michelin de Part. Ind. e Com. Ltda.	Private Sector
Ana Cristina Barros	The nature conservancy Brasil	NGO
Paulino Toyoshima	Toyota do Brasil	Private Sector
Sidnei Kendi Kakazu	Toyota do Brasil	Private Sector
Bernardo Alvim	TTC Engenharia	Consultant
Eduardo Vasconcellos	TTC Engenharia	Consultant
Elmir Germani	TTC Engenharia	Consultant
Gabriel Murgel Branco	TTC Engenharia	Consultant
Vernon Kohl	TTC Engenharia	Consultant
Marco Aurélio Giordano	Unibanco	Private Sector

Name	Affiliation	Sector
Kamyla Borges da Cunha	UNICAMP	Academia
Julia Spinassé	Universidade de São Paulo (USP)	Academia
Orlando Strambi	Universidade de São Paulo (USP)	Academia
Jackeline A. Bezerra	Viação Cometa S.A.	Private Sector
Isadora Leoni	Volkswagen do Brasil	Private Sector
Antonia Gawel	World Business Council for Sustainable Development (WBCSD)	Business Association
George Weyerhaeuser	WBCSD	Business Association
Mihoko Kimura	WBCSD	Business Association
Shona Grant	WBCSD	Business Association
George Eads	WBCSD and CRA International	Business Association

Appendix 4
Greenhouse gases emissions in the production and use of ethanol from sugarcane in Brazil: 2005/2006 averages and a prediction for 2020

BIOMASS AND BIOENERGY 32 (2008) 582–595

Available at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

Green house gases emissions in the production and use of ethanol from sugarcane in Brazil: The 2005/2006 averages and a prediction for 2020

Isaias C. Macedo[a,*], *Joaquim E.A. Seabra*[b], *João E.A.R. Silva*[c]

[a]*Interdisciplinary Center for Energy Planning (NIPE), State University of Campinas (Unicamp), CEP 13084-971, Campinas, SP, Brazil*
[b]*College of Mechanical Engineering, State University of Campinas, Cidade Universitária "Zeferino Vaz", CEP 13083-970, Barão Geraldo, Campinas-SP, Brazil*
[c]*Centro de Tecnologia Canavieira (CTC), CEP 13400-040, Piracicaba, SP, Brazil*

ARTICLE INFO

Article history:
Received 13 April 2007
Received in revised form
27 November 2007
Accepted 7 December 2007
Available online 14 January 2008

Keywords:
Energy balance
CO_2
Nitrous oxide
Methane
Fertilizers
Diesel consumption
Cane residues
Trash burning
Avoided emissions
Ethanol blends

ABSTRACT

This work presents the evaluation of energy balance and GHG emissions in the production and use of fuel ethanol from cane in Brazil for 2005/2006 (for a sample of mills processing up to 100 million tons of sugarcane per year), and for a conservative scenario proposed for 2020. Fossil energy ratio was 9.3 for 2005/2006 and may reach 11.6 in 2020 with technologies already commercial. For anhydrous ethanol production the total GHG emission was 436 kg CO_2 eq m^{-3} ethanol for 2005/2006, decreasing to 345 kg CO_2 eq m^{-3} in the 2020 scenario. Avoided emissions depend on the final use: for E100 use in Brazil they were (in 2005/2006) 2181 kg CO_2 eq m^{-3} ethanol, and for E25 they were 2323 kg CO_2 eq m^{-3} ethanol (anhydrous). Both values would increase about 26% for the conditions assumed for 2020 mostly due to the large increase in sales of electricity surpluses.

A sensitivity analysis has been performed (with 2005/2006 values) to investigate the impacts of the huge variation of some important parameters throughout Brazilian mills on the energy and emissions balance. The results have shown the high impact of cane productivity and ethanol yield variation on these balances (and the impacts of average cane transportation distances, level of soil cultivation, and some others) and of bagasse and electricity surpluses on GHG emissions avoidance.

1. Introduction

The transport sector is almost exclusively dependent on petroleum-based fuels and attention has been given to the potential use of biomass as the basis for production of an alternative (and renewable) motor vehicle fuel. The global warming issues have been increasingly a focus of attention and greater use of biofuels, which have been able to compete with (and displace) petroleum-based fuels in the transportation market, could help to comply with the Kyoto Protocol. However, the extent to which biofuels can displace fossil fuels depends on the way in which they can be produced. All processing technologies involve (directly and/or indirectly) the use of fossil fuels; the benefit of biofuels displacing their fossil fuel equivalents depend on the relative magnitude of fossil fuels input to fossil fuel savings resulting from the biofuel use [1].

Among the biofuels, ethanol is the one that is attracting most attention; it is already produced in large scale (Brazil and USA) and it can be easily blended with gasoline to operate

*Corresponding author. Tel.: +55 19 3289 3125.
E-mail address: isaiasmacedo22@terra.com.br (I.C. Macedo).
0961-9534/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biombioe.2007.12.006

in spark ignition (SI) engines. In Brazil, bioethanol is used as neat ethanol in 100% alcohol-fuelled passenger cars (hydrous ethanol) or is blended (anhydrous ethanol) with all the gasoline in proportions of usually about 24% to operate in gasoline engines; or it is still used (as hydrous ethanol) in any proportion in flexible-fuel vehicles (FFV).

Fuel ethanol utilization in Brazil reached 14.1 hm^3 in 2006 (production was 17.7 hm^3), close to 40% of the fuel for SI engines; it also generated 11.3 TWh electricity and mechanical power, which were mostly used internally by the cane processing industry. In addition, the use of bagasse as fuel was 20.2 Mt of oil equivalent, equivalent to all fuel oil plus Natural Gas used in Brazil, again mostly for internal use in the sugar and ethanol industry [2].

The environmental advantages of sugarcane-based ethanol, regarding gasoline substitution and GHG emissions mitigation, have been known since the first comprehensive energy balance [3] and GHG emissions in the life cycle [4] were available. In 1998, Macedo [5] updated and revised these estimates using 1996 data. In 2003 (data from 2002), the information was again updated indicating a value of 8.3 for the ratio (renewable energy in ethanol) $\times$ (fossil fuel energy input)$^{-1}$ in the life cycle, and avoided emissions corresponding to 2.6 and 1.7 t CO_2 eq m^{-3} ethanol anhydrous and hydrous, respectively, for the Brazilian Center-South conditions [6].

The rapid growth of the cane sector in Brazil (from 357 Mt cane in 2003 to 425 Mt cane in 2006, and expected 728 Mt cane in 2012) and some legal constraints and technology developments are changing important parameters in this evaluation. New varieties and productivity changes the legal restrictions to burning sugarcane and the increased harvesting mechanization influence energy and the GHG emissions in different ways. The mills started a strong action in selling surplus electric power and the use of portion of the cane trash for energy will be seen in the next years. In addition, the end use has changed, with the growing fleet of flexible-fuel vehicles (82% of the new cars).

This work presents the situation (energy balance and GHG avoided emissions) today, based on the 2005/2006 average conditions (2002 parameters [6] are also presented for comparison), with the best available and comprehensive data for the Brazilian Center-South Region. Some important parameters for this evaluation present a large range of variation from mill to mill, so a sensitive analysis was performed in order to cover the different possibilities of impacts on energy/emissions balance throughout Brazilian mills. It was also evaluated the situation for a 2020 scenario; this scenario is very conservative, considering only the commercially available technologies (today) and the trends clearly identifiable.

The basic biomass production and conversion data, as well as the most important coefficients used (energy conversion, efficiencies, energy to produce materials, energy for chemical inputs) are presented so that the results for GHG emissions can be compared to other biomass-based energy systems. The specific parameters for the Brazilian end uses of ethanol are used to estimate GHG emission mitigation.

2. Database

The great attention that has been given to ethanol in the last years as an important tool for greenhouse emissions mitigation is leading to some studies about energy balance and GHG emissions in the production and use of Brazilian ethanol. Most of the analyses, however, are based on information provided by only a few mills (sometimes only one) and they may be far from representative of the average national scenario. Unfortunately, a comprehensive countrywide database for the sugarcane sector has not yet been established; the use of a database covering part of the sector, but based on reliable and traceable information, has been preferred by the last comprehensive studies [5,6]. In those cases, the main references were Sugarcane Technology Centre, in that time, Copersucar Technology Centre (CTC) surveys about agricultural and industrial performance parameters of its associated units. Because of the quality of the information (traceable and well-established procedure for data collection and laboratorial analysis, over the last decade), CTC's database was used in this study with data of 2005/2006 and 2006/2007 seasons for agricultural and industrial parameters of 44 mills ($\sim$100 Mt cane $year^{-1}$). It is important to point out that most of these mills are placed in Center-South of Brazil, which is responsible for more than 90% of all ethanol currently produced in Brazil [2]. The evaluation for the agricultural parameters used the weighted average of the individual values for each mill with respect to its size (cane crushing rate). For the industrial parameters, the weighting factor was the cane processed exclusively for ethanol production.

One point deserves further comments. Diesel consumption is a key parameter in this analysis, and for its estimation we considered the methodology used by Macedo et al. [6]. In this procedure the total consumption is obtained through the equipments' specific fuel consumption and the level of their utilization in the different productive operations (see details in [6]). The data used in that analysis had been originally taken from Copersucar reports (Agricultural Monthly Performance Follow up Program and Agricultural Benchmark Program), which were revised for this present evaluation. Through this methodology, we found a total diesel consumption of 164 L ha^{-1}.

These calculations consider all the essential operations involved in the sugarcane production chain, but there is a portion of the total diesel consumption (other, diversified operations) that is not accounted for. The information of the sugar mills about this portion is incomplete and non-homogeneous; based on the information to CTC, for a sample of 40 mills, the total diesel consumption (agricultural processes) varied from 68 to 285 L ha^{-1} in 2005/2006 season (without including the fuel for stillage and filtercake mud distribution). Those values also may not include third party tractors. On the other side, the total diesel consumption related in some other cases includes operations not related to the ethanol production (sugar transportation in the mill, operations with cattle raising and other cultures, new land development, operations with third party cane, etc.). This leads the huge variation of the values, and to the preference for the direct calculation methodology. In an (conservative) estimation of the total diesel consumption average, we took (arbitrarily) only the values higher than 160 L ha^{-1} and added to them 15 L ha^{-1} (for stillage and filtercake mud distribution operations [6]). The weighted average of these values was 230 L ha^{-1}, which has been adopted as the total diesel consumption of the average mill. Actually, when we consider all activities performed by the mill, we may find values higher than that (eventually 400 L ha^{-1}) [7]. A large share of this consumption, however, is related to certain services which were already accounted in other items of the analysis (maintenance, for example), or it is not even related to sugarcane production chain (e.g. soybean or peanut cultivation, land development for new areas).

The difference between these estimations (164 and 230 L ha^{-1}) is associated to other activities and small services that are performed during productive operations, but are not individually identified. This difference was allocated as "other agricultural activities". It is desirable that in the near future the complete, homogeneous information may be added to the database.

3. Ethanol fuel chain: expected evolution

3.1. *Sugarcane production (agriculture)*

The complete sugarcane crop cycle is variable, depending on local climate, varieties and cultural practices; in Brazil, usually it is a 6-year cycle, in which five cuts, four ratoon cultivation treatments and one field reforming are performed. Generally, the first harvest is made 12 or 18 months after planting. The following ratoon cane harvests are made once in a year, during 4 consecutive years, with gradual decrease in cane productivity. In the Center-South of Brazil the average productivity is about 78–80 t of cane per hectare (tc ha^{-1}), while in São Paulo State it ranges from 80 to 85 tc ha^{-1}, both considering a complete cycle with five cuts [2].

Since early 1980s the evolution trend in cane productivity has been continuous, from 70 tc ha^{-1} to more than 80 tc ha^{-1} in early 2000s [8]. This trend might be kept for the next years, and the same can be said about cane quality (sucrose content), for which is expected an increase of one basis point in the next 15 years [9].

The agricultural operations in cane cultivation are not expected to change much in the next years, except for the modifications due to increasing harvest mechanization. However we might see an increase of low tillage practices in the next years. The main alteration expected is the adoption of mechanical planting, in substitution of separated operations of furrowing and fertilizer application and seed distribution [9].

The most important changes may happen in cane harvesting, which will move from burned cane manual harvesting to mechanical harvesting of unburned cane. Essentially, this change is related to a schedule adjustment with Government (Federal and State levels) specifically for the gradual reduction of the cane trash pre-burning (see Fig. 1). Recently, UNICA signed a protocol of intentions in which its associates (individually and voluntarily) may accept to phase out trash

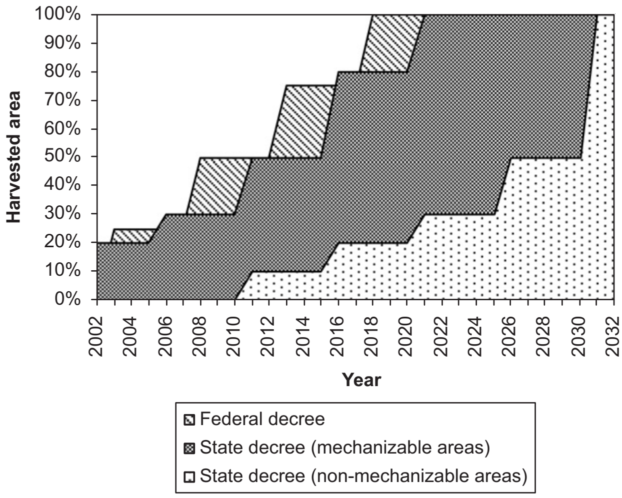


Fig. 1 – Phase out schedules for trash burning practices (based on [10]).

burning practice until 2014, in mechanizable areas, and 2017, in non-mechanizable areas.

As a consequence, great amounts of trash will be available, and its use as energy source is already becoming an attractive option for mills, although the route for trash recovery (harvest and transportation) is still not well established. For those cases in which the trash recovery is intended, the best alternative at the moment is the mechanical cane harvesting with partial cleaning [11], i.e. part of the trash would be transported to the mill with cane, and there it would be separated and used as fuel.

For the logistics the trend is the replacement of single load trucks by trucks with lower specific fuel consumption and higher load capacities (3 and 4 wagons). Nonetheless, the eventual implementation of government regulations restricting the load capacity for cane transportation in the next years could impose large barriers to such evolution [12].

The summary of the main agricultural parameters considered for energy and emission analyses for 2005/2006 and the projected values estimated for the 2020 scenario are presented in Tables 1 and 2 (2002 data is also presented for comparison). For 2020 scenario, many opinions from different specialists were considered in order to identify the most probable scenario [9,13]; we adopted a very conservative set of conditions, and it may be considered a "minimum" expected performance.

3.2. *Sugarcane processing (industry)*

Because of the great advantages of producing sugar and ethanol simultaneously, the most adopted mill configuration in Brazil is an ethanol distillery annexed to the sugar mill. In this study an autonomous distillery was considered, just to facilitate the evaluation of energy and materials flows concerned only to ethanol production, disconnected from sugar. This assumption does not compromise the quality of the analysis, since ethanol and sugar production involve processes clearly distinguished, with very well known system boundaries, specific equipment and energy use. The data

Table 1 – Basic data for sugarcane production, harvesting and transportation

Item	Units	2002[a]	2005/2006[b]	Scenario 2020[c]
Sucrose	% cane stalks	14.53	14.22	15.25[d]
Fiber	% cane stalks	13.46	12.73	13.73[e]
Trash (dry basis)[f]	% cane stalks	14	14	14
Cane productivity	$t\ cane\ ha^{-1}$	82.4	87.1	95.0
Seed efficiency	$(ha\ cane)\ (ha\ seed)^{-1}$	7.0	6.9	7.0
Fertilizer utilization				
P_2O_5				
Plant cane	$kg\ ha^{-1}$	120	125	134
Ratoon without stillage	$kg\ ha^{-1}$	25	25	34
K_2O				
Plant cane	$kg\ ha^{-1}$	120	117	138
Ratoon without stillage	$kg\ ha^{-1}$	120	114	138
Nitrogen				
Plant cane	$kg\ ha^{-1}$	30	48	48
Ratoon with stillage	$kg\ ha^{-1}$	90	75	55
Ratoon without stillage	$kg\ ha^{-1}$	80	88	120
Lime	$t\ ha^{-1}$	2.2	1.9	2.0
Herbicide[g]	$kg\ ha^{-1}$	2.2	2.2	2.2
Insecticide[g]	$kg\ ha^{-1}$	0.16	0.16	0.16
Filtercake application	$t\ (db)\ ha^{-1}$ (% area)[h]	5 (30%)	5 (30%)	5 (30%)
Stillage application	$m^3\ ha^{-1}$ (% area)[i]	150 (30%)	140 (77%)[j]	140 (90%)[j]
Mechanical harvesting	% area	35	50	100[k]
Unburned cane harvesting	% area	20	31	100[k]
Machinery utilization				
Tractors+harvesters	$kg\ ha^{-1}$	41.8	41.8	210
Implements	$kg\ ha^{-1}$	12.4	12.4	13
Trucks	$kg\ ha^{-1}$	82.4	82.4	100

[a] [6].
[b] [14].
[c] Author's projections.
[d] 2020: increasing 1 point (%) in 15 years (variety development and better allocation).
[e] Apparent fiber increasing with increase in green cane harvesting (trash).
[f] [11].
[g] Macedo, 2005.
[h] Reforming areas (1/6 of total area).
[i] Ratoon areas (4/6 of total area).
[j] Stillage is an ethanol production residue, but it is spread over both cane areas, for sugar and ethanol production, since they are not distinguished in cane field. However, to limit ethanol system boundaries, in this study it was considered that all stillage is destined exclusively to "ethanol cane area", but keeping the suitable level of application ($\sim 140\ m^3\ ha^{-1}$).
[k] Considering the legislation and phase out schedules for cane trash burning in São Paulo, 2006.

Table 2 – Parameters for diesel consumption estimation

Parameter	Units	2002[a]	2005/2006	Scenario 2020[b]
Agricultural operations				
Plant cane	$L\ ha^{-1}$	102.6	102.6	132.3
Ratoon	$L\ ha^{-1}$	9.1	9.1	9.1
Harvester	$L\ tc^{-1}$	0.898	1.050	0.986
Loader	$L\ tc^{-1}$	0.154	0.163	0.171
Tractor hauler/transloader	$L\ tc^{-1}$	0.257	0.376	0.395
Transportation distance	km	20	23	30
Trucks' energetic efficiency	$t\ km\ L^{-1}$	49.0	52.4	62.0
Other activities[c]	$L\ ha^{-1}$		67.0	85.0

[a] [6].
[b] Authors' projections.
[c] See details in text body (Section 2). For 2020 scenario, the projection was based on the increase of diesel consumption expected for basic productive activities.

obtained for combined sugar and ethanol production considers the allocation issues for the industry (energy consumption, equipment, inputs) and agriculture (residue recycling), using also the long experience in Brazil with the autonomous distilleries in the 1970–1980 period. Most of the new projects involve only autonomous distilleries.

The production scheme is basically the same for an integrated mill: the process begins with cane cleaning and crushing, when the juice is separated from bagasse (which is sent to power island section). The treated and slightly concentrated juice follows to fermentation, producing the wine, which will result in hydrous ethanol after the distillation; the hydrous ethanol may be stored as final product or dehydrated to produce the anhydrous ethanol.

Process yield depends on cane quality (sucrose content) and the efficiency in sucrose utilization. At present the industrial efficiency (sugar recovery) is around 90% and it is difficult to expect a large evolution considering only today's commercial technologies. So, for 2020 the possibilities to enhancing ethanol yields are basically related to cane quality improvements.

The main (energetic) co-products of ethanol production are bagasse and electricity surpluses. Nowadays, the energy generation in mills is based on "pure" cogeneration steam cycle systems (at pressure of 2.2 MPa), which are capable to attend whole mill energy demand and still produce small amounts of bagasse (5–10% of biomass) and electricity surpluses (0–10 $kWh\,tc^{-1}$). However, new mill units are already equipped with high-pressure steam systems (e.g. 6.5 MPa—480 °C; some units with 9.0 MPa), besides the utilization of more efficient equipment and better process integration designs. The implementation and evolution in cane trash recovering will enable the production of greater amounts of electricity surplus, easily overcoming 100 $kWh\,tc^{-1}$.

The main residues are filtercake mud and stillage; they are very important for their use as fertilizers, reducing the need for agricultural inputs. For the coming years, since their production is determined by the amount of cane crushed and ethanol production, the only expected change is the increase of the total area in which they are used (optimizing the fertilizer savings, and using more energy).

The basic parameters considered for ethanol production phase are presented in Table 3. The projections for the 2020 scenario, again, were made based on specialists' opinions [9,13].

4. Methodology

4.1. Energy input and GHG emissions

In this analysis a "seed-to-factory gate" approach was adopted, which comprehends the sugarcane production and processing, coming to fuel ethanol at the mill gate. Three levels of energy flows were considered in the energy

Table 3 – Basic data: cane processing to ethanol

Item	Units	2002[a]	2005/2006[b]	Scenario 2020[c]
Electricity use in processes	$kWh\,tc^{-1}$	12.9	14.0	30
Mechanical drivers	$kWh\,tc^{-1}$	14.7	16.0	0
Surplus electricity	$kWh\,tc^{-1}$	0	9.2[d]	135[e]
Trash recovery	% total	0	0	40
Surplus bagasse	% total	8	9.6	0[f]
Ethanol yield	$L\,tc^{-1}$	86	86.3	92.3[g]
Equipments[h]				
Boilers	t	310	2400	2400
Crushers and driving devices	t	312	1300	1300
Conveyors	t	225	450	450
Distillery	t	476	3000	3000
Tanks	t		1540	1540
Buildings				
Industrial buildings	m^2	5000	12,000	12,000
Offices	m^2	300	800	800
Labs, repair shops	m^2	1500	3800	3800
Yards	m^2	4000	10,000	10,000

[a] [6].
[b] [9].
[c] Authors' projections.
[d] Based on Cogen's estimations [15]. But only about 10% of the mills operate with higher pressure boilers, and the remaining 90% still use 2.1 MPa/300 °C, with very low surplus energy.
[e] All mills operating at 6.5 MPa/480 °C, CEST (condensing extraction steam turbine) systems; process steam consumption ~340 (kg steam) $(t\ cane)^{-1}$, and using recovered trash (40%).
[f] All biomass (bagasse and 40% trash) is used for power generation.
[g] Only the increase in sucrose % cane was considered.
[h] 2002 data were based on a 120,000 $L\,day^{-1}$ distillery size; for 2005/2006 and 2020 scenario we considered an 860,000 $L\,day^{-1}$ unit.

balance and GHG emissions evaluation:

1. The direct consumption of external fuels and electricity (direct energy inputs).
2. The additional energy required for the production of chemicals and materials used in the agricultural and industrial processes (fertilizers, lime, seeds, herbicides, sulfuric acid, lubricants, etc.).
3. The additional energy necessary for the manufacture, construction and maintenance of equipment and buildings.

The energy flows were calculated in terms of Gross Energy Requirement (GER), i.e. the energy inputs required during the extraction, transportation and production of fuels (or electricity) were measured, as primary energy [1]. The possible evolution of energy and emission factors along the time was not considered in this analysis, so the same values were adopted for both studied cases: 2005/2006 and 2020 projected conditions. The coefficients used to determinate the energy consumptions and GHG emissions are discussed below.

4.1.1. *Fuels*

Since local reliable data were not available, we used international consolidated data about energy consumption and GHG emissions in the production of oil-derived fuels [16,17]. Brazilian particularities regarding oil extraction technology (most of the oil comes from deep water) and oil type (mostly heavy oil) may result in higher energy consumption for extraction and refining, but eventual variations in comparison with international values would not be so that may compromise this analysis. Table 4 shows the values considered.

4.1.2. *Electricity*

Despite the recent investments in the construction of NG thermoelectric plants, the power generation in Brazil is still based on hydroelectric stations (>85%). Actually, power generation from fossil fuels accounts for less than 10% of all electricity produced in Brazil [18]. Evidently this low fossil fuel consumption is reflected in GHG emissions. According to the evaluations presented by MME for the determination of baselines (CDM projects), in 2006 the emissions related to power generation in Southeast-Midwest Region were between 78 and 180 $kg\,CO_2\,MWh^{-1}$. Bearing these values in mind and the low utilization level of external, acquired electricity in cane ethanol life cycle (it's related only to embodied energy in machinery, equipments and chemicals), this share of energy consumption was not considered for global energy and GHG emissions accounting.

4.1.3. *Embodied energy in agricultural machinery and industrial equipments*

Usually, embodied energy uses in equipments manufacturing (agricultural and industrial) and buildings are low in comparison to energy flows associated to energy production. In the case of cane ethanol, however, this share is not so small, once there is no demand for fossil fuels in the ethanol production step (differently from other biofuels). Actually, in the last evaluation [6] this share was equivalent to 30% of the total energy requirement.

In this evaluation, we kept the same characterization for equipment types division made by Macedo et al. [6], but the data about embodied energy in materials and their respective GHG emissions was updated. Only one additional simplification was made: all materials were considered generally as metallurgical products.

According to the Brazilian Energy Balance [18], the specific energy consumption in metallurgical industry was 27.2 $MJ\,t^{-1}$ (in 2005), of which around 65% were provided by fossil energy sources. In terms of emission, Kim and Worrell [19] estimated a Brazilian emission factor of 1.25 $t\,CO_2\,t^{-1}$ of iron-steel, considering a specific energy requirement near to the 2005 data. So, here we considered a fossil energy requirement of 17.7 $MJ\,t^{-1}$ and an emission factor of 1.25 $t\,CO_2\,t^{-1}$. For the machinery and equipments manufacturing step, since electricity is the main energy source, here this share of energy was not considered.

4.1.4. *Embodied energy in mill's constructions*

The energy consumption for buildings construction varies from 3.0 to 5.0 $GJ\,m^{-2}$, according to their type. For a Brazilian standard residential construction, it is estimated an energy

Table 4 – Energy demand and GHG emissions in fossil fuels production

Fuel	Energy demand[a] ($MJ\,MJ_f^{-1}$)[b]	Direct emission[c] ($gC\,MJ_f^{-1}$)	Emissions in production[d] ($gC\,MJ_f^{-1}$)	Total emissions ($gC\,MJ_f^{-1}$)
Gasoline	1.14	18.9	3.41	22.3
Diesel	1.16	20.2	3.87	24.1
Fuel oil	1.24	21.1	4.95	26.1
Natural gas	1.12	15.3	9.53	24.8
Petroleum coke[e]	1.00	27.5	–	27.5

[a] [16].
[b] MJ_f = Mega Joule of fuel.
[c] [17].
[d] [16]; considering extraction, transportation and processing.
[e] Considered as residue; emissions related to its production were not considered.

requirement of 3.5 GJ m^{-2}, in which the energy associated to cement production is the main part [20]. In the national cement industry [18], about 60% of energy requirement is provided by fossil fuels (petroleum coke mainly) and, for simplification, here we extended this ratio to all building types. With these considerations, and for the different types of mill's constructions, we proposed the values presented in Table 5 as defaults for calculations. The emission factor was equivalent to the petroleum coke emission factor, i.e., 100.8 kg CO_2 GJ^{-1}.

4.1.5. *Energy requirement for fertilizers production*

Fertilizers have received a special attention in life cycle analyses especially because mineral nitrogen, which, besides its N_2O emission, also demands large amounts of energy for production. When local data about energy consumption for fertilizers (and defensives) production were not available, we used international data (EBAMM and GREET models' values). The correspondent emission factors were also based on the values presented by EBAMM and GREET models [21,22], which represent the US default values (see Table 6).

4.1.6. *Energy requirement for chemicals production*

The estimation of energy requirements and associated emissions in chemicals production were based on general information of Brazilian chemical industry. In 2005, the specific energy consumption in chemical industry in Brazil was 8.1 MJ t^{-1} of shipment, with 73% been provided by fossil sources (essentially NG and petroleum coke) [18]. For simplification, this coefficient was attributed to all chemicals and with an emission factor of 95 kg CO_2 GJ^{-1} (derived from NG and petroleum coke use). Table 7 shows the energy consumption per liter of ethanol associated to each product.

The evaluation of the GHG emissions included the emissions due to fossil fuel utilization (all three levels) and those not related to fossil fuels. The most important emissions that are not derived from use of fossil fuels are:

- methane and N_2O emissions from the burning of sugarcane trash before harvesting;
- N_2O and CO_2 emissions from soil by fertilizers and lime application and crop residues returned to soil.

The process conditions allowed for stillage recycling adopted today (stillage cannot stay in ponds; application volume is site dependent) do not promote anaerobic digestion. The same is true for bagasse storage (usually less than 5%; short off season periods); so methane emissions are not included in the analysis.

Emissions from sugarcane trash burning in the field and soil emissions were evaluated according IPCC (2006) recommendations [17], with the corrected values for the GWP-100 [24]. Since urea is the main N-fertilizer used [25], besides N_2O emissions, the emissions of CO_2 must also be accounted for [17]. Nitrous oxide emissions regarding unburned trash that is not taken to the mill, added to stillage and filtercake mud emissions (industrial residues that carry part of cane nitrogen), were determined with IPCC values indicated for "residues returned to soil" category [17], although they do not necessarily represent the reality verified for sugarcane biomass. The summary of emission factors used for emissions not derived from the use of fossil fuels considered in this analysis is presented in Table 8.

4.2. *Energy output and GHG avoided emissions*

The total renewable energy produced in ethanol life cycle was considered as the sum of the thermal energy contribution of ethanol and co-products (bagasse and electricity surpluses).

Table 5 – Estimated embodied energy for mill's buildings[a]

Building	Embodied energy[b] (GJ m^{-2})
Industrial buildings	1.8
Offices	2.4
Labs, restore shops	2.4
Yards	1.2

[a] Based on [20].
[b] Fossil energy.

Table 6 – Energy demand and GHG emissions in fertilizers/defensives production[a]

Fertilizer	Energy demand (MJ kg^{-1})	Emission factor (kg CO_2 eq (kg^{-1})
Nitrogen (N)	56.3[b]	3.97
Phosphorus (P_2O_5)	7.5[b]	1.30[c]
Potash (K_2O)	7.0	0.71
Lime	0.1	0.01[d]
Herbicide	355.6	25.00
Insecticide	358.0	29.00

[a] [21,22].
[b] [23].
[c] Adapted from [21].
[d] Author's estimation.

Table 7 – Energy associated to chemicals and lubricants (ethanol production step)

Chemical	Fossil energy (kJ (L ethanol)$^{-1}$)
NaOH	98.6
Lime	64.9
Sulfuric acid	48.0
Cyclohexane	5.2
Antifoam	2.6
Lubricants	1.6
Others	2.0
Total	222.9

Table 8 – Emission factors in processes not related to fossil fuels use

Source	Emission factor ($kg\,CO_2$ eq (kg-source)$^{-1}$)
Trash burning	
N_2O[a]	0.021
Methane[b]	0.062
Nitrogen application[c]	
N_2O[d]	6.163
CO_2[e]	1.594
Lime[f]	
CO_2	0.477
Returned residues[g]	
N_2O (stillage)[h]	0.002
N_2O (filtercake mud)[i]	0.071
N_2O (unburned trash)[j]	0.028

[a] Based on IPCC emission factor: 0.07 (kg N_2O) (t dry matter burnt)$^{-1}$ [17].
[b] Based on IPCC emission factor: 2.7 (kg CH_4) (t dry matter burnt)$^{-1}$ [17].
[c] Urea is the main N-fertilizer used [25].
[d] 1.325% of N in N-fertilizer is converted to N in N_2O [17].
[e] For urea, the emission factor indicated by IPCC is 0.2 kg C (kg urea)$^{-1}$ [17].
[f] Based on IPCC default emission factor for dolomite (0.13 kg C kg^{-1}) [17].
[g] For residues, it was considered that 1.225% of N in residue is converted to N in N_2O [17].
[h] Stillage nitrogen content: 0.36 kg m^{-3} [26]. During distillation, about 11 L of stillage are produced for each liter of ethanol.
[i] Filtercake nitrogen content: 12.5 kg t^{-1} [26]. After juice treatment, 6–8 kg (dry basis) of filtercake mud per ton of cane are produced.
[j] Trash nitrogen content: 0.5% [11].

For ethanol and bagasse, the energy content were the low heating values (LHV), while for electricity, we considered the thermal equivalences for power plants with 40%$_{LHV}$ (for 2005) and 50%$_{LHV}$ (for 2020) efficiencies. This is quite arbitrary, but the data present allows the use of other hypotheses, if needed for comparisons. The energy ratio of the system was calculated as

$$\text{Energy ratio} = \frac{\sum \text{Renewable energy output}}{\sum \text{Fossil fuel energy input}}. \quad (1)$$

The evaluation of avoided emissions depends on the equivalences between the renewable fuel (ethanol, bagasse and electricity) and the fossil fuels replaced (therefore, on the processes used and energy contents); and, of course, on their respective life cycle emissions.

For ethanol there are a number of possibilities. The experience in Brazil and in some other countries shows that today's technologies lead to averages as listed below [27] (however, there are large differences):

- Anhydrous ethanol in blends up to 10% (volume) with gasoline: 1 L ethanol = 1 L gasoline.
- Hydrous ethanol, dedicated ethanol engines (Brazil): 1 L ethanol = 0.75 L gasoline.
- FFV engines in Brazil, 2005: variable, with average: 1 L ethanol = 0.72 L E25 (25% anhydrous ethanol, 75% gasoline).

It must be emphasized that for each application the specific equivalences (gasoline:ethanol) related to the technology employed must be considered. In general, most applications in the world (in the near future) will be using gasoline–ethanol blends, lower than 10% ethanol so that an equivalence of ~1:1 is acceptable. In Brazil, ethanol is mainly used as E25 blends, for which we adopted an equivalence of 1 L ethanol (anhydrous) = 0.8 L gasoline. However, here again the data presented allows for the use of other hypotheses for comparison.

For bagasse, we considered the substitution of bagasse fired boilers (79% efficiency, LHV) for oil fired boilers (92% efficiency, LHV), which is the most significant application in Brazil. For electricity, the analysis was based on the world average emission factors for power generation considering both scenarios (2005 and 2020). According to IEA evaluations [28], the world emission factor for power generation in 2002 was ~579 t CO_2 eq GWh^{-1}; for 2030, IEA estimates total emissions of ~16.9 G t CO_2 eq for a total generation of 31,657 TWh, which would lead to an emission factor of ~535 t CO_2 eq GWh^{-1}. Taking 2002 and 2030 values as reference, it was adopted, arbitrarily, an emission factor of 560 t CO_2eq GWh^{-1} for the 2020 scenario. These are not standard baselines used for computing carbon credits (within the CDM); actually there has been much controversy about the baselines in Brazil. They are used here because they indicate clearly the mitigation obtained with the ethanol production and use, as related to the global emissions. Comparisons with other standards can be made from the data presented.

5. Results

5.1. *Energy balance*

Table 9 shows the fossil energy consumption regarding production, harvesting and transportation of sugarcane. Taking 2005/2006 values, the fossil energy required to produce 1 t of cane is 210 MJ, while, for 2002 evaluation, this value was estimated in almost 202 MJ. This difference is small, but important differences can be seen in energy use distribution; the main reasons are the updating of embodied energy coefficients and diesel consumption for cane production. For the 2020 scenario, a considerable increase is expected (to 238 MJ), mainly due to diesel consumption associated to the growth of mechanical harvesting and trash recovering. Furthermore, higher levels of agricultural machinery utilization will lead to higher values of embodied energy. Higher utilization of residues in ferti-irrigation, however, will lead to significant reductions of mineral fertilizers demand.

In ethanol processing evaluation (see Table 10), the differences in value from 2002 analysis correspond mainly to the updating of embodied energy coefficients, chemicals use and mill scale. But for 2020 scenario few changes are expected, related only to the improvement of ethanol yield.

Table 9 – Fossil energy consumption (MJ tc^{-1}) in sugar-cane production, harvesting and transportation

Item	2002[a]	2005/2006	Scenario 2020
Agricultural operations	16.4	13.3	14.8
Harvesting	21.7	33.3	46.9
Cane transportation	39.0	36.8	44.8
Inputs transportation	4.0	10.9	13.5
Other activities		38.5	44.8
Sub total	81.0	132.8	164.8
Fertilizers	66.5	52.7	40.0
Lime, herb., insect.	19.2	12.1	11.1
Seeds[b]	5.9	5.9	6.6
Sub total	91.6	70.7	57.7
Machinery	29.2	6.8	15.5
Subtotal	29.2	6.8	15.5
Total	201.8	210.2	238.0

[a] [6].
[b] Energy for seeds corresponds to 2.9% of total for cane.

Table 10 – Fossil energy consumption (MJ tc^{-1}) in the production of ethanol

Item	2002[a]	2005/2006	Scenario 2020
Chemicals and lubricants	6.4	19.2	19.7
Buildings	12.0	0.5	0.5
Equipments	31.1	3.9	3.9
Total	49.5	23.6	24.0

[a] [6].

Table 11 – Energy balance, external flows (MJ tc^{-1})

	2002[a]	2005/2006	Scenario 2020
Cane production/transportation	201.8	210.2	238.0
Processing to ethanol	49.5	23.6	24.0
Fossil input (total)	251.3	233.8	262.0
Ethanol	1921.3	1926.4	2060.3
Bagasse surplus	168.7	176.0	0.0
Electricity surplus[b]	0.0	82.8	972.0
Renewable output (total)	2090.0	2185.2	3032.3
Renewable output/fossil input			
Ethanol+bagasse	8.3	9.0	7.9
Ethanol+bagasse+electricity	8.3	9.3	11.6

[a] [6].
[b] The values for electricity surplus are 9.2 and 135 kWh tc^{-1} for 2005/2006 and 2020, respectively. Considered thermal-electricity equivalences were 9 MJ kWh^{-1} (2005) and 7.2 MJ kWh^{-1} (2020).

Table 12 – Emissions not derived from fossil fuels use (kg CO_2 eq tc^{-1})

	2002[a]	2005/2006	Scenario 2020
Methane (trash burning)	6.6	5.4	0.0
N_2O (trash burning)	2.4	1.8	0.0
N_2O (N fertilizers, residues)	6.3	8.9	8.6
CO_2 (urea, lime)		3.4	3.0

[a] [6].

The total energy produced in industrial phase (result of the sum of ethanol and the surpluses of bagasse and electricity energy flows) is presented in Table 11, with a comparison with fossil energy demands. In order to facilitate comparisons with other biofuels these flow values are presented separately. The fossil energy demand decrease and the increasing of electricity surplus lead to significant alterations of energy ratios between 2002 and 2005/2006, leaving from 8.3 to 9.3. For 2020, a more significant increase is expected (to 11.6), when electricity surplus will reach 135 kWh tc^{-1}, consuming all bagasse and still a portion (40%) of the trash. Eventually, higher levels of trash could be used for power generation, which would enable even higher enhancements in energy ratio.

5.2. *GHG emissions balance*

In cane production significant alterations in the emissions pattern are expected in the coming years, essentially by reductions in trash burning (see Table 12). From 2002 to 2005/2006, however, the large difference is associated to the incorporation of N_2O emissions from agriculture/industrial residues that are returned to soil and CO_2 emissions from lime and urea application (in the occasion of 2002 analysis the main N-fertilizer was of NH_4 type). For the 2020 scenario, the banishment of trash burning and the reduction of mineral fertilizers application will lead to drastic emissions reduction, although there might be a small increase of emissions associated to the residues that are returned to soil (once again it must be stressed that such values were obtained from "default" emission factors suggested by IPCC). In short, the emission not derived from fossil fuels use would be reduced from 19.5 kg CO_2 tc^{-1} (in 2005/2006) to 11.6 kg CO_2 tc^{-1}, in the 2020 scenario.

In the ethanol production phase (industrial process), many changes were verified in comparison to the 2002 data (because of the differences in energy use), but small changes are foreseen for the 2020 scenario—from 2.15 kg CO_2 tc^{-1}, in 2005/2006, to 2.19 kg CO_2 tc^{-1}. Considering both agricultural and industrial phases, the total

Table 13 – Total life cycle GHG emissions (kg CO_2 eq m^{-3}-ethanol hydrous or anhydrous)

Year	2002[a]		2005/2006		Scenario 2020	
Ethanol	Hydrous	Anhydrous	Hydrous	Anhydrous	Hydrous	Anhydrous
Total emissions	390	401	417	436	330	345
Fossil fuels	217	223	201	210	210	219
Trash burning	102	105	80	84	0	0
Soil emissions	71	73	136	143	120	126

[a] [6].

Table 14 – Avoided emissions (kg CO_2 eq m^{-3}-ethanol hydrous or anhydrous)

Year	2002[a]		2005/2006[b]		Scenario 2020		
Ethanol[c]	HDE	E25	HDE	E25	HDE	FFV	E25
Avoided emissions	2190	2401	2181	2323	2763	2589	2930
Use of biomass surplus[d]	141	145	143	150	0	0	0
Electricity surplus[e]	0.00	0.00	59	62	784	784	819
Use of ethanol[f]	2049	2256	1979	2111	1979	1805	2111

[a] Based on [6]. The equivalence for HDE was considered here as 1 L ethanol = 0.75 L gasoline, and not 0.7. For E25, it was considered an equivalence of 1 L anhydrous ethanol = 0.8 L gasoline, instead of 1 (L et.) (L gas.)$^{-1}$.
[b] Gasoline heating values for 2005 (Brazil) are from the official Brazilian Energy Balance [16].
[c] HDE: hydrous-dedicated engines; E25: ethanol–gasoline blend with 25% anhydrous ethanol; FFV: flexible fuel vehicles (ethanol–gasoline), in Brazil.
[d] Considering the substitution of biomass-fuelled boilers (efficiency = 79%; LHV) for oil-fuelled boilers (efficiency = 92%; LHV).
[e] Considering emission factors of 579 and 560 t CO_2 eq GWh_e^{-1} for 2005 and 2020, respectively. See details in text (Section 4).
[f] Using the equivalencies listed in Section 4; note that in each case the ethanol–gasoline technical equivalence for the specific utilization must be considered.

emissions of hydrous and anhydrous ethanol production for 2005/2006 were evaluated as 417 and 436 kg CO_2 eq m^{-3}, respectively. For the 2020 scenario the estimates are 330 kg CO_2 eq m^{-3} hydrous and 345 kg CO_2 eq m^{-3} anhydrous; the contribution of each source is presented in Table 13.

Analyzing the avoided emissions for 2005/2006, ethanol and co-products use in substitution of fossil resources represent savings of 2181 kg CO_2 eq m^{-3} hydrous and 2.323 kg CO_2 eq m^{-3} anhydrous (see Table 14). In the 2020 scenario the possibility of hydrous ethanol use in FFV lead to emission avoidances of 2589 kg CO_2 eq m^{-3} hydrous, while for ethanol-dedicated engines this value would be 2763 kg CO_2 eq m^{-3} hydrous. For anhydrous ethanol, used in blends with gasoline (E25), the total avoided emission would be 2930 kg CO_2 eq m^{-3} anhydrous. Here we must remember the large contribution of surplus electricity to the total avoided emissions.

The net avoided emissions associated to ethanol utilization in Brazil may be then evaluated. For sugarcane ethanol we have verified values of 1764 kg CO_2 m^{-3} hydrous and 1886 kg CO_2 m^{-3} anhydrous, but with much more potential for the 2020 scenario, reaching 2433 kg CO_2 m^{-3} hydrous (2259 kg CO_2 m^{-3} considering FFV) and 2585 kg CO_2 m^{-3} anhydrous through the better use of sugarcane's energy (higher levels of electricity surplus) coupled with the banishment of trash burning practices.

The energy flows and GHG emissions are presented in Fig. 2 for 2005/2006 and Fig. 3 for the 2020 scenario.

5.3. *Sensitivity analysis*

As showed in Fig. 4, trash burning and N-fertilizers play an important role in GHG emissions, while diesel consumption in agriculture is a decisive parameter for energy balance and with a considerable contribution for emissions also. On the end use, besides the large emissions avoidance allowed by the use of ethanol substitution for gasoline, there is a considerable additional contribution with the use of bagasse in biomass fuelled boilers (replacing oil-fuelled boilers) and/or producing electricity surpluses. All these aspects have a considerable range of variation among the more than 400 Brazilian mills, leading to large differences in energy and emissions balances. For this reason, a sensitivity analysis was performed considering the ranges verified for the sample of mills used in this work. Table 15 shows the parameters used in the analysis and their ranges of variation.

The individual impacts of each of the main parameters variation were evaluated separately, although of course there are interactions between many (for instance, the percentage of unburned cane and the level of mechanical harvesting). The individual results, therefore,

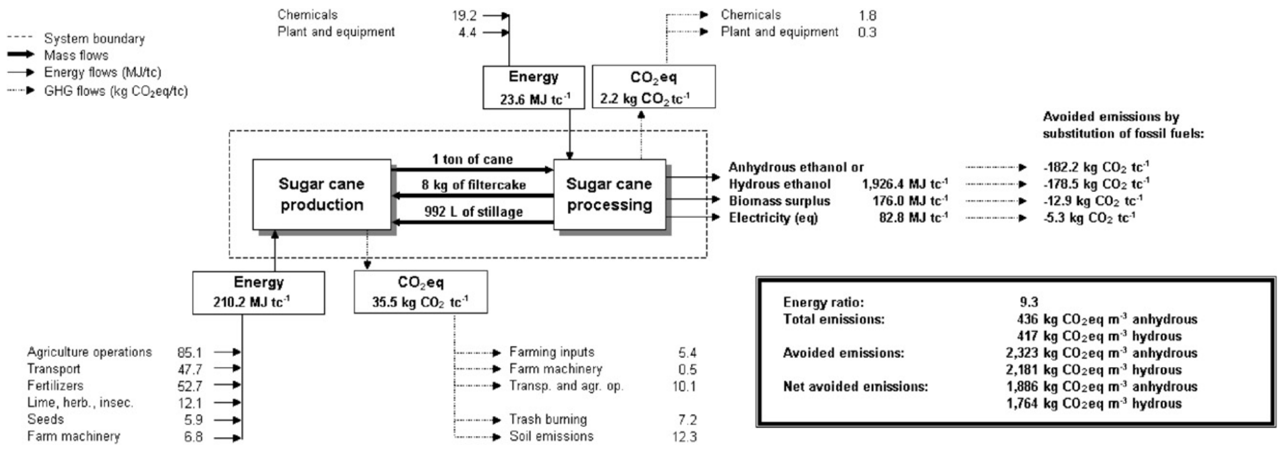


Fig. 2 – Energy flows and GHG emissions in ethanol production and use for 2005/2006 (tc = ton of cane).

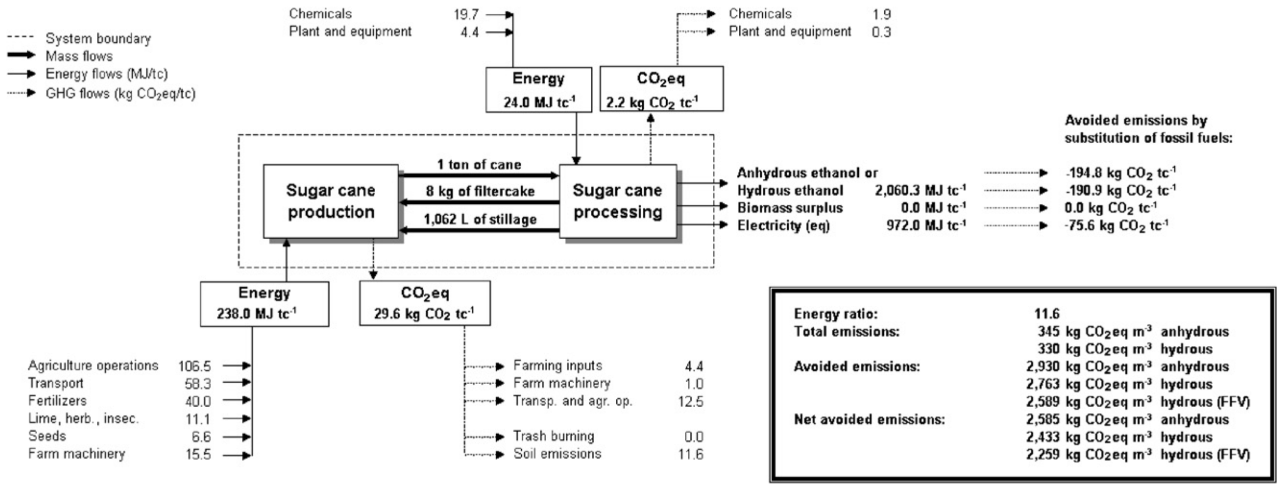


Fig. 3 – Energy flows and GHG emissions in ethanol production and use for 2020 scenario (tc = ton of cane).

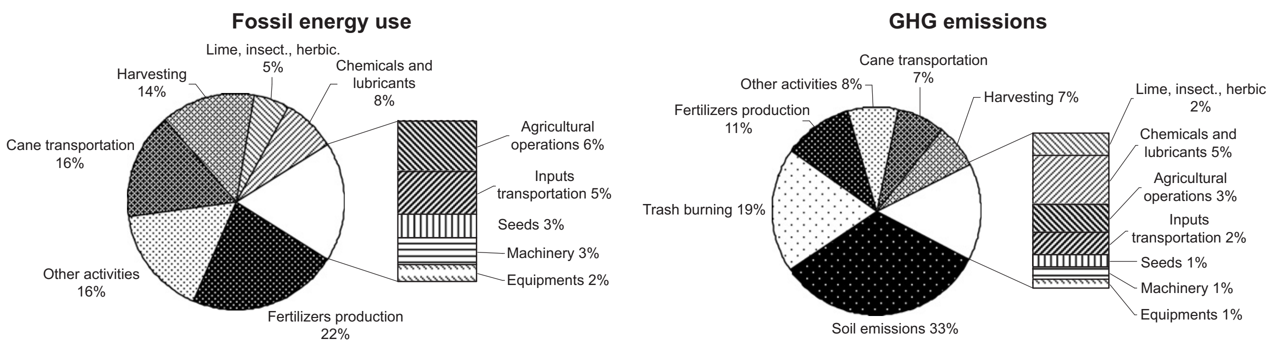


Fig. 4 – Fossil energy use and GHG emissions breakdown (2005/2006 values).

are not to be added up. As can be seen in Figs. 5 and 6, ethanol yields and cane productivity are the most impacting parameters for both energy and emissions balance. Ethanol yield has larger specific impact on the balances, but since the range of variation of cane productivity is far higher, it leads to higher final impacts (GHG emissions vary from 377 to 586 kg CO_2 (m^3 ethanol)$^{-1}$). The high range of variation for electricity surplus, however, presents a relatively low impact on energy ratio and avoided emissions.

For the parameters considered, individually, the maximum variation of energy ratio has been from 6.7 to 11.0, following the variation of cane productivity. Such range seems to be high, but, in fact, it represents just a small variation of fossil energy savings—from 85% to 91% (actually, above an ER of 6.0, even high variations would result in small

Table 15 – Parameters considered for sensitivity analysis (2005/2006 values)

Parameter	Units	Average	SD[a]	Min.	Max.	No. of mills	Cane[b]
N-fertilizer use	kg N (ha year)$^{-1}$	60	16	35	97	31	72.52
Trucks' energy efficiency	t km L^{-1}	52.4	9.7	38.9	74.3	36	80.83
Transportation distance[c]	km	23.1	6.1	9.3	39.0	39	84.50
Mechanical harvesting	%	49.5	27.1	0	87.7	44	98.59
Other agr. activities	L ha^{-1}	67	38	2.7	136	27	67.23
Unburned cane	%	30.8	21.7	0	87.7	44	98.59
Cane productivity	tc ha^{-1}	87.1	13.7	51.3	119.8	44	98.59
Ethanol yield	L tc^{-1}	86.3	3.5	78.9	94.5	41	43.71[d]
Bagasse surplus	%	9.6	6.4	0	30.0	30	29.48[d]
Electricity surplus[e]	kWh tc^{-1}	9.2		0	50.0	22	28.61[d]

[a] Standard deviation.
[b] Mt year^{-1}.
[c] For cane transportation; this parameter is reflected on inputs transportation either.
[d] In the case of industrial parameters, for weighted averages calculation we have considered only the amount of cane used exclusively for ethanol production.
[e] Since the average value was obtained elsewhere (Cogen's estimation [15]), it was not possible to evaluate the standard deviation.

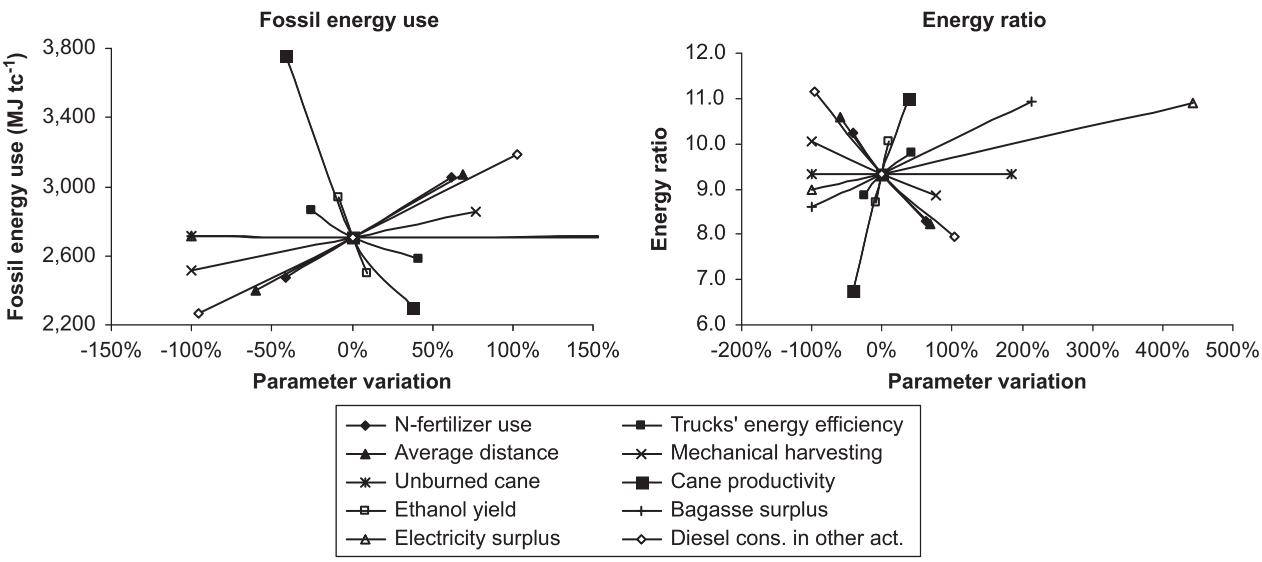


Fig. 5 – Sensitivity analysis for energy balance (2005/2006 values).

alterations of fossil energy savings—see Fig. 7). This small variation in fossil energy savings is reflected on net avoided emissions, which, for such range, varies from 1736 to 1945 kg CO_2 m^{-3} of anhydrous ethanol. Higher variation of net avoided emissions is from 1736 to 2205 kg CO_2 m^{-3} for anhydrous ethanol, verified for the different levels of bagasse surplus.

Considering the assumptions made here, the adoption of modern technologies for power generation (high-pressure CEST systems—condensing extraction steam turbines) associated to smaller process energy demands (lower steam consumption) would be much more effective to increase net avoided emissions than the reduction of diesel use in agriculture, or even some trash burning reduction, for instance. Even though the values presented are associated to local assumptions, there is no doubt about the importance of the better use of sugarcane's energy for further improvements of the already huge potential of ethanol as a good alternative for GHG emissions mitigation.

6. Conclusions

- A time series of studies on ethanol from cane have consolidated the data and refined the methodology, since 1992. The methodology used here includes a more detailed computation of fossil fuel use in agriculture; the N_2O emissions from soil with residue recycling (stillage, filter cake, sugarcane trash); and the emissions from agricultural and industrial input materials and processes have been updated.
- The methodology uses the stand-alone ethanol mill as a model. Data obtained for combined sugar and ethanol production considers the allocation issues for the industry

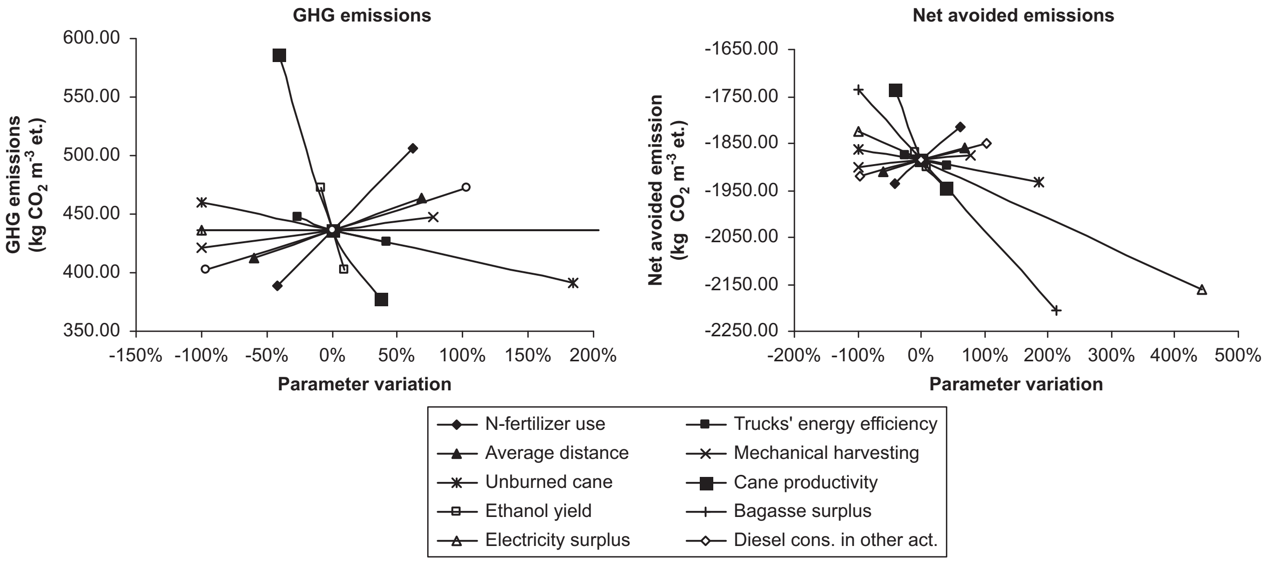


Fig. 6 – Sensitivity analysis for GHG emissions balance (2005/2006 values).

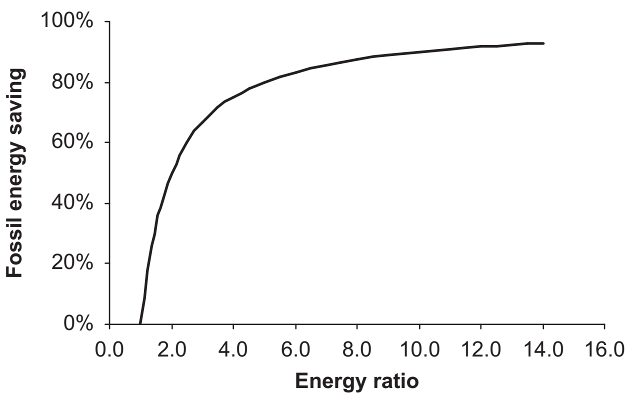


Fig. 7 – Relation between energy ratio and fossil energy savings.

(energy consumption, equipment, inputs) and agriculture (residue recycling).

- Significant process changes, including the phasing out of cane burning (in course) and the increase in surplus electricity are already shown in the results for 2005.
- The extension of improvements in cane growing and harvesting, as well as the more efficient use of cane biomass for electricity, will not only increase ethanol yield significantly over the next 14 years, but will also improve the net energy balance and reduce the GHG emission. One moderate scenario for 2020 (only commercial technologies, all surplus biomass used for electricity generation) presents average GHG emission of $345\,kg\,CO_2\,eq\,m^{-3}$ ethanol, compared to 436 in 2006; and energy ratio reaching 11.6 (9.3 in 2006).
- A sensitivity analysis based on actual data (2006) for 35 mills shows that both the energy ratio and the GHG total emissions in ethanol production (calculated for each parameter variation, independently) may vary significantly among the mills. The average energy ratio was 9.3 but it could vary from 6.7 to 11.0 (cane productivity, electricity and bagasse surpluses, diesel utilization were the most important factors). Average GHG emission was $436\,kg\,CO_2\,eq\,m^{-3}$ ethanol; values from 377 to 586 were found (cane productivity, N-fertilizer use and ethanol yield were the main factors). This is important as some mills are starting to consider ways for improving their energy ratio and reduce emissions.

Acknowledgments

The information provided by the scientists and technologists at the Centro de Tecnologia Canavieira (Piracicaba, São Paulo) on the agricultural and industrial parameters for ethanol production in 2005, and their help in estimating the parameters for 2020, were essential to this work.

REFERENCES

[1] Malça F, Freire J. Renewability and life-cycle energy efficiency of bioethanol and bio-ethyl tertiary butyl ether (bioETBE): assessing the implications of allocation. Energy 2006;31:3362–80.
[2] UNICA. União dos Produtores de Cana de Açúcar, 2006, ⟨www.unica.com.br⟩.
[3] Macedo IC, Nogueira LAH. Balanço de Energia na produção de açúcar e álcool nas usinas cooperadas. Boletim técnico Copersucar 1985;31/85:22–7.
[4] Macedo IC. The sugar cane agro-industry and its contribution to reducing CO2 emissions in Brazil. Biomass and Bioenergy 1992;3(2):77–80.
[5] Macedo IC. Greenhouse gas emissions and energy balances in bio-ethanol production and utilization in Brazil (1996). Biomass and Bioenergy 1998;14(1):77–81.
[6] Macedo IC, Leal MRLV, da Silva JEAR. Balanço das emissões de gases do efeito estufa na produção e no uso do etanol no Brasil. Secretaria do Meio Ambiente, Governo de São Paulo. Abril de 2004. 19pp+anexos.
[7] Sarto C. Personal communication. CTC, Piracicaba, 2007.

[8] Macedo IC and Nogueira LAH. Biocombustíveis. Cadernos NAE 02-2005, Núcleo de Assuntos Estratégicos, PR, Brasília, Brasil, 2005. 233pp.
[9] CTC. Technical information provided by scientists and engineers to I Macedo and J Seabra. Piracicaba: Sugarcane Technology Centre; 2006.
[10] Paes LAD. Palha—potencial como combustível adicional ao bagaço. In: Geração de energia por biomassa: bagaço e palha de cana. Projeto BRA/96/G31, Piracicaba, 2006.
[11] Hassuani SJ, Leal MRLV, Macedo IC. Biomass power generation: sugar cane bagasse and trash. Piracicaba: PNUD Brasil and Centro de Tecnologia Canavieira; 2005.
[12] Paes LAD. Personal communication. Piracicaba: CTC; 2006.
[13] UNICA. União de Agroindústria Canavieira de São Paulo. Information provided at the Strategic Planning Seminars (unpublished), São Paulo, 2007.
[14] CTC. Controle mútuo agrícola annual—safra 2005/2006, Piracicaba, 2006. 126pp+anexos.
[15] Silvestrin M. Personal information, Cogen, 2007.
[16] EUCAR. CONCAWE and JRC/IES. Well-to-wheels analysis of future automotive fuels and powertrains in the European context. Tank-to-wheels report, version 2b, May 2006. 88pp.
[17] IPCC. 2006 IPCC guidelines for national greenhouse gas inventories, Prepared by the National Greenhouse Gas Inventories Programme. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. Japan: IGES; 2006.
[18] BEN. Brazilian energy balance. MME; 2006 Available at ⟨www.mme.gov.br⟩.
[19] Kim Y, Worrell E. International comparison of CO_2 emissions trends in the iron and steel industry. Energy Policy 2002;30:827–38.
[20] Tavares SF. Análise do ciclo de vida energético de edificações residenciais brasileiras. Universidade Federal de Santa Catarina; 2006.
[21] EBAMM Release 1.0. The ERG biofuels analysis meta-model, December 26, 2005.
[22] GREET 1.6. Greenhouse gases, regulated emissions, and energy use in transportation. Argonne, IL, USA: Argonne National Laboratory.
[23] IPT. Instituto de Pesquisas Tecnológicas do Estado de São Paulo. Manual de recomendações: conservação de energia na indústria de fertilizantes, São Paulo, 1985.
[24] IPCC. Climate Change 2001: the scientific basis. Contribution of working group I to the third assessment report of the Intergovernmental Panel on Climate Change. In: Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA, editors. Cambridge, UK and New York, NY, USA: Cambridge University Press; 2001. 881pp.
[25] Donzelli JL. Personal communication, CTC, 2006.
[26] Macedo IC. Sugar cane's energy—twelve studies on Brazilian sugar cane agribusiness and its sustainability. São Paulo: Berlendis & Vertecchia: UNICA; 2005 (organizer).
[27] Joseph Jr H. The use of ethanol blends as regular fuel for existing vehicular fleets. Report for the Brazilian ethanol mission to Japan, UNICA–COIMEX, 2005.
[28] IEA. World energy outlook 2004. Paris: OECD/IEA; 2004.

Bibliography

BIBLIOGRAPHY

Abraciclo (2007) *Estatísticas de produção*, São Paulo.

Affonso, N S (2007) “Adaptação dos meios de transporte às pessoas portadoras de deficiência” em Brasiliense A (editor) *Trânsito no Brasil, avanços e desafios*, Fenaseg/ANTP, São Paulo, pp 193-195.

Anfavea (2007) *Anuário estatístico da Anfavea*, São Paulo.

ANTP – Associação Nacional de Transportes Públicos (2005) *Mobilidade na cidades brasileiras, Sistema de Informação da Mobilidade Urbana*, São Paulo

ANTP/BNDES (2006) *Panorama da mobilidade urbana no Brasil*, São Paulo.

ANTP/IPEA (1998) *Melhoria do transporte público com as reduções dos congestionamentos*, Brasília.

_________ (2003) *Custos dos Acidentes de Trânsito nas Aglomerações Urbanas Brasileiras*, Brasília.

Castro N. R. Logistic Costs and Brazilian Regional Development, NEMESIS - Nucleo de Estudos e Modelos Espaciais Sistemicos Working Paper No. NXXL 2004

CET – Cia de Engenharia de Tráfego (2007) *Acidentes fatais no município de São Paulo*, São Paulo.

CET – Cia de Engenharia de Tráfego (2006), *Desempenho do sistema viário de São Paulo*, São Paulo.

CET – Cia de Engenharia de Tráfego (2000) *Fatos e estatísticas de acidentes de trânsito em São Paulo – 2000*, São Paulo.

CET – Cia de Engenharia de Tráfego (1997) *Desempenho do sistema viário de São Paulo*, São Paulo.

CET – Cia de Engenharia de Tráfego (1996) *Vítimas de acidentes de trânsito*, São Paulo.

CET – Cia de Engenharia de Tráfego www.cetsp.com.br

CMSP – Metrô de São Paulo (1998) *Pesquisa Origem-Destino da RMSP*, São Paulo.

CMSP – Metrô de São Paulo (2002) *Aferição da pesquisa origem-destino*, São Paulo.

Denatran – Depto Nacional de Trânsito (2007), *Estatísticas de frota registrada de veículos*, Denatran, Brasília.

EMPLASA – Empresa de Planejamento Metropolitano de São Paulo (2008) *Dados Seleciodados das Metrópoles Paulistas*, São Paulo.

Geipot (1997) *Estatísticas de transporte no Brasil*, Brasília.

IPEA/ANTP (2003) Impactos sociais e econômicos dos acidentes de trânsito nas aglomerações urbanas brasileiras, Brasília.

Itrans – Instituto de Desenvolvimento e Informação em Transporte (2004) *Mobilidade e pobreza – pesquisa sobre a mobilidade da população de baixa renda*, Brasília.

Kair A (1999) “Financiamento dos municípios brasileiros”, *Revista dos transportes Públicos* 82, pp 107-116.

Matos, J. Daniel (2005), *Distribuição de randa, fatores condicionantes e comparação entre as regiões metropolitanas pesquisadas pela PED*, SEP-RS< Porto Alegre.

MS – Ministério da Saúde (2007) *Dados de Acidentes – Sistema DataSus*, Brasília

Souza, Ana Odila p (2007) “Novos paradigmas da integração temporal”, *Integraçãos nos Transportes Públicos*, Cadernos Técnico no. 5, ANTP/BNDES, São Paulo, pp 81-98.

Saldiva P H (1998) *Poluição atmosférica e saúde, uma abordagem experimental*, Greenpeace, São Paulo.

SOCICAM – Terminais e Corredores Inteligentes, (to be published)

Vasconcellos, e a (1984 E 1985) A sinalização de trânsito e a qualidade da vida urbana, *Revista Trânsito* 8, 1984 (parte 1, pp 143-176) e 9, 1985 (parte 2, pp 9-26), Departamento de Operações do Sistema Viário, São Paulo.

Vasconcellos. E A (2001) *Urban transport, environment and equity – the case for developing countries*, Earthscan, UK.

Vasconcellos E A (1996) *Circular é preciso, viver não é preciso – a história do trânsito na cidade de São Paulo,* Annablume, São Paulo.

WBCSD (2004) *Mobility 2030: Meeting the Challenges to Sustainability,* Switzerland.

About the WBCSD

The World Business Council for Sustainable Development (WBCSD) brings together some 200 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 35 countries and 22 major industrial sectors. We also benefit from a global network of about 55 national and regional business councils and partner organizations.

Our mission is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

Our objectives include:

Business Leadership – to be a leading business advocate on sustainable development;

Policy Development – to help develop policies that create framework conditions for the business contribution to sustainable development;

The Business Case – to develop and promote the business case for sustainable development;

Best Practice – to demonstrate the business contribution to sustainable development and share best practices among members;

Global Outreach – to contribute to a sustainable future for developing nations and nations in transition.

www.wbcsd.org

Development Focus Area

Through its Development Focus Area, the WBCSD is seeking to:

Help companies develop their understanding of how global development issues affect them, generate learning and document good practice case studies of how companies tackle specific development challenges

Work with companies, Regional Network partners and other development partners to broker inclusive business solutions that are good for business and good for development and provide companies with guides and tools that help them align their business ventures with the needs of society

Advocate for framework conditions that create an enabling investment environment for business to increase its contribution to sustainable development, through working with policy-makers and other stakeholders.

Development Focus Area Core Team

AES, Anglo American, BG Group, BP, Brisa, Codelco, ERM, General Electric, GrupoNueva, S.C. Johnson, Toyota

The Mobility for Development project

The Mobility for Development project set out to investigate what the sustainable mobility challenge means for some of the world's fastest growing cities – Bangalore in India, Dar es Salaam in Tanzania, São Paulo in Brazil and Shanghai n China – and to discuss solutions with key stakeholders in each location.

www.wbcsd.org/web/m4dev.htm

Photo credits Flickr

Secretariat
4, chemin de Conches
CH-1231 Conches-Geneva
Switzerland

Tel: +41 (0)22 839 31 00
Fax: +41 (0)22 839 31 31

E-mail: info@wbcsd.org
Web: www.wbcsd.org

WBCSD North America Office
1744 R Street NW
Washington, DC 20009

Tel: +1 202 420 77 45
Fax: +1 202 265 16 62

E-mail: washington@wbcsd.org