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Issues and trends on sustainable transportation: the case of Brazilian cities (2003-2010)

Marcelo Sampaio Dias Maciel
Professor CEFET/RJ
Av. Maracanã 229, Maracanã
zip code 20.110-110/ Rio de Janeiro – RJ Brazil
phone: 55-21-2566-3031
msdmaciel@gmail.com
mmaciel@cefet-rj.br
Energy Planning PhD (Coppe / UFRJ). Master of Business Administration (IBMEC-RJ). MBA in Strategic Information Management (UFRJ). Graduated in Economics from UERJ. Advised on strategic planning for industries in the oil and gas. He served as Commercial Manager and Technical TNCs in PDVSA, Citgo Petroleum Corporation and Chevron. He is currently Professor of Engineering programs and Industrial Administration Cefet RJ, where is responsible of Economic Theory and Environmental Sciences. Currently is the the Knowledge Management and Innovation research group leader. He is also the Chief Strategy Officer at CEFET - RJ.

Úrsula Gomes Rosa Maruyama
Professor CEFET/RJ
Av. Maracanã 229, Maracanã
zip code 20.110-110/ Rio de Janeiro – RJ Brazil
phone: 55-21-2566-3031
maruyama.academic@hotmail.com
Master degree in Science, Technology and Education (PPCTE/ CEFET-RJ), scientific internship advisor in Innovation studies in Technological Education. Bachelor in Industrial Administration CEFET-RJ. MBA Project Management, MBA Public Management, and specialization in Human Resources and English Language. She had worked at CEPEL / Eletrobras and multinationals such as ABB, Lanxess, Royal Dutch Shell and Praxair. She lived, studied and worked in Washington DC (2003-2005). Visiting professor CEFET-RJ English Language courses for Administration and Industrial Engineering and GIS (Management Information Systems). Currently teaches Management 101, Entrepreneurship, SOM, Quality and OTN. Thus, she also teaches Quality Management and Marketing II in Business Administration (CEFET-RJ).

Antonio Mauricio Castanheira das Neves
Professor CEFET/RJ
Av. Maracanã 229, Maracanã
zip code 20.110-110/ Rio de Janeiro – RJ Brazil
phone: 55-21-2566-3031
mauricio.castanheira@gmail.com
Associate Professor in Social Psychology Institutional UGF in 1992. Master in Social Psychology from UFRJ. Specialist in Social Psychiatry by ENSP-FIOCRUZ (1984). Specialist in Social Psychology by the Psychology Federal Council. Psychologist, bachelor's in Psychology and Social Sciences. He is currently Associate Professor (CEFET-RJ). Former Professor in the Master of Education at the Catholic University of Petrópolis (2002-2011), Assistant Professor in UNISUAM Master in Local Development psychology (2010). 40 book chapters, five books published. Works in Philosophy with an emphasis in Ethics and Technology in Education, with emphasis on knowledge and innovation. Ad hoc is currently evaluating of undergraduate MEC.

Abstract

Brazilian transport system accounts for negative externalities in terms of energy consumption, carbon dioxide, local pollution emissions, social costs and infrastructure expenditures. These elements results on unsustainable mobility system. Resources usage is considerable and trend lines depict growing concerns in the following years. Brazilian cities continuous expansion increasing passenger mobility demand as well as social improvements (including C social level group) combined with public transportation low quality causes exponential increments on external transport system costs. For methodological means, the Brazilian cities case study was based on documental and literature research within public administration in Brazil. Therefore, this paper purpose is to present external costs and urban transportation tendencies in Brazil. Research data states significant growth in public infrastructure expenditures provoked by exaggerated energy consumption in the last years. In conclusion, based on literature and the aforementioned data basis, it can be inferred that sustainable transport system relies on public transportation. Pursuing such scenario will lead Brazilian cities to save relevant amount of financial and natural resources.

Keywords: Brazilian cities; Greenhouse Gas Emission & local pollution; Energy; Social costs; Sustainable transportation.

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1 Introduction

Urbanization is increasing the world population share living in cities. Thus, urban mobility issues have significantly impacted on goods supply of these urban agglomerations. Passenger and freight transportation generates over 23% of greenhouse gas emissions worldwide and accounts for at least 26% of the planet's fuel use (Kahn, 2007; AEO, 2008; EIA, 2007; BP, 2007; IEA, 2008; IPCC, 2007;OPEC, 2007; WBSCD, 2004).

The transportation sector answers for 25% and 60% of land occupation in major cities (Litman and Burwell, 2006; Vasconcellos, 2000; Litman, 1995), and the time wasted in traffic congestion to economic losses ranging from 1% to 3% of GDP in many countries (Gwilliam, 2002).

Furthermore, over a million people die and 3 million are injured every year in road traffic accidents worldwide (WHO, 2004; Granados, 1998; Quinet, 1994), resulting in economic expenditures of approximately 5% of GDP in some of these countries (Vasconcellos, 2008).

In emerging economies, for instance, Brazil have adopted transportation systems repeating errors already committed by industrialized countries including individual motorized transportation stimulus as standard model. Such behavior has not proved to be the optimal solution (Pucher et al., 2005; Rosa, 2003).

In addition, poverty origins research in cities marginal areas, in both developed and emerging countries point to a lack of public transportation as one of the main social concerns (World Bank, 2002). Therefore, economies suffered significant losses in adequate urban transportation policies absence. Promoting sustainable transportation options contributes to cities environmental, economic and social development (Gwilliam, 2002).

In this sense, the Brazilian government regularly proclaims its overriding commitment to both efficient public resources utilization and population living standards enhancement. However, Brazilian cities still need a currently unsustainable transportation system overhaul.

Therefore, Brazilian transportation system resource consumption and atmospheric emissions accurate calculation in the last years is the key factor for ensuring adequate management of public policies towards higher social benefits.

2 Research methodology

This Systematic Review research method (Thomas et al, 2004) presents motorized passenger transportation external costs in Brazilian major urban areas. Considering the aforementioned methodology, it also uses a simple equation to calculate the input-output ratio or its transportation system efficiency. In the first section, it is presented the sustainable transportation concept.

In the second section Brazilian urban areas passenger transportation data is analyzed, particularly those related to energy emissions, infrastructure and social costs. Based on this information, a comparative study is presented considering Brazilian urban transportation efficiency. Finally, the last section includes final remarks of this research.

3 Sustainable transport definition

According to sustainable development concept, one should use available resources to meet present requirements only to the extent which such use does not prejudice sustainability, in other words, the capacity to satisfy future generation needs (WCED, 1987). Therefore, according to the *European Foundation for the Improvement of*

Living and Working Conditions, sustainable development is a continuous economic development that does not threaten the environment or natural resources (Litman and Burwell, 2006).

In general, sustainability may be defined as the capacity to impart long-term continuity to our present actions. Litman and Burwell (2006) note that sustainability reflects on the ethics of conservation, where production and consumption standards are framed to minimize the resources usage and waste of materials.

Putting this concept into practice requires significant changes in economy and public policies that have historically rewarded production and consumption inefficiency. In this way, how does this sustainability view apply to a transportation system?

For Litman and Burwell (2006), the main sustainable transportation tenet is governments must address environmental, economic and social factors in their transportation agenda. This idea is firmly endorsed by Feitelson (2002), while other authors (e.g. Gudmundsson and Höjer, 1996) argue there are four key elements to transportation sustainable development concept: natural resources protection, intergenerational productive capital maintenance, quality of life's enhancement and fair distribution.

In addition, Black (2010), Buehler and Pucher (2011) states that sustainable transportation system is one which provides transportation and mobility from renewable energy sources, thereby minimizing local and global emissions, preventing avoidable casualties and injuries from road traffic accidents. Henceforth, economic productivity loss due to traffic congestion is mitigated.

The transportation systems actual scenario remains far removed from the ideals visualized in academic theories and urban planners offices. As a matter of fact, individual motorized transportation usage expansion, particularly those of motor private car deploys transportation systems deteriorating drastically worldwide (Bouf and Hensher, 2007).

Large-scale private cars usage for urban journeys results in energy and social inefficiency, as well as environmental unsustainability (Wright and Egan, 2000; Anable, 2005). Based on Tolley and Turton (1995), figure 1 depicts private transportation inefficiency in comparison to public transportation modes.

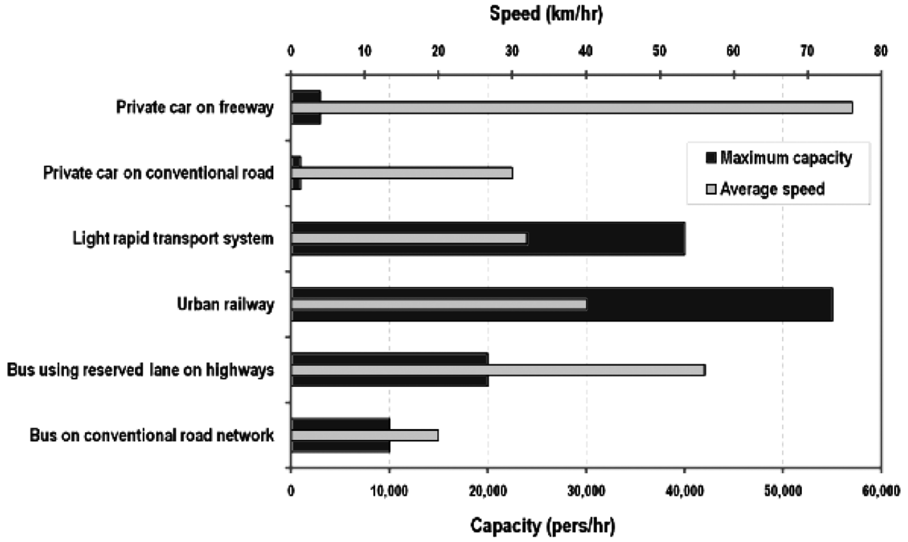

Figure 1: Transportation capacity and speed: Public Transportation X Cars
*Considering the scarcity of available data in recent years.
Source: Tolley and Turton (1995)

Figure 1 also presents cars as the most inefficient urban transport type in terms of capacity (from 1,000 to 3,000 passengers per hour). On the other hand, it has excellent speed ratio. No doubt urban transit mode is better fitted to mass transportation but it shows less flexibility in terms services frequency and transport system entry points.

Schipper (2011), Parry et al (2007), Schipper and

Eriksson (1995) illustrate the negative impacts of motor car utilization in city transportation systems. Then, eight cardinal sins of such use are listed: accidents, atmospheric pollution, urban space inefficient use, congestion, noise pollution, energy waste, greenhouse gases emission and cargo inefficient distribution.

The more a transportation system relies on individual motorized vehicles, the more unsustainable the system becomes. As a result, Table 1 depicts the main individual motorized transportation impacts on sustainability.

Table 1: Individual motorized transportation impacts on society

Economic	Social	Environmental
Congestion	Unequal distribution of impacts	Water and air pollution
Barriers to mobility	Inequality in terms of mobility	Loss of habitats
Accidents	Impact on human health	Hydrological impact
Infrastructure costs	Community interaction	DNRR
Others	Habitability	
DNRR	Aesthetics	

Note: DNRR - Depletion of non-renewable resources
Source: Litman and Burwell (2006).

In addition, current trend points representing unsustainability increase (Chapman, 2007), such as car production and vehicle utilization within cities is growing rapidly. This feature is supported by industry productivity growth, cost production reduction and broaden the open access to world population financial resources.

In consonance with Sperling and Gordon (2008), IMT (individual motorized transportation) usage will become serious problem in the following decade. These authors also states although the number of individual motorized vehicles is not increasing significantly in industrialized (developed) countries, the number of vehicles in developing countries, such as China and India increases 8% per year. Actually, OECD countries car passenger amount is forecasted to achieve an increase of 119 million cars by 2030, while in developing countries it will surpass 430 million cars over the same period (WOO, 2010).

In Brazil, the number of motor cars grows 8% per year, while motorcycles 14% per year (DENATRAN, 2010). These rates may increase due to positive income effects on Brazilian economy. Between 2003 and 2009, income per capita increased annually from R$ 9,511 (approximately USD 5,705) to approximately R$ 17,467 (approximately USD 10,481) (IBGE, 2011). Moreover, current vehicles owners increase the use of their cars travelling longer distances crossing over the town, commuting daily and making the use of vehicles increasingly inefficient on traffic congestion (MMA, 2011). In this sense, Table 2 depicts sustainability, sustainable transportation, its objectives and possible solutions for the aforementioned questions.

4 External costs and changes on urban transportation in Brazil

This section presents environmental, energy and social (considering health and mobility) costs related to passenger transportation in Brazilian urban areas with over 60,000 inhabitants (ANTP, 2009). Available data analysis indicates Brazilian transportation system wastes social, financial, and natural resources to a degree that is incompatible with the country social, economic and environmental conditions (Elvik, 2006). Therefore, unsustainable transportation system leads to public resources waste in Brazil.

Henceforth, these waste of resources results in social costs, as the society has to deal with individual motorized vehicles negative consequences, which are not fully covered by Government taxes

Table 2: Sustainability and sustainable transportation issues

Sustainability		Transportation	
Goal	Objective	Objective	Solution
Ecological integrity	Reduce climate change	Reduce climate change emissions	CAFE standards, emission taxes, TDM, alternative fuels
	Preserve wildlife habitat	Reduce impervious surface	Reduce parking and road capacity standards, TDM, parking management, design roads to minimize habitat impacts, encourage higher-density infill development
	Reduce pollution	Reduce harmful vehicle air and water emissions	Emission standards, TDM, I/M programs
Human health	Reduce injuries	Reduce traffic accidents	Crash prevention, crash protection, TDM
	Reduce pollution exposure	Criteria emission controls	Emission standards, I/M programs, alternative fuels, TDM
	Increase exercise	Increase active transport	Improve walking and cycling conditions, traffic calming, encourage non-motorized transport, TDM
Economic welfare	Consumer's mobility	Insure adequate transport services, provide mobility choices, reduce traffic congestion and barriers	Adequate road capacity, transit services, TDM, walking and cycling improvement, lovable communities, delivery services
	Business productivity	Freight mobility and affordability, facility siting options	Adequate road/rail/air freight capacity, efficient land use, freight priority, TDM
	Public investment productivity/tax reductions	Transportation facility and service efficiency	Planning and management for efficiency, efficient pricing, TDM
Equity	Horizontal equity	User pay principle	Cost-based pricing, internalize externalities, reduce externalities
	Vertical equity	Progressive pricing	Low prices/taxes for basic driving
		Mobility for non-drivers	Provide adequate walking, cycling, rideshare, transit services; multi-modal community/land use
Social welfare	Community cohesion and livability	Improve mobility within neighborhoods	Neotraditional street planning, traffic calming, pedestrian/cycle planning, mixed land use
		Enhance the public realm through street improvements	Traffic calming, pedestrian planning, livable community design features

Notes: CAFE - Corporate average fleet efficiency, a standard based on the overall average fuel efficiency of all vehicles sold by each manufacturer; I/M – Inspection and maintenance; TDM - Transportation demand management.

Source: Litman and Burwell (2006)

(Gwilliam, 2008). Passenger transport evolution data and its calculated demand by ANTP (2011) in billions of passengers versus kilometers/year between 2003 and 2010 are shown in table 3.

One can see that there is a direct correlation between demand transportation, individual motorized transportation storage and use, population growth and income increasing.

Figure 2 depicts a strong correlation among transportation demand, household income and vehicle storage in Brazilian cities. For each demand the term 'km-passenger' needs features provided by Government such as energy, atmosphere, infrastructure and health care. Depending on transportation mode, the demand will consume a higher amount of natural and financial resources. For instance, one can see that motorcycle usage is growing faster. Although motorcycles are more efficient than automobiles in terms of energy consumption and CO_2 emissions, this type of transportation causes more accidents and pollution emissions per capita than automobiles. Furthermore, it brings more damage and harm, as well as stimulates individual rather than public transportation. The aforementioned growth rate is pressuring health costs and local pollution emissions.

Table 3: Social issues and passenger transport demand in Brazilian cities

	Information / Activities	2003	2004	2005	2006	2007	2008	2009	2010
	Population (million)	108	111	113	115	117	120	121	122
	Jobs (million)[1]	13	13	14	14	14	15	15	15
	Household month average income (USD)	608	603	614	642	664	747	771	799
Vehicles	PT (million)	0.093	0.095	0.098	0.097	0.101	0.102	0.103	0.106
	IMT (million)	17.9	18.9	19.9	20.9	23.9	25.9	27.9	29.9
	Total (million)	18	19	20	21	24	26	28	30
Billion Km-Pass	PT	187	192	199	208	217	226	230	236
	Auto	106	108	113	116	119	122	123	128
	Moto	7	8	9	10	11	12	14	15
	IMT - total	113	116	121	125	130	134	137	143
	Total	300	308	320	333	347	360	367	379

Notes: 1- Industry and commerce (FIBGE, 2011); PT = Public Transport; IMT = Individual Motorized Transportation
Source: Authors based on ANTP (2011).

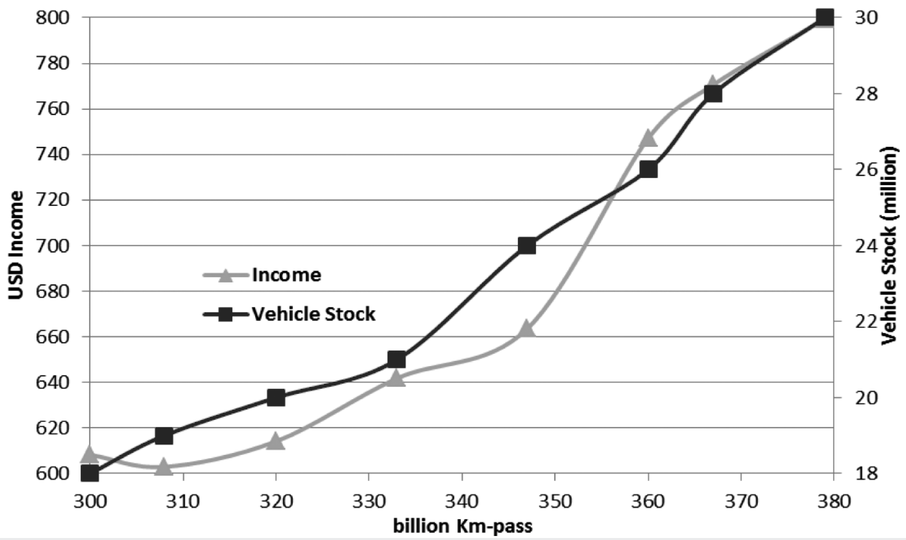

Figure 2: Household income, vehicle storage and transportation demand (2003-2010)

4.1 Health costs

Health costs are presented as costs of traffic accidents and those derived from atmospheric pollution. Firstly it will be described traffic accidents features and later on it will be discussed the effects of atmospheric pollution costs. Globally, traffic accidents are one of the public health main concerns. Over a million people die and 50 million are injured worldwide in road accidents every year (WHO, 2004).

Most of the victims are low income group members in developing countries – that is, people who are already amongst the world most socially and economically vulnerable ones. The infrastructure for urban transportation in major cities worldwide had been constructed in the last four decades. Particularly in the world population most unstable segment, inadequate planning and light-duty vehicles predominance lead to high accident risk transportation system (Downtown, 2000; Vasconcellos, 2005a and 2005b).

Road systems were constructed in public spaces and designed to maximize the amount and speed of vehicles: a large quantity of these roads does not even have sidewalks, resulting in struggle amongst vehicles and unprotected pedestrians.

In Brazil, the situation is even worse: in practice, aggressive or drunk drivers run freely, subsidized by traffic management system that encourages speed and impedes free pedestrian circulation. As a result, R$ 8.9 billion (USD 5.3 billion) is spent annually on social costs due to road traffic accidents in Brazilian urban areas with over 60,000 inhabitants. Out of this number, R$ 7.7 billion (USD 4.6 billion) is attributable to damage caused by individual motorized vehicles.

Additionally, atmospheric pollution costs include human health harm and environment damage. Pollution may arise directly from vehicles emissions or indirectly from the transportation system infrastructure maintenance: oil & gas upstream and downstream procedures, roads construction and maintenance, vehicles production (Litman, 2009). Motor vehicles are the dynamic pollution source, once vehicles operate in close proximity to people (vehicle users and pedestrians), and imprints direct impact over society.

In Brazil, there has been a significant effort to reduce motor vehicles pollutants. Although considerable advances have been made (MMA, 2010), the total ammount of pollutants emitted by the passenger transportation sector is still substantial. Yet, individual motorized transportation (IMT) is responsible for 83% transportation sector CO_2 emitted (public transport generates only 2%). IMT also generates 23% CO2 sector emission, opposed to less than half its ratio of mass transportation (11%). Table 3 deploys both types (IMT and mass transportation) representing almost the same number of passengers per year (*circa* 17 billion) in Brazil.

Out of the 28.1 million ton pollutants generated in 2008 by passenger transportation in Brazil, 18.3 million were produced by IMT (17.1 million ton by motor cars). Mass transport emitted 9.8 million tons. As a result, IMT accounts for 65% total pollutant emissions in Brazilian cities. In computing accident costs and pollutant costs – total of USD 55.0 billion (in the last 7 years) - USD 40.1 billion was generated by IMT and only USD 10.7 billion from mass transport (ANTP, 2010). Moreover, public transportation deployed more than 2,338 billion km-passengers in 7 years while IMT produced 2,266 billion. Figure 3 shows transportation health costs evolution.

Table 3: Passengers transported (public x individual), local pollutants and greenhouse gases emissions

Emissions 2008/2009	Public Transport	Individual Transport
Passengers/year	16.8 billion	17.0 billion
CO	(2%) 34,000 ton	(83%) 1,500,000 ton
NOx	(14%) 147,000 ton	(9%) 94,500 ton
CO2	(11%) 18,700,000 ton	(23%) 39,100,100 ton

Source: MMA (2010).

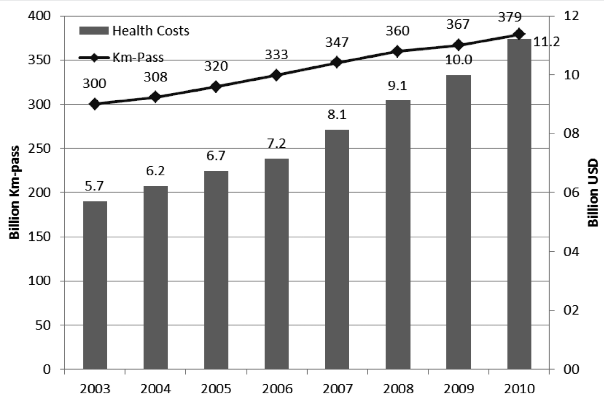

Figure 3: Passenger Transport Health costs

4.2 Energy Costs

The transportation system requires large petroleum products amounts both in the system construction and then in its infrastructure management (Brand and Preston, 2010). The energy usage intensity in the transportation sector increases substantially in societies that chose an automobile-centered system.

Although Brazil has fewer motor vehicles per thousand inhabitants compared to other countries, a significant upward trend can be seen in this index since 2003, as shown in Figure 4. Considering data in others emerging countries is possible to check the tendencies: Latin America and Caribbean have 118 cars per thousand inhabitants (2003); Chile has 109 cars per thousand inhabitants (2009); Paraguay has 39cars per thousand inhabitants (2008); Venezuela has 107 cars

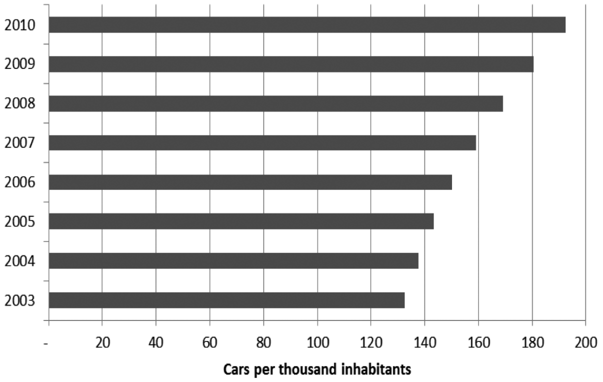

Figure 4: Cars per thousand inhabitants in Brazil
Source: DENATRAN (2010).

per thousand inhabitants and Uruguay has 151 cars per thousand inhabitants.

Data in developing countries depicts the consolidated major numbers: USA has 451 cars per thousand inhabitants; United Kingdom has 463 cars per thousand inhabitants; Switzerland has 522 cars per thousand inhabitants; and France has 495 cars per thousand inhabitants in 2009 (Denatran, 2010; World Bank, 2011). Nowadays, Brazilian cities with over 60,000 inhabitants consume around 80 million tones in their journeys between 2003 and 2009. Motor cars alone consume almost 73% of this total energy, while public transportation consumes 24.65% (figure 5).

The situation is worsened in cities with over a million inhabitants. Due to the massive IMT usage large cities deploys eight times more energy per inhabitant than smaller cities.

Figure 6 presents large cities with more than a million inhabitants. Approximately 634 petroleum equivalent grams (PEG) are consumed per person per day, while in small cities (less than 100,000 inhabitants) this ratio is only 78 PEG (ANTP, 2009).

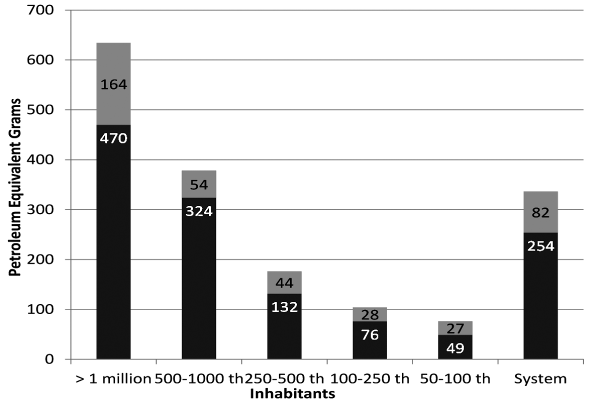

Figure 6: Energy consumed per inhabitant per day by transport type (Petroleum Equivalent Grams) - 2009
Key: CT – Public Transport; IT – Individual Transport
Source: MMA, 2010.

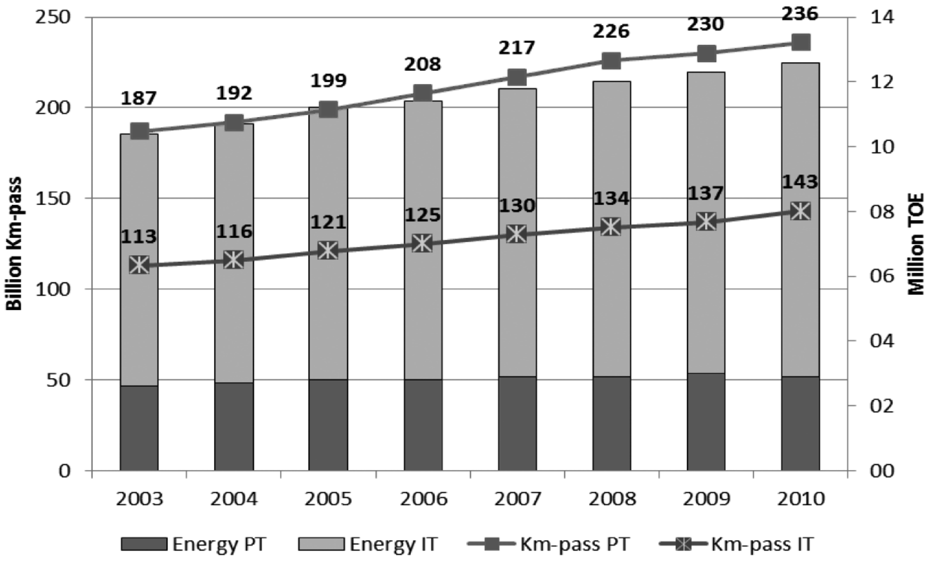

Figure 5: Consumption of final energy in Brazilian cities (cars X overall consumption)

4.3 Infrastructure costs

The transportation infrastructure management cost in Brazil includes public expenditures on transportation system maintenance. It sums R$ 11.1 billion (approximately USD 6.66 billion) per year: R$ 10.4 billion (USD 6.2 billion) are IMT mobility promotion-oriented, and only R$ 0.7 billion (approximately USD 0.4 billion) is mass transport-oriented (ANTP, 2009).

Considering the value of assets (e.g. land, constructions, etc.) allocated in urban transportation, it amounts up to R$ 1.65 trillion (USD 1.00 trillion). Figure 7 presents that out of this total, R$ 1.44 trillion (USD 0.86 trillion) is allocated to IMT and R$ 0.21 trillion (USD 0.12 trillion) is allocated to mass transport.

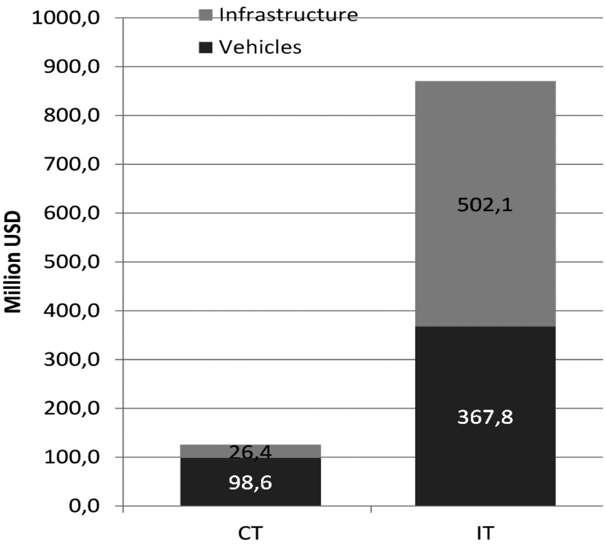

Figure 7: Infrastructure costs, 2009 (Million USD)
Key: CT – Public Transport; IT – Individual Transport
Source: MMA (2010).

4.4 The use of public space

Modal transportation is related to urban space usage of transportation and also with its geographical availability. Figure 8 depicts spatial, speed and performance features of some urban transportation modes. Performance index represents the speed over space consumption ratio. Public transportation accounts for 10 times less space than individual motorized transportation. In individual motorized transportation oriented-cities a large amount of space must be used in order to urban mobility than those mass transportation oriented-cities.

Taking the bus (mass transportation) as a benchmark, Figure 8 illustrates a flagrant disproportionality in the usage of Brazilian cities road space. For instance, cars occupy 21 m^2, buses 54 m^2, and motorcycles 8 m^2, average. However, cars represent less than 2 people per vehicle (Brazilian statistics average 1.5 person per vehicle) and motorcycles carry 1.1 person per vehicle. On the other hand, buses transport 30 passengers per vehicle average in Brazil (ANTP, 2009).

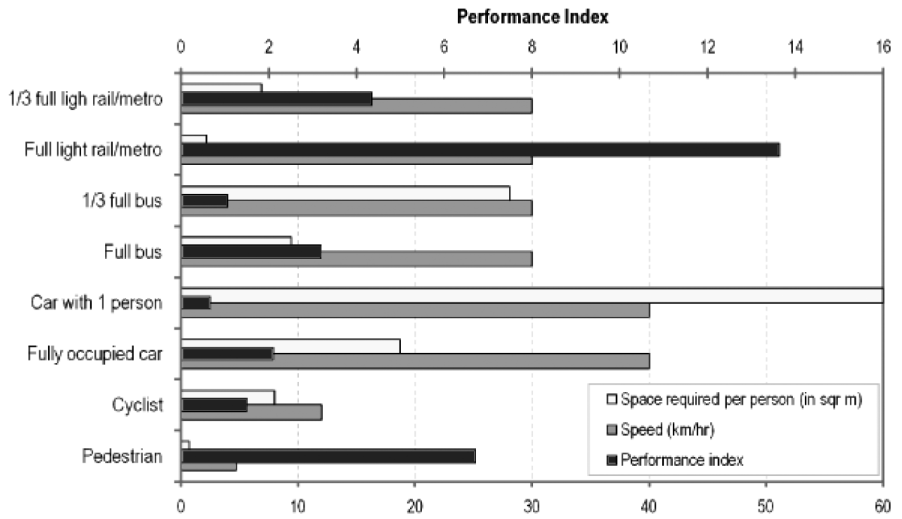

Figure 8: Performance of transport modes
Source: Tolley and Turton (1995).

Quinet (1994) argues the road system expansion is socially justified. According to him, the region real estate value where road system expansion occurs is increased. Litman (1995), however, states this view ignores time expenditure, money and manpower required to accommodate a system based on light-duty vehicle, which is greater than to boost other means of transportation.

Litman (1995) also notes that the land designation for road construction results in a scale diseconomy due to the providing services costs, such as electricity, water, and garbage collection, to a sparsely populated area.

This transportation system model also has an expansionist effect in urban areas, in some cases leading to unregulated expansion, and creates independent or isolated zones within the city. This can lead to further public expenses, including passage of vehicles infrastructure duplication, public and private services doubled efforts, and expanded areas for parking and private garages (Kelbaugh, 1992).

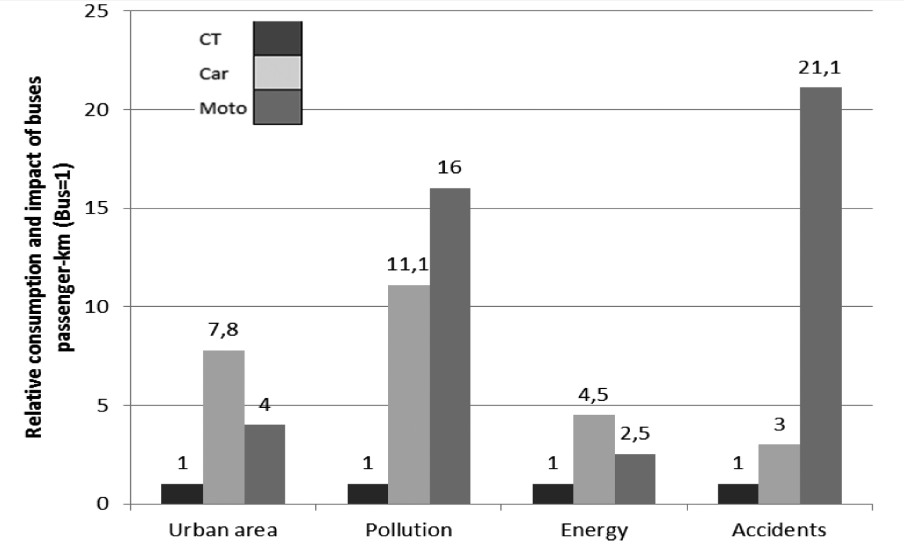

Figure 9: Relative consumption and impact of the use of buses, motorcycles and cars in Brazilian cities
Key: CT – Public Transport
Source: ANTP (2009).

5 Comparative performance model

A simple comparative model was developed in order to illustrate the inefficiency conflict between IMT and PT (public transportation) mode. Firstly demand data and its costs will be presented (table 4). Secondly a comparative model will be shown to demonstrate the efficiency discrepancy between IMT and PT mode (table 5).

The numerical simulation of efficiency was obtained thought this simple equation:

Efficiency = input / output ratio = costs/ km-passengers

The aforementioned equation means transportation system efficiency equals system generated costs divide by passengers amount times considered distance. Besides, table 5 provides information related to the comparative efficiency model where CT (collective transport) is 4.5 times more efficient than IMT (avoiding health costs) and around 17 times more efficient (avoiding infrastructure costs). Considering greenhouse gas emissions, CT is almost 3 times more efficient than cars and almost 2 times than motorcycles. In the case of pollution emissions, CT is 9.7 times more efficient than cars and 16.2 times than motorcycles. In terms of energy consumption CT is 5.3 times more efficient than cars and 2.16 times more efficient than motorcycles.

A new scenario could be estimated, considering a more restricted potential situation. If it is possible to substitute the whole transportation demand pro-

Table 4: External costs from realized demand – Brazilian Cities

	Year	2003	2004	2005	2006	2007	2008	2009	Sum
Billion Km-pass	Moto	7	8	9	10	11	12	14	71
	Cars	106	108	113	116	119	122	123	807
	CT	187	192	199	208	217	226	230	1459
	Total	300	308	321	334	347	360	367	2337
Energy Millions TOE	Moto	0.2	0.2	0.3	0.3	0.3	0.4	0.4	2.1
	Cars	7.6	7.8	8.1	8.3	8.6	8.8	8.9	58.1
	CT	2.6	2.7	2.8	2.8	2.9	2.9	3.0	19.7
	Total	10.4	10.7	11.2	11.4	11.8	12.1	12.3	79.9
Pollution Thousand Tones	Moto	176	175	176	175	175	176	179	1,232
	Cars	1,160	1,172	1,100	1,146	1,200	1,237	1,272	8,287
	CT	255	230	226	218	214	212	208	1,563
	Total	1,591	1,577	1,502	1,539	1,589	1,625	1,659	11,082
CO$_2$ Thousand Tones	Moto	602	653	712	788	890	1,005	1,107	5,757
	Cars	13,813	14,167	14,716	15,129	15,559	15,909	16,118	105,411
	CT	8,720	9,093	9,376	9,281	9,386	9,604	9,617	65,077
	Total	23,135	23,913	24,804	25,198	25,835	26,518	26,842	176,245
Health Costs Billion USD	TI	4.22	4.61	5.06	5.39	6.17	6.94	7.67	40.1
	CT	1.22	1.33	1.39	1.44	1.61	1.78	1.89	10.7
	Total	5.90	6.45	6.99	7.41	8.43	9.46	10.36	55.0
Infrastructure Billion USD	TI	4.06	4.44	4.72	4.94	5.28	5.78	6.11	35.3
	CT	0.28	0.33	0.33	0.33	0.39	0.39	0.44	2.5
	Total	4.70	5.18	5.48	5.72	6.14	6.69	7.11	41.0

Table 5: Comparative Efficiency Model

Input/output	Year	2003	2004	2005	2006	2007	2008	2009	Sum/Av
Billion Km-pass	Moto	7	8	9	10	11	12	14	71
	Cars	106	108	113	116	119	122	123	807
	CT	187	192	199	208	217	226	230	1459
	Total	300	308	321	334	347	360	367	2337
Energy Efficiency Millions TOE/bi km-pass	Moto	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Cars	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	CT	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Average	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Pollution Efficiency Thousand Tones/ bi Km-pass	Moto	25.14	21.88	19.56	17.50	15.91	14.67	12.79	18.20
	Cars	10.94	10.85	9.73	9.88	10.08	10.14	10.34	10.28
	CT	1.36	1.20	1.14	1.05	0.99	0.94	0.90	1.08
	Average	12.48	11.31	10.14	9.48	8.99	8.58	8.01	9.86
CO2 Efficiency Thousand Tones/ bi km-pass	Moto	86.00	81.63	79.11	78.80	80.91	83.75	79.07	81.32
	Cars	130.31	131.18	130.23	130.42	130.75	130.40	131.04	130.62
	CT	46.63	47.36	47.12	44.62	43.25	42.50	41.81	44.76
	Average	87.65	86.72	85.49	84.61	84.97	85.55	83.98	85.57
Health Costs Efficiency bi USD/ bi km-pass	TI	0.037	0.040	0.041	0.043	0.047	0.052	0.056	0.045
	CT	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.007
	Average	0.022	0.023	0.024	0.025	0.027	0.030	0.032	0.026
Infrastructure Efficiency bi USD/ bi km-pass	TI	0.036	0.038	0.039	0.039	0.041	0.043	0.045	0.040
	CT	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	Average	0.019	0.020	0.020	0.020	0.021	0.022	0.023	0.021

duced in IMT mode by CT mode, what should be the results in terms of energy consumption, gases emissions and social costs? We can do this simulation using the ratio I/O's (input output ratio). The new costs chart is shown on table 6.

6 Conclusions

This study demonstrated the Brazilian cities case, which struggles facing the absence of adequate and urgent public policies. Unless the real individual motorized transportation expenditure is calculated, a shortage of roads and highways space will remain. Growing amount demanded for public transportation space is lesser than those of public administration infrastructure supply. The shortage appears in the form of road congestion, increasing energy consumption, pollutant emissions and financial costs.

By calculating the impacts of keeping unchanged the current urban transportation system in Brazilian cities, we found negative externalities at high levels in Brazilian cities which tend to increase rapidly in the next years. CO$_2$ emissions from passenger transportation in Brazil are estimated to be responsible for 44% (approximately 59 million tons in 2009) of total transportation sector, out of this rate, 65% is caused by cars and motorcycles.

Thus, it can be inferred that it provides a significant negative effect on Brazilian efforts to curb such emissions. Currently, the individual motorized vehicles growth and their increasingly use

Table 6: Comparative analysis

Input/output	Year	2003	2004	2005	2006	2007	2008	2009	Sum	Saved
Billion Km-pass	Moto	0	0	0	0	0	0	0	0	
	Cars	0	0	0	0	0	0	0	0	
	CT	300	308	321	334	347	360	367	2337	
	Total	300	308	321	334	347	360	367	2337	
Energy Millions TOE	Moto	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	CT	4.2	4.3	4.5	4.5	4.6	4.6	4.8	31.6	
	Total	4.2	4.3	4.5	4.5	4.6	4.6	4.8	31.6	48.3
Pollution Thousand Tones	Moto	0	0	0	0	0	0	0	0	
	Cars	0	0	0	0	0	0	0	0.0	
	CT	409	369	365	350	342	338	332	2,504	
	Total	409	369	365	350	342	338	332	2,504	8,578
CO$_2$ Thousand Tones	Moto	0	0	0	0	0	0	0	0	
	Cars	0	0	0	0	0	0	0	0	
	CT	13989	14587	15124	14903	15009	15298	15345	104,256	
	Total	13,989	14,587	15,124	14,903	15,009	15,298	15,345	104,256	71,989
Health Costs Billion USD	TI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	
	CT	1.96	2.14	2.24	2.32	2.58	2.83	3.01	17.1	
	Total	1.96	2.14	2.24	2.32	2.58	2.83	3.01	17.1	37.92
Infrastructure Billion USD	TI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	CT	0.45	0.53	0.54	0.54	0.62	0.62	0.71	4.0	
	Total	0.45	0.53	0.54	0.54	0.62	0.62	0.71	4.0	37.02

in Brazil more than offset the advances in motor vehicles fuel efficiency. In addition, social costs related to road accidents and hospital costs rise progressively estimating to reach USD 19 billion in 2020. Similarly, infrastructure costs will exceed USD 154 billion (ANTP, 2010).

The limited investment on road infrastructure should constrain the car usage in large Brazilian cities at the end of the under analysis period. Based on our findings, we recommend that Brazil implement an emergency State Policy requiring new planning to expand public transportation modes, as well as restraining the use of private cars and motorcycles in cities. This policy should consider investments in public transportation modes cost-benefit analysis, including the avoided external costs estimated in this study.

Given the lack of public revenues, the market volatility and the short-term alternatives focus, it is common in emerging economies to prioritize expenditures on infrastructure for road transportation, especially for private cars. This emphasis does not account for the external costs which were identified in this paper.

References

AEO, (2008) Anual Energy Outlook, Washington, EIA.

Anable, J. (2005) Complacent Car Addicts or Aspiring Environmentalists? Identifying travel behaviour segments using attitude theory. Transport Policy, 12, pp. 65-78.

ANTP (2009) ANTP, accessed on 26 Jan 2010, available at www.antp.org.br: http://portal1.antp.net/site/default.aspx

ANTP (2011) Http://portal1.antp.net/site/simob/default.aspx.Accessed on 9 jan 2012, available at www.antp.org.br/: www.antp.org.br/.

ANTT (2011). www.antt.gov.br. Acessed on 11 jul 2011, available at www.antt.gov.br.

BACEN (2011) BACEN, accessed on 19 may 2011, available at http://www.bcb.gov.br/.

Black, W. (2010) Sustainable Transportation: problems and solutions, Guilford Press, NY.

Bouf, D. and Hensher, D. (2007) The dark side of making transit irresistible: The example of France, Transport Policy,14, pp. 523-532.

BP(2007) BP Statistical Review of World Energy 2007, BP, London.

Brand, C. and Preston, J.M. (2010) '60-20 emission'—The unequal distribution of greenhouse gas emissions from personal, non-business travel in the UK, Transport Policy, 17 (1), pp. 9-19.

Buehler, R.and Pucher, J. (2011) Making public transport financially sustainable, Transport Policy, 18, pp. 126-138.

Chapman, L. (2007) Transport and climate change: a review, Journal of Transport Geography, 15 (5), pp. 354-367.

DENATRAN. (2011) DENATRAN, Accessed on 25 Feb 2011, available at www.denatran.gov.br: http://www.denatran.gov.br/frota.htm.

EIA (2007) Anual energy outlook 2007.DOE/EIA.

Feitelson, E. (2002) Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls, Transportation Research Part D, 7, pp. 99-118.

Elvik, R. (2006) Are individual preferences always a legitimate basis for evaluating the costs and benefits of public policy? The case of road traffic law enforcement, Transport Policy,13 (5), pp. 379-385.

Granados, J., (1998) Reducing automobile traffic: an urgent policy for health promotion, Rev Panam Salud Publica, pp. 227-241.

Gudmundsson, H., and Höjer, M. (1996) Sustainable development principles and their implications for transport, Ecological Economics, 19 (3), pp. 269-282.

Gwilliam, K.(2002) Cities on the move : a World Bank urban transport strategy review, World Bank, Washington D.C.

Gwilliam, K. (2008) A review of issues in transit economics, Research in Transportation Economics, 23 (1), pp. 4-22.

Han, J. and Hayashi, Y. (2008) A system dynamics model of CO2 mitigation in China's inter-city passenger transport, Transportation Research Part D,13 (5), pp. 298-305.

IEA. (2002) Bus systems for the future: Achieving Sustainable Transport Worldwide, OECD/IEA, Paris.

IEA.(2008) CO2 Emissions From Fuels Combustions, OECD/IEA, Paris.

IPCC (2007) Summary for policy makers, Working group I contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report: climate change 2007—The physical science basis, Paris.

Kahn et al, S. (2007) 2007: Transport and its infrastructure. In: B. E. Metz. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth, Cambridge University Press, NY.

Litman, T. (1995) Land use impact costs of transportation, World Transport Policy and Practice, 9-16.

Litman, T. (2009) VTPI. Accessed on 26 Sept 2009, available at www.vtpi.org: http://www.vtpi.org/future.pdf.

Litman, T., and Burwell, D. (2006) Issues in sustainable transportation, Int. J. Global Environmental Issues, 6, pp. 331-347.

MMA. (2010) MMA, Accessed on 3 July 2010, available at www.mma.gov.br

OPEC. (2007)World Oil Outlook 2007,OPEC, Vienna.

Parry, I., Walls, M., and Harrington, W. (2007) Automobile Externalities and Policies, Journal of Economic Literature, XLV, 374-400.

Pucher, J. et al. (2005) Urban transport crisis in India, Transport Policy, 12, pp. 185-198.

Quinet, E. (1994) The social costs of transport: evaluation and links with internalization policies. In: Button, K. Internalizing the Social Costs of Transport, OECD, Paris.

Rosa, L. P. (2003) Climate changes and gases emissions in the energy system:contributions from transport sector In: S. E. KAHN, Transportation and climate change (pp. 7-10), COPPE, Rio de Janeiro.

Schipper, L., and Eriksson, G. (1995) Taxation Policies Affecting Automobile Characteristics and Use in Western Europe, Japan and the United States. In: D. Sperling, and S. Shahen, Transportation and Energy: Strategies for a Sustainable Transportation System (pp. 217-242), America Council for an Energy Efficient Economy, Washington.

Schipper, L. (2011). Automobile use, fuel economy and CO2 emissions in industrialized countries: Encouraging trends through 2008?, Transport Policy, 18 (2), pp. 358-372.

Sperling, D., and Gordon, D. (2008) Two Billion Cars. TR News, 259, pp. 2-9.

Thomas, J. et al. (2004). Integrating qualitative research with trials in systematic reviews. British Medical Journal, vol. 328, n. 7446, pp. 1010–2.

Tolley, R. and Turton, B. (1995) Transport systems, policy and planning: a geographical approach. New York: Longman.

Vasconcellos, E. (2000) Transporte urbano nos países em desenvolvimento, Anablume, São Paulo.

Vasconcellos, E. (2005a) Transport metabolism, social diversity and equity: The case of São Paulo, Brazil, Journal of Transport Geography, pp. 329-339.

Vasconcellos, E. (2005b) Urban change, mobility and transport in São Paulo: three decades, three cities, Transport Policy, 12 (2), pp. 91-104.

Vasconcellos, E. (2008) Transporte e meio ambiente: conceitos e informações para análise de impactos, Anablume, São Paulo.

WBSCD. (2004) Mobility 2030: Meeting the challenges to sustainability, World Business Council for Sustainable Development, Geneva.

WHO (2004) World Report on Road Traffic Injury prevention, World Health Organization, Geneva.

WOO (2010) Organization of the Petroleum Exporting Countries, OPEC Secretariat, Vienna.

World Bank (2002) Cities on the Move: A World Bank Urban Transport Strategy Review, The International Bank for Reconstruction and Development, Washington.

World Bank (2011) World Bank, Accessed on 31 May 2011, available at http://data.worldbank.org/indicator.

Wright, C. and Egan, J. (2000) De-marketing the car, Transport Policy, 7 (4), pp. 287-294.