TeMA

Journal of
Land Use, Mobility and Environment

There are a number of different future-city visions being developed around the world at the moment: one of them is Smart Cities: ICT and big data availability may contribute to better understand and plan the city, improving efficiency, equity and quality of life. But these visions of utopia need an urgent reality check: this is one of the future challenges that Smart Cities have to face.

Tema is the Journal of Land use, Mobility and Environment and offers papers with a unified approach to planning and mobility. TeMA Journal has also received the Sparc Europe Seal of Open Access Journals released by Scholarly Publishing and Academic Resources Coalition (SPARC Europe) and the Directory of Open Access Journals (DOAJ).

Vol.7 n.3 December 2014

print ISSN 1970-9889 e-ISSN 1970-9870
University of Naples Federico II

TeMA Journal of
Land Use, Mobility and Environment

SMART CITY CHALLENGES : PLANNING FOR SMART CITIES.

DEALING WITH NEW URBAN CHALLENGES

3 (2014)

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

TeMA is realised by CAB - Center for Libraries at “Federico II” University of Naples using Open Journal System

Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Lycence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

Editorial correspondence
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples
web: www.tema.unina.it
e-mail: redazione.tema@unina.it

TeMA Journal of Land Use, Mobility and Environment

TeMA. Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include: engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science and complex systems.

The Italian *National Agency for the Evaluation of Universities and Research Institutes* (ANVUR) classified TeMA as scientific journal in the Area 08. TeMA has also received the *Sparc Europe Seal* for Open Access Journals released by *Scholarly Publishing and Academic Resources Coalition* (SPARC Europe) and the *Directory of Open Access Journals* (DOAJ). TeMA is published under a Creative Commons Attribution 3.0 License and is blind peer reviewed at least by two referees selected among high-profile scientists. TeMA has been published since 2007 and is indexed in the main bibliographical databases and it is present in the catalogues of hundreds of academic and research libraries worldwide.

TeMA Journal of
Land Use, Mobility and Environment

SMART CITY CHALLENGES: PLANNING FOR SMART CITIES. DEALING WITH NEW URBAN CHALLENGES 3 (2014)

Contents

TeMA
Journal of
Land Use, Mobility and Environment

TeMA

Journal of
Land Use, Mobility and Environment

TeMA 3 (2012) 301-314
print ISSN 1970-9889, e- ISSN 1970-9870
DOI: 10.6092/1970-9870/2489

paper received 21 October 2014, accepted 28 November 2014

www.tema.unina.it

How to cite item in APA format:
Marins, C. S., Orrico, R. D. F., Nascimiento, W.S. (2014). Urban Taxing Alternatives for Private Vehicles as an Urban Mobility Management System. *Tema. Journal of Land Use, Mobility and Environment*, 7(3), 301-314. Doi:http://dx.doi.org/10.6092/1970-9870/2489

ALTERNATIVE CHARGES ON PRIVATE VEHICLES AS A WAY OF MANAGING URBAN MOBILITY

CRISTIANO SOUZA MARINS[A], 2 RÔMULO DANTE ORRICO FILHO[B]
WELLINGTON NASCIMENTO SILVA[C]

[a,b,c] Universidade Federal do Rio de Janeiro - UFRJ
[a] e-mail: cristianosouzamarins@yahoo.com.br
[b] e-mail: romulo@pet.coppe.ufrj.br
[c] e-mail: wn.silva@uol.com.br

ABSTRACT

In this article, we reflect on proposals for the use of urban tolls on private vehicles as a form of urban mobility management. The methodology used exploratory research for the development of a theoretical basis and a table was drawn up showing the experience in various countries. The conclusion is that toll fees are economic viable, the social and environmental benefits are considerable and this can be considered an important sustainable mobility strategy.

KEYWORDS:
Urban Taxing Alternatives; Private Vehicles; Urban Mobility Management

TeMA Journal of Land Use, Mobility and Environment

TeMA 3 (2014) 301-314
print ISSN 1970-9889, e- ISSN 1970-9870
DOI: 10.6092/1970-9870/2489

paper received 21 October 2014, accepted 28 November 2014 Licensed under
the Creative Commons Attribution – Non Commercial License 3.0
www.tema.unina.it

How to cite item in APA format:
Marins, C. S., Orrico, R. D. F., Nascimiento, W.S. (2014). Urban Taxing Alternatives for Private Vehicles as an Urban Mobility Management System.
Tema. Journal of Land Use, Mobility and Environment, 7(3), 301-314. Doi:http://dx.doi.org/10.6092/1970-9870/2489

城市交通管理系统：

城市私家车征税方案

CRISTIANO SOUZA MARINS[A], 2 RÔMULO DANTE ORRICO FILHO[B]
WELLINGTON NASCIMENTO SILVA[C]

[a,b,c] Universidade Federal do Rio de Janeiro - UFRJ
[a] e-mail: cristianosouzamarins@yahoo.com.br
[b] e-mail: romulo@pet.coppe.ufrj.br
[c] e-mail: wn.silva@uol.com.br

摘要

本文就对私家车征收通行费作为城市交通管理的一种方式进行了思考。文中采用了探索性研究的方式对这一领域的理论成果和在不同国家中的相关经验进行了详尽阐述，并由此得出结论：征收通行费在经济上是可行的，并能产生巨大的社会和环境效益，可以视作一个重要的可持续交通战略。

关键词
城市征税方案；私家车；城市交通管理

1 INTRODUCTION

Transport plays a significant role in environmental problems, mainly due to it being the largest and a growing consumer of non-renewable energy and a pollution generator. Furthermore, means of transport as mobility agents have a direct impact on people's quality of life, allowing them to come and go and access to goods and services, leisure, study and work. One of the main causes of environmental problems has been the excessive use of the automobile as the main form of urban transport. It will be difficult to change this in the short or even medium term, mainly due to the advantages and significance that the automobile presents and represents to society.

To Banister (2005, 2008), the features that cause the automobile to be a global icon are: they are goods manufactured by companies that are themselves icons of industrialization and world capitalism; they give their users status; it is a complex product that makes use of numerous accessories and, for that reason, feeds a broad and varied sector; it provides individual mobility that is superior to other means of getting around (public transport, bicycle and walking); and it shapes and organizes the lives of people (work, leisure, study, etc.). Another important aspect is the flexibility and freedom that the car represents, allowing the users to come and go as they please, while the transport alternatives (public and non-motorized) have lost their ability to attract and retain users. Taking the city of Rio de Janeiro as an example, in the last two decades, the population growth was approximately 5%, while the growth in the automobile fleet was 50% and that of motorcycles was 300%. As shown in Table 1, there is one automobile for every four people. The big problem is not the ownership of automobiles, but the fact that they are in everyday use for short, medium and long distance travel. The ideal would be to use the public transport system, in any of their combined modes, and non-motorized transport. The trouble with this is the lack of quality and investment in these forms of transport, which makes them less attractive than utilizing the automobile. (Orrico et al. 2012).

	Year	**Number**
Population	1999	5,814,750
	2010	6,323,037
Automobiles	1999	1,062,190
	2010	1,521,716
Motorcycles	1999	40,903
	2010	161,306

Tab. 1 Population, automobiles and motorcycles in Rio de Janeiro, from 1999 to 2010.

Within this scenario, it is necessary to seek alternatives that allow for the management of mobility and the control of automobile use, so as to minimize its impact on the environment and on people's quality of life. In this respect, urban toll fees have become an important strategy for sustainable urban mobility, as they help to offset the impact by generating a source of revenue that can be invested in improving the public transport and the transport infrastructure in general, as well as discouraging automobile use as the principal means of transport (Wu and Shang, 2014). The methodology of this study was to examine the use of the urban toll system as a form of urban mobility management. For this purpose, qualitative and exploratory research was conducted, for the development of a theoretical and descriptive basis for presenting some models that have been adopted by the world's major cities. The overall objective was to analyze the urban toll system as a form of management of urban mobility and incentive to sustainable transport and to analyze and compare the different urban toll models adopted in different countries, as well as to reflect on the importance of urban tolls as a way to manage automobile use and encourage the use of public and non-motorized transport.

In addition to the present section, this work is organized in the following manner: in Section 2, the theoretical basis for sustainable mobility and urban tolls is presented, while in Section 3, we show the analysis and reflection on using urban tolls as a form of mobility management, and the last section presents the final considerations.

2 THEORETICAL BASIS

2.1 SUSTAINABLE URBAN MOBILITY

Sustainable mobility is one of the most central and complex aspects in public transport planning, especially with regard to infrastructure, utilization of renewable energy sources, vehicles, non-motorized transport and improved land use.

Originally, papers and discussions about mobility, transport and sustainable development were restricted to environmental factors, dealing with matters such as climate change, pollution, the use of natural resources and sources of non-renewable fuels, etc. A more up-to-date approach incorporates other dominant aspects for achieving a sustainable transport system, such as social, economic, cultural and technological factors, while the term "sustainable" now embraces a set of interacting and interdependent elements.

The term mobility involves a set of elements that permeate public administration and involve the planning, management and regulation of public transport, urban freight logistics, land use and accessibility. Mobility has a direct impact on people's quality of life, allowing access to the means of production, leisure and education. As a consequence of the lack of planning, there has been an increase in the pollution from gas emissions, increased traffic congestion due to the use of private automobiles, centralization in the use of land, etc. (BRAZIL, 2007, 2012). Another definition offered by the National Urban Mobility Policy, presented by SEMOB (BRAZIL, 2007, p.41) is:

> (...) "an attribute associated with people and goods; it corresponds to the different responses of individuals and economic agents to their transportation needs, considering the dimensions of the urban space and the complexity of the activities carried on within it", or, more specifically, "urban mobility is an attribute of cities which refers to the ease of moving people and goods around within the urban space". Such movements are made using vehicles, roads and the entire urban infrastructure (streets, sidewalks, etc.)" (...) "It is the result of the interaction between the movement of people and goods and the city itself."

Given the need for a reformulation of the current paradigms involving mobility and public transport, some concepts and sustainability models, applicable to urban mobility, have become necessary. According to Richardson (2005) and Ramani (2008), sustainable transport can be defined as the capacity to meet the demand for transport without compromising future generations. This definition is based on three key areas: economic, environmental, and social. Also based on these three areas, according to those authors, is a set of variables that can be used as sustainability indicators: safety, traffic, fuel consumption, vehicle gas emissions and accessibility. Moreover, according to Richardson (2005), each transport system is complex and its complexity derives from the multiplicity of the infrastructure, people and organizations involved. This is intensified by the different legislation and regulations, service providers, financing systems, technologies, land use strategies and consumer behavior.

According to Litman (2008, 2012), a sustainable transport system must:

- meet the basic needs of the people, businesses and society in a manner that is safe, consistent and healthy, while protecting the ecosystem and the interests of future generations;
- be accessible, seeking to be efficient and effective, operating as fairly as possible, offering choices of transport, and stimulating economic competition and balanced regional development;
- recognize the planet's limited ability to absorb the waste and pollution generated by the current model, utilize renewable resources at below their regeneration capacity and non-renewable resources more slowly than the rate of development of renewable alternatives, while minimizing the impact on land use and generation of pollution.

According to Banister (2005, 2008), every form of transport is unsustainable, as it consumes non-renewable resources, and the non-motorized means of transport are closer to being sustainable, since they consume little non-renewable energy, even while consuming other types of resources, such as space. Banister presents a hierarchy of energy consumption and external effects generated by the different forms of transport.

A study carried out in 2008, in 168 European cities, by the European Conference of Ministers of Transport, identified the main barriers to a sustainable urban transport policy. Among them are: "weak integration and coordination policies, counterproductive institutional roles, unsustainable regulatory frameworks, pricing deficiencies, bad data, limited public support and lack of political will". It also considered as critical factors in sustainable transport strategies: improvements in public transport, charging for automobile use and controlled land use. (May and Ison, 2008). Douglas et al. (2011) relates the use of the automobile as the main form of transport to public health problems, connecting human health and global sustainability. The authors argue that the use of the automobile should be compared to the use of tobacco, due to its health-endangering effects. Furthermore, the use of bicycles or walking lead to a decrease in obesity, the reduction of air and noise pollution and in the number of accidents, as well as enabling greater interaction between people and helping to mitigate climate change. They also point to the efforts of the automotive industry, just as with the tobacco industry, in lobbying for increasing consumption and use of private automobiles. The dependency on the use of the automobile occurs at the individual and social levels.

2.2 AUTOMOBILE USE AND TRAFFIC CONGESTION

In the last few decades there has been an exponential increase in the use of automobiles in urban centers and what used to be a problem exclusive to great metropolis' has now spread to medium and small sized urban centers. The problem has become particularly acute in developing countries, due mainly to economic growth and the social rise of the less favored classes. Linked to this are the government incentives (tax reduction and extension of financing lines) for the automotive industry, and subsidies and exemptions on fuels, which make the acquisition and use of automobiles cheaper. Litman (2002) states:

"Automobile dependency is defined as high levels of per capita automobile travel, automobile oriented land use patterns, and reduced transport alternatives. Automobile dependency increases many costs: higher vehicle expenses, reduced travel choices, increased road and parking facility costs, congestion, accident damages, and a variety of environmental impacts. Beyond an optimal level, excessive automobile dependency may reduce economic productivity and development. A more balanced transportation system can provide many benefits to consumers and society."

The automobile has become an important symbol in modern society and has a considerable influence on people's lives and the redefining of society, urbanization and land use. It provides freedom and enhanced mobility, but its effects entail high social costs, making it one of the biggest problems and challenges for public administrators today (Toralles and Paulitsch, 2010). Despite the transport benefits, the burden is excessive, generating operational (accidents, noise and atmospheric pollution, congestion, etc.) and infrastructural costs that fall upon the population as a whole. According to Litman (2002), in the USA, parking costs are estimated to represent as much as 30% of transportation spending. The use of the automobile generates external factors (indirect or external costs) that fall upon all of society and, as Button (1993) and Torres (2007) state, they come about when there are negative effects from one group affecting another without any compensation. Litman (2012) argues that for each amount invested in expanding the road network, parking and traffic control, an equal amount must also be invested in alternative means of getting around, such as bicycles, walking and public transport. A study carried out by the ANTP (2010, apud Gomide and Morato, 2011) presented data on urban mobility between 2003 and 2009 and it was possible to verify that the increase in the number of vehicles, by around 7%, was greater than the increase in roads, of 2%. It was also greater than the population and income growth. The consequence is an increase in traffic congestion on the roads and in a low level of sustainable mobility. According to Gomide and Morato (2011), the period between 2009 and 2010 saw an even bigger increase in the number of automobiles, at 8.4%.

	2003	2004	2005	2006	2007	2008	2009	Growth Rate
Population (million)[1]	108	111	113	115	117	120	121	2.5%
Breadwinner Income (R$)	1034	1025	1044	1091	1128	1270	1310	4.0%
Roads (thousand km)	294	304	309	314	319	328	332	2.0%
Public transport (thousand)[2]	93	95.2	97.6	97.1	100.6	102.3	103.4	1.8%
Vehicles (million)[3]	18.4	19.3	21.2	21.2	24.0	25.9	28.0	7.2%

The 437 municipalities with 60,000 inhabitants or more in 2003

Includes urban and inter-city buses and rail passenger vehicles

Includes automobiles, vans, trucks, buses, micro-buses, motorbikes and motor-scooters

Tab. 2 Data progression in selected municipalities that comprise the ANTP1 mobility data system (2003-2009)

The same study also presents an estimate of the internal (fixed and variable) and external (social) costs for each type of transport. The automobile has the highest overall cost, compared to other types of transport. However, it should be noted that the ANTP study (2010, apud Gomide and Morato, 2011) includes accidents and air pollution, but doesn't include costs such as lost time, excessive use of public areas for the expansion of roads and public parking lots, fragmentation of urban space, energy consumption and other problems deriving from excessive urban traffic.

	Buses	Motorcycles	Automobiles[5]
Fixed cost[1]	R$ 0.00	R$ 0.84	R$ 2.88
Variable cost[2]	R$ 0.00	R$ 0.74	R$ 2.31
User cost (A+B)[3]	R$ 2.17	R$ 1.58	R$ 5.19
Social cost[4]	R$ 0.20	R$ 1.87	R$ 0.50
Total cost (C+D)	R$ 2.37	R$ 3.45	R$ 5.69

1. Buses: includes ticket price. Motorcycles and automobiles: depreciation, maintenance and taxes.
2. Buses: includes ticket price; Motorcycles: fuel; Automobiles: fuel and parking.
3. Buses: ticket price. Motorcycles and automobiles: sum of A plus B. Represent internal costs.
4. Accident (greater for motorcyclists) and pollutant emission costs. Represent external costs.
5. Average of gasoline and alcohol powered automobiles.

Tab. 3 Fixed, variable, social and total cost per capita for each type over a 7 km urban journey

According to Torres (2007), the external factors could be immediate (as with traffic congestion), cumulative (CO_2 emissions), local or global. From an economic perspective, they can be intra-sectorial or inter-sectorial.
According to Freeman (1997, apud Torres, 2007), the external factors can be divided into four categories: damage caused by transport services (congestion, accidents); pollutant gas emissions; infrastructure investment; and vehicle and fuel production impacts. On the other hand, Button (1993, apud Torres) defines the external factors as technological (production or transport use) or pecuniary (produced by other parties). And in the transportation process there are five types of external factors: atmospheric and noise pollution, accidents, additional energy consumption and traffic congestion. Litman (2012) characterizes as indirect costs investment in infrastructure (road network, traffic services and parking).
Traffic congestion is one of the main external factors and it causes harmful effects on drivers, pedestrians and public transport users, as well as increasing the atmospheric, noise and visual pollution and journey time.
According to Torres (2007, p. 22) congestion may be categorized as:

- **Circulatory**: related to the excessive number of vehicles in relation to the road capacity;
- **Destination**: related to the time wasted in searching for a parking space;
- **Recurrent**: repeated and possibly seasonal occurrences in cycles;
- **Non-recurrent**: random occurrences that are caused by contingencies such as accidents, special events or weather conditions;
- **Arterial**: restricted to a section of the network, on a structural or arterial road that does not compromise the rest of the network;
- **Network**: occurs in a part of the network, or all of it.

According to Torres (2007), the classifications and typologies are not mutually exclusive, but they can be interdependent. Some examples mentioned are the circulatory and destination congestion being related, since the increase in the number of vehicles results in a decrease in the number of parking spaces available and an increase in demand.
According to Litman (2002), the dependency on automobile use leads to an increase in infrastructure costs, creating the need to expand the road network by up to three times the size that would be required under a more balanced model. This generates greater occupation of physical and symbolic space, depending on the means of transport, speed and idle (parked) time (Torres, 2007). Figure 1 shows the occupation of road space, by means of transport.

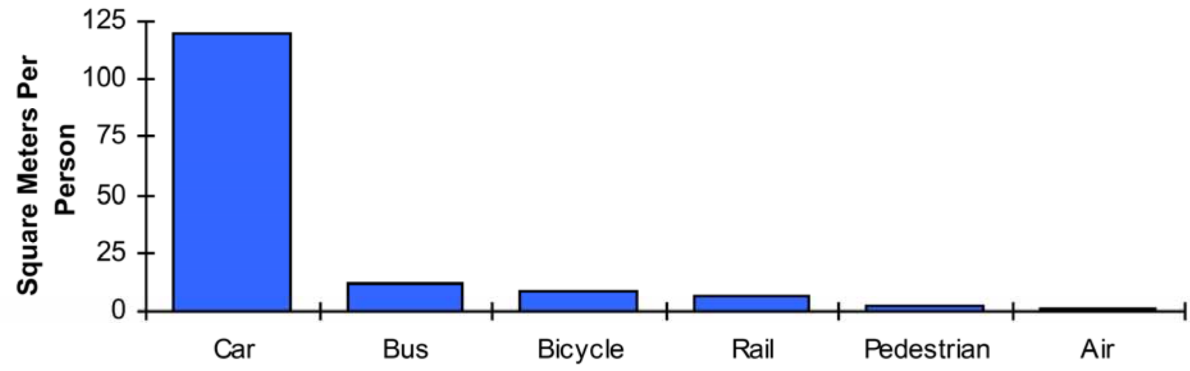

Fig. 1 Road Space By Mode

It is clear that the car is by far the transport mode that occupies the most road space, followed by buses, bicycles, trains, pedestrians and air travel. According to Torres (2007), what causes traffic congestion is people's need to move from one place to another, or the need for mobility. However, it is the concentration of automobiles and the limited road space that determines the congestion. The author also notes the space-time aspect of congestion, whereby "journeys with great time elasticity can be transferred to other less heavy hours, thereby avoiding traffic jams". However, it is the objectives or activities to be performed that impose limits on reorganization. Consequently, it is the rush hours (time for going to work, school, etc; lunch time; coming home from work, school, etc.) that will determine when and where the traffic jams will occur. The annual cost of congestion in São Paulo has reached R$ 350 million and in Rio it is R$ 70 million (IPEA/ANTP, 1999; Torres, 2007).

According to Torres (2007, p. 28) there are two approaches for dealing with the problem of congestion:

- **Traffic Engineering**: treats the phenomenon as an inadequacy in the ratio between the supply and demand for road capacity and studies vehicle circulation based on the relations between the three main variables: speed, flow and density;
- **Economics**: treats congestions as a failure by the market mechanisms to achieve a balance between supply and demand. It states that congestion is caused by the fact that the road transport products and consumers do not consider the external costs that are borne by others. They consider only the internal costs in their transportation decisions.

IPEA (Institute for Applied Economic Research) and the ANTP (National Public Transport Association) conducted a study in 1999 aimed at evaluating the impact of congestion in terms of cost. The main effects identified were: excessive time spent on main and tributary roads, fuel consumption, air pollution, direct operational costs, cost of establishing and maintaining the road network, and the urban space occupied by automobiles and buses. The study provided an analysis of the diseconomies (costs) generated by congestion in ten Brazilian cities and Table 4 shows the results.

City	Additional time lost (million passenger hours)		Additional fuel consumption (million liters))		Additional pollution emissions (t)						Road network	
					Cars		Buses					
	Cars	Buses	Cars	Buses	HC	CO	HC	CO	NOx	MP	For circulation (m^2)	For parking (m^2)
Belo Horizonte	6,06	40,54	5,57	0,55	252,59	2.851,91	22,66	55,44	39,88	1,98	246.318,75	61.579,69
Brasilia	0,50	2,41	0,57	0,11	20,40	178,58	3,06	7,48	5,38	0,27	457.800,00	114.450,00
Campinas	3,51	2,45	4,10	0,20	181,92	2.012,79	8,05	19,69	14,17	0,70	193.687,50	48.421,88
Curitiba	2,82	2,37	2,50	0,06	115,07	1.309,74	2,92	6,56	4,72	0,23	14.347,50	3.586,88
João Pessoa	0,77	1,21	0,60	0,05	27,46	310,70	1,84	4,51	3,25	0,16	122.910,00	30.727,50
Juiz de Fora	0,18	1,69	0,14	0,05	6,68	76,24	2,11	5,16	3,71	0,18	-	-
Porto Alegre	3,00	3,42	2,57	0,18	116,10	1.309,78	6,93	16,96	12,20	0,60	79.031,25	19.757,81
Recife	1,79	3,67	1,36	0,11	66,38	759,62	5,42	14,22	9,53	0,82	117.750,00	29.437,50
Rio de Janeiro	33,03	80,41	35,85	2,11	1.605,43	17.884,39	86,44	209,75	150,89	7,48	206.100,00	51.525,00
São Paulo	198,43	117,87	198,53	3,65	8771,38	95.992,53	157,65	385,76	277,50	13,75	5.551.496,25	1.387.874,06
Total	**250,09**	**256,03**	**251,79**	**7,06**	**11.163,42**	**122.686,26**	**297,08**	**725,53**	**521,22**	**26,17**	**6.989.441,25**	**1.747.360,31**

Tab. 4 Summary of total annual costs caused be severe traffic congestion in ten cities

As the table above shows, the cities of Rio de Janeiro and São Paulo present the worst results, mainly due to being the largest and most populous cities in the country. Two important details are that in the ten cities there is additional time wasted totaling over 500 million passenger hours, due to the congestion in these cities, and the amount of space devoted to parking totals 1,747,360.31 m^2. Taking into account that this study is from 1999 and that, in the last 14 years, it is estimated that the automobile fleet has grown by more than 50%, one can imagine how much worse these numbers would be today. According to Torres (2007), there are three possible steps that can be taken by the administrators:

- **Non-intervention**: involves letting congestion reach its saturation peak. This is based in the concept whereby congestion is a natural phenomenon and a normal consequence of road traffic. In other words, with the increase in congestion there will be a tendency for some drivers to stop using the automobile and turn to other means of transport, or at least to take alternative routes;
- **Supply Side**: involves increasing road capacity by building new roads or widening and duplicating existing roads. The increase in road space will involve employing Traffic Engineering techniques in road expansion and the regulation and coordination of traffic lights. This is the main emphasis given to traffic management and planning in Brazil and it can generate increased demand (generated traffic and induced demand), due to the increase in the supply of road space. According to Litman (2012), "generated traffic and induced demand" can be defined as the increase in journeys resulting from an increase or improvement of the road system. While congestion can lead to migration or displacement of journeys to alternative routes or to a changing of travel time, the improvement of the roads can lead to an expansion in the number of automobiles. According to Toralles and Paulitsch (2010), "the increase in road capacity creates space for new automobiles and also for those that were not previously circulating, because their drivers were put off by the state of saturation". Meanwhile, Downs (1992, *apud* Litman, 2012 and Torres, 2007) introduces the concept of "triple convergence", which is the transfer of users from other roads (spatial convergence), times (temporal convergence) and other types of transport (modal convergence), due to, among other reasons, the increase in capacity and improvement of the road system. According to the author, a solution to "triple convergence" would be regulation through "urban tolls", which would bring about "triple divergence" (transfer of journeys to other roads, times and types of transport);
- **Demand Side**: According to Torres (2007), demand management will have the objective of inducing demand, be it in a coercive manner or by developing awareness, to alter its travel behavior and seek more sustainable means of transport. It involves acting to minimize the use of the automobile through regulation, which is achieved through public sector intervention on three fronts: physical, institutional and pricing.

Physical intervention involves the prohibition and restriction of the circulation of vehicles on specific roads, in certain locations and at certain times, following defined criteria. An example of this occurs in São Paulo, with the "license plate rotation" and "rush hour operation" and in Mexico City, with "*Hoy no circula*". This type of restriction can lead to the acquisition of a second vehicle or to fraud (Torres, 2007; Toralles and Paulitsch, 2010). Economic regulation involves the reduction or prohibition of circulation on specific roads or in certain locations, subject to payment of a fee, such as an urban toll. Examples of this are the toll on the "*Linha Amarela*" express highway and on the Rio-Niterói bridge, as well as London's "Congestion Charge", which started in 2003 and was the pioneer for this type of intervention. According to Kelly and Clinch (2006), for transport demand management (TDM), the urban toll is the best alternative, followed by parking policy and charges.

Quoting Torres (2007), there are a few strategies that can be utilized in demand management:

- **Regulating the ownership and use of private automobiles**: restrictions on the ownership of vehicles and parking spaces, with a system of acquisition quotas;
- **Limiting parking space**: physical control by suppression of parking spaces, reservation of spaces for certain user categories and charging parking fees.;
- **Controlling moving vehicles**: Segregated traffic and selective access;

– **Regulating through taxation**: taxation of vehicle ownership, paid parking, fuel taxation and fees for distance traveled.

3 ANALYSIS AND REFLECTION

Gomide and Morato (2010) state that, according to economic theory, the most effective measure for discouraging the use of the automobile and canceling out the external factors would be through toll fees, based on the costs generated by automobile use. The resources raised could be utilized for improving the public transport and the development of non-motorized transport.

Urban charges would be aimed at limiting the circulation and use of vehicles in specific areas and locations. The main form of urban charge is the urban toll fee, which was first used successfully in 1974, in Singapore, and remains in operation to this day (Toralles and Paulitsch, 2010).

In Brazil, the main examples of urban tolls are the on the "*Linha Amarela*" and the "Rio-Niterói bridge". The best known case and a successful example of an urban toll is in London, which was implemented in 2003 and innovated by linking urban traffic management and fund raising for improvement and expansion of public transport and non-motorized transport.

The toll can be classified as: a financing or concessionary toll, aimed at raising funds for investment in infrastructure and not for regulating demand; or regulatory or environmental.

According to Torres (2007), there are three types of urban toll, according to the method of application:

	Arterial Toll	ALS Toll	Zonal Toll
Main purpose	Infrastructure financing	Traffic control in a specific area	Traffic control in a specific area
Scope	A single highway, bridge or tunnel	All roads within the specific area	All roads within the specific area
Fee-generating trigger	Going through the road billing point (toll plaza)	Crossing the limit for access to the restricted area	Entering, circulating or parking within the specific zone
Form of inspection and billing	Manual or automatic at the toll plaza	Electronic inspection and automatic billing	Electronic inspection and automatic billing
Billing period	Every day (24/7)	Morning and afternoon on business days	Morning and afternoon on business days
Rate flexibility	Fixed fee	Variable: higher during rush hour	May be fixed or variable
Effectiveness in fee collection	High	Low	Low
Effectiveness in reducing congestion	Low	High	High
Examples	Rio-Niterói bridge	Singapore	London

Table 5: Main types, characteristics and examples of congestion fees.

The urban toll has shown itself to be a viable and efficient alternative for regulating and managing urban mobility. In London, for example, since its introduction in 2003, it has brought about a 30% reduction in congestion, diminishing the circulation of vehicles and increasing the use of non-motorized transport. It provides an incentive to other types of more sustainable transport.

Many cities in the world, besides those already mentioned, have implemented or are planning to implement the urban toll fee as a way of regulating urban traffic, and among them are Milan, in Italy, Stockholm, in Sweden, San Francisco, in the USA, Manchester and Cambridge, in the UK, and Barcelona, in Spain. In Brazil there have been moves along these lines in São Paulo, Campinas and Salvador (Torelles and Paulitsch, 2010).

Table 6 presents some of the experience with the implementation of urban toll fees in various countries, along with the benefits and forms of application. As can be seen, the urban toll systems provide considerable benefits and are economically viable.

However, their efficiency depends on the use of intelligent traffic control systems and investment in public and non-motorized transport. In fact, the use of these systems should be aimed at encouraging the use of means of transport other than the automobile.

According to Hau (1992) and Torres (2007), the following driver behavior is likely to occur when faced with the implementation of a toll system: pay the toll fee; use toll-free routes; change the time of journeys (outside billing hours); change to other types of transport; change the destination or cancel the journey.

Care must be taken not to cause congestion on other roads outside the toll zone. This can be done through traffic monitoring on all roads. To obtain the desired success, significant investment is necessary in sustainable mobility alternatives, giving priority to non-motorized transport. Some cities around the world have developed successful educational and even prohibitive campaigns.

In Bogotá (Colombia), a network of bicycle lanes was built that was integrated with the BRT (*Bus Rapid Transit*) system and there was a "Car-Free Sunday Program" that combined to reduce the automobile traffic by 40%. It is recommended that the toll system be directed towards promoting and economically supporting more sustainable urban mobility systems. Some precautions should be taken to ensure the success of the toll system, among which is the matter of popular approval. This is possible when there is transparency regarding the expected results (social, environmental and economic benefits), the collecting of funds and investment of economic resources. Moreover, it is necessary to seek political approval and support, so that it can become integral to a larger long term program for urban mobility.

It is important to emphasize that the urban toll fee should be part of an overall mobility program, including expansion of the public transport network and improving its quality.

This would provide options and would meet the extra demand of automobile users who opt for public transport due to the urban toll. In other words, there is no point introducing the toll without first offering mobility options, especially for those who are unable to pay the toll fee.

As noted by Kottenhoff and Freij (2009), the urban toll model introduced in Stockholm, Sweden, was a good example, as part of a three-part public policy package: the congestion fee, the expansion of public transport and improvement of the roads and access areas.

Moreover, it was an inter-sectorial action plan involving six phases, starting with the expansion of public transport and the subsequent introduction of the fee. And it was precisely the improvement of the public transport that contributed decisively to the popular acceptance of the urban toll fee. The improvement and expansion of the public transport network and non-motorized transport help to justify the introduction of the fee and facilitates its acceptance by the population.

Different configurations can arise from the proposal to introduce an urban fee, as shown by Ieromonachou, Potter and Warren (2007), who compared the introduction of a toll at cities in the UK (Durham and London) and Norway (Bergen and Oslo). It was found that there were different levels of popular acceptance, forms of investment, technologies used, public sector performance and needs met. The important thing is that in all cases, the efforts were successful.

The urban toll is not the only form of urban charge aimed at managing the traffic and the transport demand. Although, for decades, parking was treated as just a part of the fixed cost of travel, many studies have been carried out that highlight the use of parking fees as a strategy that offered an alternative or was complementary to the urban toll for regulating urban traffic, including those of Barata, Cruz and Ferreira (2011), Caicedo and Diaz (2013), Kelly and Clinch (2006) and Ieromonachou, Potter and Warren (2007).

In their study, Kelly and Clinch (2006), for example, examined how different price bands can affect the behavior of demand, in a study carried out in Dublin, Ireland.

As shown by Ieromonachou, Potter and Warren (2007), an urban toll is not always sufficient to bring about a reduction in motor vehicles. In Bergen, Norway, after the introduction of the urban toll, the number of motor vehicles actually went up, but the traffic management involved a mix of toll fees and control of the quantity and prices of parking spaces. Parking fees went up 20 times faster than the toll, leading to a diminishing of traffic within the city.

Caicedo and Diaz (2013) emphasized that, in developing countries, it is common for illegal use to be made of urban space for parking and that the control and billing, as well as being a source of funds for investment to meet social demands, also increases the level of control over the circulation of vehicles.

The free supply of parking, whether legal or illegal, encourages automobile use and consequently increases the demand. In some cases, according to Murray (2001), charging for parking can be used to balance the use of the public transport system with automobile use, especially when use of public transport has been rejected.

Moreover, different agents, such as public and private institutions, can be used in this strategy, both in the planning and the execution. The operation of parking areas can receive public and private resources, directly or indirectly. In Brazil, for example, it is common for the state to make improvements in infrastructure and subsequently grant and regulate a concession to a private company or consortium. In any case, it is an interesting and effective strategy.

In Brazil there are major barriers to the introduction of urban tolls, among which is the low quality, variety and efficiency of the public transport.

Furthermore, most of the political decisions on mobility are taken in a disorganized manner and the country has a strong tendency to make inefficient use of public resources. Long-term policies are always tied to keeping a particular group or political party in power, otherwise decisions only last until the end of the political term, leading to a lack of continuity in the development and implementation of public policies. There is still no tradition of organizing mobility policies along with other important sectors, such as housing, education, health and administration, which hinders their effectiveness.

An example of this was the license plate rotation introduced in São Paulo in 1997, with the aim of curbing automobile use and encouraging the use of public transport.

However, since there was no significant improvement or expansion of the public transport to meet the likely increase in demand, it ended up stimulating the purchase of a second vehicle with a license plate that could be used on different days.

The result is that São Paulo became the only city in Brazil in which the use of private transport is greater than that of the public transport.

4 FINAL CONSIDERATIONS

This paper was aimed at demonstrating the effectiveness of the urban toll as a system for mobility management and reducing congestion and automobile use. It was possible to ascertain that there are significant operational and environmental gains. It also leads to improved transport efficiency a changing habits in the movement of people. It was also possible to verify in the examples that the system is economically viable and can be the principal means of financing more sustainable mobility. A limitation of the work is the lack of models and examples in Brazil that would have allowed a broader and approach that compared local examples with other models adopted around the world. In future work, other approaches may be developed, such as the matter of determining the ideal price for the fees, operational aspects, and the use of information and communication technology in the toll systems, among others.

REFERENCES

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy,* 15(2), 73-80.

Banister, D. (2005). *Unsustainable transport: city transport in the new century*. London, UK: Routledge.

Barata, E., Cruz, L., & Ferreira, J. P. (2011). Parking at the UC campus: Problems and solutions. *Cities*, 28(5), 406-413.

Barczak, R., & Duarte, F. (2012). Impactos ambientais da mobilidade urbana: cinco categorias de medidas mitigadoras. *Revista Brasileira de Gestão Urbana*, 4(1), 13-32.

BRASIL (2007) SEMOB - *Plano de mobilidade urbana*. Brasília: Ministério das Cidades.

Burton, K. J. (1993). *Transport economics*, 2nd ed. Cheltenham, UK: Edward Elgar.

Goh, M. (2002). Congestion management and electronic road pricing in Singapore. *Journal of Transport Geography*, 10(1), 29-38.

Caicedo, F., & Diaz, A. (2013). Case analysis of simultaneoous concessions of parking meters and underground parking facilities. *Transport Research Part A*, 49, 358-378.

Duarte, F., Sanchez, K., & Libardi, R.(2012). Introdução à mobilidade urbana. Curitiba, Juará, 2012.

Fan, W., Khan, & M. B. (2012). Modeling the parking pricing of multiple parking facilities under diferente operation regimes. *Journal of Transportation Techonologies*, 2, 260-266.

Gomide, A., Morato, R. (2011). *Instrumentos de desestímulo ao uso do transporte individual motorizado:* lições e recomendações. São Paulo: Instituto de Energia e Meio Ambiente, Série Temas em Debates.

Ieromonachou, P., Potter, S., & Warren, J.(2007). Analysing road pricing implementation processes in the UK and Norway. *European Journal of Transport and Infrastructure Research*, 7(1), 15–38.

IPEA (Instituto de Pesquisa Econômica Aplicada); ANTP (Associação Nacional dos Transportes Públicos). (1999) Redução das deseconomias urbanas com a melhoria do transporte público. *Revista dos Transportes Públicos* - ANTP - ano 21, 1º trimestre.

Kelly, J.A., & Clinch, J.P.(2006). Influence of varied parking tariffs on parking occupancy levels by trip purpose. *Transport Policy*, 13, 487-495.

Kottenhoff, K., & Freij, K.B. (2009). The role of public transport for feasibility and acceptability of congestion charging : the case of Stockholm. *Transportation Reseach Part A*, 43, 297-305.

Litman, T.A. (1993). Socially optimal transport pricing and markets – Principles, strategies and impacts. *Victoria Transport Policy Institute.* <*www.*vtpi.org> (June 2013.).

Litman, T. A. (2009). Sustainable transportation indicators: a recommended research program for developing sustainable transportation indicators and data. In *Transportation Research Board 88th Annual Meeting* (No. 09-3403).

Litman, T. A. (2005). London congestion pricing: Implications for other cities. *Victoria Transport Policy Institute*. <www.vtpi.org> (June 2013.).

Litman, T.A. (2002). The costs of automobile dependency and the benefits of balanced transportation*. Victoria Transport Policy Institute..* <www.vtpi.org> (June 2013.).

Murray, A. (2001) Strategic analysis of public transport coverage. *Socio-Economic Planning Sciences*, 35(3), 177-188.

Orrico, R., Affonso, N., De Bonis, R., & Oliveira, M. (2012) *Mobilidade urbana sustentável: questões do porvir*. COPPE/UFRJ.

Ramani, T.L. (2008). *An improved methodology for multi-criteria assessment of highway sustainability.* Master of Science Thesis, Texas A&M University.

Richardson, B.C. (2005). Sustainable transport: analysis frameworks. *Journal of Transport Geography*, 13, 29-39.

Secretaria Nacional de Transporte e Mobilidade Urbana - SEMOB (2007). *PLANMOB*: caderno de referência para elaboração de plano de mobilidade urbana. Brasília: Ministério das Cidades. <http://www.cidades.gov.br/images/stories/ArquivosSEMOB/Biblioteca/LivroPlanoMobilidade.pdf>. (March 2012).

Toralles, C.P., & da Silva Paulitsch, N. (2010). Vehicular restriction and taxation: the congestion charges as urban solution and kind tax. *Revista Brasileira de Gestão Urbana*, 2(2), 179-190.

Torres, H.M., (2007) *Eficiência, equidade e aceitabilidade do pedágio urbano*. PhD thesis, Universidade Federal do Rio de Janeiro.

May, A., & Ison, S. (2008). Decision-support for sustainable urban transport strategies. Transport Policy, 15(6), 325-327.

Wu, W.X., Sang, H.Y. (2014). Determining the toll and capacity of a highway to be constructed in parallel with subway. *Mathematical Problems in Engineering*, 2014, 1-9.

IMAGE SOURCES

Tab. 1: Orrico et al. (2012, p.8) (Adapted)

Tab. 2: ANTP (2010, apud Gomide and Morato, 2011)

Tab. 3: ANTP (2010, apud Gomide and Morato, 2011)

Tab. 4: (IPEA and ANTP, 1999)

Tab. 5: Gomide and Morato (2010, p. 22)

Fig. 1: Litman (2002, p. 15)

AUTHOR'S PROFILE

Cristiano Souza Marins

Phd in Transportation Engeneering at Federal University of Rio de Janeiro

Romulo Orrico Dante Filho

Professor of Transportation Engeneering at Federal University of Rio de Janeiro

Wellington Nascimento Silva

Phd in Transportation Engeneering at Federal University of Rio de Janeiro