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Working Paper

Evolution of the Transport System in Santiago de Chile: Stopping the car vicious circle?

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Abstract

This paper makes a review of the transport policy for Santiago de Chile for the period 2000-2010. Its aim is to be critical but constructive in relation to this policy, as the discussion will not only help the transport Chilean community, but also practitioners from other countries in the same stage of evolution of its transport systems. First, a description of the Santiago's urban characteristics is made. Next, comparing the 1991 and 2001 Origin and Destination Trip Surveys the evolution of Santiago's transport system is illustrated. The numbers show that the city is following the well-known car-public transport vicious circle that developed countries have gone through. Then, the Santiago's transport policy is summarised and discussed. During this discussion, we raise a number of concerns about some of the measures to be implemented for consideration of decision makers as well as for the transport professionals, which will ultimately have the responsibility of assembling the policy on the street.

1. Urban facts about Santiago

The Metropolitan Region of Santiago, Chile has a population of 6.1 million inhabitants and an area of over 15 thousand km^2. It concentrates 40% of the population of the country, 15.1 million people. According to the latest census, the population of the Metropolitan Region of Santiago has grown in a 15.3% during the last 10 years (INE, 2003). There is located Santiago City, the capital of Chile. It has a population of 4.7 million inhabitants and covers a continuing area of

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62,000 hectares. This “urban spot” has expanded in a 25% during the period 1991-2000 (Ducci, 2002).

The city of Santiago de Chile is divided administratively into 32 municipalities. However, for the purpose of the transport system study, other municipalities in the Region that have progressively become united to the city are added. For example, the Origin and Destination Trip Survey 2001 Great Santiago (SECTRA, 2002) considered 38 municipalities, with a total of 5.6 million inhabitants and a catchment area of 480,000 ha. This set of urban units linked among them is usually called “Gran Santiago”. In the following we call this study area as “Santiago”.

The average density of Santiago is of 78 inhabitants per hectare. This density may be considered low for the standards of developed countries, but it presents a great variability between poor and rich municipalities. Thus it may go down to less than one inhabitant per hectare at higher income suburbs (0.73 inhab/ha in Lo Barnechea), up to 150 inhab/ha in low income municipalities (v.g., Lo Espejo, Lo Prado, San Ramón). Average earning municipalities have intermediate densities; thus, Santiago municipality (downtown or CBD), Providencia and Ñuñoa have 90 inhab/ha. Others of higher income as La Reina and Las Condes vary between 25 and 40 inhab/ha, respectively.

In geographical terms, income distribution is quite segregated in Santiago. The greater proportion of municipalities with higher income households is located in the northeast quadrant of the city. Most average earnings are located in the central perimeter. All the rest of the city presents a high percentage of low-income households.

In short:

- Santiago is a city with a population of 5.6 million inhabitants, equivalent to 37% of the population in the country.
- Average density of Santiago is lower than 100 inhab/ha, but it ranges from less than 1 to over 150 inhab/ha, depending on the income level.
- Santiago is strongly segregated. High-income households are concentrated on the NE of the city; the rest corresponds to average and low earnings households.
- These particularities of Santiago contribute to the characteristics of its transport system, as it will be seen hereinafter.

2. Transport system and evolution

According to the 2001 Origin and Destination Trip Survey (SECTRA, 2002) in Santiago there are almost 16.5 million trips during a typical working day. Thus, trip generation average rate is 3 trips per inhabitant. At peak morning hour (07:30-08:30) 11.4% of all daily trips is made (1.9 million).

Of these trips, 62.5% are made by motor vehicles. The remaining 38.4% is made on foot or bicycle. A 55.7% of daily trips have a different destination from the place of work or of study; meanwhile 26.2% are to the working place and

18.0% to a place of study. An important characteristic of trips of study is that school students and 60% children in primary school make more than 80%.

The total quantity of cars in Santiago is approximately 850 thousand vehicles, with an average of 0.56 vehicles per household, equivalent to 140 vehicles for every 1000 inhabitants, a little higher than the national average (130). Nevertheless, variance in the motoring rate is high between municipalities with different income levels. In this way, the lowest income municipality has only 0.18 automobiles per household; meanwhile the highest income one has 1.65 cars per household.

Summarizing, some particulars of the transport system in Santiago are:

- The average motoring rate is low – as compared with developed countries – but its variance is highly dependent on the income level.
- Almost 3 trips a day are generated per inhabitant in Santiago.
- Over half of the trips have a destination different from the place of study or of work.
- Most of the students' trips correspond to children under the age of 13.

The current distribution of trips by a means of transport (modal share) in Santiago is shown in Table 1 and its order of importance is presented in Fig. 1. This order, with slight variations, stays on during peak morning hour.

From Table 1 and Fig. 1 it can be concluded that:

- The main way of transport is walking.
- This is followed by bus journeys.
- Car journeys are only in the third place.
- The metro captures less than 5% of all trips.

Table 1: Modal share in Santiago

Mode	Number of Trips [trips/day]x10^6	Modal share [%]
Car	3.88	23.5
Bus	4.27	25.9
Metro	0.74	4.5
Taxis[1]	0.61	3.7
Walking	6.02	36.5
Other[2]	0.97	5.9
TOTAL	16.49	100.0

[1]: taxis and shared taxis
[2]: school buses (414,000), bicycles (313,000), motorcycles, train and others.

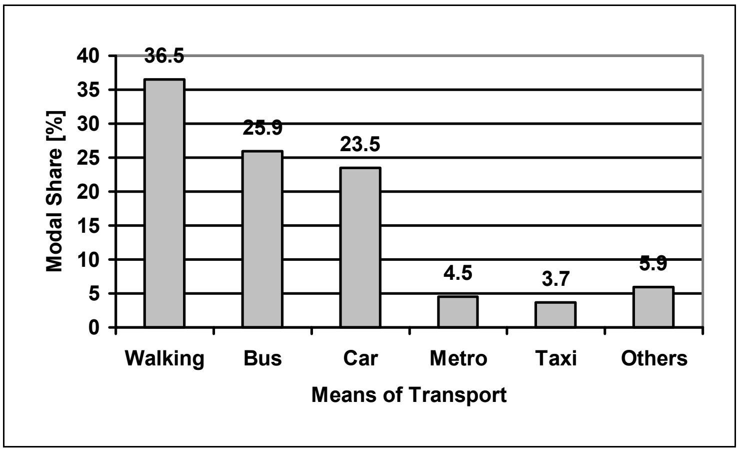

Fig. 1: Ranking of modal share in Santiago

Another distinctive characteristic of Santiago is that still the greatest part of motor trips (55.5%) corresponds to public transport: buses, metro and taxis. The rest corresponds to some private means. The main way of public transport are buses (42.1% of motor trips), followed at a long distance by use of the metro (7.4%). The reason is that the metro network has only 3 lines and 49 stations, meanwhile buses cover the city with 353 routes and more than 7,500 stops. However, this infrastructure is going to be the object of important changes from the year 2005 onwards, as stated bellow.

Buses in Santiago provide a good accessibility in terms of coverage and frequency, plus their operation in a "hail-and-ride" way – i.e. they stop on demand – along most part of its route. Also its commercial speed is reasonable. Nevertheless, other characteristics of the Level Of Service (LOS) are deficient (safety, comfort, and reliability).

Vehicle speed in Santiago is one third lower for buses than for cars, but it is still high as compared with other cities. Table 2 shows average speed obtained from measurements carried out in 1,000 km sectors of the road network.

Table 2: Average speeds in Santiago's road network

Period [hours]	Average Speed [km/h] Cars	Average Speed [km/h] Buses	Difference [km/h]
07:00-07:30	43	30	-13
07:30-08:30	35	24	-11
08:30-09:00	39	26	-13
10:00-11:00	42	27	-15

Motorization rate doubled in Santiago between 1991 and 2001. In 1991 there were only 70 automobiles per every 1,000 inhabitants. At the same time the number of cars increased in almost 102%. This increase in car ownership caused that the way in which trips are made changed substantially, as shown in Fig. 2.

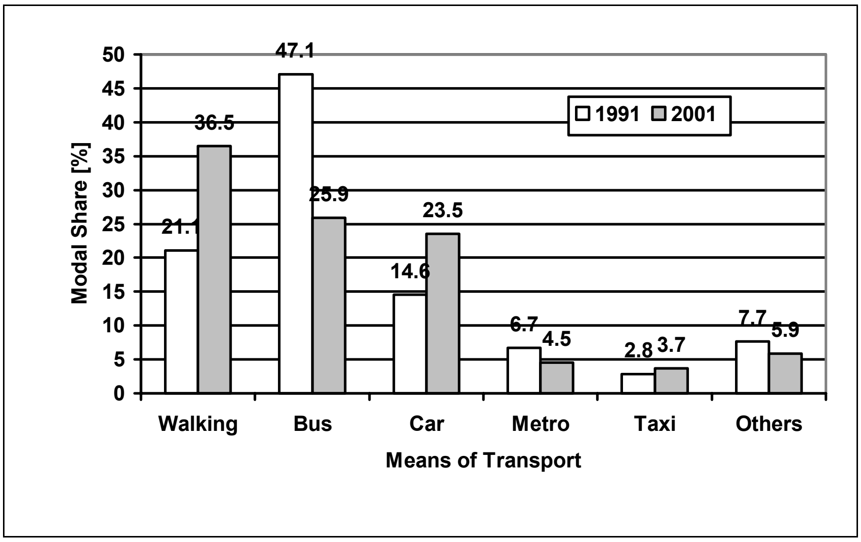

Fig. 2: Evolution of modal share in Santiago 1991-2001

The information collected by the Origin and Destination Trip Survey revealed that between 1991 and 2001 a dramatic change took place as regards proportion of trips performed in public transport and private car. Considering only motor trips, bus trips decreased from 59.6% to 42.1% and metro trips decreased from 8.5% to 7.4%. In contrast, car journeys climbed up from 18.5% to 38.1%. So the nearly 20 percent points the main ways of public transport declined in combination were compensated by the private car. This took place within a context of extremely high urban expansion in the last 15 years.

The change in modal share during the period 1991-2001 is due mainly to the decrease in number of low-income households and the strong increase of those of average and high earnings. This caused that the car ownership rate of low-income households – usually captive by public transport – increased, as shown in Table 3.

Table 3: Variation of income and car ownership in Santiago 1991-2001

Variables by income	Years		Variation
	1991	2001	[%]
No of households by income			
Low[1]	799,000	303,000	-62
Medium[2]	246,000	994,000	+304
High[3]	45,000	215,000	+378
Motorization [car/household]			
Low	0.146	0.171	+17
Medium	0.713	0.472	-34
High	1.732	1.479	-15

[1]: Under 8,000 US$ a year
[2]: Between 8,000 and 28,000 US$ a year
[3]: Over 28,000 US$ a year

A detailed analysis for the period under study is the variation in modal share of the principal motor trips, according to the level of earnings of the Santiago population. A summary of this variation is presented in Table 4.

Table 4: Evolution of modal share by income level in Santiago 1991-2001

Income and mode	Modal share [%]		Variation
	1991	2001	[%]
Low income			
Metro	7	4	-43
Bus	71	55	-23
Automobile	8	22	+175
Medium income			
Metro	12	7	-42
Bus	44	46	+5
Automobile	31	31	0
High income			
Metro	8	9	+13
Bus	16	16	0
Automobile	64	65	+2

According to the table, a dramatic increase on car use is observed in low-income strata; meanwhile in medium and high-income groups the variation is not significant. A clear decrease of the use of the metro is also observed in the low and medium income strata. Only in the high-income stratum there is a small increase of its use. Consistently with the increase in car use, buses loose patronage from the low-income stratum and, in practical terms, the use of buses is maintained in the medium and high strata.

In summary, the evolution in the use of the Santiago transport system in the period under analysis may be characterized as follows:

- The number of cars has more than doubled.
- As a product of economic growth, car ownership has doubled in a period of 10 years.
- The greatest increase in the car ownership has taken place in the lowest income stratum, usually captive of public transport.
- As a consequence, the use of public transport has been dramatically reduced, increasing that of the private car.

If this trend keeps on, the predominant way of transport in Santiago will be the private car. This shall have the well-known consequences on emissions and traffic congestion, due to the car/public transport vicious circle that developed countries have gone through (Ortúzar and Willumsen, 1990), as shown in Fig. 3.

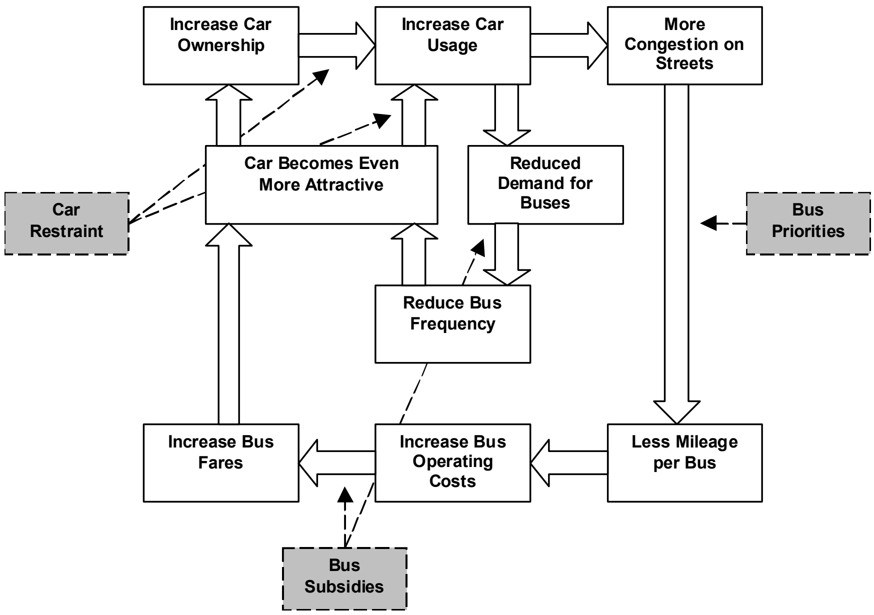

Fig. 3: Car/public transport vicious circle and breaking measures (Ortúzar and Willumsen, 1990)

The measures to revert the vicious circle of public transport deterioration are shown in the shaded rectangles of the figure. Bus priorities have the objective of protecting buses from the congestion caused by cars or between buses; e.g. bus lanes, "busways" (exclusive ways), changes in traffic lights settings and proper design of bus stops. Car restraint seeks a more rational use of these vehicles; e.g. control of parking places, traffic calming (traffic and speed reduction zones) and congestion charging in certain areas. Bus subsidy pursues that the operation cost increase due to congestion or revenue reduction due to a lower demand does not mean fare increase or service frequency deterioration. This subsidy can be delivered to bus operators or to bus users. The application of some of these measures for Santiago is reviewed hereinafter.

3. The transport policy for Santiago

Santiago has seen at least three transport plans in the past 15 years. Some of them have been developed partially. Others have been partially skipped because of lack of funds. For example, in the 1995-2005 plan there was the intention of building 75 km of busways in order to keep the bus patronage. However, taken as excuse the Asian crisis only investments in urban motorways and metro extensions were carried out. As a result of the failure of previous plans, in the year 2000 the new Government set up the "Urban Transport Plan for Santiago 2000-2010" (PTUS for its Spanish acronym). This plan tries to restore some of the missing pieces of the previous ones in an attempt to produce a comprehensive effort to amend the evolution of the travel behaviour towards a car-dependent city.

3.1. *Overview of PTUS 2000-2010*

As defined in the PTUS, this is an instrument that "shall inspire and arrange any initiatives needed to provide Santiago with an efficient and modern transport system that is both economically and environmentally sustainable and, above all, consistent with mobility, accessibility and quality of life requirements" (MOPTT, 2000).

PTUS is based on the following policy definitions as guiding principles for its programs and initiatives:

- Promotion of public transport as the principal means of transport in the city, and car usage rationalization.
- Rationalization of trends in housing and production location.
- Increased participation and responsibility of non-government players involved in issues related to the city and quality of life. Also increased participation and responsibility of citizens.

PTUS objectives can be summarized as follows:

- Maintaining the present modal share of the public transport (at the year 2000).
- Reducing average trip length.
- Promoting non motorized transport – i.e. pedestrians and bicycles.
- Creating awareness of the actual mode option costs among private car users.
- Reducing air pollution from transport.
- Promoting a rational urban development.

PTUS consists of 12 programs, the actions of which are briefly described hereunder.

P1. Public transport modernization. Redesigning the public transport system to include improvement of information systems for users; technological service upgrading; offer diversification; physical, operational and fare integration in different modes, such as metro, suburban trains, vehicles, etc.; infrastructure for public transport; incentives for operators to entrepreneur and drivers to professionalism.

P2. Road investment and private transport regulation. Traffic congestion control via congestion charging; traffic management by the Area Traffic Control Unit (UOCT in Spanish) of Santiago; parking control; development of road infrastructure and maintenance projects; creation of a compensation chamber for revenues from tolling and parking.

P3. Relocation of schools. Preventing the concentration of schools in a few municipalities, and increasing the number of admissions available in deprived areas, including subsidies to establish private schools in poor areas of the city.

P4. Promoting new shopping and service areas. Developing new shopping and service areas to prevent long distance trips. Subsidies are being proposed to develop some city sectors with already visible autonomous commerce.

P5. Changing household location trends. Introducing subsidies for middle and lower-middle class housing, as well as low-cost housing, thus favouring already firmly settled municipalities that can accommodate new households, such as Santiago's downtown.

P6. Promoting non-motorized transport modes. Creating explicit facilities for pedestrians and bicycles through pedestrian areas, particularly in downtown, and a cycle network that will cover most of the city; developing initiatives to promote combined bicycle-metro trips.

P7. Short-term scheme. Traffic management initiatives defined in March 2001 consisting of: Six roads exclusively used by buses during morning peak hours (07:30-10:00), three – of the existing five – lanes physically reserved for buses in the main city avenue (Alameda Bernardo O'Higgins), and eight tidal flow roads in place during morning (07:30-10:00) and evening (17:00-21:00) peak hours.

P8. Urban freight transport regulation. Freight transport regulations ruling the city road network; creation of freight stock and transfer centres; enforcement of regulations applicable to transported materials: weight, load/unload and spill out.

P9. Enforcement. Strengthening the enforcement mechanisms, improving their efficiency through new technologies; empowering citizens with enforcement tasks, improving the reporting and communication systems with authorities.

P10. Funding. Appraising the investment required to implement the PTUS, designing and implementing the funding mechanisms, and defining an investment schedule.

P11. Dissemination and public consultation. Conducting a citizen participation process to disseminate and collect opinions regarding the PTUS; developing a training process for transport system users at different levels: students, youth, adults and drivers.

P12. Administration. Establishing a PTUS Manager responsible for the implementation of the different programs, and reporting to regional and national authorities.

Below are discussed some of the most relevant PTUS programs. These deal with public transport improvement (P1), road investment and private transport regulations (P2), incentives for non-motorized transport modes (P6) and short-term scheme (P7).

3.2. *Public transport improvement*

The public transport system in Santiago has increasingly deteriorated over the past two decades. This results in collapsed services and infrastructure, increasingly longer trips and environmentally unfriendly operations. The operation of public transport buses currently rests on inefficient and informal businesses, with inadequate routing structures, vehicle owners under a presumptive income tax regime, and a series of labour law violations.

Modernizing public transport in Santiago in a comprehensive fashion is one of the key commitments undertaken by the Chilean Government. One product of this challenge is called the "Transantiago" (Program for Improving Santiago's Public Transport), aimed at turning scattered services into a central public transport system that may network and complement the different modes (Transantiago, 2003). An ambitious goal defined for Transantiago is to increase public transport use, since only 50% of Santiago's motor travellers use it at present, against 68% of them a decade ago. Such expansion should result from a new transport system that is better in LOS as well as socially and environmentally sustainable.

The Transantiago would introduce a new public transport system in 2005. This will feature an expanded metro network, a new set of bus services, integrated fares, bus fleet renewal, modified business and labour management for the sector, and infrastructure investment on busways, bus stops, and interchange stations. A following stage (2005-2010) will be focused on infrastructure expansion, with more metro lines and stations, and interchanges, as well as on superior information technology and complete bus fleet renewal.

Such a strategic change will impact on all routes of the current system, which is also one of its weaknesses: most routes run on the same avenues. The entire routing scheme will be remapped revolving around two types of service: services that involve the main avenues or "corridors", and services that meet local demands or "feeder areas", which will deliver passengers to both metro and buses in the corridors. The figure below shows one of the five business units to cover city corridors in Santiago. These business units will be offer in concession to private operators.

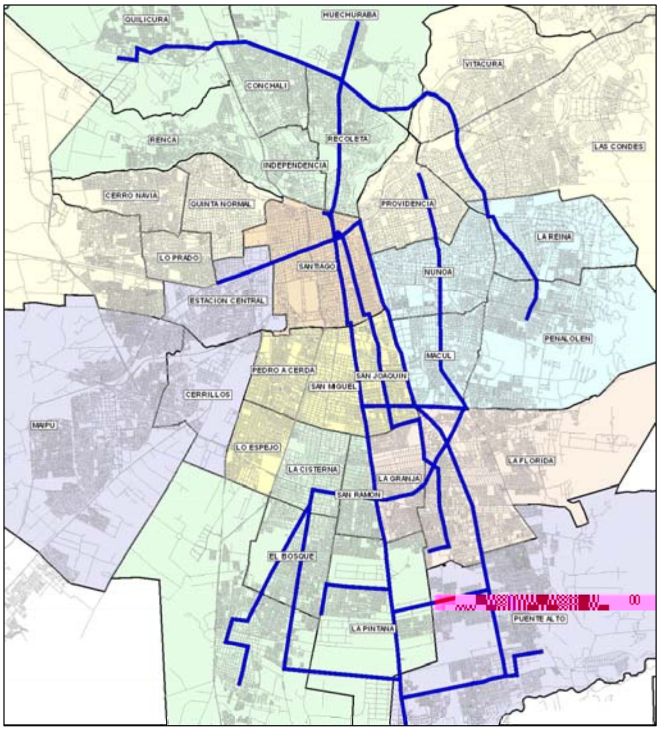

Fig. 4: Corridor business unit 2 (Transantiago, 2004)

The current metro network consists of three lines and covers 40 km. It will double its coverage by 2005 as a result of an expansion in its current services, for 11.3 km will be added to lines 1, 2 and 5, and the new line 4 will start operations adding another 33 km. Fig. 5 shows a scheme with lines projected as of 2005.

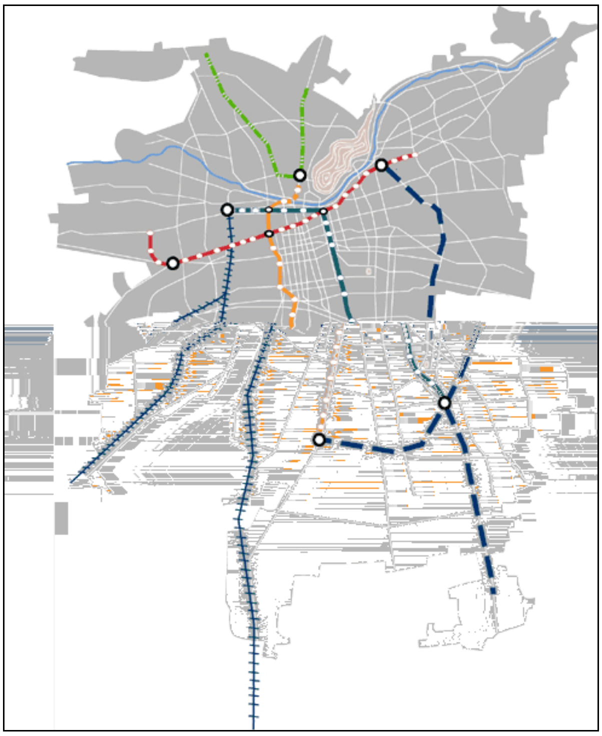

Fig. 5: Santiago's Metro expansion for 2005 (dotted lines)

According to Transantiago Authorities, it is expected that the new public transport system will significantly reduce its share in traffic congestion, air and noise pollution in the city due to a number of reasons: the overall bus fleet will be downsized, trip lengths will be shorter, public transport will gradually shift to technologies compliant with tighter engine emission standards, cleaner vehicles will be introduced and less polluting fuels will be available in the market. Because of the concession of each business units to one operator, it is expected the end to passenger hunting will change driving habits, thus ceasing bus races and consequently, constant speeding up and sudden braking.

The bus fleet is expected to descend from the current 7,300 units to approximately 4,900, with 2,240 of them brand new. The Transantiago buses will be fit for their operational service network: the corridor network will have modern articulated low-floor buses or high-capacity buses (12 to 15-m vehicles), while local and feeder services will have medium and low capacity buses.

Transantiago was planned to meet the public transport requirements stated in the Pollution Prevention and Removal Plan for the Metropolitan Region (PPDA). They require 75% reduction in PM_{10} releases and 40% reduction in NOx emissions by 2005, compared to the 1997 baseline. This means 140 tons of PM_{10} and 3,700 tons of NOx per annum. The new system is expected to generate only 106 tons/year of PM_{10} and 2681 tons/year of NOx by 2005, thus 34% and 60% less than the PPDA requirements, respectively for PM_{10} and NOx annual emissions.

Summarizing, the goals defined by the new public transport system are:

- Increasing public transport usage through an integrated and sustainable system.
- Improving living standards in Santiago and reducing pollution.
- Turning the current competitive fragmented system into an integrated one.
- Turning the current 335 services offered by 130 operators that represent 3,000 small businesses, into 15 or 20 operators that gather 200-700 buses each.
- Downsizing the current 7,300-bus fleet to 4,887 high standard vehicles.
- Reducing the current average route length from 62 km down to 25 km – 19 km for feeder services and 36 km for corridors.
- Metro network expansion from 40 km to 81.3 km.

Despite the first goal above, our opinion is that the best that Transantiago can achieve, given the increase in car ownership, is to maintain the current public transport patronage. This is based on the analysis of expected changes in LOS variables (access time, waiting time, in-vehicle travel time, safety, comfort, and reliability). Firstly, a brand new system will probably meet the in-vehicle travel time, safety and reliability standards. However, fleet reduction can impact on bus frequency, so in waiting time and comfort if buses are overcrowded – some sources indicate that the design capacity for Transantiago buses is 6 passengers per square meter, which means overcrowding. Second, in a network that will work on the basis of feeder routes and main routes, there will be additional access and waiting times because of interchanges (the well-known interchange time penalty). Some figures indicate that the average number of interchanges per trip will rise from 0.2 at present to 0.8 when Transantago will be in operation. The best interchange takes no less than 5 minutes, so the total travel time will be increased in at least such amount for Transantiago users. Third, at corridor routes fares will be related to distance travelled, compare with the present flat fare throughout the city. Although exact figures have not been unveiled yet, it is expected that fares will increase in 30% at least. Considering the price elasticity of public transport demand, this fact can have a negative impact on bus patronage unless some subsidies to the users are applied. In addition, if new highways will be implemented at the same time than Transantiago (see 3.3 below), the opportunity of attracting car users to public transport will be relegated.

Other issue to be remarked is the huge investment in metro lines compared to the low investment in bus infrastructure. Only the extension of Line 2 (yellow dotted line in Fig. 7) costs the same as the entire investment program in bus infrastructure (260 million US$). The expansion of the rest of the metro network will cost other 1.5 billion US$. This is particularly inconvenient if we note that metro investments will come from public funds, meanwhile the money for bus infrastructure must be more that 70% private. We have argued elsewhere that the same transport capacity can be achieved by a high-capacity bus system at a fraction of the capital cost required for a rail transit system (Fernandez and Planzer, 2002).

In the goal in which Transantiago will be successful is in reducing air pollution in Santiago, so in improving the quality of life of its citizens. This is shown by the authors elsewhere (Osses and Fernandez, 2004). However, our opinion is that loads of social benefits from Transantiago are been quoted as coming from air quality. On the other hand, accessibility-enhancing impacts have been overlooked – for a further discussion on the difference between a movement-based policy and an accessibility-based policy see Tyler (2002). In addition, other environmental impacts such as noise, risk, severance, intimidation and visual intrusion have not been considered in the design of Transantiago.

Finally, a goal that is being assessed during the year 2004 is the capability of Transantiago in turning the current 3,000 small operators into an integrated system. It is a matter of political power of the Government to force the actual fragmented operators in a different business scheme. At present, more than a dozen of large companies have shown interest in the tendering process (Transantiago, 2004)

3.3. *Road investment and private transport regulations*

Control of traffic congestion and its perceived actual costs are two of the priorities in the PTUS. There is technical consensus about congestion charging being the way to achieve all the above. This idea is backed by the London case. Efforts are being made to establish a zone pricing scheme in the city, like the one in London.

Nevertheless, a legal instrument is required to apply such congestion charging, and the Chilean congress has been discussing such instrument for almost ten years. It also requires a thorough analysis of the impact expected from new traffic allocations in a priced road network. As a result, new traffic management schemes will be necessary. According to the PTUS this will be in the hands of the Area Traffic Control Unit (UOCT), which has been running the centralized control of the 2,000 traffic lights in Santiago since 1987.

However, in our opinion complementary traffic measures to congestion charging has not been analysed nor discussed with local authorities, which will ultimately implement the new traffic schemes outside the pricing zone. This not only means traffic signals adjustment, but also other comprehensive traffic management measures such as: traffic calming in residential areas, parking control, park and ride or kiss and ride facilities, pedestrian facilities to and from public transport stations, etc. The London experience should be taken into account on this issue (see Transport for London, 2004).

This P2 Program will also conduct the development of road infrastructure and maintenance projects. As of now there are four private projects for citywide urban highways being erected: the East-West highway known as Costanera Norte (34 km); the North-South highway called Autopista Central (61 km); the Américo Vespucio ring road highway (51 km), which completes the current ring road planned during the sixties; and the south access to Santiago connected the Américo Vespucio ring road (47 km). There are two other urban highways being tendered: the North-East access to Santiago linking Costanera Norte (21.5 km) and the El Salto-Kennedy intermediate ring road. Being all such projects from the private sector, investment owners will be charging according to distance from users. It should be noted that is a different concept than congestion charging, as the owners of these highways are not looking at reducing traffic impacts but increasing revenue from traffic.

Even though the road infrastructure in Santiago needs to be enhanced, our concern is the construction of a 220-km network of urban highways – i.e. to be used by cars – against a transport policy aimed at "*the promotion of public transport as the principal means of transport in the city, and car usage rationalization*", (MOPTT, 2000). Investment numbers do not appear consistent with the intended purpose: 2 billion US$ will be invested in highways, but only 55 million US$ in busways.

3.4. *Promoting non-motorized transport modes*

This program is aimed at the development of explicit – physical and operational – facilities for pedestrians and cyclists in the city transport system.

Some city areas will be subject to become pedestrians (particularly in downtown Santiago) in order to create safe and pollution-free areas with an adequate town-planning approach. This plan will also promote non-motorized means of transport by structuring a cycle network and implementing modern public-space infrastructure, to make on foot, pushchairs and bicycle rides more comfortable and safer.

This cycle network originally covers 70 kilometres, which will be completed by 2005 in three municipalities, namely downtown Santiago, Providencia and Ñuñoa. For example, Fig. 6 shows the 45-km project for Ñuñoa. This initial cycle network implementation will gradually cover other city areas.

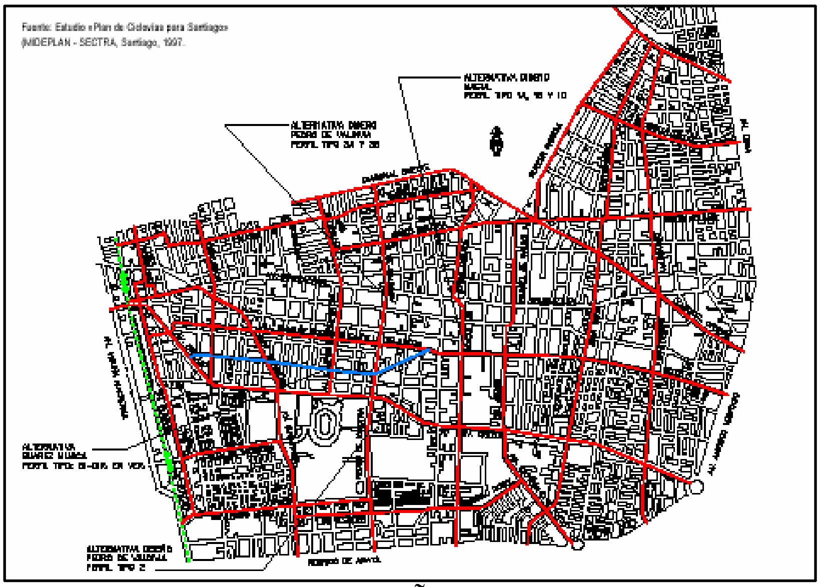

Fig. 6: Cycle network in Ñuñoa, Santiago (45 km)

We think that this initiative goes in the right direction. In particular if the cycle network is connected with public transport interchanges (metro stations and main bus stops) with the possibility of bike and ride facilities. In addition, pedestrian facilities should meet the standard for accessibility networks sated by Tyler (2002).

3.5. *Short-term scheme*

The so-called short-term scheme (P7) is defined as an early stage of the PTUS 2000-2010. Such measures consist of a set of complementary strategies implemented on March 2001; these are:

- *Road management*: including the definition of roads to be exclusively used by public transport, tidal flow roads for private cars, and bus lanes in the main city avenue, Alameda Bernardo O'Higgins (in the following, "Alameda").
- *Restraint policies*: vehicle usage restraints by plate registration number for every transport mode.
- *Transport operation management*: includes new criteria for bus-metro interchanges, changes in routes of interurban buses, and operational organization of taxis in Alameda.
- *Regulatory measures*: increases to three per annum the number of inspection and maintenance licenses required (comparable to the British MOT) for non-catalytic, commercial and diesel vehicles, and provides for gradual reduction of school bus age, fuel (diesel) purify and other regulatory enforcement.

For these measures there are some performance assessment available; therefore, an analysis of road management related measures follows.

One of the measures provides the exclusive usage by buses of six city avenues. Buses, taxis and emergency vehicles can only use them. Such exclusiveness rules from 07:00 A.M. to 10:00 A.M., Monday through Friday. In high pollution situations exclusiveness will also apply from 6:00 P.M. to 8:00 P.M. A preliminary assessment of exclusive roads for public transport suggests that bus travel time decreased by 12.7% on average (Malbrán et al, 2001).

Another short-term measure physically reserved three out of five lanes in Alameda exclusively for buses. Such separation was implemented using stack lines (Fig. 7). Results obtained are irregular. For example, bus journey time decreased by 27% during peak hours. However, bus journey time increased by 6% for the rest of the day (MOPTT, 2000). The efficiency of this measure remains uncertain because the number of off-peak hours exceeds peak hours by four or five times, and there are no statistically significant results on car journey times.

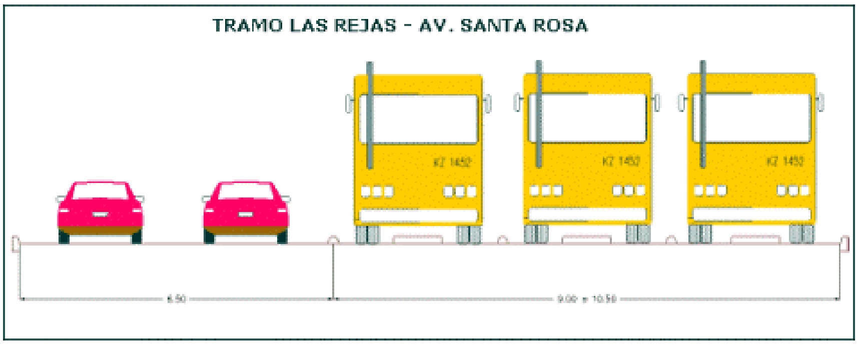

Fig. 7: Bus-lane scheme in Alameda, Santiago (right hand driving)

Some improvements suggested by the authors after assessing the operational conditions of exclusive roads and Alameda's segregation follows (Fernández, 2001).

Weaving Removal. That is the main problem for cars and buses when turning right and left, respectively. Should it be unfeasible to ban such turnings, it would be better to redirect them to alternative roads for both buses and cars. For example, a right turn could become a "q-shaped" turn – driving one more block and taking a "u-shaped" turn around the central reservation to find the destination street. Buses turning left could take a "t-shaped" turn – turning right one block in advance, taking the next parallel street and finding the destination street – or a "p-shaped" turn – driving one more block, turning right, returning on a parallel street and finding the destination street.

Allow taxis and high occupancy vehicles in bus-lanes. If segregation aims at privileging public transport and being taxis a public transport mode, taxis should be able to use exclusive lanes, as in other cities (e.g. bus and taxi lanes in London). A trip in any kind of taxi means less private cars in circulation looking for a parking place and/or using the road to park. In any exclusive lane, taxis with passengers can use the bus-lanes to travel. However, this would require infrastructure to take and leave passengers on the left side. For example, bays so that they do not interfere with other vehicles flow. The use of private vehicles of high occupancy (minibuses and cars with 3 or more passengers) should not be discarded.

Traffic signal setting. Segregation tends to collapse car lanes, while alleviating bus lanes. Therefore traffic signals should be adjusted. Bus-lane requires a shorter cycle time and a longer green time to reduce delays. This also reduces queue lengths in car lanes. The traffic congestion perceived by car drivers is consequently decreased, even if crossing a junction takes more than one cycle (due to oversaturation queues). Nevertheless, it is necessary to use models such as SIDRA and TRANSYT to program traffic signals under criteria other than those presently applied.

The last road management measure included in the program of short-term measures provides for eight tidal flow roads in Santiago. Generally speaking such normally two-way roads work in one direction only during peak hours: heading for downtown from 07:30 A.M. to 10:00 A.M. and heading for outskirts from 17:00 A.M. to 21:00 A.M.

Public transport on such roads is very low or equal to zero. Therefore, such tidal flow traffic was applied as a compensation for car drivers being moved out of exclusive roads for public transport. This spots another inconsistency with a transport policy that officially promotes public transport. A consequence of tidal flow is a significant reduction in journey time for car drivers, ranging from 13% to 71%. But it has also raised driving speed up to dangerous levels. Cars can typically reach 65 or 80 km/h (40-50 mph) on roads crossing residential or commercial areas.

Even though no evidence of their application been found so far in tidal flow roads, Fernández (2001) advanced the following proposals in order to improve the scheme.

Keeping access to public transport. A tidal flow road usually generates surplus capacity in the beginning. If there is public transport, then one bus-lane should be made available in contra-flow (opposite to the valid driving flow). It keeps accessibility and readability for public transport users in such roads and does not require a lot of enforcement. Other vehicle types, such as emergency or service vehicles, could use the same lane. The counter-flow lane should be visibly signalled, possibly on top of mobile units, such as cones, curbs, barriers, etc.

Dynamic signalling. One problem with tidal flow roads is transition time. Drivers should not be looking at their watches. On the contrary, some dynamic signalling system should tell them at certain intervals if they can continue on the same direction or if they need to leave next exit. Simple gateways with red or green lights and arrows should suffice. More sophisticated dot matrix systems should be advantageous.

Lane allocation. Some tidal roads are wide enough to allow reallocation of the number of lanes when operating one-way only. For example, passing from two wide lanes in one direction to three normal ones or four narrow ones in the same direction. This should be clearly delimited. Particularly at arriving and leaving intersections. The use of narrow lanes, plus increasing capacity at intersections, tends to make dangerously high speeds diminish when the road is used one-way only.

Functional continuity. Every tidal flow road should have a clear beginning and a clear end in order to alleviate traffic congestion in parallel roads with equivalent functional continuity. Therefore, the need for maintaining, extending or removing some short tidal flow roads should be assessed, in case they are not serving the intended purpose. If that is so, models such as TRIPS, SATURN, EMME/2 could play a crucial role in forecasting traffic assignment.

4. Conclusions

In this paper we have reviewed the evolution of Santiago's transport system since 1990 as well as we have described and discuss the policy that is being planned until 2010. To summarise, the following concluding remarks can be stated.

The characteristics of the transport system of Santiago are not too different from others developing countries: low – though increasing – car ownership, still high percentage of daily travels on public transport, uncoordinated public transport systems, and considerable pollution caused by road transport. However, average numbers not always describe the system well. For example, the average car ownership can be similar to that in Greece (140 cars per 1,000 population). But figures range from a car ownership like Britain at high-income areas (413 cars per 1,000 population) to that found in Turkey at low-income sectors of the city (45 cars per 1,000 population). Therefore, two styles of travel behaviour are observed within the city. One is typical of developed countries in which people makes an intensive use of cars for their daily journeys. As a consequence, they demand for an expansion of the road capacity. The other behaviour is typically found in developing countries: buses make most motor trips in Santiago (42%). As a consequence, the bus fleet is vast (7,300 vehicles). Both behaviours have implications on Santiago's transport policy.

The revealed transport policy for Santiago shows that both the pressure for the expansion of road capacity and the urgency for a better public transport are present. Frequently, it tends to be a contradiction between these two tendencies. The figures show that the investment in expanding road capacity – either from public or private funds – will be ten times the investment in improving public transport via the Transantiago plan. This inconsistency is even present in the short-term scheme discussed above. In addition, the schemes for promoting non-motorised transport are rather cautious. For example, none authority has proposed a car-free zone or a car-free day as in other cities around the world (e.g. Tokyo, Bogotá).

Another issue to be argued is the conception of Transantiago. This plan was

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