CHAPTER 5

Transport and air quality in Santiago, Chile

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Abstract

This chapter offers a review of the evolution of the transport system in Santiago de Chile during the period 2000–2010, and the implications of local transport policy on vehicle emissions and air quality. The chapter comprises five sections, starting with a general overview of the Metropolitan Region of Santiago and its population, as well as a description of the current transport system. The relationship between transport and air quality is analysed for the period 1991–2001, describing car ownership and modal split trends, the technological evolution of vehicles, pollutant emissions from transport, and air quality trends. Finally, a critical review of Santiago’s transport policy is made, using the main programs of the 2001–2010 Urban Transport Plan for Santiago as a case study. The new public transport plan is included in this critical analysis (Transantiago), as well as a set of short-term strategies, road investment and car-use regulations, and non-motorized transport plans for pedestrians and cyclists in the city. Transport trends, however, show that Santiago is following the well-known car-public transport vicious circle that developed countries have gone through. This may offset the environmental effects from vehicle and transport improvements within the city.

1 Urban characteristics of Santiago

The Metropolitan Region of Santiago, Chile, has a population of 6.1 million inhabitants, concentrating 40\% of the whole population in the country. According to the latest census, the population of the Metropolitan Region of Santiago has grown by 15.3\% during the last 10 years [1]. Santiago City, the capital and largest city of Chile, has a population of 4.7 million inhabitants and
covers an area of 62,000ha. This ‘urban spot’ has experienced an explosive expansion of 25% during the period 1991–2000 [2].

The city of Santiago is divided administratively into 32 districts or municipalities. However, for the purpose of the transport system study, other municipalities in the region have been added, which have progressively become attached to the city. For example, the 2001 Origin and Destination Trip Survey in Santiago [3] considered 38 municipalities, with a total of 5.6 million inhabitants and a total area of 72,000ha. This set of urban districts is called the Santiago Metropolitan Region (SMR).

The average density of Santiago City is 78 inhabitants per hectare. This density may be considered low in contrast to developed countries, but it presents a great variability between poor and rich municipalities. It may decrease to less than one inhabitant per hectare at higher income suburbs (0.73 inhabitants/ha in Lo Barnechea), up to 150 inhabitants/ha in low income municipalities (e.g. Lo Espejo, Lo Prado, San Ramón). Average earning municipalities have intermediate densities, such as the Santiago Municipality (downtown or CBD), Providencia, and Ñuñoa (90 inhabitants/ha). Others of higher income, such as La Reina and Las Condes, vary between 25 and 40 inhabitants/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. 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 inhabitants/ha, but it ranges from less than 1 to over 150 inhabitants/ha, depending on the income level.
- The city is strongly segregated. High income households are concentrated on the NE of the city; the rest corresponds to average and low earnings households.

2 Trip characteristics

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

Of these trips, 62.5% are made by a motor means. The remaining (38.4%) are made on foot or by 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 more than 80% are made by school students and 60% by children in primary school.
The total amount of cars in Santiago is approximately 850,000 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 particularities of the transport system in Santiago are:

- The average motoring rate is low – as compared with developed countries – but its variance is high depending on the level of income.
- 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 split) in Santiago is shown in table 1 and its order of importance is presented in fig. 1. This order, with slight variations, continues during peak morning hour.

### Table 1: Modal split of journeys in Santiago.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Number of trips [trips/day]x10^6</th>
<th>Modal split [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>3.88</td>
<td>23.5</td>
</tr>
<tr>
<td>Bus</td>
<td>4.27</td>
<td>25.9</td>
</tr>
<tr>
<td>Metro</td>
<td>0.74</td>
<td>4.5</td>
</tr>
<tr>
<td>Taxis¹</td>
<td>0.61</td>
<td>3.7</td>
</tr>
<tr>
<td>Walking</td>
<td>6.02</td>
<td>36.5</td>
</tr>
<tr>
<td>Other²</td>
<td>0.97</td>
<td>5.9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>16.49</td>
<td>100.0</td>
</tr>
</tbody>
</table>

¹ Taxis and shared taxis.
² School bus and institutional bus, bicycles, motorcycles, train and others.

From the above data it can be concluded that, for total daily trips in Santiago:

- The main way of transport is walking.
- It is followed by bus transport.
- Cars, as a transport means, are only in third place.
- The metro captures less than 5% of all trips.

Another distinctive characteristic of Santiago is that the greatest part of motor trips (55.5%) still corresponds to public transport: buses, metro and taxis. The rest corresponds to some private means. The main choices of public transport are buses (42.1% of motorized 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,
while buses cover 353 routes and more than 7500 stops in the city. However, this infrastructure will be the object of important changes from the year 2005 onwards, as stated in section 4.2.

Buses in Santiago provide a good accessibility in terms of coverage and frequency, plus their operation in the mode ‘hail-and-ride’ – i.e. they stop on demand – along most parts of their journey. Also their commercial speed is reasonable. Nevertheless, the other level of service indexes is deficient (safety, comfort, reliability).

Vehicle speed in Santiago is one-third lower for buses than for automobiles, but it is still high compared with other cities. Table 2 shows average speed obtained from measurements carried out in 1000km of stretches selected from the road network.

<table>
<thead>
<tr>
<th>Period</th>
<th>Average speed [km/h]</th>
<th>Difference [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>07:00–07:30</td>
<td>43</td>
<td>Buses</td>
</tr>
<tr>
<td>07:30–08:30</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>08:30–09:00</td>
<td>39</td>
<td>24</td>
</tr>
<tr>
<td>10:00–11:00</td>
<td>42</td>
<td>27</td>
</tr>
</tbody>
</table>

3 Transport and air quality evolution in Santiago (1991–2001)

3.1 Motorization and modal split

Motorization rate doubled in Santiago between 1991 and 2001. In 1991 there were only 70 automobiles per 1000 inhabitants. At the same time the number of cars increased by almost 102%. This increase in motorization resulted in the way in which trips are changed substantially, as shown in fig. 2.
The information collected by the Origin and Destination Survey revealed that between 1991 and 2001 a dramatic change took place as regards proportion of trips performed in public transport and private cars. 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, the displacements in automobiles increased from 18.5% to 38.1%.

The change in modal split during the period 1991–2001 is mainly due to the decrease in the number of low income households and the strong increase of those of average and high earnings. This caused the motorization rate of low income households – usually those using public transport – to increase, as shown in table 3.


<table>
<thead>
<tr>
<th>Variables by income</th>
<th>1991</th>
<th>2001</th>
<th>Variation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nº of households by income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Low(^1)</td>
<td>799,000</td>
<td>303,000</td>
<td>- 62</td>
</tr>
<tr>
<td>• Medium(^2)</td>
<td>246,000</td>
<td>994,000</td>
<td>+ 304</td>
</tr>
<tr>
<td>• High(^3)</td>
<td>45,000</td>
<td>215,000</td>
<td>+ 378</td>
</tr>
<tr>
<td>Motorization [car/household]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Low</td>
<td>0.146</td>
<td>0.171</td>
<td>+ 17</td>
</tr>
<tr>
<td>• Medium</td>
<td>0.713</td>
<td>0.472</td>
<td>- 34</td>
</tr>
<tr>
<td>• High</td>
<td>1.732</td>
<td>1.479</td>
<td>- 15</td>
</tr>
</tbody>
</table>

\(^1\) Under US$7,800 a year.
\(^2\) Between US$7,800 and US$27,600 a year.
\(^3\) Over US$27,600 a year.
A detailed analysis for the period under study is the variation in modal split of the principal motorized ways, according to the level of earnings of the Santiago population. According to table 4, a dramatic increase of automobile use is observed in low income strata; meanwhile in medium and high income groups the variation is not significant. A clear decrease in the use of the metro is also observed in the low and medium income strata. Only in the high income stratum is there a small increase of its use. Consistent with the increase in automobile use, buses lose users from the low income stratum and, in practical terms, the use of buses maintained in the medium and high strata. A summary of this analysis is presented in table 4.

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, motorization has doubled in a period of 10 years.
- The greatest increase in the motorization rate 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 up, the predominant way of transport in Santiago will be the automobile. This shall have the well-known consequences of emissions and traffic congestion, due to a decrease in the use of public transport, a vicious circle will ensue as evidenced by developed countries, as shown in fig. 3.

<table>
<thead>
<tr>
<th>Income and mode</th>
<th>Modal split [%]</th>
<th>Variation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1991</td>
<td>2001</td>
</tr>
<tr>
<td>Low income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Metro</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>• Bus</td>
<td>71</td>
<td>55</td>
</tr>
<tr>
<td>• Automobile</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>Medium income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Metro</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>• Bus</td>
<td>44</td>
<td>46</td>
</tr>
<tr>
<td>• Automobile</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>High income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Metro</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>• Bus</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>• Automobile</td>
<td>64</td>
<td>65</td>
</tr>
</tbody>
</table>

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), and changes in programming of traffic lights and proper design of 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 road pricing in certain areas. Bus subsidy ensures that the operation cost increase due to congestion or the income reduction due to a lower demand does not mean fare increase or service frequency deterioration. This subsidy can be delivered to enterprises or to users. The application of some of these measures for Santiago is reviewed hereinafter.

3.2 Technological evolution of vehicular fleet

Between 1991 and 2001 the population in the SMR increased by 15%, the number of vehicles increased by 102%, the total number of trips grew by almost 70% and trips lasted on average considerably longer. From a total of nearly 6 million motorized daily trips in 1991, 18.5% corresponded to trips made in private cars. In the year 2001 daily motorized trips overpassed 10 million, of which 38.1% corresponded to private cars. On the other hand, during the period 1990–2000 the expansion of the economy reached an average annual rate of 6.3%, with a total increase of 96.4% between 1989 and 2000 [4]. In this same period the population increased by 1.7% annually, so it may be expected that
activity or traffic indexes go on growing, with a strong impact on the city in terms of congestion and air quality.

As a way of reducing this growth negative effect produced on the city air quality, Santiago’s authorities have impelled a series of technological measures to be applied to the transport sector. Among these measures, those oriented to improve environmental characteristics of vehicle fleet are highlighted, such as demand of emission standards of new vehicles entering the country, inspection/maintenance automated procedures for vehicles in use, emission control in public thoroughfares, incentives for cleaner vehicles, emission control devices, conventional fuel improvement and more frequent use of alternative fuels. This set of actions has produced significant changes in the technological evolution of the vehicular fleet.

In 1991, there was a fleet of 420,000 light and medium vehicles in the Metropolitan Region, most of them with gasoline engines and without a catalytic converter. An important demand was introduced in 1992 [5], wherein light vehicles should meet emission standards equivalent to 1983 US Environmental Protection Agency (EPA) demands. These demands resulted in the commercialization of vehicles equipped with catalytic converters and modern injection systems, along with unleaded gasoline distribution. Lead was completely removed in 2001 all over the country.

The introduction of light vehicles with catalytic converters has caused a significant change in the fleet composition during the last decade. After the demand, incorporated at the end of 1992, a gradual fleet renewal started, reaching 51% of vehicles equipped with TWC (three way catalyst) in 1997 and 85% of the total of light vehicles in Santiago city in the year 2000.

Modernization of public transport for environmental purposes started in 1993 when Decree 55 was implemented [6], establishing requirements of gas and particulate emissions for buses circulating in the Metropolitan Region. Since September 1993, all buses entering Santiago shall fulfill EPA91 standard (corresponding to the one promulgated in 1991 by EPA) or EURO1 (the equivalent one adopted by the European Commission). In September 1996, EPA94 or EURO2 became effective and from September 2002 EPA98 or EURO3 is required. Tendered buses prior to September 1993 did not comply with the emission demands.

These measures have resulted in significant reductions of breathable particulate matter (PM10) and tailpipe exhaust gases (HC: hydrocarbons, CO: carbon monoxide, and NOx: nitrogen oxides). The schedule of standards is parallel to the quality improvement of diesel fuel that is distributed in the city, mainly via sulfur content reduction: from 300 parts per million of sulfur (ppmS) allowed in the year 2001 to 50ppmS in 2004 (one part per million is equivalent to one sulfur gram for every one thousand kilos of fuel). Prior to year 2001, the averages of diesel fuel production in Santiago were 400–500ppmS, while in the rest of the country this value is about 1500ppmS. As regards gasoline, sulfur content will be decreased from 400ppmS (2001) to 150ppmS (2003), and afterwards to 30ppmS (2006). Additionally, olefin contents in gasoline will be reduced by 26% in 2003 and by 57% in 2006, along with 10% of aromatic reduction.
Along with the standards for new vehicles entering into the country, more demands to vehicles in use have been incorporated, through HC and CO (gasoline), opacity (diesel) and safety conditions measurements in the regular process of technical inspection. Environmental demands are particularly strict for tendered public transport. PPDA reformulation (Plan on Prevention of Atmospheric Decontamination in Metropolitan Region) demands that sector emissions in 2005 aim at a decrease of 75% of PM$_{10}$ (particulate matter or solid fraction of tailpipe pollutants) and 40% of nitrogen oxide, both referred to the 1997 basis inventory.

Besides the use and improvement of vehicles fed by conventional fossil fuels, Santiago city has promoted several programs to encourage the use of alternative fuels and technologies. Among these are: the use of compressed natural gas (CNG), liquefied petroleum gas (LPG), hybrid and electric vehicles. However, the introduction of alternative systems has not had a massive impact on the transport sector, only very few examples of fleet conversion exist, such as some taxis and light commercial vehicles running with CNG (3000 by 2002) and small delivery fleets using electric systems fed by batteries.

### 3.3 Accountability of mobile sources for pollutant emissions

One of the main sources of atmospheric pollutants in Santiago is the transport sector activity. The kind of pollutant depends on the fuel used (gasoline or diesel oil). The amount of pollutants emitted to the atmosphere depends on the number of vehicles, kind of technology of the vehicle, and its maintenance condition. Driving habits are also relevant (annual mileage, driver attitude), load on the engine, congestion level, etc.

To calculate the total emission of atmospheric pollutants caused by vehicular activity in Santiago, a bottom-up methodology is used, including warm-state, cold start, and evaporative emissions, with emission factors for 60 different vehicular categories. Traffic information is provided by strategic models of transport equilibrium [7], as well as direct measurement of flow and fleet composition. All this methodology is integrated in a computer program called MODEM [8], which is mainly based on the European methodology CORINAIR-COPERT [9], being specially adapted to local conditions in Santiago [10] and other Chilean cities [11].

Transport appears as the most pollutant sector of the Metropolitan Region, with 48% of breathable particulate matter (PM$_{10}$), 84% of nitrogen oxides (NOX) and 91% of carbon monoxide (CO), according to emission inventory of the year 2000. The latter joined to an important participation in emissions of volatile organic compounds (VOC) and sulfur oxides (SOX), with 30 and 34%, respectively. For example, total VOC emissions in 2000 were about 80,000 ton/year, where transport sector contributed about 24,500 ton/year, split into 5000 ton/year per diesel vehicle and 19,000 ton/year per gasoline vehicle [12]. Vehicle emissions are temporally and geographically disaggregated over the city, as shown below.
Public transport buses and the rest of diesel vehicles play a significant role in the emission of particulate matter and nitrogen oxides. On the other hand, private gasoline vehicles have a high degree of accountability for carbon monoxide and volatile organic compound emissions. This difference in emission accountability is mainly due to the kind of fuel used.
Buses emit 800 ton/year of PM$_{10}$, from a total of 2400 ton/year emitted by the rest of mobile sources. Gasoline vehicles do not have significant PM$_{10}$ emissions; however, they are accountable for over 90% of total carbon monoxide produced by the transport sector [13].

Emission Inventory from mobile sources for Santiago de Chile has been calculated for years 1997, 2000 and 2005 [12]. Figure 5 shows the results obtained in 1997. Both pollutant emissions and fuel consumption (FC) are given in thousand tons per year, whereas activity level (ACT) is calculated in vehicle-km/year, and passenger travel (PAS) represents carried passenger-km/year.

Urban buses are an important source of particulate matter, SO$_2$ and NOx (34–40% of total mobile sources), burning 20% of the fuel used for transport in the region, sharing 5% of total traffic activity and carrying 55% of total number of passengers driven by on-road vehicles.

### 3.4 Air quality trends

In 1987 the first Network of Automatic Atmospheric Pollutants Monitoring (MACAM I) in the Metropolitan Region was installed, financed by Inter American Development Bank (IDB). It consisted of four stations located in the central area of the capital city: Plaza Gotuzzo (A), Providencia (B), La Paz (C), Parque O’Higgins (D) and a fifth mobile station that was placed in Las Condes municipality (M). Systematic measurements of particulate matter, corresponding to manual samplings with dichotomous equipment are reported from May 1988 [14].

The ongoing analysis refers mainly to manual sampling results with dichotomous equipment, carried out between 1988 and 2000. Plaza Gotuzzo Station, which stopped working in the year 1996, was not considered. This analysis does not consider either the stations of Pudahuel, El Bosque, Cerrillos and La Florida, which integrated to MACAM2 network in April 1997. In these new stations, PM$_{10}$ measurement is performed by continuous monitors and there is no dichotomous equipment installed.

On 12 April 1988, Ministry of Health issued a resolution defining an Air Quality Index of Particles (ICAP), which determines categories in respect of PM$_{10}$ daily concentrations and people health effects. ICAP was set in 100 for 24h average concentration equal to 150µg/m$^3$ (set value in PM$_{10}$ primary standard) and in 500 for 24h average concentration equal to 330µg/m$^3$, varying linearly in the intermediate section.

Prior to 1997, to prepare ICAP the value of the station with higher 24h concentration (manual sampling with dichotomous) was considered, usually obtained after 48h of the measurement. Since 1997, continuous monitors have been used to deliver hour-to-hour concentrations in MACAM network stations, thus the ICAP is calculated like the day highest mobile average (from latest 24h) and for the station presenting the highest value.

In 1998, Supreme Decree No. 59 of the General Secretariat of the Presidency, establishing the primary PM$_{10}$ quality standard, defined the concentration values corresponding to PM pollution **critical episodes**. Then a critical episode took place when air quality levels reached are over ICAP 200 level or **warning** level.
As air quality worsens, pre-emergency levels are reached if ICAP 300 level is surpassed, and emergency if it is over the 500 level.

Since 1994, there has not been any emergency in the historic network stations. There is a sudden decrease in the number of excesses and warnings between 1997 and 1998. In 1996, Santiago was declared a PM$_{10}$-saturated zone, and in 1997 a Plan on Prevention and Decontamination in Metropolitan Region began to be implemented. On the other hand, since 1997 the PM$_{10}$ emission limit for industries has been decreased by half (from 112 to 56 µg/m$^3$). Then the value decrease could be attributed, in part, to these measures.

Another important point is the episode duration, i.e., number of consecutive days over the standard. There is a clear tendency to decrease both in number and in duration of the PM$_{10}$ episodes. In 1990 there was an episode that lasted 11 days, while in 2000 the longest episode lasted 3 days, which happened only twice that year.

PM$_{10}$ primary standard sets the value 150µg/m$^3$ as a limit value for the PM$_{10}$ 24h averages. The standard is considered exceeded if during a year, the 98 percentile of the 24h concentrations is greater than 150µg/m$^3$ or if there are more than 7 days with concentrations greater than 150µg/m$^3$.

Table 5 presents days when the standard value was surpassed. For this calculation the highest PM$_{10}$ daily recorded value at the stations is considered.

<table>
<thead>
<tr>
<th>Year</th>
<th>No° Number of days over PM$_{10}$ daily average standard (150µg/m$^3$)</th>
<th>Autumn – Winter Period (March 1 through September 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January to December</td>
<td>Autumn – Winter</td>
</tr>
<tr>
<td>1988</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>1989</td>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>1990</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>1991</td>
<td>70</td>
<td>70</td>
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<tr>
<td>1992</td>
<td>76</td>
<td>76</td>
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<tr>
<td>1993</td>
<td>73</td>
<td>72</td>
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<tr>
<td>1994</td>
<td>90</td>
<td>90</td>
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<tr>
<td>1995</td>
<td>56</td>
<td>56</td>
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<tr>
<td>1996</td>
<td>68</td>
<td>68</td>
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<tr>
<td>1997</td>
<td>55</td>
<td>55</td>
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<tr>
<td>1998</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>1999</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>2000</td>
<td>31</td>
<td>31</td>
</tr>
</tbody>
</table>
It is interesting to study the evolution of PM$_{10}$ and PM$_{2.5}$ annual averages and also the PM$_{2.5}$/PM$_{10}$ relation recorded at the stations of the historical network of MACAM, for the period 1988–2000 (fig. 6). This analysis indicates that on average there has been a decrease of PM$_{10}$ of 37% between 1988 and 2000, meanwhile, for PM$_{2.5}$ this decrease approaches 53%.

In spite of the decrease in concentrations, the annual average of the last years is close to 75μg/m$^3$, above the value of the primary standard for annual averages, which sets 50μg/m$^3$ for the averages of the last 3 years starting with measurements of 2002.

The USA Environmental Protection Agency recommends a value of 15μg/m$^3$ for annual averages of PM$_{1.0}$, which is under the values recorded at the historical network stations that register concentrations between 30 and 40μg/m$^3$ during the last years.

The PM$_{2.5}$/PM$_{10}$ ratio shows a decreasing trend, with values around 0.65 during the early 1990s, and then down to 0.45 in the 1995–1998 term. Over the past few years, however, this ratio has seen a slightly increasing trend. Such behavior is depicted in fig. 6 below, which considers the average values measured by every station.

Figure 6: PM$_{10}$ and PM$_{2.5}$ annual averages and PM$_{2.5}$/PM$_{10}$ ratio, historical network, 1998–2000 [14].

Summarizing:

- A clear decreasing trend is found in both number and length of PM$_{10}$ episodes. Year 1990 saw an 11-day episode, while the longest one in 2000 persisted for 3 days, though it only occurred twice that year.
• There is a progressive decreasing trend in the number of alert, pre-emergency and emergency episodes. The last actual emergency was recorded in 1994.
• The highest concentration of days with PM$_{10}$ pollution episodes ranges from May to July. Those three months seem to concentrate 75% of alerts, 80% of pre-emergencies, and 88% of emergencies. June historically concentrates the highest number of days with alerts, pre-emergencies and emergencies over the 1988–2000 periods.
• Such reductions in both number and length of PM$_{10}$ pollution episodes result from the introduction of new measures included in the Environmental Pollution Prevention and Removal Plan (PPDA for its Spanish acronym) in the Metropolitan Region. Contingency plans have been additionally introduced in order to reduce PM$_{10}$ pollution releases during both actual and forecast episodes. Such argumentation is supported by the fact that meteorological conditions underwent no significant changes over the 1988–2000 periods.

4 The 2001–2010 urban transport plan for Santiago

4.1 Overview

Santiago has seen at least three transport plans in the past 15 years. Some of them have been developed partially while others have been partially skipped due to lack of funds. For example, in 1995 there was the intention of building 75km of new busways in order to keep the bus patronage. However, because of the Asian crisis, only investments in private motorways and underground extensions were carried out. As a result of the fiasco in previous plans, the new Government set up the ‘Urban Transport Plan for Santiago 2000–2010’ (PTUS for its Spanish acronym). This plan tries to restore the missing pieces of the previous ones in an attempt to moderate the existing travel tendency towards a car-dependent city.

As defined by the authors, the 2000–2010 Urban Transport Plan for Santiago 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’ [15].

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

• Promotion of public transport as the principal mean 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 split in public transport.
- Reducing average trip length.
- Promoting non-motorized transport – i.e., pedestrians and bicycles.
- Creating awareness of the actual modal option costs among private transport users.
- Reducing pollution released by transport.
- Promoting organic urban development.

The PTUS consists of 13 programs (P0 through P12), the actions of which are briefly described hereunder.

**P0. Institutionalism.** Establishing the PTUS Management as responsible for the implementation of different programs, and reporting to regional and national authorities.

**P1. Public Transport Modernization, Orderliness and Integration.** 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.; specialized infrastructure for public transport; incentives for operators to entrepreneur and drivers to professionalize.

**P2. Road and Maintenance Investment, and Private Transport Regulation.** Traffic congestion control via road pricing; traffic management by the Traffic Control Unit (UOCT) of Santiago; parking space control; development of road infrastructure and maintenance projects; creation of a compensation chamber for revenues from tolling and parking.

**P3. Location of Schools.** Preventing the concentration of schools in a few municipalities, and increasing the number of admissions available in deficient areas, including subsidies to erect private schools in deficient areas.

**P4. Promoting New Trade and Service Areas.** Developing new trade and service areas to prevent long distance trips. Subsidies are being proposed to develop some city sectors with already visible autonomous trade.

**P5. Changing Household Location Trends.** Introducing subsidies for middle and lower-middle class housing, as well as low-cost housing, thus favoring already firmly settled municipalities that can accommodate new households, such as downtown Santiago.

**P6. Non-motorized Transport Modes.** Creating explicit facilities for pedestrians and bicycles through pedestrian areas, particularly in downtown, and a bike track network that will cover most of the city; developing initiatives to promote combined bicycle-metro trips.

**P7. Short-Term Scheme.** 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 the morning (07:30–10:00) and evening (17:00–21:00) peak hours.

**P8. Urban Cargo Transport Regulation.** Cargo transport regulations ruling
the city road network; creation of cargo stock and transfer centers; enforcement of weight, noise, release and fall regulations applicable to transported materials.

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

P11. Communications. Conducting a citizenry participation process to disseminate and collect opinions regarding the PTUS; developing a training process for transport system users at different levels: students, youths, adults and drivers.

P12. Other programs. This includes another initiative not listed in any other environmental, security or management PTUS initiatives.

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

4.2 Public transport upgrade

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 labor law violations. One consequence of the above is the high number of traffic accidents: there were 7023 accidents in the Metropolitan Region during 2002, which involved either urban or rural buses and resulted in 134 fatalities and 5788 injuries.

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 Transantiago, aimed at turning scattered services into a central public transport system that may network and complement the different modes [16]. A goal defined in the Transantiago Program for Public Transport Upgrade is to increase the share of public transport in the overall city transport, since only 50% of Santiago inhabitants use it at present, against 68% of them a decade ago. Such expansion should result from a new transport system that is: safe, punctual, accurate, fast, and financially, socially and environmentally sustainable.

The Transantiago Plan for Urban Transport will introduce a new public transport system in 2005. This will feature an expanded metro network, a new set of ground transport services, integrated fares via prepaid multimode cards, constant bus fleet renewal, modified business and labor management for the sector, and infrastructure investment on new roads, bus stops, and modal interchange stations. Stage II (2005–2010) will be focused on infrastructure
enhancement and expansion, with more metro lines and stations, and modal interchange stations, as well as on superior information technology and full bus fleet renewal.

Such a strategic change will impact one of the structural corridors in the current system, which is also one of its weaknesses – overlapped routes. The entire routing scheme will be remapped complementing two types of services: those ones that involve the main avenues or city corridors, and services that meet local demands or feeder areas, which will deliver passengers to both metro and buses in the corridors. Figure 7 shows one of the five business units to cover city corridors in Santiago. These business units will be offered in concession to private operators.

The current underground network consists of three lines and covers 40km. It will double its coverage by 2005 as a result of an expansion in its current services, for 11.3km will be added to lines 1, 2 and 5, and the new line 4 will start operations adding another 33km. Figure 8 shows a scheme with lines projected as of 2005.

According to Transantiago authorities, it is expected that the new public transport system will significantly reduce its share in traffic congestion, and air and noise pollution in the city due to a number of reasons: the overall bus base 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 that the end of 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 7329 units (on urban tender), to approximately 6000, with 1000 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 15m vehicles), while local and feeder services will have medium and low capacity buses. The bus fleet will be entirely renewed in 2010.

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 141 tons of PM$_{10}$ and 3665 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 quality of life in Santiago and reducing pollution.
- Turning the current competitive fragmented system into an integrated complementary one.
- Turning the current 297 services offered by 127 operators that represent 3000 small businesses, into 15 or 20 operators that gather 200–700 buses each.
• Downsizing the current 7659-bus fleet to 6147 high standard vehicles.
• Reducing the current average trip length from 62km down to 25km – 19km for feeder services and 36km for corridors.
• Metro network expansion from 40km to 81.3km.

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 Transantiago 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 traveled compared with the present flat fare throughout the city. Although exact figures have not been unveiled yet, it is expected that fares will increase in about 20 to 30%. 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 as Transantiago, the opportunity of attracting car users to public transport will be relegated.

Another 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 costs the same as the entire investment program in bus infrastructure (US$260 million). The expansion of the rest of the metro network will cost another US$1.5 billion. 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 [17].

The goal in which Transantiago will be successful is in reducing air pollution in Santiago, so improving the quality of life of its citizens. 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, [18]. 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 2005 is the capability of Transantiago in turning the current 3000 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.

4.3 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 10 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 Traffic Control Unit (UOCT), which has been running the centralized control of the 2000 traffic lights in Santiago since 1987.

However, complementary traffic measures to congestion charging has not been analyzed nor discussed with local authorities, which will ultimately implement the new traffic schemes outside the pricing zone. This not only means traffic signal adjustments, 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 [19].

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 (34km); the North–South highway called Autopista Central (61km); the Américo Vespucio ring road highway (51km), which completes the current ring road planned during the 1960s; and the south access to Santiago connected the Américo Vespucio ring road (47km). There are two other urban highways being tendered: the North–East access to Santiago through Costanera Norte (21.5km) and the El Salto–Kennedy intermediate ring road. All such projects are 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 220km 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’ [18]. Investment numbers do not appear consistent with the intended purpose: US$2 billion will be invested in motorways, but only US$55 million in busways.
4.4 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 designated as pedestrian areas (particularly in downtown Santiago) in order to create safe pollution-free areas with an adequate town-planning approach. This plan will also promote non-motorized means of transport by structuring a bicycle track network and implementing modern public infrastructure, to make pushchairs and bicycle rides more comfortable and safer.

This bicycle track network originally covers 70km, which will be completed by 2005 in three municipalities, namely downtown Santiago, Providencia and Nuñoa. For example, fig. 9 shows a 45km project in Nuñoa. This initial bicycle track implementation will gradually cover other city areas.

The authors of this chapter 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 stated by Tyler [18].

4.5 Short-term scheme

The so-called ‘immediate measures’ (P7) are defined as a development area by the PTUS 2000-2010. Such measures consist of a set of complementary strategies implemented on 26 March 2001:

- **Road Management**: including the definition of roads to be exclusively used by public transport, tidal flow roads for private cars, and lanes reserved for public transport in the main city avenue, Alameda Bernardo O’Higgins.

- **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, diesel improvement and regulatory enforcement.

For these measures there are some performance assessments 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 07:00h to 10:00h, Monday through Friday. In high pollution situations exclusiveness will also apply from 18:00h to 20:00h. A
preliminary assessment of exclusive roads for public transport suggests that bus travel time decreased by 12.7% on average [20].

Another short-term measure physically reserved three out of five lanes in Alameda exclusively for buses. Such separation was implemented using stack lines (fig. 10). 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 [15]. 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.
Some improvements suggested by the authors after assessing the operational conditions of exclusive roads and Alameda’s segregation follow [21]:

- **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, then 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.

- **Allowing taxis and high occupancy vehicles on bus-lanes.** If segregation aims at privileging public transport and taxis being a mode of public transport, taxis should be able to use exclusive lanes, as in other cities (e.g., only-bus lanes, taxis and interurban buses in London). A trip in any kind of taxi means less private cars in circulation looking for a parking place and using the road to park. In any exclusive way, taxis with passengers could use the bus-lanes to park. 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 vehicle flow. The use of private vehicles of high occupancy (minibuses and automobiles with three 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-lanes require shorter cycles and longer green light periods to reduce delays. This also helps reduce queue length in car lanes. The traffic congestion perceived by car drivers is consequently decreased, even if crossing a street takes more than one traffic light 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 Santiago from 07:30h to 10:00h and heading for Santiago outskirts from 17:00h to 21:00h.

Public transport presence 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 highlights 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 the driving speed up to dangerous levels. Cars can typically reach 65km/h or 80km/h (40–50mph) on roads crossing residential or commercial areas.
Even though no evidence of their application to traffic management has been found yet in tidal flow roads, Fernández has advanced the following proposals in order to improve the scheme [21].

- **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. The same lane could be used by other vehicle types, such as emergency or service vehicles. The counter-flow lane should be visibly signaled, possibly on top of mobile units, such as cones, curbs, barriers, etc.

- **Dynamic signaling.** One problem with tidal flow roads is transition time. Drivers should not be looking at their watches. On the contrary, some dynamic signaling system should tell them at certain intervals if they can continue on the same direction or if they need to leave at the 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 road 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.

### 5 Conclusions

In this Chapter we have described the relationship between the transport system and the impact on air quality in Santiago de Chile. To summarise, the following concluding remarks can be stated.

The characteristics of the transport system of Santiago are not too different from other developing countries: low car ownership, high percentage of daily travels on public transport, uncoordinated public transport systems, 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 1000 inhabitants), but figures range from a car ownership like Britain at high-income areas (413 cars per 1000 inhabitants) to that found in Turkey at low-income sectors of the city (45 cars per 1000 inhabitants).
inhabitants). Therefore, two styles of travel behaviour are observed within the city. One is typical of developed countries in which people make 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 (42% in Santiago). As a consequence, the bus fleet is vast (about 7500 in Santiago). Both behaviours have implications on Santiago’\'s air quality and transport policy.

Regarding air quality issues and emission inventories, mobile sources appear as the most polluted sector of the Metropolitan Region, with 48% of breathable particulate matter (PM$_{10}$), 84% of nitrogen oxides (NOx) and 91% of carbon monoxide (CO), according to the 2000 Emission Inventory for Santiago. Public transport buses and the rest of diesel vehicles play a significant role in the emission of particulate matter and nitrogen oxides. On the other hand, private gasoline vehicles have a high degree of accountability for carbon monoxide and volatile organic compound emissions. This difference in emission accountability is mainly due to the kind of fuel used.

As a way of reducing the negative effects produced by mobile sources on air quality, a series of technological measures have been introduced to the transport sector. Among these measures, those oriented to improve environmental characteristics of vehicle fleet are highlighted, such as demand of emission standards of new vehicles entering the country, inspection/maintenance automated procedures for vehicles in use, emission control in public thoroughfare, incentives for cleaner vehicles, emission control devices, conventional fuel improvement and more frequent use of alternative fuels. This set of actions has produced significant changes in the technological evolution of the vehicular fleet in Santiago.

These measures, along with other efforts made by the industrial sector, have produced a sudden decrease in the annual average levels for PM$_{10}$ concentrations from 1988 to 2000. There is a progressive decreasing trend in the number of alert, pre-emergency and emergency episodes in the city during that period. The last actual emergency was recorded in 1994. However, the ratio of PM$_{2.5}$/PM$_{10}$ has shown a slightly increasing trend over the last 6 years, mainly due to the high dependence of smaller particles with diesel internal combustion emissions.

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. Some of the evidence shows 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 so-called Immediate Measure Program. In addition, the schemes for promoting non-motorised transport are rather cautious. For example, no 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 the Transantiago Plan. Transantiago was mainly aimed to meet the requirement of the Pollution Prevention and Removal Plan (PPDA). In such a condition Transantiago will
also improve the organization of the public transport system. However, some level of service variables will decay. For example, the number of interchanges will increase from 0.2 to 0.8 per trip. In addition, at trunk routes fares will be related to distance traveled, compared with the present flat fare throughout the city. Besides, although exact figures have not been published yet, it is expected that the base fare will increase by about 20 to 30%. Considering the price elasticity of public transport demand as well as the well-known interchange time penalty, all these modifications can have a negative impact on bus patronage. It must not be forgotten that one of the goals of Transantiago is to ‘increase public transport usage through an integrated and sustainable system’.

References


