TRANSANTIAGO, FIVE YEARS AFTER ITS LAUNCH

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ABSTRACT

We review the current situation of Transantiago, the fully integrated public transport system covering the Santiago Metropolitan Area, Chile, identifying its current strength, flaws and challenges. The system captured worldwide attention after its premature implementation in February 2007, before most of the infrastructure and systems conditions required by its designers were in operation. The document summarizes the current state of Transantiago focusing in the evolution of the services offered, the infrastructure available, performance indicators, the main features of the contracts between the authority and the operators and the financial situation of the system. The main achievements and challenges of the plan at present are discussed. The paper ends presenting the main lessons learned for other cities willing to follow a similar path.

Keywords: Public transportation, Transantiago, Urban transport planning

1 INTRODUCTION

Transantiago is the fully integrated public transport system covering the Metropolitan Area of Santiago, Chile. The system comprises bus services provided by private operators and a Metro system provided by a State-owned Society . Bus services were originally structured into a trunk and feeder network in which nine feeder operators enjoyed the exclusive provision of services in an area of the city, while five trunk operators enjoyed the exclusive provision of services in a set of corridors. A private consortium composed by the most important banks in Santiago and a technological operator comprise the Technological and Financial Administrator of Transantiago (AFT) which provides the magnetic payment card, its charging network the card validating devices in all of the buses, and is in charge of fare collections and clearing activities.

This ambitious system was implemented prematurely in February 2007, before most of the infrastructure and operating conditions required by its designers were in operation. The result

was extremely chaotic. In Chile, Transantiago is considered by many as the worst public policy ever implemented in the country (Herrera, 2008; Emol, 2012).

The Santiago public transport reform has been studied by several researchers from different perspectives. We can categorize these documents within four general types of reports: i) descriptive articles of the plan written before its implementation; ii) evaluations right after the crisis; iii) impacts analysis of particular aspects; and, iv) technical advances for supervision and control.

The articles written before the implementation of Transantiago were mainly prepared by members of the Chilean government participating in the planning effort. They concentrate in describing the quite unique evolution of the transit system in Santiago and the proposed reform, stressing the comprehensive effort to have a citywide integrated system and large expected social benefits (Malbran 2005; Mendeville et al, 2006; Graftieaux, 2006). There is a special focus on the technical planning tools used to plan the bus routes and services (Malbran et al, 2004), without much recognition of the risks involved in the transition. Some external authors –not participating in the process, indicated the need for more research, investment, and participation from all relevant actors (e.g. Strenio, 2006). An assessment for a World Bank operation indicated that there were modest risks, but the bank officials were confident of the ability of the institutions involved owing to the excellent record of Chile in economic management, program implementation, and transparency (World Bank, 2005).

Right after the implementation in February 2007, and due to the terrible crisis suffered by the city, there were multiple reports that intended to explain the causes of the difficulties. The initial articles were journalistic reports of the "disaster" (e.g. Pelayo, 2007; Helten, 2008), without in-depth analysis. Munoz et al, 2008 presents a thorough revision of the motivations behind Transantiago, followed by its design and early implementation. Several others concentrated on the institutional and political issues. Some of these authors stressed that the concept of quality was not central in the reform (Montesino, 2007; Maillet, 2008). Other authors indicate that the institutions both at the national and local level were very weak and did not have the capacity to control the complexity of the process (Figueroa and Orellana, 2008). The project was of special interest from the political science perspective: it generated political difficulties for the ruling party (Mardones, 2008); and placed transport as an important element of concern (Luna, 2008).

Lately, several papers concentrate on particular impacts of the project: environmental (Figueroa et al, 2012; Pardo and Pedrosa, 2012), social exclusion (Laso-Corvalán, 2008), contracts evolution (Gomez-Lobo and Briones, 2013), and recommendations for public policy (Navas-Quintero, 2008; Hidalgo and Carrigan, 2010). Finally, Transantiago has also become a test-bed for advancing several technical elements to improve information and control (e.g. Fernández et al., 2008; Cortés et al., 2011; Munizaga and Palma 2012; Navarrete y Ortúzar, 2012; Delgado et al, 2012).

Authors evaluating the system and providing recommendations for other systems tend to coincide in four elements as critical causes of the initial operational problems in Santiago: the large scale reorganization ("big-bang") was too difficult to manage; there was undersupply of services and lack of control in the initial operations; and there was a focus on cost reductions and environmental impacts, but not in service quality (e.g. Hidalgo and Graftieaux, 2008; Muñoz et. al, 2008; Gomez-Lobo, 2011). This paper provides a comprehensive assessment of the plan five years after its implementation.

Section 2 of this document summarizes the current state of Transantiago focusing in the evolution of the services offered, the infrastructure available, performance indicators, the main features of the contracts between the authority and the operators and the financial situation of the system. Sections 3 and 4 present the main achievements and challenges of the plan at present, respectively. Section 5 presents the lessons for implementation similar public transport plan in other cities. Finally, Section 6 presents the conclusions of this study.

2 CURRENT STATE OF TRANSANTIAGO

2.1 Public transport services

In this section we focus on the characteristics of the services offered, the state of the fleet and the total number of kilometers driven. We distinguish bus services from Metro services.

2.1.1 Buses

The tendering documents of Transantiago considered an operational fleet of only 4,600 buses. However, before the inauguration of Transantiago the government requested 1,000 extra buses, so the initial operational plans considered a fleet of 5,600 buses. The system started with 1,375 new buses that had already been operating for the pre-launch or transition phase. The inauguration of Transantiago in the mid of the summer holidays of 2007 was extremely rough, with a notorious lack of bus services citywide and unacceptably low levels of service (high walking and waiting time, and overcrowding) to users. The initial fleet actually operating was clearly insufficient so during the first year of Transantiago the authorities focused on significantly increasing the effective supply of bus services in the city. Table 1 displays the kilometers driven, and the registered fleet and number of services offered by the end of years 2008 to 2011. Driven kilometers have an increasing trend until March 2010, when national government changed. From 2010, the government made an effort to reduce the total kilometers offered as a way to reduce the subsidy to finance the system.

Table 1 – Evolution of public transport commercial kilometers, fleet and services after Transantiago (Source: Transantiago)

Year	Commercial km (million)	Fleet	Services
2007 (starting February 10)	371.1	4,489	223
2008	481.4	6,399	322
2009	487.2	6,572	334
2010	512.4	6,564	357
2011	483.0	6,165	370

The current fleet of over 6,000 buses has been in permanent renewal to dispose of the old style buses (actually converted lorries) inherited from the previous system. During 2009 and 2010 a total of 1,151, new buses joined the system. By the end of 2013, Transantiago plans to replace 1,108 extra buses. Table 2 shows the fleet composition in terms of 160-pax

articulated buses, standard 95-pax buses and the rest of the fleet with capacities ranging between 50 and 80 passengers (these capacities assume a rather high 6 pax/m2 density). The aggregated capacity of the fleet in terms of seats/standings places and the average age of the fleet are also displayed. Table 2 shows that the authority has reduced the emphasis on large articulated buses in the new fleet focusing more in renewing standard medium-sized buses since the fleet of articulated buses has not grown. The capacity drop of 2011 is due to the extension of the Metro network which triggered a reduction in the number of buses operating in the vicinity of the new lines.

Table 2 – Distribution of bus types and their aggregated capacity in Transantiago (Source: Registro Nacional de Transporte Público)

Year	Fleet (buses)	Articulated	Standard	Smaller buses	Capacity (sit/standing places)	Avg. Age (years)
2008	6,399	23%	20%	58%	607,178	8.4
2009	6,572	22%	26%	52%	626,527	7.4
2010	6,564	22%	40%	38%	650,003	5.9
2011	6,165	24%	45%	31%	626,647	5.3
2012	6,167	23%	46%	31%	627,695	5.2

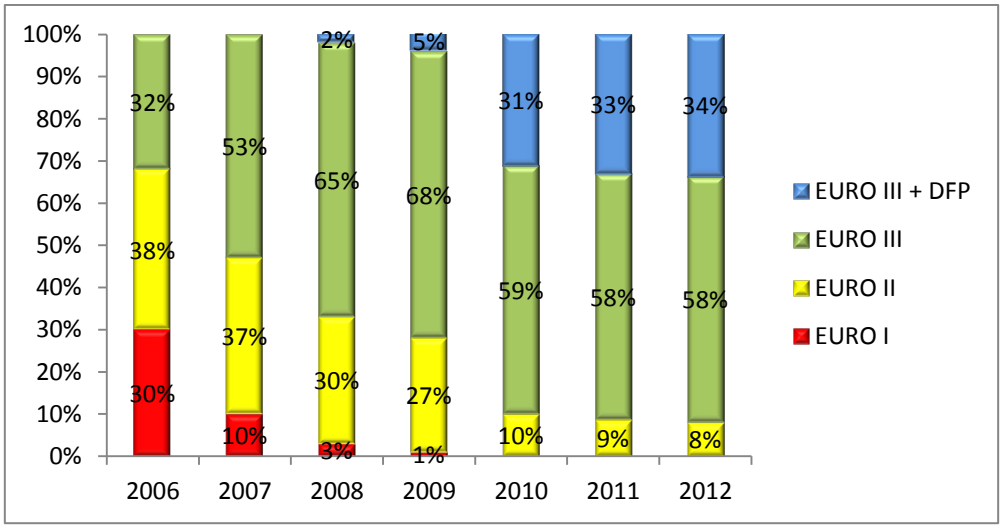

Figure 1 – Evolution of bus technological standards after Transantiago (Source: Registro Nacional de Transporte Público)

The registered fleet has better environmental standards. Figure 1 shows the evolution of the percentage of buses satisfying different (and progressively more stringent) international environmental standards. By May 2012, 92% of the fleet was Euro III, from which one third was also equipped with a Diesel Particulate Filter.

Until recently, the new added services kept most of the original trunk and feeder structure under which the system was originally organized, aiming at reducing the average number of transfers per trip by joining and extending some services, and relaxing the strictness of the exclusivity of feeder zones and corridors. However, this flexibility couldn't be extended as much as it was desired since the contracts were quite rigid in this sense. Although the new contracts recently signed do not change the services operating in Transantiago, they eliminate the trunk and feeder logic by not distinguishing between both types of services.

Thus, it is expected that this trunk and feeder structure will become more blurred in the future. The new contracts with bus operators shift from giving them exclusive to preferential use of streets. With the recently negotiated contracts, some previously trunk and feeder concessions have merged giving birth to larger firms whose services are a mixture of feeding and trunk services.
Also, the bus system has shifted its image from a system-wide into a firm-based logic. Initially, buses from all trunk operators shared the same image (white and green), and all buses from each feeder operator had its own color. Now, buses from each firm (no matter which feeder or trunk service they operate) share the same color. The authority expects that users will recognize and differentiate operator firms, orienting their travel decisions.

2.1.2 Metro

After Transantiago, Metro adapted its services to improve the level of service offered to users. We must recall that Metro almost doubled its ridership when Transantiago started for several reasons: i) fare integration allowed users to take Metro without paying a second fare, ii) the bus network was designed such that passenger make intensive use of the subway, iii) the bus system was providing a very poor level of service, and iv) the card payment charging-network was extremely insufficient, as a result Metro looked like the only place to charge the card and attracted more passengers. Since 2007 the fleet of train cars and the kilometers driven has grown as shown in the Table 3. Also, a very innovative skip-stop operation was implemented in three of the four lines during peak periods. This operation allows the system to provide a higher level of service to most passengers, increase the capacity of the system by approximately 10% and reduce the operational costs per kilometer (Metro, 2009). Finally, since Transantiago started, Metro has extended its operations starting earlier and ending later in the day than before 2007. An order for 108 extra train cars will start arriving by mid 2012 and should improve significantly the level of comfort experienced by users during peak periods.

Table 3 – Evolution of the characteristics of Metro network, services and ridership (Source: Transantiago and Metro)

	2005	2006	2007	2008	2009	2010	2011
Network length (km)	66	85	85	85	85	95	104
Number of stations	78	92	92	92	93	101	108
Number of train cars	636	666	751	751	751	967	967
Car kilometers driven (million)	52	71	94	105	106	119	131
Annual ridership (million)	267	331	601	642	608	621	640

2.2 Infrastructure

In this section we focus on the characteristics of the infrastructure available for operating Transantiago. Again, we distinguish between infrastructure for buses and Metro.

2.2.1 Buses

Even though Transantiago was planned considering a broad set of segregated lanes for buses, this infrastructure was mostly absent when the system was inaugurated. This had a very significant impact in increasing travel times, reducing bus productivity and capacity, increasing waiting times and vanishing the potential advantages of a trunk and feeder system when compared with the planned performance. It also damaged reliability which turned to be one of the main complaints of bus users. Since the inauguration of Transantiago the number of segregated bus corridors has grown steadily as shown in Table 4. However, the current network of high standard rolling infrastructure covers only a small fraction of the citywide trunk network of Transantiago which is over 1,500 kilometers long.

Table 4 − Evolution of the infrastructure for buses (kms) (Source: Transantiago)

Year	Segregated corridors	Bus only lanes	Exclusive streets (peak hrs only)
2007	13	68	8
2008	16	77	31
2009	65	101	31
2010	90	101	31
2011	90	101	31

The implementation of segregated corridors has been slow partly because local residents and local authorities oppose them because they perceive bus corridors as a delay to their expectations of having a Metro line in their neighborhoods and fear of significant property expropriations. On the other hand, the authorities argue that segregated corridors can only be built in wide avenues. Thus, they have designated several lanes that were previously assigned for mixed traffic as “Bus only”. The evolution of the number of these lanes grew in the first two years of Transantiago as shown in Table 4. But these lanes have been quite ineffective since they are too often used by private vehicles and also not enough attention has been paid in terms of priority for buses at their intersections. The authority has implemented some sort of automatic enforcement through photographic evidence to prevent cars from invading bus ways, improving bus speed in up to 24% (La Tercera, 2012). Some bus lanes have also been painted red to make them visually clearer. However, these efforts have been quite focalized on only the most utilized corridors.Table 4 also shows the evolution of exclusive streets for buses implemented during 2008 (these are streets devoted exclusively for buses during peak periods only) mainly in the central business district, unfortunately its network has not grown since then.

According to Muñoz et al (2012), the average speed offered by the various types of corridor infrastructure varies significantly. The average speed observed in the morning rush hour for downtown headed bus services is 25.9 km/h on segregated corridors and exclusive streets, 17.2 km/h on bus-only lanes and 15.1 on mixed traffic streets. The average feeder speed is approximately 17 km/hr, but varies significantly among different areas of Santiago reaching only 11 km/hr in some other zones.

The authority has also focused on providing adequate bus stops for the system. In 2007, Transantiago had only 3,013 roofed stops that had grown to 8,580 by 2010 (from a total of

approximately 11,000 stops). Lately, Transantiago has installed solar lighting at about 300 stops in the suburbs and have a signed contract for additional 1,000 of these stops. Additionally, 129 of the stops operate with off-bus payment mechanisms during peak periods. Even though they are quite effective in terms of speeding up dwell times, reducing fare evasion and loading buses homogeneously, they were designed to play a transient role while a more definitive solution was under way. After five years the more definitive stations have not been installed, and the current ones contribute very little to the expected harmony between the public transport infrastructure and the urban space.
The 2011-2015 Infrastructure Master plan for Transantiago establishes that around US$760 million will be invested in building 86 km of extra bus corridors and improving 16 km of mixed traffic ways with a high proportion of buses. It also includes US$210 million to improve the quality of the stops and of the stations with off-bus payment system, and US$25 million to install 700 cameras for bus priority enforcement.

2.2.2 Metro

Two extensions of existing metro lines have been inaugurated since 2007. As the rest of the network, these are run at high frequency (intervals of less than 3 minutes during peak periods) and quite reliably. Thus, they were very well received, even though they did not attract as many new passengers as planned. Metro is clearly experiencing a decreasing marginal ridership contribution from new lines added to the system. However, new lines have also contributed to improving comfort by reducing the overcrowding in some critical links. Table 3 shows the evolution of the network (kilometers and stations), the size of the fleet (train cars), the annual kilometers driven and the annual ridership. Last year two new lines were announced to be inaugurated during 2016-2018, adding 37 extra kilometers to the network.

2.3 Demand

Users of Transantiago tap in to enter each bus or to enter the Metro network, but are not required to tap out neither in buses nor Metro (transfers within the Metro network are not registered). The fare system allows passengers to take up to three legs to finish their trips (i.e. two transfers at the most). The time lasting from the first to last tap in cannot exceed two hours. So, during two hours, passengers may make up to three single-leg trips paying a single fare as long as they do not take Metro more than once or repeat the same bus line.
Thus, the ridership is estimated as the number of passengers entering the system paying their fare (even if they make more than one trip). The ridership captured by public transport (excluding shared taxis) in Santiago apparently dropped after Transantiago since it was approximately 10% below the projected demand for 2007. On one hand this is due to the difficult beginning of Transantiago, but it is also not unexpected as the country has continue growing strongly and the car fleet in Santiago has increased by one third in five years as shown in Table 5.
Figure 2 shows the evolution of the monthly validated trip legs in bus feeder, bus trunk and Metro services, showing a total number around 150 million trip legs. The graph also shows

the ridership that can be inferred from this information which, as is based on the card validation of users, neglects the multiple trips that can be made within two hours and the growing number of trips that evade the fare.

Table 5 − Car fleet in Santiago Metropolitan Region in thousands (Source: National Institute of Statistics, INE)

Year	Cars	Cars and motorbikes
2006	918	943
2007	972	1013
2008	1027	1081
2009	1055	1113
2010	1128	1186
2011	1222	1285

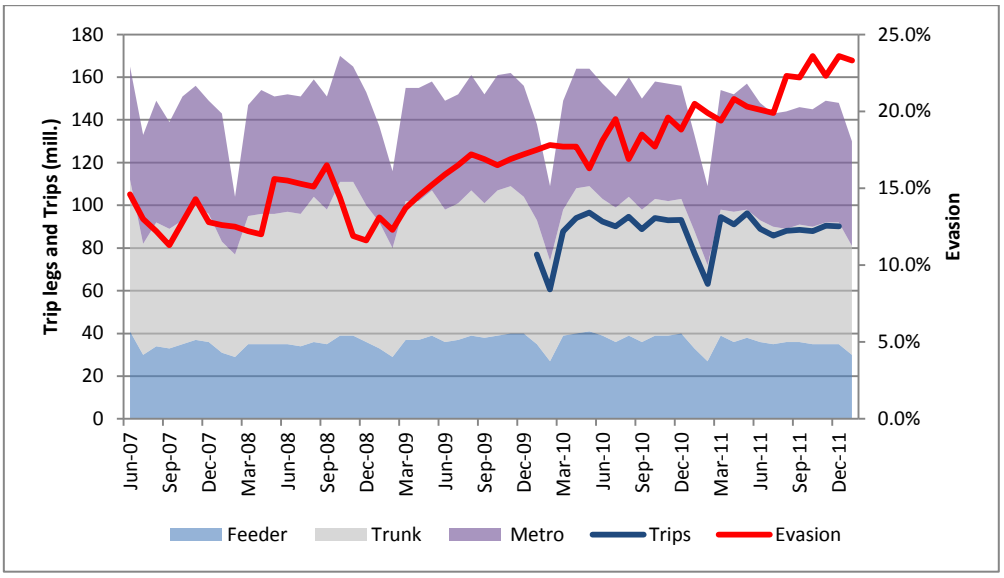

Figure 2 − Evolution of feeder, trunk and metro trip legs, total trips and evasion (Source: Transantiago)

High fare evasion has been observed in bus services in several parts of the city (fare evasion in Metro is almost inexistent) and it has become alarmingly high according to some studies. The red curve of Figure 2 corresponds to the estimated percentage of passengers evading the bus fare which has recently gone over 20%. The reasons for this evasion are manifold. Some people simply want to keep the money (fares have increased by 50% in the last three years and for a significant fraction of the population paying the fares twice on every workday represents around 15% of their income), others enter through the back door as a convenient way to enter a heavily loaded bus (validators are only located at the front door), while others may not have a facility nearby to charge their cards (the network for charging the payment card is still insufficient in some areas of the city, particularly during some periods). Notice that these last two evaders may pay their fare in a subsequent or previous leg of the same trip allowing Transantiago to receive its income, but not the evaded operator. Evasion not only has become a regular habit in certain areas, also the probability of getting a fine for evading is still so low that it pays off to evade if a user wants to minimize his/her trip costs, so there is very little social or financial deterrent to stop evasion. The figure shows a slightly diminishing number of trips which is probably influenced by the notoriously long student strikes that

affected public schools and higher education in Santiago through the whole second semester of 2011.

As was mentioned, one of the main drivers of the high evasion rates is the fare. During the first three years of Transantiago operation the fare barely changed; however, the last two years have seen a significant increment of almost 50%. Figure 3 shows the striking correlation between fares and evasion rates. The bus fare jumped from around US$0.70 when Transantiago started to around US$1.15 nowadays.

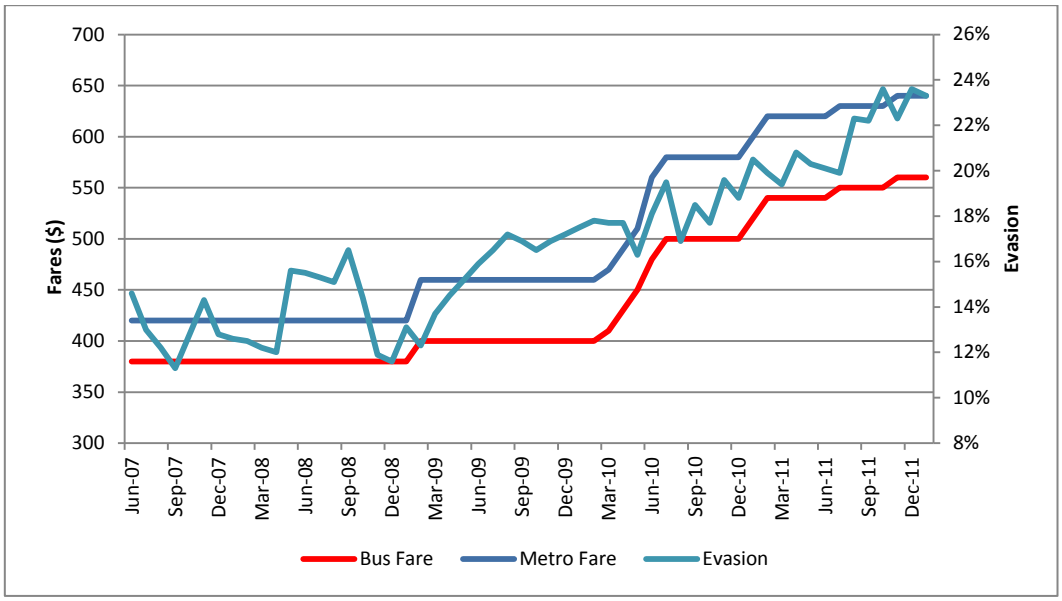

Figure 3 − Evolution of a single bus trip fare, a single metro trip fare (peak period) and fare evasion (Source: Transantiago)

It is interesting to notice that Metro demand on the second year of Transantiago was particularly high even though the network did not grow (see Table 3). Since demand later dropped to its 2007 level, this raise and drop could be associated to the poor level of service offered by the bus system at the beginning of Transantiago and the lag taken for the bus demand to recover. Also, it could be associated to an increment in the difference between Metro and bus fares starting in early 2009 as shown in Figure 3.

2.4 Performance indicators

The operational performance of a public transport system as complex as Transantiago must be characterized by many different dimensions and should consider the integrated level of service provided by the system as a whole (metro and buses). At least we should consider: access times, waiting times, travel times and number of transfers. The performance indicators of this section were obtained from Muñoz et al (2012), in which a representative sample of 400 trips in Santiago was thoroughly analyzed (400 was selected to provide a statistically significant estimation for the average travel time for the whole city, however for a more disaggregated analysis the number of trips do not guarantee the same level of statistical robustness). The background of Figure 4 displays a histogram of the distance (measured over the network) travelled by different Transantiago users. The same figure displays the average time spent by a traveler walking, waiting and inside the vehicle for each

distance segment. According to this study, during the morning peak the average origin to destination distance corresponds to 11.4 km, while the average walking, waiting and travelling times for Transantiago users are 13.8, 8.2 and 28.6 minutes respectively.

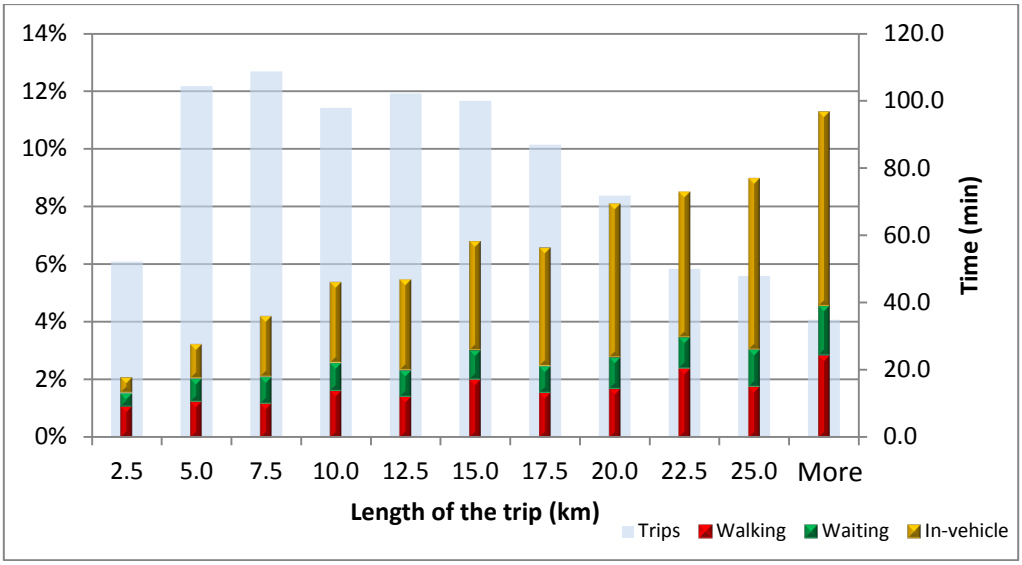

Figure 4 − Average trip conditions across all public transport users. Background: histogram of the distance traveled; front: access time, waiting time and in-motion time for each distance (Source: Muñoz et al, 2012).

However, not only average indicators are relevant here; the performance is strongly linked to the reliability of these indicators across different times when the same trip is started. Indeed, even though the average door to door travel time across all trips corresponds to approximately 50.6 minutes, its standard deviation has been estimated as 5.9 minutes. This means that once every 20 trips, the total travel time is more than 10 minutes longer than the average.

On the other hand, travel conditions are very different in different areas of the city. Figure 5 shows the average total travel time for all trips within a given distance interval including the confidence interval in which 95% of the average trip times fall. This means that while some 15 kilometers long trips may take 37 minutes in average, others will take 84 min in average. This explains why the experience of different users varies so much along the city, with some users considering Transantiago a modern and efficient system, whilst others criticize it as slow, crowded, infrequent and inaccessible.

The results of Muñoz et al (2012) are somehow consistent with those reported by OMU (2009) and presented in Table 6 in which the travel time for road and rail trips are compared across 15 Latin-American cities. The document is not clear regarding how these travel times are computed. Apparently, the travel times reported in the document correspond to 2007 which coincides with the worst moment for Transantiago. Even under these circumstances, the system appears to provide a better level of service that most of the remaining cities considered in the sample.

In a parallel study, DICTUC (2011) has been measuring the same set of trips since the beginning of Transantiago. Figure 6 displays the evolution of their measurements during the morning peak period. The study also includes the average travel time obtained during two different studies developed during 2001 and 2006 yielding 46.7 and 52.6 respectively.

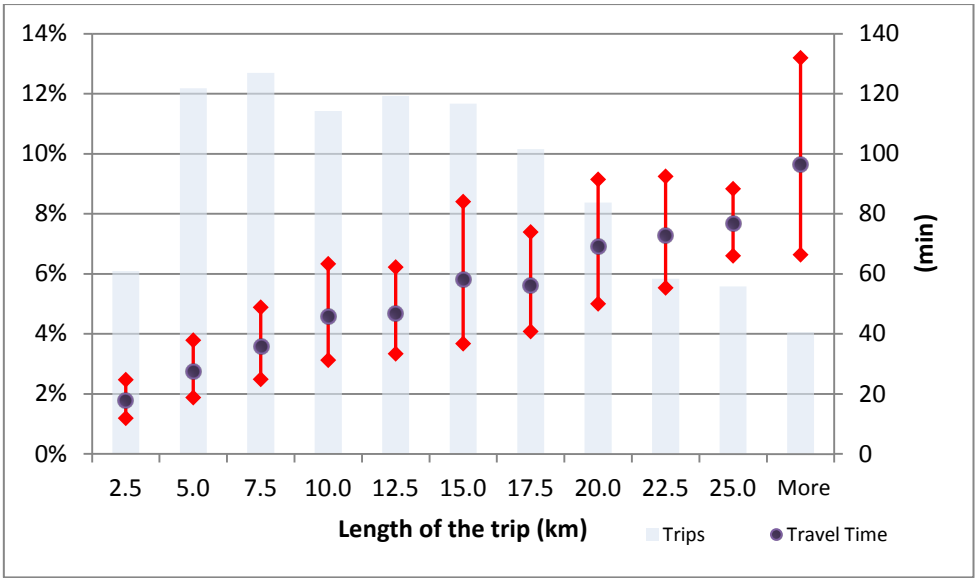

Figure 5 − 95% confidence interval for average travel time across all public transport users in Santiago (Source: Muñoz et al, 2012).

The average level of service (access time, waiting time, travel time, number of transfers, comfort, reliability, etc.) in the city started significantly below the one offered by the previous system. However, as can be observed from Figure 6, significant improvements were already observed by the end of 2007 that have remained quite constant since then. According to DICTUC (2011)'s results, nowadays the travel time offered by Transantiago is better than the one offered by the previous system in 2006. This is an outstanding result, if the impact of the projected level of citywide congestion is considered. Even though, crowdedness inside the vehicles has become a recurrent complain especially in Metro, as can be inferred from Table 3, since the demand doubled in a single year without a corresponding capacity increment.

Table 6 − Travel times in public transport in different Latin-American cities in 2007 (Source: Observatorio de Movilidad Urbana - CAF, 2009).

City	Country	Travel time (min)		
		Road	Rail	All
Belo Horizonte	Brazil	38.1	35.0	38.1
Bogotá	Colombia	72.1	0.0	72.1
Buenos Aires	Argentina	37.0	39.1	37.3
Caracas	Venezuela	55.3	20.0	53.0
Ciudad de México	México	45.5	40.0	45.1
Curitiba	Brazil	36.5	0.0	36.5
Guadalajara	México	47.8	35.0	47.4
León	México	52.2	0.0	52.2
Lima	Peru	60.0	0.0	60.0
Montevideo	Uruguay	34.7	25.0	34.7
Porto Alegre	Brazil	35.2	25.0	34.8
Río de Janeiro	Brazil	41.6	35.7	41.4
San José	Costa Rica	57.0	43.0	57.0
Santiago	Chile	47.0	29.0	43.6
São Paulo	Brazil	46.1	41.4	45.6

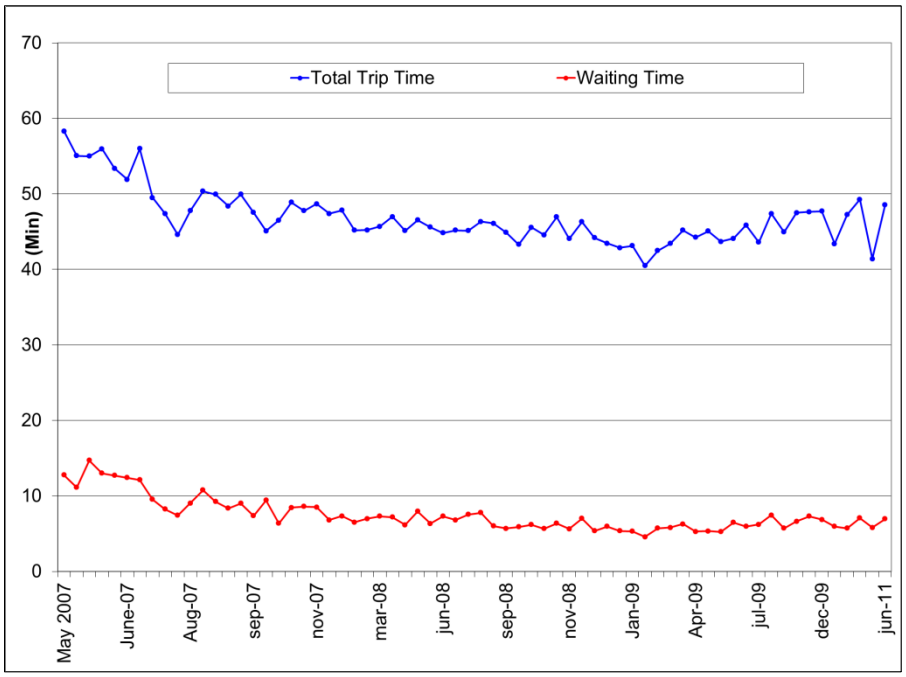

Figure 6 − Evolution of average total travel time (walking+waiting+in vehicle) and waiting time for a sample of Transantiago trips (Source: DICTUC, 2011)

A very important element of the bottom line performance of a system is its evaluation by the users. This has been a difficult battle for Transantiago since its evaluation is (almost) at its lowest since it was inaugurated five years ago. Figure 7 shows the approval rate of Transantiago. The graph does not distinguish users from non-users. On the other hand, Figure 8 shows the net satisfaction (defined as the difference between approving and disapproving passengers) for frequent users of Transantiago which is slightly higher than for the general citizen. Both graphs are consistent, showing that approval peaked by the end of 2009, right before fares started to increase systematically. Although the drop could be associated to a national government change on March 2010, it appears that its main driver is the fare increment, while the level of service has remained constant (with the exception of the period from march to September 2010 in which the volume of services dropped) and fare evasion rates have grown.

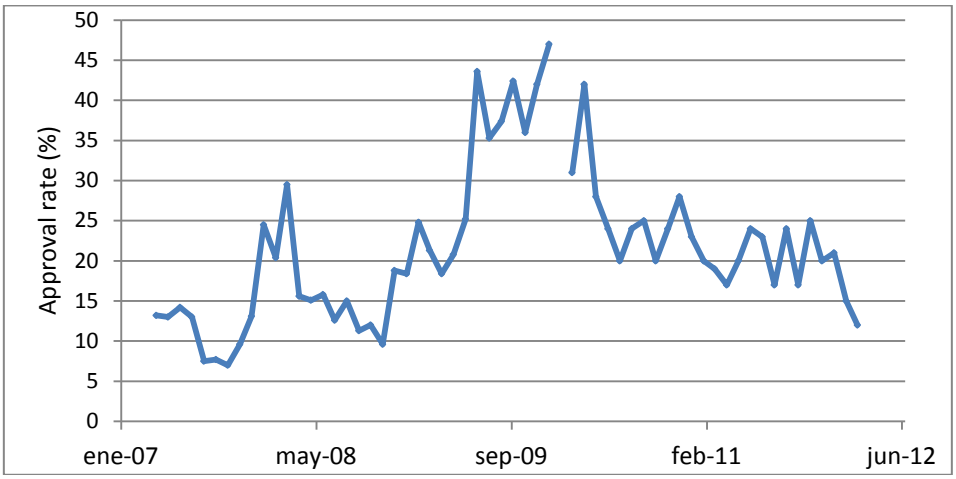

Figure 7 − Transantiago approval rates (%) within Santiago citizens (Source: Adimark, 2010; 2012)

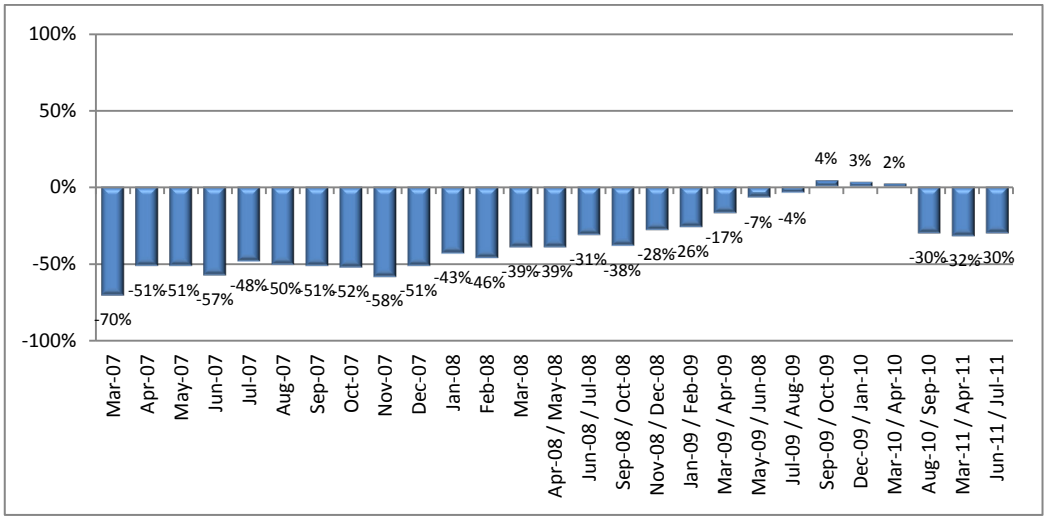

Figure 8 − Net satisfaction within Transantiago frequent users (Source: Collect Gfk, 2011).

2.5 Contracts

It is difficult to imagine a set of contracts that have been amended as often as those of Transantiago's operators. Since February 2007 they have been changed 17 times, four of those modifications being quite structural in nature. Even though all these amendments kept the structure of the original contracts, several of them imposed new incentives to the operators. The original contracts aimed at providing a low risk operation in which changes in ridership had a minimal effect in the revenues captured by the firms. This reduced demand risk helped to attract new and international operators to Transantiago and to guarantee a very competitive bidding process. The contracts specified important fines and revenue deductions for operators who did not provide the services that were agreed in the operational plan. However, the contracts also established that once an operator accumulated a certain (pretty low) number of fines, its contract should expire. Very soon the authority realized that it was captured by this contract since getting rid of the operators did not help to improve the system. Thus, the fines were useless and the authority lost one of the main tools provided by the original contracts to enforce a high quality of service.

When Transantiago started, the operators did not provide the services that were committed or planned. They kept most buses at the terminals providing very insufficient services. A first change in the contracts came by mid-2007 when the authority decided to link payment to firms to the buses actually operating. As can be seen from Figure 9, this change had a dramatic impact increasing the operating fleet from 4,600 to 5,800 buses in only three months.

The control measures to force the operators to effectively comply with the operational program prepared by the authority became more and more sophisticated. Several new indicators had been linked to the operators' revenues. The first implemented indicator, called ICPH, measures the number of seat/standing places offered by an operator aggregated for all its services. It is constructed as the number of buses multiplied by their capacity that were actually operating every half an hour, divided by the theoretical figure indicated by the operational program. The average ICPH increased from 0.85 in September 2007 until 0.99 in

March 2011 (Beltran et al., 2011). Transantiago modified the ICPH to capture not only the seat/standing places offered, but also the kilometers actually driven by the buses. This new indicator was called ICPKH. It was computed for every service in every direction and was linked to the revenues received by operators. The average percentage obtained in this indicator directly affected the revenues obtained by an operator.

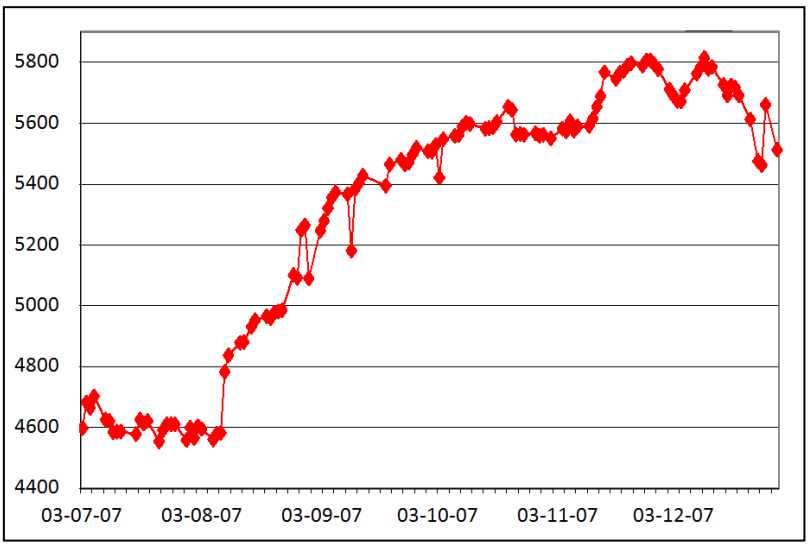

Figure 9 − Number of operating buses in Transantiago from July to December 2007 (Source: Beltran et al., 2011)

Another indicator called ICF measures the frequency effectively fulfilled by each service in each direction. It is constructed as the percentage of programmed bus-trips effectively offered. The ICF measured in the morning peak period evolved from 0.75 in August 2008 to 0.95 in June 2011 once it was incorporated into the contracts (Beltran et al., 2011).

Finally, the ICR is an indicator that measures the regularity of the headway offered by each service in each direction. The index is based on the coefficient of variation (CV) of the observed headways. The CV is transformed into an index between 0 (minimum) when the CV exceeds 1.5 (this is indicative that the headway variability is huge) and 1 (maximum) when the CV is lower than 0.4 (meaning little variability across bus headways). For values of CV between 0.4 and 1.5, the ICR decreases linearly until 0. The ICR measured on the morning peak has evolved with volatility from 0.74 in August 2008 to 0.83 in June 2011 (Beltran et al., 2011).

The three previous indicators have impacted the performance of the operators. However, in the case of ICR, this impact has been considerably weaker. Indeed, reliability is still one of the main complaints of Transantiago users. Also, even though these indicators succeeded in getting the operators to adequate their operation, they also induced them to some undesirable behavior as having drivers not stopping at certain stops just to improve the performance indicators that were part of the contracts. The authority expects that the incentives added in new contracts (discussed later in this document) will address these issues effectively.

Even though the fulfillment of the operational programs was solved by the first amendment of the contracts, a mismatch remains between the incentives faced by operators and the goals of the authority. By mid 2011, this discrepancy had materialized in the form of operators being insensitive to passengers evading the fare or to drivers skipping some bus stops in

order to reach the performance indicators associated with the operational plan (although hard to believe, this last issue has become quite frequent among passenger complaints about Transantiago).

The authorities and operators have recently signed a new set of contracts (they are not amendments of the previous ones) imposing a new regulatory framework that significantly increased the impact of the ridership captured by operators in their revenues. The contracts improve and increase the indicators that relate revenues to the quality of service being offered. The contracts also incorporate a cap to the potential subtractions in revenues when the effective supply of services differs from the plan or if the regularity of services drops below a certain standard. In total, the operators face a higher demand risk with the new contracts. The authority expects that, in this new scenario, operators will be more worried about the quality of service being offered and will fight fare evasion since it damages their revenues. The authority is also confident that this new incentives will not bring on-the-street wild competition for passengers, which is one of the main achievements of Transantiago. Finally, it is worth mentioning that in this last renegotiation of contracts the authority also tried to keep financially sustainable firms operating in the system by including some stabilizing mechanisms for firms' revenues limiting the maximum revenue discounts to be applied, and mechanisms to adapt to urban and economic conditions that cannot be predicted today. Since Transantiago started, three feeder operators went bankrupt and had to leave the system creating a significant headache to the authorities and damaging the level of service to users in the process. Thus, one of the outcomes of the negotiation process was merged service areas served by fewer and larger players.

2.6 Financial situation

Transantiago was designed to operate without subsidies and to offer a similar average fare per trip than the previous system; however it was launched at a slightly reduced average fare. Even though this constraint implied fewer and larger buses, this goal was never achieved since the operation of a formal public transport system is considerably more expensive than an informal one (e.g. considerably higher labor costs), an integrated fare is more expensive to manage and it allows for more than one trip per fare within the 120 minutes time window. Very soon it became clear that Transantiago would need significant subsidies to operate. In fact, the annual costs of the system have reached approximately US$1,700 million a figure which is significantly larger than the costs originally planned. The government has raised funds for Transantiago with two purposes. The first has been to subsidize students that pay only one third of the regular fare and the difference is now coming from central funds and not from the rest of the users of the system. The second has been to bring central funds to cover the operating deficit of Transantiago. The total subsidies are significant and have reached over US$50 million per month (around 40% of the total costs) as shown in Figure 10 which presents the evolution of the monthly deficit expressed in US$. From this figure, over 50% goes to finance students, over 15% goes to finance new Metro lines, leaving less than 20% to finance the operational deficit of the system (Metro and buses).

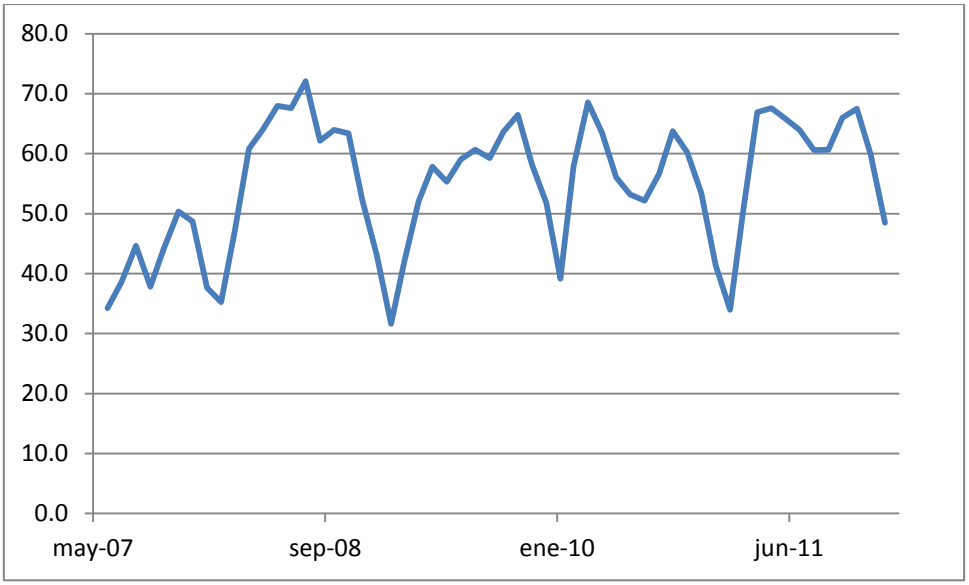

Figure 10 − Monthly deficit (in millions of US$) from June 2007 to January 2012

An integrated public transport system like Transantiago should be subsidized for several reasons. On one hand it causes significantly less congestion, pollution and accidents than cars. On the other hand, subsidies allows the provision of more and more frequent services reducing access times and waiting times for all users of the system. This efficiency gains have been highlighted as one of the more relevant reasons justifying subsidies. Finally, they can hardly been accused of being regressive since the large majority of public transport users belong to the poorest sectors in the city.

3 ACHIEVEMENTS

The main achievements of Transantiago can be listed as follows:

a) The bus industry has been formalized. We have moved from thousands of small operators to a group of seven firms corresponding to only five different financial groups which are easier to inspect, monitor and coordinate. Also, drivers have now formal contracts that must obey labor legislation.
b) Transantiago has reduced transit externalities significantly. As shown in Figure 11, the accidents involving buses have dropped by half for several reasons: drivers do not work long shifts, nor compete for passengers in the streets, vehicles are more reliable since they are better maintained, vehicles no longer move with their doors open. Also, bus-based pollution and noise have been reduced significantly. According to a study developed by the Mario Molina Centre in 2009, Transantiago has contributed to reduce the concentration of ultrathin particles (mainly associated to buses) by reducing the number of kilometers driven and requiring buses with higher technological standards. For example, in Alameda, the main street in Santiago, the concentration of ultrathin particles dropped by 25%. Episodes of high air pollution are less frequent than before even though the city, its activities, and the vehicle fleet have continued to grow.

c) Low floor buses (80% of the fleet) equipped to handle users with reduced mobility have given this group increased accesibility.
d) Fares in the system are fully integrated. Passengers perceive the total set of public transport services as a system and can take the most advantage out of the full network.
e) Metro moves twice as many passengers as before while still providing a good level of service. The firm has proven very dynamic and innovative to deal with such a challenge without a proportional increment in its fleet. In early 2012, it got the "Best Metro of the Americas" award.
f) Also, two social conflicts which used to happen inside the bus have been eradicated: student discrimination by drivers (since operators are paid the same by all types of passengers as long as they pay) and drivers' assaults (since new buses run cash-less).
g) Finally, the introduction of subsidies for the public transport system can also be considered a success as long as these funds end up improving the quality of service beyond what users can finance with their own fares, instead of financing the fares of those users that refuse to pay.

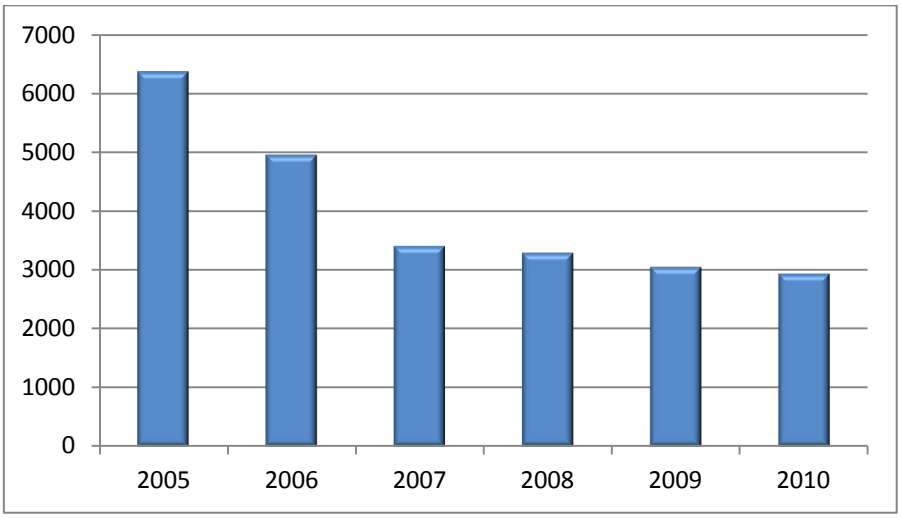

Figure 10: Annual number of accidents involving an urban bus in Santiago (Source: CONASET).

4 CHALLENGES

Transantiago faces, however, several challenges in different areas.

4.1 Operational

The main challenges here are the following:

a) Improve bus headway control. A regular service not only increases service reliability, it also reduces waiting times and improves comfort (Delgado et al., 2012). Unreliability on bus services is one of the most common complaints of Transantiago.

b) Improve bus speeds which are quite low in several corridors of the city (Muñoz et al, 2012). Increasing speed reduces cycle times which increase frequency and capacity. Thus, higher speeds improve travel times, waiting times and comfort. Transantiago should expand its bus infrastructure as this has proven to increase bus speeds significantly, extend and strengthen bus priority enforcement in bus lanes and corridors, implement an extensive bus priority program at traffic signals and formalize (use proper buses and have scheduled services) its "super expresos" services which use the urban highways to join very distanced and dense city areas. As the level of service in Transantiago varies significantly across the city. The authorities should focalize their efforts in those areas were the service is worst.
c) Fight fare evasion. This has implications that transcend the public transport system. Evasion has become so massive in certain areas that it could affect the morals of the city. The government is now resting on the operators to give this fight, but should not step back in its own responsibility to bring evasion back to international standards.
d) Transantiago already has six years of experience. The demand patterns involved in every day's trips are well understood. However, this knowledge has only recently been processed and is now being used for developing operational plans or taking decisions. It seems that there is still a gap to be filled which should benefit the unavoidable trade-off between user level of service and system costs.

4.2 Infrastructure

The government has prioritized the infrastructure for Metro over buses. Even though Metro offers a very high level of service which will probably improve even further with the new fleet being added (and may capture more demand to fill those trains instead of providing more comfortable trips), it is clear that new lines will suffer from the inescapable network effect of decreasing marginal productivity. Indeed, as most users combine bus with metro in their trips, new lines replace the access mode to the existing lines, therefore total ridership of metro does not increase in the same proportion as the extension of the network do. If we add to the above the high cost of Metro infrastructure, it is clear that Transantiago should direct their investments towards bus infrastructure, particularly BRT. Since its beginning Transantiago has had a bus infrastructure master plan that has been continuously delayed. The authorities should implement this infrastructure, even if it implies removing some privileges for the car drivers. Congestion in the city during peak periods is reaching high levels and some areas urgently require public transport services that could attract car owners. Bus infrastructure is a key player in this fight. To win this battle, the corridors and lanes already built for buses must be respected by cars. The government has started an enforcement project in a few corridors based on automatic photo evidence and red painted bus lanes which should be extended to the whole city. Also, very often the intersections of these bus corridors are not well designed so the interaction between buses and pedestrians and/or cars is so inefficient that the travel time savings gained from the high speeds experienced at the corridor are lost.
The system started without pre-paid stations for buses. This mistake was corrected quite fast through a series of temporary fence-based stations operating during peak periods only. They were very successful in terms of speeding up dwell times, reducing evasion and improving

the boarding experience for the user. However, after five years the city has not turned this transitory infrastructure into something definitive that could add value to the urban landscape of the city as is observed in many other Latin-American cities.

4.3 Information

The public transport system that preceded Transantiago lacked a user information system. Transantiago has made some progress by implementing a call center, a web-based trip planner, and a real-time system informing the arrival time of the next few buses to each stop based on text messages. However, the information provided for users at buses and stops is still notably poor. The main hurdles have been vandalism and bureaucracy. The system should install more devices at the most important stops providing on-line information about the arrival time for the coming buses. Only one of these devices has been installed and has worked very well for over two years. Certainly, having better infrastructure in the most visited stations would help to implement such a system there.
Also, even though Metro is the spinal chord around which Transantiago was built, the users perceive Metro and Transantiago as separated entities. Metro has a big responsibility in this issue since very little of its information system has changed from when it was a fully independent transport mode.

4.5 Finance

Transantiago has brought subsidies that were strongly needed to public transport. However, the total amount of subsidies assigned has not been the result of a rationale decision balancing the social short and long term benefits of these subsidies with those that could be obtained in alternative investments. Instead, the magnitude of the subsidies is obtained as the one needed to prevent fares from escalating. Also, some effort should be done to allocate subsidies to the socioeconomic groups that need them most.

4.6 Institutions

Even though Transantiago is a fully integrated system, too many agencies are involved in key aspects of the plan. This has often prevented important decisions from being taken. Thus, one of the main problems of Transantiago is the lack of a single authority that could simplify the decision process by looking at the system as a whole. Such an authority should look at all transport modes in Santiago, not just at public transport. In the last five years, the functions of the Ministry of Transport have been strengthened, and a permanent public transport subsidy has been approved. The next step should be a citywide authority as those that have been successfully implemented in London, Madrid or New York.

4.7 Contracts

New contracts with the operators have been signed recently and their consequences are hard to predict (see Gomez-Lobo and Briones, 2013 for a thorough analysis). However, one

important concern is that the number of firms operating in Santiago has been reduced to only seven, but corresponding to only five economic groups (with one of them operating one third of the Transantiago fleet), so these firms will face the authority with a much stronger hand. Another concern is that this situation could increase the consequences of already conflictive relations between driver unions and firms. Finally, in the future the authority should reduce the length of the contracts, their current length of over 10 years is unnecessary long.
A second issue is the relation between the authority and the Technological and Financial Administrator of Transantiago (AFT). The performance of this entity, controlled by the most relevant banks in Chile, has been disappointing. The AFT has provided a very weak charging network for the payment card, it has been very static to develop new financial opportunities for this card that has 100% penetration in Santiago, etc. The AFT has turned to be an obstacle for the evolution of the system. The authority has announced that the AFT will be next in the set of contracts to be revised.

As a final comment, Transantiago needs to earn the heart of the citizens which have not forgiven its catastrophic beginnings and its later consecutive fare increments. Transantiago has obtained significant achievements, which many cities worldwide would consider almost impossible. However, it is still in debt in relation to key elements that a public transport system should provide; some of these elements, as the infrastructure, have been quite well solved in several cities in neighbor countries.

5 LESSONS FOR OTHER CITIES

Most cities in the developing world lack transit integration, while few are advancing in that direction, remarkably Bogotá, Colombia and México City. Santiago provides a very relevant reference for transit integration in large urban areas. As shown in the previous section the overall impacts of the system are positive, particularly in reducing negative externalities. Nevertheless, the process went through severe design, implementation and operational problems. This section presents some relevant lessons that should be taken into account to improve deliverability and reduce risks during the process of integrating transit systems citywide.

5.1. Design issues

Regarding the operational design there were several elements that a city integrating its services should avoid: i) forcing a financial equilibrium constraint without requiring a minimum level of service, ii) lack of systematic introduction of critical BRT components in the high demand sections, iii) a too rigid feeder-trunk design, and iv) lack of special accelerated or express services since the beginning of the operations.
The design of the system focused on minimizing a generalized costs function (travel time and operational costs) subject to very severe financial constraints, without assuring minimum levels of service. This resulted in a severe undersupply of service –coverage and frequency; on one hand too few services, particularly feeder ones forcing passengers to walk too much, on the other the system abused of (low cost) large articulated buses often operating at

middle to low frequencies expected to reach a maximum average occupancy of 6 standing passengers per square meter and finally, the network expected too many combinations from users trips. This, added to lack of infrastructure to operate the speeds that were considered during the design phase, lack of delivery of the contractual bus-km by the operators, and severe bunching resulted in an extremely chaotic implementation. Regarding quality of service, Hidalgo (2009) suggested introducing constraints guaranteeing a minimum level of service, so that the new service network provides at least a similar generalized time (walking, waiting and travel) than the one it replaces. The requirement of not providing operational subsidies resulted in insufficient service, which was later solved by providing a permanent subsidy. As is well known (Mohring, 1972; Parry and Small, 2005), some subsidies for public transport are efficient since they not only increase capacity, but also allow all users to walk and wait less. Thus, cities should be creative to bring extra funds from other sources to the transit system, to provide a service that is beyond what users can strictly finance with their fares. However, the process that Santiago followed to reach these subsidies was clearly inadequate.

The design of Transantiago considered insufficient infrastructure: no dedicated lanes, small bus stops, lack of adequate transfer stations. This marked a sharp contrast with the world class quality of Santiago's metro, and with some successful bus corridors in neighbor Latin-American countries. One crucial design failure was discarding pre-payment in the critical stations, especially the transfer points. This reduced the stations throughput as passengers were only able to board the buses through one, instead of three doors. The issue was partially improved through the introduction of makeshift prepaid areas, called "little corrals", in around 150 critical transfer points. These functional but improvised facilities had a very low quality standard, preserving the poor image of the system in the eyes of Santiago's citizens. Since also expressways were not built, the operational speed was significantly lower than planned, and therefore the effective capacity offered was lower as well.

The feeder-trunk design was excessively rigid, even banning local services in the trunkways and forcing the passengers for unnecessary transfers sometimes for short distances. This is particularly absurd since buses and stations design were compatible all around the city (doors in the right, low floor, no platforms at stations). Very fast the authority started lifting some of these constraints allowing for a smoother trip with fewer interruptions. After the last negotiation of contracts, the concept of trunk and feeder is much more blurred.

Finally, an integrated system allows you to design its elements differently. Travelers could take advantage of point to point or express services to connect distant and dense nodes in the city directly and then transfer to feeder services. These services should use the fastest routes available, as urban freeways, and in such a case a new safer and more efficient bus should be designed for this purpose. If needed they may not have a high frequency, but then they should operate according to a schedule. After its implementation Transantiago implemented some express services, but it seems still very modest.

Regarding the business model design, the incentives structure resulted in some of the service problems observed. Payment by kilometer served places all the commercial risk in the authority and requires strong supervision mechanisms to assure that service is delivered as planned. At the beginning of the operations these mechanisms were not in place and some operators not even bothered to operate the vehicles, causing additional stress. Even though improvements in control were later introduced, several qualities of service elements

were left out. Recently the contracts were modified to transfer commercial risk to the operators. An interesting lesson here is that contracts do not need to be static and they can contemplate different phases during the operation, beginning with a low-risk phase to attract operators to new systems, while shifting towards more incentives (high-risk phase) to attract demand once the operator better understands its new business.
The institutional framework was also not designed to respond to the implementation requirements. The system was managed from a coordination office within the Ministry of Transport, without enough capacity to supervise and adapt operations. It is advised to have a dedicated institution with legal powers and technical staff to adapt the operation to the needs and respond to the challenges rapidly. Also, unimodal planning agencies (e.g. Metro, buses, streets, etc) should be avoided.
Lastly, an integrated system forces passengers to transfer. These pose two new challenges. On one hand provide information devices that are understandable by the users; this is not trivial for a multi-hierarchical (feeder vs trunk) and multimodal system, particularly in developing countries with low-educated transit passengers. Also, transfers are not attractive to users, so they must be designed as informed, safe, secure and fast experiences. On the other hand, since transfers tend to concentrate in few points of the city, they offer an interesting opportunity to bring different types of services closer to the users, adding value to the traveling experience.

5.2. Design of the implementation

Santiago adopted a citywide modification of services coupled with reduction of fleet, fare integration and change in payment device in a single process, and without all the elements in place –facilities, fare collection and control were lacking at the start of operations. While it is important to ensure that the overall system will be covered, and to implement the full new system in a relative short time frame (one to two years), the process could be designed to manage risks better. A corridor by corridor (or zone by zone) implementation forces two systems to coexist since some passengers will need to travel between an origin located in the old system to a destination located in the new one. This quite expensive and confusing for the users, and doesn't guarantee that the process could be interrupted in between.
Based on the Santiago experience, the following steps are proposed as an alternative of the big-bang that will address the previous concerns:

1. Implement fare integration citywide in all modes without modifying the routes. This will allow users to restructure their trips taking full advantage of the integration over a well-known network. Therefore, except for eventual crowdedness in some services, most users should be satisfied by the enhanced opportunity. However, this will redistribute the trips across the city and some segments of some services will be overcrowded while others will be over supplied.
2. Based on the new load profiles of the routes, reallocate buses to routes and incorporate new services to balance supply and demand and reduce costs; i.e. add a short route to complement a very popular route in its most crowded segment, merge two routes in cases where too many transfers are observed, etc. This should result in

an increment of the effective supply offered with an effect in the level of service perceived by the user.

3. Introduce new infrastructure, vehicles and advanced operations for selected high demand sections using high end BRT principles (Hidalgo and Muñoz, 2013).
4. Continue the adaptation of the system keeping high quality of service, with improved express and accelerated services, integration facilities, advanced user information systems.

The fare integration for a large number of buses would require additional capital and operational costs, but these would be offset by the reduced hardship on the passengers. Operational control mechanisms are critical since the beginning of the operation as well.
This approach for citywide implementation but gradual adaptation of services reduces the high risks of undersupply that comes with complete reorganization of routes based on transport models, which are usually adequate at the strategic level, but insufficient at the operational level. It is also easier to understand for users since services adapt one by one. Complete adaptation of sections also brings the benefits of improved service and lower total operational cost. When corridors do not have all the elements, speed and reliability are reduced, requiring a larger fleet and larger total user travel time.
Also, Transantiago dramatically showed that a system-wide transformation like this one requires all its elements in place. This means infrastructure, buses, incentives to operators, control mechanisms, effective communication channels with users, etc. Few failures may make the implementation collapse.

5.3. Operations, control and communications

During the operational phase the most important element is having the flexibility to adapt services to the dynamic nature of urban mobility. Rigid contracts and institutions without legal and technical capacity hamper that ability. The importance of a good operational control system and the maintenance of facilities shall not be minimized. Finally a communications framework targeted to needs of the users is needed.
Transantiago authorities were successful in re-negotiating core elements of the contracts in 2007-2008 and 2011-2012. In the first re-negotiation the parties agreed on increasing the fleet and introducing performance indicators (mainly supply in critical points during different times of the day). In the second re-negotiation the parties agreed to cluster feeder and trunk operations, extended the contracts in time and introduced a component for payment for passengers to assign the commercial risk to the operators. But re-negotiations are not easy and often unbalanced in favor of the operators.
It will be advisable to have better incentives in the contracts in the first place, and introduce mechanisms that allow the operations to be adjusted according to demand changes, due to city growth, urban development projects and the introduction of changes in the transport supply. In Santiago there has been a significant expansion of the Metro system affecting the travel patterns in the city while route operators have been affected. Changing bus service supply based on those contracts has not been easy.
On the other hand the coordinating institution for Transantiago does not have full control of critical elements in system operation, mainly the decisions on the operations of the Metro

system, ability to manage the bus lanes, implement stations, terminals and other facilities for improved systems operation. It also has limited opportunity to react to service needs, as the actual dispatch is in hands of the private operators. Its ability is limited to apply ex-post penalties. This is especially critical in case of contingencies. Having a centralized control is important for service delivery; it does not necessarily mean public control, as the activity can be outsourced (like in Guayaquil).

Regarding maintenance of facilities, it is recommended to have clear assignment of responsibilities and funding. Clean, well-kept and illuminated bus lanes, stations, buses and terminals; with clear signage to help passengers find their way is a key component of good level of service and increase perception of safety. We should not forget that the service perception starts during the walking legs at the beginning and end of each trip.

Finally, communications shall be a permanent and well-funded activity. Communications shall be targeted to the end users according to their needs and may include several platforms, from static and dynamic displays, guides, to flyers and media spots. Also community involvement is important, working directly with schools and neighborhood associations.

6 CONCLUSIONS

Transantiago is a remarkable reference on transit reform. It was the most ambitious effort by a large developing city to improve service delivery citywide, and proved very complex. While the overall concept was well conceptualized –citywide multimodal intervention to reduce externalities and improve the modal share of public transport, it suffered from several problems of design, implementation and operation.

Design problems like the definition of incentives, the strong focus on minimizing cost and not necessarily improving the service for the passengers, and the large scale implementation with significant changes in routes and supply, led to a chaotic implementation. Government authorities have introduced permanent subsidies to improve quality of service, and have championed changes in the contracts that resulted in significant improvements in service, but stalled after the first year.

Several expected positive impacts as the environment and road safety, two key externalities, have been achieved. With the fare integration the metro became accessible to many users that were priced out before. Nevertheless there are still several actions needed to improve the service to the users. For instance, it is possible to upgrade the facilities –busways, stations, terminals, and reduce the sharp contrast between the world class metro and the buses on the surface.

The experience of Santiago is very valuable for most developing cities which still have disintegrated and low quality services as the norm in public transport delivery. The citywide approach is valid, with adequate design and implementation. For instance, Santiago assumed a very high implementation risk by changing all the routes and reducing the vehicle fleet in one-shot (the so called “big-bang”). We suggest to start with fare integration citywide, and a gradual process of service changes based on information of the user demand and needs, and introduction of high level BRT components in the high demand corridors. While this may increase the initial capital and operational costs of fare collection, it allows for

managed risks in service adjustment, would reduce the total cost, and most importantly would minimize passenger frustration.

According to Hidalgo and Carrigan (2010) three elements arise as critical in any transport reform: high level political commitment, adequate and results-oriented planning and implementation team, and suitable level of funding for preparation and implementation. Santiago has varied levels on the three levels: lukewarm support form the highest level national authorities and constant tension with metro development; very capable technical teams in SECTRA and the Ministry of Transport focused on the tactical level, but very weak in operations and implementation and with lack of authority on multiple stakeholders; significant investments in Metro and urban freeways, and very low funding for infrastructure for quality bus services, and the public commitment that Transantiago would never receive subsidies.

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