ASSESSING THE IMPACT OF CERTAIN REGULATORY POLICIES IN URBAN PUBLIC TRANSPORTATION SYSTEMS: THE CASE OF TRANSANTIAGO

Carlos Melo Riquelme, Industrial Engineering School, Diego Portales University, Santiago, Chile, carlos.melo@udp.cl

Juan Edgardo Goldenberg, Department of Transport Engineering and Logistic, Pontificia Universidad Católica de Chile, Santiago, Chile

ABSTRACT

The urban transport system in Santiago, Chile, underwent a major change with the launching of the new Transantiago system, in February 2007. This dissertation analyzes the effects on the travel and waiting times of some of the measures that were taken to correct the initial faults of the system. Tests were developed in order to estimate the statistical significance of the observed changes.

In particular, the analyzed measures were the contract renegotiation with the operators companies, and the implementation of some indexes for the system regulation: ICF (*Índice de Cumplimiento de Frecuencia)*, ICR (*Índice de Cumplimiento de Regularidad*), ICPKH and DSC (*Índice de Cumplimiento de Plaza-Kilómetro-Hora*). The renegotiation improved travel times in roughly four minutes, increased the system stability (less variability from one week to the other), and diminished waiting times especially during rush hours. In addition, more service regularity was accomplished.

The ICF and ICR implementation decreased travel times at afternoon rush hours. These measures did not have an effect on average waiting times, but they did have it on its variability, since the standard deviation went down.

Finally, the ICPKH and DSC implementation did not affect neither average waiting times nor its variability. Nevertheless, they improved the travel time variability at afternoon rush hours.

Keywords: Public transportation, Transantiago, Compliance measures, Transit

INTRODUCTION

A Brief Description of Transantiago

The new integrated public transport in the city of Santiago, called Transantiago, began operating in February 2007. It was introduced as a new public transport system, modern, efficient, integrated and high level of service for users of Santiago. Was looking for solve the problems detected of the old system: end the fragmented system of ownership, provide integrated fare between bus and subway system, improve the quality of the buses and the system in general, improve the working conditions of drivers, perform a restructuring of the mesh of routes and reduce the accident rate. Furthermore, the system tried to promote the use of public transport by improving service levels, to reduce congestion and pollution.

It was established as a trunk-feeder system, dividing the city into zones and areas of exclusive operation for business units. This distribution is intended to reduce congestion on main roads and achieve more efficient occupancy rates in the buses. In addition, through the implementation of an electronic card as the only payment device, bus and subway fares were integrated.

The system faced many implementation problems, and was criticized in the beginning. For more details about these facts, see Muñoz and Gschwender (2007), and Muñoz, Ortúzar and Gschwender (2009).

Faced with the problems presented by the operation, the authority developed several compliance measures to ensure the implementation of operational programs by the concessionary companies of each business unit. Operational programs define routes, stops, frequency and capacity of vehicles, among other features that each operator must deliver. Since the original concession contracts incentivized not adequately fulfill these programs by the operators, the authority was in the need to modify the operating contracts, and establish indicators to measure the actual performance of these programs. Among the measures considered, include:

1. Renegotiation of contracts, from August 2007.

2. Implementation of frequency and regularity compliance index (ICF; *Índice de cumplimiento de frecuencia* and ICR; *Índice de cumplimiento de regularidad* respectively), from August 2008.

3. Update of regularity compliance index (ICR) and frequency compliance index (ICF), from October 2008.

4. Implementation of rate of seat/standing places-kilometers per hour that are satisfied (ICPKH; *Índice de cumplimiento de plazas-kilómetro-hora*), from August 2009.

5. Discount per failure of seat/standing places-kilometers per hour (DSC; *Descuento por incumplimiento de plazas-kilómetros-hora*), since September 2009.

This paper studies the statistical effect of these measures on system performance, in order to quantify the changes that occurred. Considered the performance indexes of average travel time of the system and average waiting time of the system as a measure of the service provided. These indicators were measured from June 2007 onwards. We compare the situation before and after the implementation of each measure using mathematical tools. This paper expands on the results and analysis of Beltran et al. (2013), which describes in detail these indexes and presents an approach to the effect on operational indicators of Transantiago.

We have chosen this methodology because travel and waiting times are an excellent barometer of the operation of the system, which directly affect users. Moreover, these indicators have the advantage that they are easily quantifiable and comparable between the situation before and after a specific event, so that to study objectively evolved over time.

METODOLOGY AND INFORMATION PROCESSING

Operational performance indicators of the system considered in this study (average travel and waiting time), were calculated from measurements made from May 2007 to December 2010 (Transantiago-Dictuc, 2010).

To calculate the first indicator, 30 O-D pairs were chosen, that were considered representative of the city, and then weighed to obtain the average travel time. For indicator of waiting times, distinguished two situations: bus stops and prepaid bus stop platforms, in each of which we selected some key points in the city to estimate the average waiting time. The following describes in detail the methodology of collecting data and the procedure performed to obtain the average values.

Travel Time: Data collection and calculation method

30 OD pairs were considered, which are representative of the whole city, which were selected in 2007 based on information from the 2001 Origin Destination Survey of Santiago. These 30 pairs were chosen because they represented well the distribution of travel distances in the city.

For data collection, business days were considered in only two measurement periods: morning peak (6:30 to 9:30) and evening peak (17:30 to 20:30).

For each of these pairs, is measured travel time from origin to destination for each stage of the travel. For each OD pair considered three different observations.

From the information in the 2001 Origin-Destination Survey is assigned a relative weight to each OD pair. Then, to calculate the total travel time, each pair is weighted by the relative weight that corresponds.

Waiting Time: Data collection and calculation method

For the waiting time index separately analyzed the cases of bus stops (P) and prepaid bus stop platforms (ZP).

For this we chose a sample of 18 bus stops and 26 prepaid bus stop platforms of the city. In each place was registered the arrival time of the passenger's to the stop and the time gets on the bus. We considered the same two measurement periods: morning peak hour (6:30 to 9:30) and evening peak hour (17:30 to 20:30).

Taking these data is difficult and requires many operators. A major difficulty occurs in crowded bus stops, where it is difficult to determine the waiting time for each passenger. Therefore the number of registered passenger (who actually was taken data) is different from the number of passengers (the number of people who entered the bus stop). The selection of persons to be measured was random.

The procedure performed with the information of counts was: dividing each measurement period in intervals of five minutes, calculating the average wait of each interval, calculate a weighted average waiting time of the period from the affluence to the bus stop and time expected of people surveyed in each interval and calculate the standard deviation and the maximum deviation of each period.

The standard deviation calculation is performed using the average waiting times of each of the stops in each of the intervals within the period, and not disaggregated data of each of the passengers surveyed.

In the case of the maximum deviation is calculated from the maximum waiting time of each interval, taking into account all the stops. That is, taking into account the maximum waiting time of each interval.

Description of compliance measures implemented

Renegotiation of contracts (August 2007)

Among other things, looked the following:

- Increase the number of buses on the streets.
- Adjust the hours of operation.
- Demanding compliance with contracts, paying as agreed: implemented a compliance rate of "Places-Hour" (ratio of available seat-hour actually offered and committed).
- Incentives to operators for better service levels and reducing the rate of evasion: it increases the payment per passenger.

- Introduction of compensation and guarantees to operators.

As can be seen, some of the changes include the implementation of the compliance rate of seat-hour (ICPH). It is calculated as the ratio of available seat-hour actually offered (calculated) and places-hours committed, to be met by operational program.

The intention with this index was to get more buses out into the streets since early in Transantiago were not circulating which were committed by contract. Was used the information from the GPS, to see if the bus sent positioning messages, and if indeed it was moving.

Implementation of frequency and regularity compliance index (August 2008)

The ICF is a compliance rate of frequency by service. It is calculated as the ratio of observed outputs and outputs that must exist by contract (required). The operator was charges with a penalty when the index is less than 95%.

The ICR is a regularity compliance index by service. Regularity is measured at the output of the buses on the heads terminal in each period of the day. Penalty applies when the index is less than 90% by service.

Then the differentiation between the two indices became clearer, as the ICF was determined in the beginning of the service and the ICR was calculated on the route. The idea is to regulate the frequency and regularity of buses from its output, to achieve a better level of service for users.

Update of regularity compliance index (ICR) and frequency compliance index (ICF) (October 2008)

This was intended to fully regulate the regularity and frequency of services committed by the operators, as there were few ways to evade compliance with the number of buses, frequencies and regularities involved in operational programs.

Implementation of rate of seat/standing places-kilometers per hour that are satisfied (ICPKH) (August 2009)

The ICPKH is a compliance rate of seat-kilometers an hour. Corresponds to the number of places per kilometer per half hour, depending on periods of the day. Was fined the operator's revenue at the same rate of the default: i.e., an ICPKH of 95% implies a 5% decrease in revenue. Corresponded to the last significant change in the fulfillment of frequency and regularity of services.

Beltran et al. (2013) provide a complete description of these indicators and how they are calculated.

INFORMATION ANALISYS

In this section, we present a statistical analysis for both operation indicators (travel and waiting times), to try to determine the effect that compliance measures have in system operation.

The effect on travel times

We compare the values of the mean and standard deviation of travel times of the system for a set of measurements before and after the implementation of each measure. This procedure is repeated to analyze the two periods of the day where records exist (morning peak and evening peak hour). In all cases, the observations are removed for weeks where the behavior of transport system is abnormal (mainly holiday periods).

An important point in this analysis is that the variance of the indicator is greater when the reduction in travel time was greater in absolute value, regardless of the trend of the observations. To correct this potential inconsistency, we designed a method for calculating the variance that incorporates the "linear trend" performance indicator. The method consists of obtaining the line represents the linear trend of the observations, and calculate the variance with respect to this line and not from the average. For this we calculated the difference in travel time data of the week compared to the trend for that period, and then squared. Then all these values are added and divided by the number of data minus one.

Thus, the variance indicator is calculated as:

$$Var(x) = \frac{1}{n-1} \cdot \sum_{i=1}^{n} \left(y_i - x_i \right)^2 \qquad (1)$$

Where,
$y_i =$ Travel time in minutes of the week i (lineal trend).
$x_i =$ Travel time in minutes of the week i (measurement).
$n =$ Number of measurements.

It also analyzes the statistical significance of the reduction in travel times after implementing each measure: Is statistically significant change in average trip between the pre and post? For this, it uses a statistical significance test based on Student's t distribution, to accept or reject the null hypothesis that the change in the average values of travel time is not statistically significant for the whole period analyzed.

Below are the results for the measures implemented, first in the morning peak period and then in the evening peak period.

Results for morning peak hour travel time

1. Renegotiation of Contracts (August 2007)

In Table I, we present the results obtained for the situation before the renegotiation of contracts, from May to August 2007.

Table I – Travel Time – Morning Peak Hour, May-August 2007

Average	53,4 min
Standard Deviation	2,03 min

Table II shows the situation after the renegotiation of contracts through 2007.

Table II: Travel Time – Morning Peak Hour, August-December 2007

Average	48,1 min
Standard Deviation	1,35 min

The results show that the renegotiation of contracts in 2007 helped to stabilize the system, and decrease variability. Then we study the statistical significance of the reduction in travel times following the renegotiation:

Table III: t Test of Travel Time (Renegotiation of Contracts) – Morning Peak Hour

t Test	
Degrees of freedom	19
α	5%
T	3,607
|T|	3,607
t(df;1-α/2)	2,093

It can be seen in the above table that the absolute value of the statistic T (3.607) is higher than corresponding to the null hypothesis (2.093), and therefore Ho is rejected, which means that there was a significant change in the average value product to the implemented measure.

2. ICF, ICR (August 2008) and Actualization of ICPH (October 2008)

It was decided to consider these two measures as one, since its implementation occurs in very close.

The table below presents the average travel time and standard deviation for the entire period of analysis, and before and after implementation of the measures.

Table IV: Travel Time Analysis - Morning Peak Hour (April-December 2008)

	Average (min)	Standard Deviation (min)
Total	45,5	1,00
April-August 2008	45,7	0,7
October-December 2008	45,3	1,19

We can see that the averages are relatively similar and no major variations occur before and after the implementation of the measures, as well as variability. Average travel times decreased about 1%, but increases the variability (from 1% to 3%).

One might conclude that these measures did not significantly affect travel times for the morning peak period. To confirm this, we conducted a test of statistical significance of the change:

Table V: t Test of Travel Time (ICF and ICR indexes) – Morning Peak Hour

t Test	
Degrees of freedom	484
α	5%
T	0,14
|T|	0,14
t(df;1-α/2)	1,96

It can be seen that the absolute value of the statistic T (0.14) is lower than that corresponding to the null hypothesis (1.96), and therefore Ho is accepted, which means that there was no significant change in the time travel by these measures.

3. ICPKH (August 2009) and DSC (September 2009)

Again it has been decided to consider these two measures together, due to the proximity of its application.

The table below presents the average travel time and standard deviation for the period before and after the implementation of the measures.

Table VI: Travel Time Analysis - Morning Peak Hour (June-December 2009)

	Average (min)	Standard Deviation (min)
June-August 2009	45,6	4,08
October-December 2009	47,6	6,75

Might conclude that this measure did not mean an improvement in travel times in the morning peak period, and that the variability worsened. To test, we used a statistical significance test, presented in the following table.

Table VII: t Test of Travel Time (ICPKH index) – Morning Peak Hour

t Test	
Degrees of freedom	160
α	5%
T	-1,36
|T|	1,36
t(df;1-α/2)	1,97

It is appreciated that the absolute value of the statistic T (1.36) is lower than the null hypothesis corresponding to (1.97), and therefore Ho is accepted, which means that there was no significant change as to the reduced travel times.

Results for evening peak hour travel time

1. Renegotiation of Contracts (August 2007)

Table VIII shows the results obtained for the situation before the renegotiation of contracts, from May to August 2007.

Table VIII – Travel Time – Evening Peak Hour, May-August 2007

Average	56,3 min
Standard Deviation	3,03 min

Table IX shows the situation after the renegotiation of contracts until late 2007.

Table IX: Travel Time – Evening Peak Hour, August-December 2007

Average	51 min
Standard Deviation	1,74 min

The results show that the renegotiation of contracts in 2007 helped to stabilize the system, and decrease variability. Then we study the statistical significance of the reduction in travel times following the renegotiation:

Table X: t Test of Travel Time (Renegotiation of Contracts) – Evening Peak Hour

t Test	
Degrees of freedom	19
α	5%
T	2,907
|T|	2,907
t(df;1-α/2)	2,093

It can be seen in the table below which the absolute value of the statistic T (2.907) is higher than corresponding to the null hypothesis (2.093), and therefore Ho is rejected, which means that there was a significant change in the average value travel time as a result of the implemented.

2. ICF, ICR (August 2008) and Actualization of ICPH (October 2008)

As for the morning peak period analysis, it was decided considering these two actions as one, since their implementation occurs in very close.

The table below presents the average travel time and standard deviation for the entire period of analysis, and before and after implementation of the measures.

Table XI: Travel Time Analysis - Evening Peak Hour (April-December 2008)

	Average (min)	Standard Deviation (min)
Total	47,1	1,48
April-August 2008	47,6	1,01
October-December 2008	46,5	1,79

We can see that the averages are relatively similar and no major variations occur before and after the implementation of the measures, as well as variability. Average travel times decreased about 2%, but increases the variability (from 2% to 3.8%).

Might conclude that these measures did not significantly affect travel times for the evening peak period. To confirm this, we conducted a test of statistical significance of the variation:

Table XII: t Test of Travel Time (ICF and ICR indexes) – Evening Peak Hour

t Test	
Degrees of freedom	484
α	5%
T	2,44
|T|	2,44
t(df;1-α/2)	1,96

It can be seen that the absolute value of the statistic T (2.44) is greater than that corresponding to the null hypothesis (1.96), and thus rejecting the null hypothesis Ho, so that it can be said that variation is statistically significant, and therefore there was an improvement in the average travel time for the evening peak period with the implementation of the ICF and ICR.

3. ICPKH (August 2009) and DSC (September 2009)

Again, it has been decided to consider these two measures together, due to the proximity of its application.

The table below presents the average travel time and standard deviation for the period before and after the implementation of the measures.

Table XIII: Travel Time Analysis - Evening Peak Hour (June-December 2009)

	Average (min)	Standard Deviation (min)
June-August 2009	48,2	4,20
October-December 2009	47,8	3,65

Can see that there is a slight improvement in the average travel times in the evening peak period, and decreased variability. To test, we used a statistical significance test, presented in the following table.

Table XIV: t Test of Travel Time (ICPKH index) – Evening Peak Hour

t Test	
Degrees of freedom	160
α	5%
T	0,88
|T|	0,88
t(df;1-α/2)	1,97

It is appreciated that the absolute value of the statistic T (0.88) is lower than the null hypothesis corresponding to (1.97), and therefore Ho is accepted, which means that there was no significant change as to the reduced travel times.

The Effect on waiting times

Are compared the values of the mean and standard deviation of the waiting times for bus stops and prepaid bus stop platforms for a group of measurements before and after the implementation of each measure. This procedure is repeated to analyze two periods of the day (morning peak and evening peak). In all cases, the observations are removed for weeks where the behavior of transport system is abnormal (mainly holiday periods). Finally, in each case we use the t test to determine if the change in the average values is statistically significant.

1. Renegotiation of Contracts (August 2007)

The following tables present the results of the analysis conducted for waiting times in previous periods (May to August 2007) and later (August to December 2007) to the renegotiation of contracts.

Table XV: Statistical Analysis of Waiting Times – Renovation of Contracts (Bus Stops)

Period		Average	Standard Deviation	T	t	Conclusion
Morning Peak Hour	Before	5,8	5,5	32,94	2,0	Significant change
	After	3,8	3,0			
	Variation	-34,2%	-45,5%			
Evening Peak Hour	Before	5,4	4,3	1,92	2,0	There was no significant change
	After	5,3	3,8			
	Variation	-2,0%	-11,9%			

Table XVI: Statistical Analysis of Waiting Times – Renovation of Contracts (Prepaid Bus Stop Platforms)

Period		Average	Standard Deviation	T	t	Conclusion
Morning Peak Hour	Before	3,0	3,5	10,55	2,0	Significant change
	After	2,7	3,2			
	Variation	-10,1%	-7,2%			
Evening Peak Hour	Before	3,5	4,1	5,13	2,0	Significant change
	After	3,4	3,5			
	Variation	-4,1%	-15,3%			

The renegotiation of contracts presented improvements in average waiting times. Also generated more regular services, delays at bus stops were more regular, so the standard deviation decreased for all cases.

2. ICF, ICR (August 2008) and Actualization of ICPH (October 2008)

Below are the results of the analysis for waiting times before (April to August 2008) and after (October to December 2008) of the implementation of the measures. As for the analysis of travel times, it was decided to consider these two measures as one, since its implementation occurs in very close.

Table XVII: Statistical Analysis of Waiting Times – ICF and ICR (Bus Stops)

Period		Average	Standard Deviation	T	t	Conclusion
Morning Peak Hour	Before	3,3	3,6	2,49	1,96	Significant change
	After	3,2	3,1			
	Variation	-3,4%	-14,6%			
Evening Peak Hour	Before	4,7	3,7	0,89	1,96	There was no significant change
	After	4,7	3,8			
	Variation	-1,0%	1,4%			

Table XVIII: Statistical Analysis of Waiting Times – ICF and ICR (Prepaid Bus Stop Platforms)

Period		Average	Standard Deviation	T	t	Conclusion
Morning Peak Hour	Before	2,3	3,2	-3,69	1,96	Significant change
	After	2,4	2,5			
	Variation	3,9%	-19,9%			
Evening Peak Hour	Before	3,6	3,3	0,40	1,96	Significant change
	After	3,6	3,4			
	Variation	-0,3%	2,6%			

In conclusion, we can state that the main benefit of using compliance indexes ICF and ICR is to improve the regularity of services, which is reflected in the decrease of maximum standard deviations of each period, even in prepaid bus stop platforms.

3. ICPKH (August 2009) and DSC (September 2009)

Finally, we present the results of the analysis conducted for waiting times before (June to August 2009) and after (October to December 2009) of the implementation of these measures. As with the previous analysis, we decided to consider as a single, as their implementation is almost simultaneous.

Table XIX: Statistical Analysis of Waiting Times – ICPKH and DSC (Bus Stops)

Period		Average	Standard Deviation	T	t	Conclusion
Morning Peak Hour	Before	3,2	2,7	-3,86	1,96	Significant change
	After	3,4	3,2			
	Variation	4,6%	17,8%			
Evening Peak Hour	Before	3,3	2,8	-18,37	1,96	Significant change
	After	3,8	2,5			
	Variation	17,4%	-10,2%			

Table XX: Statistical Analysis of Waiting Times – ICPKH and DSC (Prepaid Bus Stop Platforms)

Period		Average	Standard Deviation	T	t	Conclusion
Morning Peak Hour	Before	2,5	2,3	-4,31	1,96	Significant change
	After	2,6	2,2			
	Variation	3,7%	-3,6%			
Evening Peak Hour	Before	2,9	2,5	0,18	1,96	There was no significant change
	After	2,9	2,3			
	Variation	-0,1%	-9,6%			

One can conclude that the application in August 2009 of ICPKH index and in September of that year of DSC was not relevant to the average waiting times at bus stops and prepaid platforms, which were relatively stable.

CONCLUSIONS

Were statistically analyzed changes in travel and waiting times that occurred once implemented the following measures taken by the authorities: Renegotiation of contracts, implementation of ICF, ICR, ICPKH and DSC indexes.

The renegotiation of contracts resulted in improved travel times for both the morning peak period and for the evening peak period. Also gave greater stability to the system, since the standard deviations decreased.

As for waiting times also experienced improvements in average, at morning peak and evening peak. Furthermore, the system presented more regular services; delays at bus stops were more regular and therefore decreased the standard deviation for all cases.

The implementation of the ICF and ICR indexes helped improve travel times for morning and evening peak periods, although the improvement was significant only in the second. The change was noticeable in waiting times, which strongly improved the regularity of services. No perceived significant improvements in average waiting times.

The implementation of ICPKH and DSC indexes achieved greater stability to travel times in the evening peak period, and had no significant improvements for the morning peak period. Finally, we can say that this was not relevant to the average waiting times at bus stops and prepaid platforms, as they were relatively stable.

In short, each of the presented compliance measures served to improve the new public transport system; some with better averages in travel times, and others giving more regularity to the services.

REFERENCES

Beltrán, P., A. Gschwender and C. Palma (2013). The impact of compliance measures on the operation of a bus system: The case of Transantiago. Research in Transportation Economics, 39 (1), 79-89

Muñoz, J.C., A. Gschwender (2008). Transantiago: A tale of two cities. Research in Transportation Economics, 22 (1), 45-53.

Muñoz, J.C., J.D. Ortúzar and A. Gschwender (2009). Transantiago: the fall and rise of a radical public transport intervention. In: Travel demand management and road user pricing: Success, failure and feasibility (W. Saleh and G. Sammer, eds.), pp. 151–172. Ashgate, Farnham, UK.

Transantiago-Dictuc (2010). Medición y Análisis de Información de Desempeño Operacional del Sistema de Transporte Público de Santiago, Orden de Trabajo 1 [Measurement of service levels of Transantiago]. Coordinación Transantiago, Chilean Government.