

PARKING AT VANCOUVER INTERNATIONAL AIRPORT:
BEFORE AND AFTER THE CANADA LINE

by

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B.A., University of Southern California, 2010

A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS (PLANNING)

in

THE FACULTY OF GRADUATE STUDIES

School of Community and Regional Planning

We accept this project as conforming
to the required standard

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THE UNIVERSITY OF BRITISH COLUMBIA

September 2012

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Executive Summary

Since the opening of the Canada Line in 2009, the number of both short and long-term parking transactions, at Vancouver International Airport (YVR) has significantly decreased; while the Canada Line may be the proximate cause for the decrease, other factors, such as parking rate changes, the number of originating passengers, and gas prices have also changed since the opening of the Canada Line. An analysis of correlations involving these elements with parking transactions at YVR informs factors correlated with the decrease.

The Canada Line appears to be the root of the decrease of long-term parking transactions. However, short-term parking transactions are most directly correlated with originating passengers, with additional indirect correlations with gas and parking prices after adjusting for monthly variation. Although the Canada Line does not appear to be a significant contributor in the decrease of short-term parking transactions, it is possible that without its construction, the significant correlations found between gas and parking prices and short-term parking transactions may not have occurred.

Contents

Executive Summary	3
Introduction	8
Objectives	8
Purpose	9
Project Description	10
History and Context.....	10
The Canada Line.....	10
Vancouver International Airport.....	10
The Canada Line and YVR.....	12
Airport rail links	13
Literature Review.....	14
Modelling passenger behaviour.....	14
Case studies within a region.....	14
Air-rail link usage in North America	15
Other effects of air-rail links	16
Airport parking.....	16
Methods.....	17
Data.....	17
Methods	18
Findings	20
Originating passengers.....	20
Canada Line	21
Parking prices	22
Gasoline prices.....	26
Summary of significant findings.....	27
Implications.....	28
Short-term parking	28
Long-term parking	30
Parking length.....	32

Conclusion	33
Limitations	33
Broader implications for YVR.....	34
Future research.....	34
Bibliography.....	37
Appendices	42
Appendix 1: Results for all t-tests	42
Appendix 2: Results for all regression analyses	43

Figures and Tables

Figure 1: Short-term parking transactions per day (monthly average) – adjusted and unadjusted, 2008-2011 ..	18
Figure 2: Posted price v length of stay at Parkade 1, 2008-2011.....	24
Figure 3: Posted price v length of stay at the Long Term Lot, 2008-2011	25
Figure 4: Enplanements/day v short-term parking transactions/day, 2008-2011 (monthly averages).....	28
Figure 5: Short-term parking transactions per day (adjusted, monthly average) v Metro Vancouver gasoline prices, 2008-2011..	29
Figure 6: Long-term parking transactions per day (monthly average) – adjusted and unadjusted, 2008-2011...	31
Table 1: Posted short-term parking rates at YVR parking lots	12
Table 2: Posted long-term parking rates at YVR parking lots	12
Table 3: Transit share at YVR (quarterly surveys).....	13
Table 4: Result of regression analyses regarding originating passengers and parking	20
Table 5: Result of regression analyses regarding short-term parking and short-term parking prices.....	23
Table 6: Result of regression analyses regarding long-term parking and long-term parking prices.....	23
Table 7: Result of regression analyses regarding gas prices and short-term parking transactions.....	26

Acknowledgements

Firstly, I would like to thank Mr. Mike Brown, Senior Planner at the Vancouver Airport Authority, for his invaluable assistance in providing me with an abundance of data, documents, and information to aid in the completion of this project, and without whom, this piece would simply not exist.

I would also like to thank Dr. Tom Hutton for his assistance throughout the many difficulties of the professional project process, as well as all the faculty, staff, and fellow students at SCARP who have made these past two years enjoyable and full of learning.

I will forever be grateful to my friends, near and far, who put up with me at all hours of the day, through thick and thin. I will never figure out how you all do it.

Finally, but most importantly, I would like to thank my family for their unconditional love and unwavering support. Although I may not always show it, it is always appreciated, and your support means the world to me.

Disclaimers

The unpublished raw data, including parking statistics and revenues, provided by the Vancouver Airport Authority is commercially confidential and is not to be further disseminated without the consent and permission of the Vancouver Airport Authority.

The opinions and recommendations in this publication do not reflect the positions of organisations mentioned in the document or organisations that provided assistance with the project, including but not limited to the University of British Columbia, the School of Community and Regional Planning, and the Vancouver Airport Authority.

Introduction

With the opening of the Canada Line in August of 2009, the Vancouver International Airport (YVR) faced major changes in the ground access patterns of its passengers. Having benefitted from a more efficient and more rapid connection to the public transportation network of Metro Vancouver, the share of airport passengers taking public transit to the airport increased.

Therefore, YVR had to adjust from receiving almost all of its passengers from vehicles to having a significant proportion arrive by public transportation. Whilst this has positive effects in certain realms, such as a decreased environmental impact (TransLink Commission, 2009), the Canada Line also introduced negative economic consequences for the airport, including decreases in parking transactions and revenues (VAA, 2010a; VAA, 2010b).

However, the Canada Line was not the only change in the parking environment at YVR. Soon after the airport-rail link opened in the summer 2009, a series of short and long-term parking price increases occurred due to rate increases by the Vancouver Airport Authority (VAA, “Airport Authority”) and changes in the provincial and federal tax regimes (VAA, 2010c). Additional changes in the driving environment – such as short-term changes in gas prices – are not controlled by the Airport Authority, but also happen on a regular basis. Furthermore, there are seasonal differences in passengers and parking at airports which play a part in parking patterns at YVR (VAA, 2010b; VAA, 2012b).

While it may seem to be responsible for much of the change observed, the Canada Line is unlikely to be the sole influence for the decrease of both short and long-term parking transactions at YVR: other changes in the parking and driving environment may also have an impact on differences in parking since August of 2009. As a result, this project endeavours to find the prevailing factors in the decrease of both short and long-term parking transactions at YVR after the opening of the Canada Line.

Objectives

The objective of this project is to find if recent changes in the ground access environment at YVR, including the construction of the Canada Line and parking and tax rate increases, as well as other factors, such as originating and departing passengers and gas prices in Metro Vancouver,

are significantly correlated with long and short-term parking transactions at YVR. These correlations do not and cannot indicate causation.

The objectives are categorised as follows:

1. Establish if there are significant correlations between originating passengers and short and long-term parking transactions.
2. Establish if there is a significant difference between parking transactions prior to and after the opening of the Canada Line.
3. Establish if a significant change in parking patterns (in the number of parking transactions or differences in time parked) was observed in response to parking rate changes.
4. Establish if there are significant correlations between gas prices in Metro Vancouver (in each month) and short and long-term parking transactions.

Purpose

In pursuing these objectives, the project looks to find factors that are correlated with parking transactions at YVR. If correlations are found, this can help inform future planning decisions; because both long and short-term parking situations at YVR are dynamic, further changes in the parking environment – be it internal, such as parking prices, or external, such as gas prices – may lead to changes in parking transactions, as well as transit use and vehicle traffic. While the opening of the Canada Line caused a shock in the parking environment, these further and continuing changes, while unlikely to be as drastic, may also have the ability to transform the market. As a result, identifying correlations – especially in the time period after the opening of the Canada Line – that are linked to parking transactions and have the potential to further affect ground access mode splits is essential in the airport's future plans, as these changes could have further implications in other realms, including airport revenue, land use patterns, necessary parking spaces, and both road and transit capacity.

Project Description

History and Context

The Canada Line

The Canada Line, a light rapid transit line, is the third SkyTrain line to be established in Metro Vancouver, and is owned by the South Coast British Columbia Transit Authority (TransLink). It opened on August 17, 2009, connecting downtown Vancouver with the suburb of Richmond and YVR, providing the airport with rapid connection to much of Metro Vancouver (CBC, 2009). This has come with multiple bus connections along the Canada Line, with further connections at the Waterfront station terminus in downtown Vancouver, allowing passengers to transfer to the Expo and Millennium light rail lines, as well as commuter rail and ferry connections (Pabillano, 2009). The Canada Line had 39.7 million riders in 2011 (Metro Vancouver, 2012).

Vancouver International Airport

YVR is an international airport on Sea Island, part of the city of Richmond, and is run by the Vancouver Airport Authority, which took over leadership from Transport Canada in 1992 (VAA, 2012c). While YVR is a large regional airport and the second busiest in Canada, competing airports, including the Seattle–Tacoma International Airport and Bellingham International Airport in Washington state, as well as Abbotsford International Airport in British Columbia, are able to siphon passengers away from YVR (McKnight, 2012; Korstrom, 2011). In 2011, YVR hosted just over 17 million passengers, and had just under 300,000 aircraft movements (VAA, 2012e; VAA, 2012f).

Future Plans

As YVR is the closest major Canadian and West Coast airport to Asia, many of its future plans are geared toward becoming a gateway between the Asia-Pacific and the Americas (VAA, 2007). For the Airport Authority, this is seen as a defining strategy due to continuing patterns in air travel markets: as worldwide trade increases, the economy grows in certain regions of the world (especially Asia), and China, India, and Latin America become larger tourist generators, the airport must be able to accommodate new growth and new passengers. With more travel and more passengers landing at YVR, further pressure is placed on the transportation system in

Metro Vancouver, as well as a need to accommodate more aircraft and passengers at the airport itself (VAA, 2007).

In its latest 20-Year Master Plan, the airport has included plans for airside projects (taxiways and runways) in order to improve efficiency and reduce taxi distances for aircraft. The plan also includes multiple options for the potential construction of a new runway; it is projected that in a best case scenario (if passenger forecasts are correct and demand management programs are successful), a new runway will be necessary at YVR by 2024. Further plans, including the expansion of the existing terminal complex and the reservation of land for air cargo purposes, are also included (VAA, 2007).

In making its long-term plans, the Airport Authority looks to follow a sustainability framework which includes economic, environmental, social, and governance pillars. As a result, the airport uses a “sustainability matrix” to measure potential options for future plans, looking to promote economic growth while considering the effect on habitat, air, and water, social impacts such as noise, and governance criteria regarding further opportunities or preclusions (VAA, 2007, pp. 10-11).

Ground transportation also remains an issue for YVR. While the opening of the Canada Line has reduced vehicle trips, it is expected that vehicle trips to YVR will continue to grow into the future. While Canada Line trips are expected to hold a steady percentage of mode share, an increase in airline travel would mean that the number of trips taken – both by Canada Line and by vehicle – would continue to increase. As a result, airport projections predict further innovation is necessary to ensure vehicle access to YVR remains, with options in parking pattern and location changes, altering existing routes to the airport, or adding new capacity (VAA, 2007). However, an option may also exist through the enhancement of Canada Line ridership; if the share projected by the airport – 15% of passengers and 18% of employees – can be increased, this would be of some relief to the road network.

Parking at YVR

Immediately after the opening of the Canada Line in August 2009, there were a series of parking rate increases at YVR. In October 2009, parking rates were increased marginally by the Airport Authority. This was repeated two months later, in December 2009, followed by an increase in the

provincial sales tax on parking effective in January of 2010. The implementation of the harmonized sales tax in July 2010 led to another increase in parking rates. While these increases had different causes, the consumer was quoted the tax-included price after all increases (VAA, 2010c). Posted prices are seen in Tables 1(short-term prices) and 2 (long-term prices).

Posted hourly rates as of:	Jan 16, 2006	Oct. 1, 2009	Dec. 1, 2009	Jan. 1, 2010	Jul. 1, 2010
Parkades	\$5.50/\$6.00*	\$6.00/\$7.00*	\$7.00	\$8.00	\$8.50
Economy	\$5.50	\$6.00	\$7.00	\$8.00	\$8.50
Long Term	\$2.97	\$3.50	\$3.50	\$4.00	\$4.25

Table 1: Posted short-term parking rates at YVR parking lots

*indicates split between POF (lesser) and cashier payment; source: VAA, 2010c

Posted daily rates as of:	Jan 16, 2006	Oct. 1, 2009	Dec. 1, 2009	Jan. 1, 2010	Jul. 1, 2010
Parkades 2 and 3	\$17.00	\$19.00	\$25.00/\$23.00*	\$28.25/\$26.00*	\$30.25/\$28.00*
Economy	\$13.00	\$15.00	\$18.00	\$20.25	\$21.25
Long term	\$10.74	\$13.00	\$13.00	\$14.75	\$15.75

Table 2: Posted long-term parking rates at YVR parking lots

*indicates split between P2 (greater) and P3 rates; source: VAA, 2010c

From September 2009, the first full month of Canada Line service, to December 2011, short-term parking transactions decreased in every month from the same month in the prior year, with the exceptions of February 2010 (an anomaly owing to the Olympic Games), April 2010, and September 2010. On a year-to-year basis, short-term parking transactions decreased 4.1% in 2009, 1.7% in 2010, and 8.0% in 2011 (VAA, 2010b; VAA, 2012b).

Long-term parking transactions at YVR have also decreased; however, these were most prominent in the first year after the opening of the Canada Line. For the 12-month period from August 2009 to July 2010, long-term parking transactions decreased every month with respect to the prior year, and a total of 14.8% from August 2008 to July 2009. On a year-to-year basis, long-term parking transactions decreased 13.0% in 2009, 9.7% in 2010, and 0.6% in 2011 (VAA, 2010b; VAA, 2012b).

The Canada Line and YVR

Access to both the domestic and international terminals at YVR on the Canada Line is from the YVR – Airport station on the Sea Island spur of the Canada Line. Travel time from the airport to downtown Vancouver in 26 minutes, costing \$8.75 on a single fare ticket. Headways are 6 minutes at peak periods, 12 minutes in off-peak periods, and 20 minutes in late evenings, running from 5:00am to 1:00am daily (VAA, 2012d). Prior to construction, the Airport Authority

contributed \$300 million to the Canada Line project, helping fund the rapid transit line and the spur line to the airport (TransLink, 2009). Based on add-fare statistics, the airport spur of the Canada Line had 5.5 million riders in 2010 (VAA, 2011a).

The opening of the Canada Line has had several effects on the airport. Aside from airport employees having a faster and more convenient ride to work, there also has been a mode shift with the general public. A prior report prepared for the airport observed a large increase in public transit usage for departing passengers upon the opening of the Canada Line (InterVISTAS, 2010). With such an increase, spillover effects are also prevalent: as mentioned above, the number of parking transactions at the airport (both short and long-term) has decreased since 2009 (VAA, 2010b; VAA, 2012b).

Ridership on the YVR spur of the Canada Line has been consistent since its opening. In quarterly surveys conducted by the airport, about 15% of departing passengers have reported that they arrived at the airport by public transit, a marked increase from rates around 5% before the Canada Line was opened, when public transit access was restricted to buses. These passengers appear to have shifted mostly from taxis (a decrease in mode share from 25% to 20%) and airport vans (6% of mode share to 2%) (VAA, 2011b).

Year-Quarter	09-1	09-2	09-3	09-4	10-1	10-2	10-3	10-4	11-1	11-2	11-3	11-4
Transit Share	5%	3%	5%*	13%	19%	16%	16%	16%	22%	16%	15%	17%

Table 3: Transit share at YVR (quarterly surveys)

* indicates survey was taken before opening of Canada Line; source: VAA, 2011b

Airport rail links

The Canada Line is the first airport rail link (also known as air-rail links) in Canada (IARO, 2011). Airport rail links are characterised as “fixed-route rail service[s] operating to established stops or terminals on a scheduled basis” (TCRP, 2000, p. 12), and can take a variety of forms, including subway, light rail, or commuter rail. These links have been established in many cities around the world, generally providing a convenient connection from airports to the city’s mass transportation network and the centre of the region. While air-rail links have been more common in Europe, the first North American link was opened in Cleveland, Ohio in 1968, and many further links have been created since the 1990s (Lin, 2004). Although the only air-rail link in operation in Canada as of 2012 is in Vancouver, plans or studies to provide a rail link to airports

have been initiated in Calgary (Calgary Transit, 2006), Ottawa (City of Ottawa, 2012), and Toronto (Metrolinx, 2012), while multiple proposals have been made in Montréal (De Lorimier & Robson, 2010). At present, the Air Rail Link to Toronto Pearson International Airport is the only proposed airport-rail link under construction in Canada (Metrolinx, 2012).

Literature Review

Modelling passenger behaviour

While air-rail links have been studied by a number of researchers, the main focus within the topic is the modelling of the behaviour of air passengers and their propensity to take rail over other modes in order to access the airport. Certain groups have been established as more inclined to use rail for airport trips: significant explanatory variables include travel time, travel cost, and the amount of luggage being taken (Harvey, 1986), as well as trip purpose, party size, and residential location (Clark & Lam, 1990 as cited in Alhussein, 2011). Variations have also been found between the casual and business traveller, with business travellers being more sensitive to time (Pels et al., 2001; Pels et al., 2003) and more willing to pay to avoid being late (Tam et al., 2008). It has also been found that an increase in travel distance makes a passenger more likely to use cars and taxis over other modes (Psaraki & Abacoumkin, 2002).

Case studies within a region

Despite the opening of many airport rail links in North America since the mid-1990s (Lin, 2004), few studies exist on the effect these connections. However, a stated preference survey was performed in order to test the viability of potential air-rail links in Austin, Dallas/Ft. Worth (DFW), and Houston by Chebil and Mahmassani (2003). Using a stated preference technique for hypothetical bus and systems, as well as an off-airport terminal, Chebil and Mahmassani (2003) found that business travellers were generally not interested in public transportation services, while sociable and energy-conscious travellers were interested. They found that a number of travellers would be willing to use new airport access modes; 28% of travellers from Houston, 19% out of DFW, and 8% out of Austin stated bus or rail as a preference for ground access in a hypothetical scenario.

Air-rail link usage in North America

A study undertaken by the Airport Cooperative Research Program in 2008 found that the mode split of rail to the 16 US airports with air-rail links was generally less than ten percent of all passengers. Two airports, Ronald Reagan Washington (DC) National Airport (DCA) and Hartsfield-Jackson Atlanta International Airport (ATL) had splits of over 10%, eight airports recorded a rail mode split between five and ten percent, and six recorded rail mode splits below five percent (ACRP, 2008).

Most air-rail links have caused an increase in the public transportation mode split of about seven percent, and have had steady ridership since opening. DCA reported a 13.5% (2.5% to 16.0%) increase in its transit access share when its Metrorail station opened in 1977, reported to be “one of the largest increases in public transportation share ever recorded” (ACRP, 2008, p. 73).

The ACRP also reported that while Chicago O’Hare International Airport (ORD) had the largest use of any US airport transit station, over 80% of those using the ‘L’ are airport employees. This is in part because the rail line is slower than taxis or private cars in non-peak hours; as a result, the train access mode split for passengers at ORD is about 5%. However, in the areas close to the field defined by the airport as the “prime market area”, the mode split is higher, at 12% of passengers (ACRP, 2008, p. 79). At Chicago Midway International Airport (MDW), a similar situation plays out. While overall airport mode share is 6%, its prime area, The Loop, has a rail access mode split of over 20%.

For fellow airports in the Pacific Northwest, Portland International Airport (PDX) was seen to have a 4% passenger rail share in the 2008 ACRP report, despite having a travel time competitive with the automobile. Data acquired from Seattle-Tacoma International Airport (SEA), which inaugurated its rail line in December 2009, found that its rail share was 5% for the period of July 2011 to June 2012 (Vande Kamp, 2011).

While the ACRP (2008) found that many European and Asian airports with air-rail links had rail ground access shares upwards of 20%, with Zurich International Airport leading the world with a 42% rail split, the ability to compare air-rail links across continents is limited somewhat by the nature of airports, public transportation, and city structure. While rail mode shares are significantly higher in Europe, Mandle et al. (2000) suggested that there is a ceiling of 15% of air

passengers using rail to access the airport in the US, with the primary market for rail being travellers going downtown, travelling alone, without luggage, familiar with the transit system, and able to walk to their final destination.

While assertions can be made that airports – especially in North America and Europe – have been built with the idea that passengers will arrive and depart by motorised transport (cars, shuttle buses, and taxis) (Vespermann & Wald, 2011), an increasing number of airports in North America, Europe, and Australia – including YVR – have placed a priority on air-rail linkage and intermodal connectivity (Lin, 2004). However, even with this caveat, certain airports – such as Hong Kong International Airport (HKG) – are ultimately incomparable to those in North America, as the mode split – both to and from the airport, and in the city in general – is significantly different from North American markets (Tam et al., 2008).

Other effects of air-rail links

Other studies have focused on different effects of air-rail links. Ferreira and Charles (2006) focused on the environmental impact of Airtrain at Brisbane International Airport (BNE) in Australia. They found savings of about 114 million kilometres of vehicle travel and 84 avoided road crashes, with further avoided fuel consumption and 24 thousand tonnes of carbon dioxide emissions within a five year period. They also state that speeds toward BNE increased 10-15 per cent due to the Airtrain.

Airport parking

A study was performed at the San Francisco International Airport (SFO) during a series of parking fee changes in 1983 and 1984 (Kanafani & Lan, 1988). Parking demand price elasticity was less for those who parked less than three hours or more than five days; those who parked between seven hours and four days had higher price elasticity. Therefore, it would be expected that short and long-term parking would stay relatively similar despite price increases, while medium-term parkers would be more likely to change to other parking services or modes.

Methods

The project endeavours to use statistical analysis, through the form of t-tests and regression testing, to find whether changes in the environment surrounding ground access (including the opening of the Canada Line, the change in parking prices, and other factors, such as the price of gasoline) are significant contributors to the decrease in parking transactions found at YVR after August 2009.

Data

Data were collected on a monthly basis for the period between January 2008 and December 2011 in the following categories:

- Originating passengers at YVR (a reasonable facsimile for originating and departing passengers, likely to be about double) (VAA, 2012g)
- The posted price at each parkade at YVR (VAA, 2010c)
- Parking transactions (categorised by parkade and lot, short and long-term) (VAA, 2010a; VAA, 2012a) and revenue (VAA, 2010b; VAA, 2012b)
- Quarterly data on mode share for ground access for passengers at YVR (VAA, 2011b)
- Gas prices (regular, self-serve) in Metro Vancouver, through Statistics Canada (StatCan 2008; StatCan 2009; StatCan 2010; StatCan 2011)

In order to make the data comparable over months, all counting numbers were divided by the number of days in that month to provide for a daily average.

Further modifications were made to the data in order to ensure that the effect of monthly variation was held to a minimum: this was accomplished by averaging the data for each specific month (for example, January of 2008, 2009, 2010, and 2011), and dividing the average by the overall average of all months to create a ratio. The raw daily average was then divided by the ratio of its month in that category to create an adjusted number. This was done for the categories of originating passengers, long-term parking transactions, and short-term parking transactions, and the data is referred to as “adjusted”.

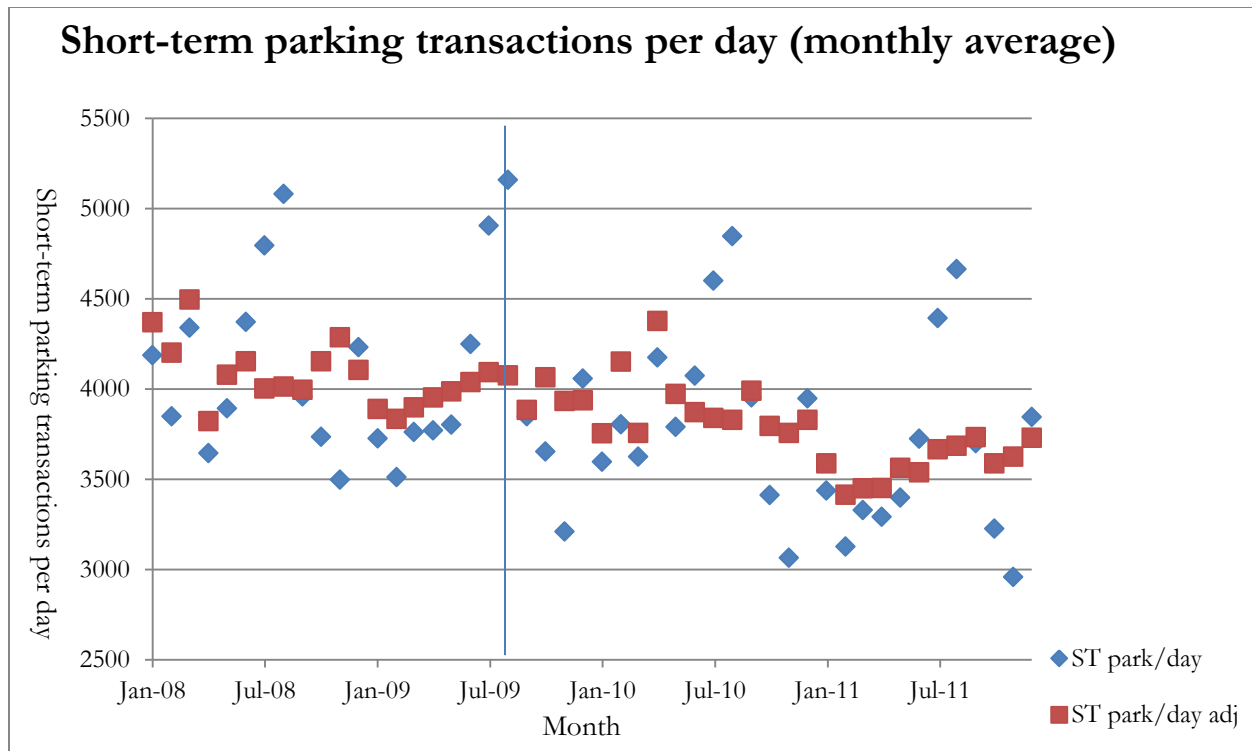


Figure 1: Short-term parking transactions per day (monthly average) – adjusted and unadjusted, 2008-2011

Raw data: VAA, 2010b; VAA, 2012b; vertical line indicates opening of Canada Line

Adjustments were also made to post-Canada Line data in regard to short-term and long-term parking transactions. For post-Canada Line adjusted data, the same process was used; however, the monthly ratios were obtained by using only data from September 2009 and later, as September of 2009 was the first full month of Canada Line service. All adjusted data labelled as post-Canada Line uses this format.

Lastly, to compensate for differing prices between lots for both short and long-term parking, an average rate was used for each period between price changes. This was found by averaging the rate (by lot parked in) of each transaction between periods of rate adjustment, therefore leading to a single prevailing rate for each period.

Methods

The methods used to evaluate data are t-tests, in order to establish differences between two time periods, and regressions, which are used to find significant coefficients of determination.

The pre-Canada Line period refers to the period from January 2008 to July 2009, the last full month without Canada Line service, a 19-month period. The post-Canada Line period refers to the period from September 2009, the first full month with Canada Line service, to December 2011, a period of 28 months. These periods are sometimes abbreviated to “pre-CL” and “post-CL”, respectively.

Findings

Originating passengers

Two questions were asked in regard to the effect of the number of originating and departing passengers:

1. Does the number of originating passengers correlate with the number of short-term parking transactions conducted at YVR? Does this change after the construction of the Canada Line?
2. Does the number of originating passengers correlate with the number of long-term parking transactions conducted at YVR? Does this change after the construction of the Canada Line?

In regard to the first question, a regression attempting to correlate originating passengers with short-term parking transactions was found as significant, both throughout the 48-month period of available data (2008-2011), as well as the period after the opening of the Canada Line. However, when the figures were adjusted for monthly variation (both originating passengers and short-term parking transactions), the correlations were no longer significant.

originating passengers v.	short-term parking [OP-1]	short-term (post-CL) [OP-1]	long-term parking [OP-2]	long-term (post-CL) [OP-2]
t-stat	9.952	7.355	-1.597	-1.728
r-square	0.683	0.675	0.053	0.103
p-value	< 0.001***	< 0.001***	0.117	0.096

Table 4: Result of regression analyses regarding originating passengers and parking

*** indicates 99.9% significance

In regard to the second question, regressions attempting to correlate originating passengers with long-term parking transactions were found as insignificant in all iterations. No significance was found in either the full or post-Canada Line period, and adjustments for monthly variation also did not lead to a finding of significance.

As a result, regarding originating passengers, it was found that:

1. Short-term parking transactions are correlated to originating passengers without adjustment; and

2. Long-term parking transactions are not correlated to originating passengers with or without adjustment.

Canada Line

Three questions were asked regarding the Canada Line:

1. Is the opening of the Canada Line correlated with an increase in the number of originating and departing (OD) passengers at YVR?
2. Since the opening of the Canada Line, has there been a decrease in the number of short-term parking transactions conducted at YVR?
3. Since the opening of the Canada Line, has there been a decrease in the number of long-term parking transactions conducted at YVR?

Each of these questions was tested through a two-sample t-test assuming equal variance, both with raw numbers, and monthly-adjusted numbers (for OD passengers, short-term parking transactions, and long-term parking transactions).

In regard to the first question, t- tests were used to find that there was no significant difference between the number of OD passengers at YVR before and after the Canada Line opened, both in terms of raw passenger numbers and monthly-adjusted numbers.

For the second question, the tests found that there was a significant decrease between the number of short-term parking transactions at YVR before and after the opening of the Canada Line, with a one-tailed t-test proving significant. For non-adjusted short-term parking transactions, significance was found at a 95% level ($t(45) = 2.29, p = .013$), showing a significant difference in short-term parking transactions pre and post-Canada Line. For monthly-adjusted short-term parking transactions, a significant difference was also found, but at the 99.9% level ($t(45) = 4.84, p < .001$).

For the third question, the tests found that there was also a significant decrease between the number of long-term parking transactions at YVR since the opening of the Canada Line. A one-tailed t-test was significant at the 99.9% level for both non-adjusted ($t(45) = 7.58, p < .001$) and monthly-adjusted long-term parking transactions ($t(45) = 13.73, p < .001$).

As a result, regarding the Canada Line, it was found that:

1. The Canada Line has not significantly affected the number of OD passengers at YVR in any direction;
2. There is a significant decrease in the number of short-term parking transactions at YVR since the opening of the Canada Line; and
3. There is a significant decrease in the number of long-term parking transactions at YVR since the opening of the Canada Line.

Parking prices

Four questions were asked in regard to parking prices:

1. Is the increase in short-term parking prices correlated with a decrease in short-term parking transactions at YVR?
2. Is the increase in long-term parking prices correlated with a decrease in long-term parking transactions at YVR?
3. Is the increase in short-term parking prices correlated with changes in the average length of a short-term parking transaction at YVR?
4. Is the increase in long-term parking prices correlated with changes in the average length of a long-term parking transaction at YVR?

For the first question, linear regressions of prevailing short-term parking price and the daily average of short-term parking transactions in a month over the four year period from 2008 to 2011 proved to be significant at the 95% level, with significance at the 99.9% level when short-term parking transactions were adjusted for monthly variations. However, this does not take into account an important conflating variable: the presence of the Canada Line. Because parking prices (both short and long-term) were not adjusted until after the opening of the rail line, it is possible that these tests would then attribute to parking price changes the effect of the Canada Line.

To combat this, linear regressions were also run plotting prevailing short-term parking price against the daily average of short-term parking transactions in each month after the opening of the Canada Line. Without adjustment for monthly variation, this regression was not significant,

but after adjustments were made, the linear regression was significant at a 95% level. This finding is also backed up by a t-test, which found that there was no significant difference ($t(26) = 0.33, p = 0.37$) between the raw daily average of short-term parking transactions from September 2009 to June 2010 and July 2010 to December 2011 (as a rate increase occurred on July 1, 2010), but a significant difference at the 99.9% level ($t(26) = 4.52, p < .001$) was found once adjusted for monthly variation.

short-term pricing v.	short-term parking [PP-1]	short-term parking (adj) [PP-1]	short-term (post-CL) [PP-1]	short-term (post-CL) (adj) [PP-1]
t-stat	-2.238	-6.145	0.099	-2.512
r-square	0.098	0.451	0.000	0.195
p-value	0.030 *	< 0.001 ***	0.922	0.019 *

Table 5: Result of regression analyses regarding short-term parking and short-term parking prices

* indicates 95% significance, *** indicates 99.9% significance

For the second question, a similar process was taken. Linear regressions of prevailing long-term parking price and the daily average of long-term parking transactions in a month over the four year period from 2008 to 2011 were significant at the 99.9% level either with or without adjustments for monthly variation. However, when comparing in the post-Canada Line period, when parking prices were increased, the linear regression was found to be of no statistical significance with both unadjusted and adjusted long-term parking transactions. Likewise, t- tests covering the same period as the first question found no significant difference in either unadjusted or adjusted long-term parking transactions.

long-term pricing v.	long-term parking [PP-2]	long-term parking (adj) [PP-2]	long-term (post-CL) [PP-2]	long-term (post-CL) (adj) [PP-2]
t-stat	-6.836	-10.761	-1.755	-0.973
r-square	0.504	0.716	0.106	0.035
p-value	< 0.001 ***	< 0.001 ***	0.091	0.340

Table 6: Result of regression analyses regarding long-term parking and long-term parking prices

*** indicates 99.9% significance

For the third question, a different set of data was used. The only reliable exclusively short-term parking data available was that of Parkade 1 (P1). As a result, revenue and transaction information from P1 were used in order to calculate an average length of stay in the parkade for each month. A regression was then run plotting the posted parking price of P1 against the length

of stay over the four year period; this was found to be significant at the 99.9% level ($p < .001$), with stays dropping from an average of 1.32 hours from January 2008 to September 2009 to 1.09 hours from July 2010 to December 2011.

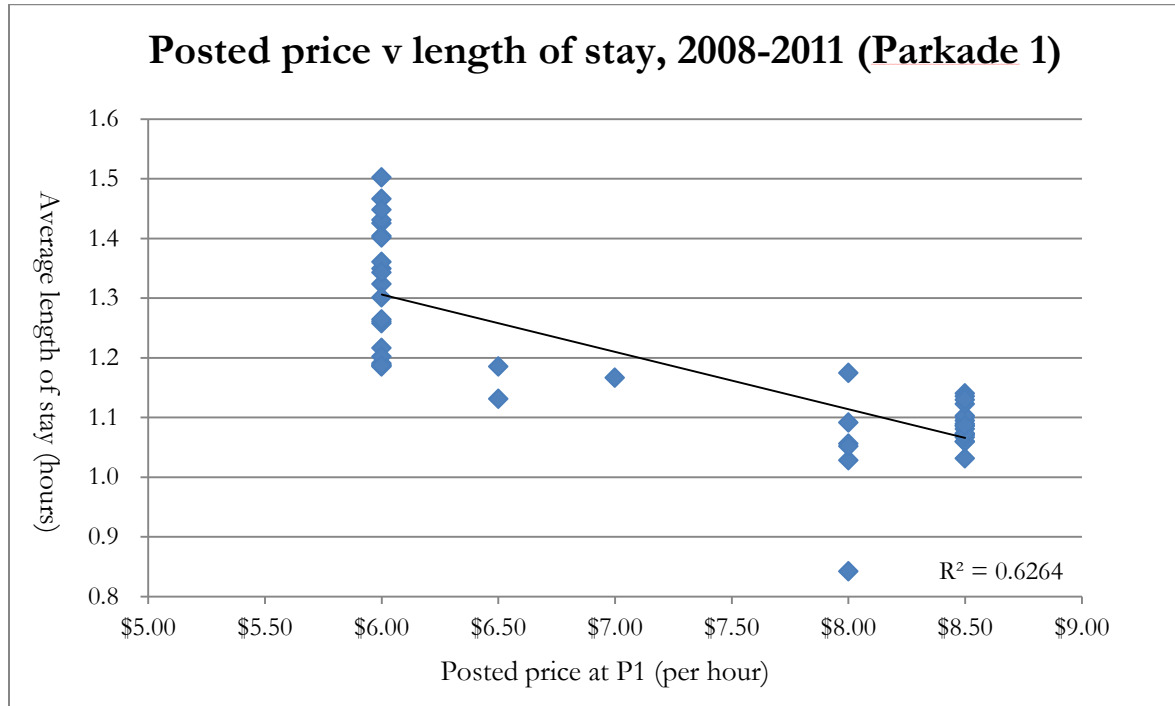


Figure 2: Posted price v length of stay at Parkade 1, 2008-2011

Raw data: VAA, 2010a; VAA, 2010b; VAA, 2010c; VAA, 2012a; VAA, 2012b

For the fourth question, similar results were found. While data for the long-term lot (LTL) was not exclusively long-term parkers, short-term parking in the lot was negligible (about 5 cars per day, or less than 2% of total transactions). Revenue and transaction information were used to calculate an average length of stay in the LTL for each month. A regression plotting the posted LTL price against the length of stay over the four year period was then run; this was significant at the 99.9% level ($p < .001$), with stays dropping from an average of 6.19 days from January 2008 to September 2009 to 4.68 days from July 2010 to December 2011.

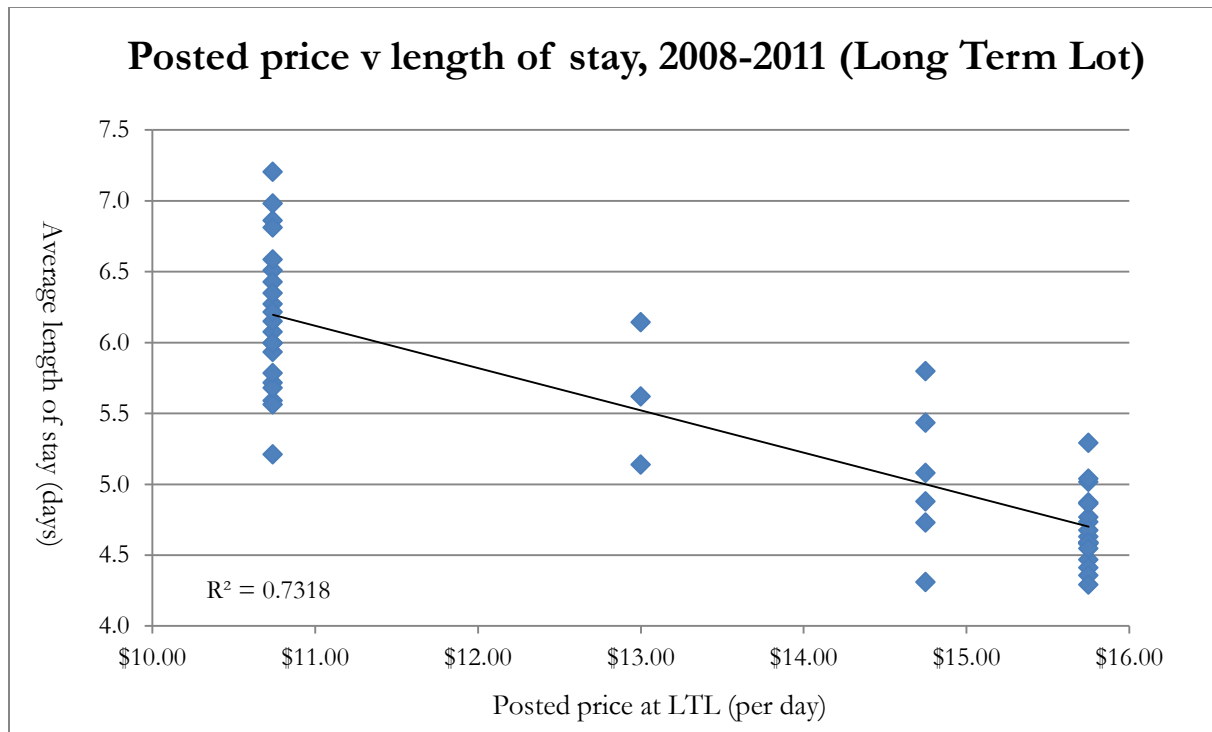


Figure 3: Posted price v length of stay at the Long Term Lot, 2008-2011

Raw data: VAA, 2010a; VAA, 2010b; VAA, 2010c; VAA, 2012a; VAA, 2012b

As a result, with regard to parking prices, it was found that:

1. While regressions over the four year period from 2008 to 2011 appear to show that short-term parking prices are correlated with short-term parking transactions, this may be conflated with the opening of the Canada Line. This is shown by the lack of a significant correlation in plotting short-term parking prices against raw transactions post-Canada Line; however, with short-term transactions modified to take into account monthly variation, there is a significant correlation post-Canada Line.
2. Regressions for the four year period from 2008 to 2011 appear to show that long-term parking prices are correlated with long-term parking transactions at YVR, but this is likely to be conflated with the opening of the Canada Line. Post-Canada Line regressions are shown to be insignificant.
3. An increase in short-term parking prices is significantly correlated with a decrease in the average length of a short-term parking transaction at YVR.
4. An increase in long-term parking prices is significantly correlated with a decrease in the average length of a long-term parking transaction at YVR.

Gasoline prices

Two questions were asked in regard to gasoline prices:

1. Do gasoline prices affect short-term parking transactions at YVR? Is there any difference due to the opening of the Canada Line?
2. Do gasoline prices affect long-term parking transactions at YVR? Is there any difference due to the opening of the Canada Line?

For the first question, it was found that regressions of Metro Vancouver gas prices against short-term parking transactions were insignificant both for the four-year period of 2008 to 2011, as well as for all months in the data set after the opening of the Canada Line. However, when short-term parking transactions were adjusted for monthly variation, the regressions were significant. For the entire four year period, the regression of gas prices against adjusted short-term parking transactions was significant at a 99% level, while the regression for months after the Canada Line was significant at a 99.9% level.

gas prices v.	short-term parking [GP-1]	short-term parking (adj) [GP-1]	short-term (post-CL) [GP-1]	short-term (post-CL) (adj) [GP-1]
t-stat	0.313	-3.056	-0.759	-6.149
r-square	0.002	0.169	0.022	0.593
p-value	0.755	0.004 **	0.455	< 0.001 ***

Table 7: Result of regression analyses regarding gas prices and short-term parking transactions

** indicates 99% significance, *** indicates 99.9% significance

For the second question, it was found that regressions of Metro Vancouver gas prices against long-term parking transactions, both unadjusted and adjusted, were insignificant for the period of 2008-2011, as well as the period after the opening of the Canada Line.

As a result, with regard to gas prices, it was found that:

1. There appears to be a correlation between gasoline prices and short-term parking transactions adjusted for monthly variation. When gas prices increases, the number of short-term parking transactions appears to decrease. This is significant both in the period of 2008-2011 as well as the period after the opening of the Canada Line.

2. There appears to be no significant correlation between gas prices and long-term parking transactions.

Summary of significant findings

Of the t-tests and regressions run, the following tests were found to be statistically significant:

1. Short-term parking transactions were significantly correlated with the raw number of originating passengers for both the 2008-2011 period, as well as the post-Canada Line period. *[OP-1]*
2. Since the opening of the Canada Line, there has been a significant decrease in short-term parking transactions; this is true for both unadjusted and adjusted parking transactions. *[CL-2]*
3. Since the opening of the Canada Line, there has been a significant decrease in long-term parking transactions; this is true for both unadjusted and adjusted parking transactions. *[CL-3]*
4. There appears to be a significant correlation between short-term parking prices and short-term parking transactions. While strong correlations exist in the 2008-2011 period, this may be conflated with the opening of Canada Line. A lesser, but still significant, correlation appears when short-term parking prices are regressed against adjusted short-term parking transactions after the opening of the Canada Line. *[PP-1]*
5. There appears to be no significant correlation between long-term parking prices and long-term parking transactions. While significant correlations exist in the 2008-2011 period, it is likely due to conflation with the opening of the Canada Line, as no significant correlation appears in the post-Canada Line period. *[PP-2]*
6. An increase in short-term parking prices is significantly correlated with a decrease in the average length of a short-term parking transaction at YVR. *[PP-3]*
7. An increase in long-term parking prices is significantly correlated with a decrease in the average length of a long-term parking transaction at YVR. *[PP-4]*
8. An increase in gas prices is significantly correlated with a decrease in the short-term parking transactions. This is true both for the 2008-2011 period as well as the post-Canada Line period. *[GP-1]*

Implications

Short-term parking

While the opening of the Canada Line had a slight effect on short-term parking transactions, other factors are also prominent in explaining the decrease of transactions after the opening of the Canada Line. While there is a statistically significant difference between the number of transactions conducted before and after the opening of the Canada Line, regressions also show that 68.3% of the variance in short-term parking transactions is explained by the number of originating passengers over the period 2008-2011, and 67.5% after the opening of the Canada Line. As a result, it is highly likely that the Canada Line is not prominent in regard to the variation in short-term parking transactions.

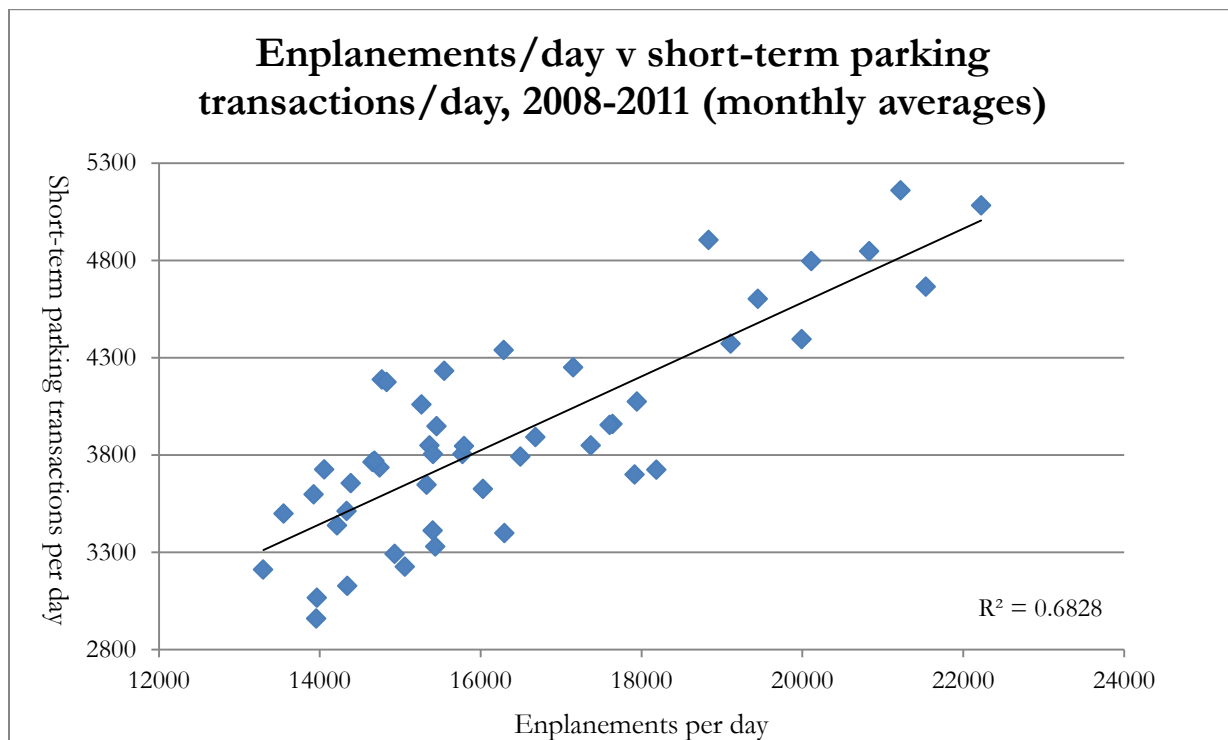


Figure 4: Enplanements/day v short-term parking transactions/day, 2008-2011 (monthly averages)

Raw data: VAA, 2010b; VAA, 2012b; VAA, 2012g

When adjusted for monthly variation, other factors are also seen to be important in explaining the variance of short-term parking transactions. In the post-Canada Line period, short-term parking pricing is seen to explain 19.5% of the variance in adjusted short-term parking transactions,

while gas prices are seen to explain 59.3% of the variance. As a result, it would appear that when monthly variations are neutralised, short-term parking transactions are well explained.

While it is possible that some of these potential short-term parkers have switched their mode of transportation to the Canada Line, there is no definitive proof of this. Other factors may come into play; for instance, potential short-term parkers may have instead chosen to pick-up and drop-off at the curb in order to save money after an increase in posted rates, or have chosen to park in off-airport lots on Sea Island or in Richmond to wait for pick-up.

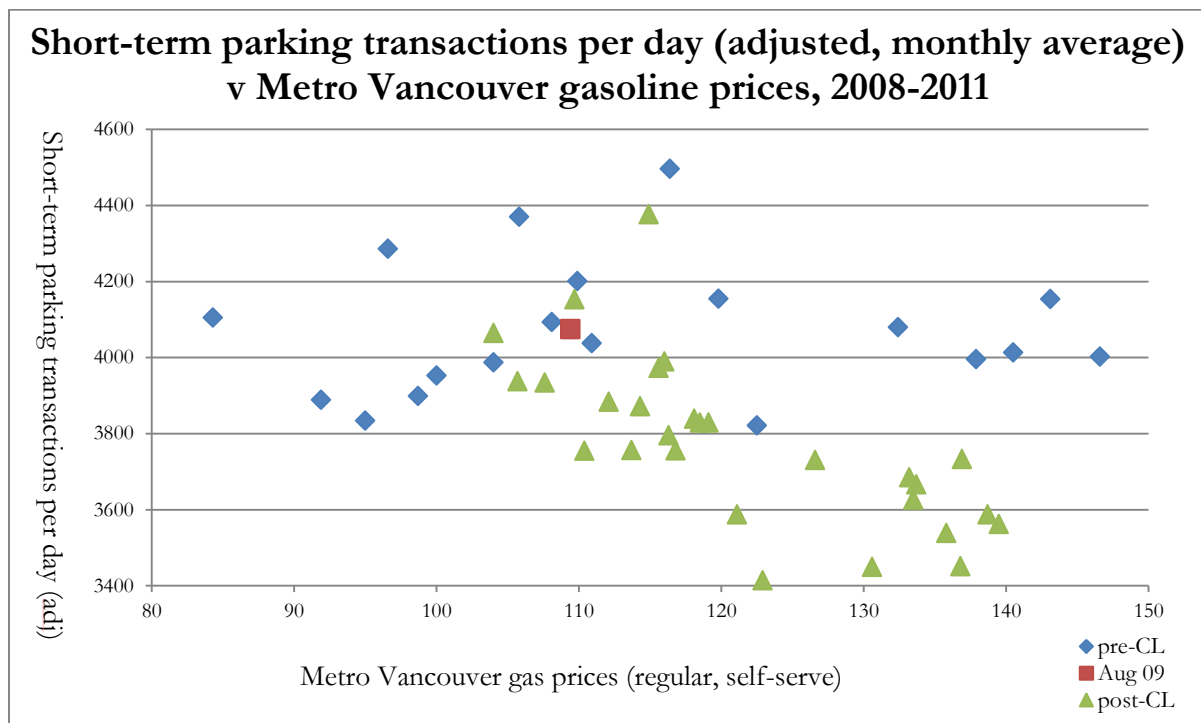


Figure 5: Short-term parking transactions per day (adjusted, monthly average) v Metro Vancouver gasoline prices, 2008-2011

Raw data: StatCan, 2008; StatCan, 2009; StatCan, 2010; StatCan, 2011; VAA, 2010b; VAA, 2012b

However, the advent of the Canada Line may be in part responsible for these post-Canada Line trends. By opening a new option to the airport, this will have allowed those who did not wish to drive to the airport to instead take an improved transit system. This is especially reflected through the insignificance of pre-Canada Line regressions between gas prices and adjusted short-term parking transactions, while a majority of the post-Canada Line variance in adjusted short-term parking transactions is explained by gas price variability.

Therefore, while there is not a specific number to explain the impact of the Canada Line on short-term parking at YVR, the Canada Line appears to have had onward effects through the creation of a new transportation option which did not exist beforehand. While these effects cannot be attributed directly to the Canada Line itself, alternative transportation to YVR (by bus) was not as effective before the rail line was built; with the Canada Line, avoiding higher gas prices has become easier, and the results may in part be seen through the high correlation between gas prices and adjusted short-term parking transactions.

While the driver of short-term parking at YVR is undoubtedly the pick-up and drop-off of passengers, as seen through the high correlation between short-term parking transactions and originating passengers, the Canada Line has likely had hidden effects. The existence of the Canada Line has allowed passengers to take a faster and more efficient form of transit if they do not wish to drive to the airport. While the only definite conclusion is that short-term parking transactions at YVR have significantly decreased since the opening of the Canada Line, the Canada Line is an option which can be used to avoid short-term parking at the airport – whether for purposes of convenience, or to avoid higher parking or gasoline prices.

Long-term parking

Long-term parking seems to have few factors which are aligned to it. Two significant findings regarding long-term parking were found: the first is that there is a significant difference between long-term parking transactions (both adjusted and unadjusted) before and after the opening of the Canada Line. This difference is about 170 transactions per day unadjusted. The second is that long-term parking prices are found to explain 50.4% of variation in long-term parking transactions, and 71.6% of variation in adjusted long-term parking transactions through the four-year period; however, this conflates heavily with the opening of the Canada Line, as parking price increases began shortly after the rail line opened.

Therefore, a potentially more relevant comparison regarding parking prices would be after the building of the Canada Line: these correlations were insignificant. In addition, no significant difference was found in long-term parking transactions (raw or adjusted) after the opening of the Canada Line, and before and after the rate increase of July 2010. Other correlations, attempting to associate originating passengers and gas prices to long-term parking transactions, both

adjusted and unadjusted, were also insignificant. Based on the significant differences found prior to and after the opening of the Canada Line, and the lack of significant differences or correlations found with other factors, it is possible that the Canada Line is almost wholly responsible for the decrease in long-term parking after its construction.

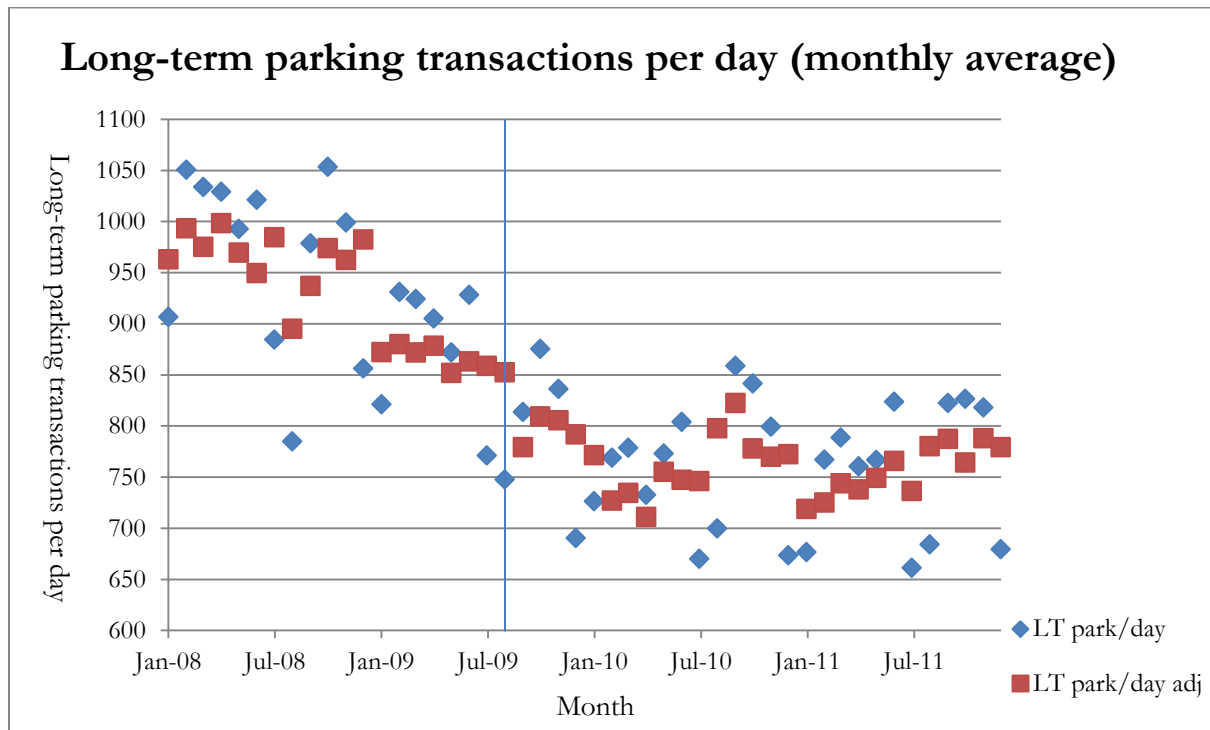


Figure 6: Long-term parking transactions per day (monthly average) – adjusted and unadjusted, 2008-2011

Raw data: VAA, 2010b; VAA, 2012b; vertical line indicates opening of Canada Line

The results suggest that long-term parking transactions are relatively inelastic. While there was a drop in long-term parking transactions immediately after the rail line opened, little difference in parking transactions occurred both in the period before and in the period after the opening of the Canada Line, and even less difference was observed when the numbers were adjusted to account for monthly variation. As a result, it can be suggested that the Canada Line has had a large impact on long-term parking transactions at YVR, especially as parking prices and gas prices were both found to be insignificant. Therefore, the data would appear to suggest that the increase in travellers who forgo driving and parking at YVR for longer trips do so in favour of using the Canada Line.

Parking length

The decrease in parking length found in both P1 and the LTL correlate with the increase of posted parking prices in each lot. It was found that 62.6% of the variation found in the length of P1 stays could be explained by the posted hourly rate at the parkade, and that 73.2% of the variation in the length of LTL stays could be explained by the posted daily rate at the lot.

While the results for P1 seem to match with those found in the Kanafani and Lan (1988) study performed at SFO, the results for the LTL do not. Kanafani and Lan (1988) found that price elasticity was most for those who parked between seven hours and four days, while it was least for those who parked for under three hours and more than five days. A decrease in the length of stay for those in P1 would appear to match with the results found at SFO: while records for individual stays were not obtained, a decrease in the average stay may be an indication that longer stays were moved or otherwise cut, perhaps in part due to alternatives such as free lots in Richmond or on Sea Island, or the Canada Line.

A decrease in the length of stay for those in the LTL, however, does not match with the Kanafani and Lan (1988) results, as this would imply that longer stays were moved or lost. Therefore, other reasons should be sought to explain the difference: at the time of the study, SFO did not have a rail line which would allow a passenger to avoid driving to and parking at the airport. Furthermore, there may also be differences in competing non-airport lots. However, without parking data and prices from off-airport lots, it would be impossible to judge if the lost transactions at YVR managed lots have simply been diverted to other, more competitive businesses, especially with regard to long-term parking.

Therefore, while the exact factors and motives (diversion to other parking lots, use of Canada Line, saving money, etc.) behind the shortening of parking lengths are unknown, it is clear that with price increases in both short and long-term parking, stays in both categories have become shorter. As a result, this becomes a consequence of raising parking rates that ought to be considered by the Airport Authority from a revenue perspective.

Conclusion

While the Canada Line has greatly affected parking patterns at YVR, it is not the only factor which has changed the parking environment at the airport. Given the lack of significant correlations for other factors, it appears that the Canada Line is the significant element in the reduction of long-term parking transactions since its opening; however, without further research, such as transactions at off-airport parking services, this cannot be confirmed.

However, the same cannot be said of short-term parking transactions: while there is a significant difference, as with long-term parking transactions, before and after the Canada Line, there appear to be more important factors which drive short-term parking, as it appears to be closely correlated to originating passengers. With monthly variation neutralised, parking rates and gasoline prices are significantly correlated after the opening of the Canada Line. While the Canada Line may contribute to this in its newfound state of existence from September 2009 onward, its mere presence does not seem to be the significant element in the reduction of short-term parking transactions.

Limitations

The project was limited by multiple facets. The first and foremost element is a lack of comparison with other North American (and Australian) airports. While many airports in North America have newly opened air-rail links, few were willing to share, or have kept track of data which may indicate rail's effect on ground access. While other airports, such as fellow West Coast airports in Seattle, Portland, and San Francisco, could have served a point of comparison, not enough information was made available for a meaningful comparison.

A lack of complete information was also a hurdle in the project. While much information was received from YVR, not all of it was usable for the project. For instance, while ridership data was available, it did not distinguish between employees and non-employees. Furthermore, surveys about passenger ground access mode were undertaken on a quarterly basis; while this can be used as a baseline, it was not accurate enough in order to predict the number of airline passengers taking the Canada Line on a monthly basis. The closest estimates calculated from the data obtained resulted in large fluctuations in both passenger and employee ridership statistics on

a month-to-month basis, the latter of which is a largely unrealistic scenario. As a result, no data using Canada Line ridership numbers were used in the significance testing.

Broader implications for YVR

Further opportunity exists for YVR to take charge in implementing progressive measures after the opening of the Canada Line. While some factors which may increase travel on mass transit are not controlled by the Airport Authority (for example, gas prices, operating hours, and the TransLink add-fare) (TransLink Commission, 2009), certain other factors, such as parking prices, have been shown to influence ridership. As a result, it may be possible for the airport to further fuel an increase in Canada Line ridership through certain factors; however, prudence is required, and further research may be required in regard to the loss of revenue to competing parking services.

Certain broader policies may also be able to further influence public transit usage. As part of a region-wide demand management system, road pricing could potentially be enacted throughout Metro Vancouver, including non-airport traffic crossing the Arthur Laing Bridge. Such a strategy may increase the cost of driving for some non-airport commuters, and may be a possible driver to mass transit outside of airport trips (VAA, 2007).

The Master Plan has not suggested tolls for all passenger vehicles to and from YVR; however, this may also serve as a driver for both passengers and employees to use the Canada Line to access the airport. As airport traffic increases, the amount of traffic on the bridges to and from Sea Island will continue to be a problem for YVR; the Canada Line can therefore be used as a solution of sorts. However, further innovation and demand management programs would be necessary. While the Canada Line is unlikely to be the only solution to the problem, prioritising and continuing the shift of current and future Sea Island traffic toward mass transit may be able to help the Airport Authority manage demand on Sea Island roadways, and may require fewer future infrastructure improvements.

Future research

For YVR, future research regarding the Canada Line can focus on other effects, similar to the study done by Ferreira and Charles (2006) for BNE. These studies can focus on environmental and traffic effects of the Canada Line, perhaps important in Metro Vancouver, and for the airport,

given its position on Sea Island. Another possible Canada Line study could be a retroactive stated preference survey for those who used the Canada Line. This would allow the airport to find what mode rail passengers have switched from, and the reasons they have done so, and may be able to better link the use of the Canada Line to other contributory factors, including higher gasoline and parking prices. Although it was found in the Bay Area that airport choice comes before access mode choice (Pels et al., 2003), such findings may also be useful in finding ways to market the Canada Line to Vancouverites to fly out of YVR instead of competing airports in Washington state.

Future research regarding parking at YVR may need to extend to off-airport parking services. While YVR could survey passengers on parking habits, it is possible that the decrease in YVR long-term parking may be mirrored in off-airport services, which would provide a stronger argument for the effect of the Canada Line. However, there may also be possibilities that off-airport parking services have increased their share of the market. For decreases in short-term parking, it may be prudent to study if those coming to the airport for drop-off and pick-up have decided not to park or to park elsewhere for free in order to avoid YVR lots. Such a choice may further blunt the effect of the Canada Line on short-term parking.

Finally, other airports with recently completed rail links may find it prudent to undertake similar studies in order to assess the impact on ground access, parking revenues, and OD passengers, especially in multiple airport areas. While it appears that few studies have been conducted, a consistent pattern may be able to inform other transit agencies and airports in North America if it is prudent or economically beneficial to fund an air-rail link, and if it can improve the quality of life for the entire region through environmental benefits and less traffic congestion. These factors have been studied in Europe and Asia (TCRP, 2000); however, a different environment for public transportation may render a need for more specific study in North America. Thus, a look at specific contexts and factors throughout North America can be used in order to find a method to improve the viability of air-rail links on the continent, looking at certain elements which may be able to give future air-rail links a greater chance at success.

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Appendices

Appendix 1: Results for all t-tests

question	comparison	null hypothesis			df	tails	t-score	p-value
CL-1	Originating passengers (raw)	pre-Canada Line	=	post-Canada Line	45	2	0.10	0.92
CL-1	Originating passengers (adj)	pre-Canada Line	=	post-Canada Line	45	2	-0.16	0.44
CL-2	Short-term parking transactions (raw)	pre-Canada Line	≤	post-Canada Line	45	1	2.29	0.013*
CL-2	Short-term parking transactions (adj)	pre-Canada Line	≤	post-Canada Line	45	1	4.84	< .001***
CL-3	Long-term parking transactions (raw)	pre-Canada Line	≤	post-Canada Line	45	1	7.58	< .001***
CL-3	Long-term parking transactions (adj)	pre-Canada Line	≤	post-Canada Line	45	1	13.73	< .001***
PP-1	Short-term parking transactions (raw)	Sep 2009 -Jun 2010	≤	Jul 2010 - Dec 2011	26	1	0.33	0.37
PP-1	Short-term parking transactions (adj)	Sep 2009 -Jun 2010	≤	Jul 2010 - Dec 2011	26	1	4.52	< .001***
PP-2	Long-term parking transactions (raw)	Sep 2009 -Jun 2010	≤	Jul 2010 - Dec 2011	26	1	0.91	0.19
PP-2	Long-term parking transactions (adj)	Sep 2009 -Jun 2010	≤	Jul 2010 - Dec 2011	26	1	-0.12	0.45

* indicates 95% significance, *** indicates 99.9% significance

For PP-1 and PP-2, September 2009 through June 2010 was chosen as the first time period as September 2009 was the first full month after the Canada Line opened, and a parking rate increase occurred on July 1, 2010.

Appendix 2: Results for all regression analyses

question	independent variable (x)	dependent variable (y)	r-square	t-stat	p-value
OP-1	originating passengers	short-term parking transactions	0.683	9.952	< .001 ***
OP-1	originating passengers (adj)	short-term parking transactions (adj)	0.027	1.134	0.263
OP-1	originating passengers	short-term parking transactions (post-CL)	0.675	7.355	< .001 ***
OP-1	originating passengers (adj)	short-term parking transactions (post-CL; adj)	0.003	0.287	0.777
OP-2	originating passengers	long-term parking transactions	0.053	-1.597	0.117
OP-2	originating passengers (adj)	long-term parking transactions (adj)	0.026	1.111	0.272
OP-2	originating passengers	long-term parking transactions (post-CL)	0.103	-1.728	0.096
OP-2	originating passengers (adj)	long-term parking transactions (post-CL; adj)	0.137	-2.034	0.052
PP-1	short-term pricing	short-term parking transactions	0.098	-2.238	0.030 *
PP-1	short-term pricing	short-term parking transactions (adj)	0.451	-6.145	< .001 ***
PP-1	short-term pricing	short-term parking transactions (post-CL)	0.000	0.099	0.922
PP-1	short-term pricing	short-term parking transactions (post-CL; adj)	0.195	-2.512	0.019 *
PP-2	long-term pricing	long-term parking transactions	0.504	-6.836	< .001 ***
PP-2	long-term pricing	long-term parking transactions (adj)	0.716	-10.761	< .001 ***
PP-2	long-term pricing	long-term parking transactions (post-CL)	0.106	-1.755	0.091
PP-2	long-term pricing	long-term parking transactions (post-CL; adj)	0.035	-0.973	0.340
PP-3	Parkade 1 posted price	Parkade 1 average stay (hours)	0.626	-8.783	< .001 ***
PP-4	Long Term Lot posted price	Long Term Lot average stay (days)	0.732	-11.204	< .001 ***

GP-1	Metro Vancouver gas prices (regular, self-serve)	short-term parking transactions	0.002	0.313	0.755
GP-1	Metro Vancouver gas prices (regular, self-serve)	short-term parking transactions (adj)	0.169	-3.056	0.004 **
GP-1	Metro Vancouver gas prices (regular, self-serve)	short-term parking transactions (post-CL)	0.022	-0.759	0.455
GP-1	Metro Vancouver gas prices (regular, self-serve)	short-term parking transactions (post-CL; adj)	0.593	-6.149	< .001 ***
^	Metro Vancouver gas prices (regular, self-serve)	short-term parking transactions (pre-CL; adj)	0.001	0.158	0.876
GP-2	Metro Vancouver gas prices (regular, self-serve)	long-term parking transactions	0.013	-0.763	0.449
GP-2	Metro Vancouver gas prices (regular, self-serve)	long-term parking transactions (adj)	0.026	-1.109	0.273
GP-2	Metro Vancouver gas prices (regular, self-serve)	long-term parking transactions (post-CL)	0.005	-0.370	0.715
GP-2	Metro Vancouver gas prices (regular, self-serve)	long-term parking transactions (post-CL; adj)	0.080	-1.500	0.146

* indicates 95% significance, ** indicates 99% significance, *** indicates 99.9% significance

^ indicates a regression not directly asked in the questions, but referenced in the implications section.