# From Fare Zones to Fair Zones: The Impact of Differentiated Transit Fares on Metro Vancouver Transit Riders

**by**

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Capstone Submitted in Partial Fulfillment of the
Requirement for the Degree of
Master of Public Policy

in the
School of Public Policy
Faculty of Arts and Social Sciences



**SIMON FRASER UNIVERSITY**

**Summer 2014**

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## Abstract

Transit scholars have long advocated the use of differentiated transit pricing to improve service efficiency and equity among riders. Using Metropolitan Vancouver as a case study, I examine the effects on transit revenues and equity measures of two strategies – distance-based and time-of-day pricing. The analysis uses an established transportation forecasting model, combined with survey data from TransLink[1] and estimates of price elasticity of demand from the literature to predict change in demand due to change in the fare structure. Information from transit agencies in Washington, DC, and Toronto, Ontario provides insights into issues of implementation complexity and public and political acceptance of differentiated fare structures. The analysis reveals an improvement in terms of increase in trips and reduced fares for lower income, captive and transit-dependent riders, and for riders from certain municipalities, with distance-based pricing. With a time-of-day fare structure there is slight improvement for low-income riders, an increase in revenues, and a small shift of trips from peak to off-peak times. The study recommends that the region's transit agency develop a fare policy with consideration of a differentiated fare structure to improve service efficiency and equity among riders.

**Keywords**: Transit pricing; distance-based fares; time-of-day fares; fare elasticity; Metro Vancouver

[1] The research and analysis are based on data from TransLink and the opinions expressed do not represent the views of TransLink

## Dedication

To my dad for instilling in me a life-long love of learning and knowledge, and whose memory still inspires me.

To my mom for dedicating your life to us and for your unconditional love and support.

To Bassem, Leila and Luke for your endless support, patience, and belief in me which kept me going through the toughest of times; I love you.

## Acknowledgements

First and foremost I would like to thank Dr. Nancy Olewiler, my supervisor, whose unconditional support of me is the reason for this work. I have had the privilege and honour to work with her over the last two years, of which I have learned invaluable skills and life lessons. Nancy, your unwavering support of your students and belief in them is an inspiration. I am forever grateful to you for the opportunity to have been in this program. I am also grateful to Dr. John Richards my external advisor for his feedback and edits that made this work more complete.

I would also like to extend my appreciation and gratitude to the faculty and staff in the Public Policy program, for an incredible experience. I have enjoyed being taught by each one of you.

I am also very thankful to the Planning staff at TransLink for providing the idea for this capstone and for allowing me access to the 2011 Trip Diary data.

And special thanks to Dr. Jonathan Moody for his guidance and help on handling the data for the quantitative analysis part of this capstone

Last but not least I want to thank my capstone research group and my cohort, in particular, Anya, Chelsea, Jonathan, Nadav, and Taryn. Thank you all for sharing this journey together over the last two years. You have made this a pleasant experience and I have learned something from each one of you. You are truly an amazing group of people.

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# Executive Summary

Metro Vancouver's transit authority, TransLink, intends to review its fare policy in 2016. It will introduce a smart card – the "Compass" card to replace its current payment methods. The smart card has the capability to generate detailed trip data to help understand riders' travel patterns and inform the review. TransLink's 2013 Regional Transportation Strategy set targets to substantially increase trips made by transit, walking and cycling and reduce driving. Transportation pricing is one of several strategies TransLink intends to use to achieve these targets.

Transit scholars have long advocated for more differentiated fare structures to improve the economic efficiency of transit agencies and equity among riders. Fare structures that more closely reflect the marginal cost of providing the service can improve the efficiency of the system, while ensuring that users consume more of the lower cost services versus the higher cost ones. It also ensures that riders are paying a price that reflects the cost they impose on the system.

The current TransLink fare structure does not establish an effective link between costs of providing the service and fares, and hence operational cost recovery has been slightly declining requiring more subsidies (obtained from a variety of taxes) over time. Moreover the system's ridership has been increasing, and the system has expanded in recent years to help meet the demand, leading to increased operations costs. At the same time, TransLink has been challenged by lower than expected revenues. In particular, the fuel tax which represents about 23 percent of its revenue has been declining due to reduction in fuel use. The other major tax revenue source is from residential, commercial, and industrial property tax, which represents about 22 percent of its revenue. Without approval of the region's mayors, that source is limited by legislation to a maximum of 2 percent increase per year. The net result is that operating costs are growing faster than growth in tax revenues, leading to the need to focus on transit fare revenues as the most sustainable source of revenue for the agency.

This work explores the effect on riders, trip demand, and transit revenue if a more differentiated fare structure is used. I explore the effect of changing the current

zone fare structure to distance-based and time-of-day fare structures. I use data from the 2011 TransLink trip diary survey to do the analysis. I also supplement my research by conducting two in-depth interviews with North American transit agencies that use similar fare structures to understand the effect on system administration and political and public acceptance of the fare structures.

The trip diary data reveals that with the current fare structure about 51 percent of trips are short distance below 10 kilometers in distance. It also shows that more than 60 percent of lower income riders' transit trips are short distance, while more than 50 percent of higher income riders' trips are longer than 10 kilometers. Lower-income riders thus pay on average higher fares per kilometer compared to higher income riders. It was also found (consistent with the literature) that lower income riders make more of their trips during the midday off-peak period while higher income riders make most of their trips during peak period. And since peak trips have a higher marginal cost than off-peak trips, then low-income riders are paying proportionally more for their trip than the cost they impose on the system compared with higher income riders using the system mostly during peak periods.

The simulations done to model the effects of both distance-based and time-of-day fare structures on riders and revenues, show improvement to revenues collected, demand for transit, and equity among riders. Distance-based results show that overall trips increase by close to 3 percent and fares collected increase by more than 2 percent. Riders from all income groups increase their overall trips, but lower-income riders have a higher increase in total trips and achieve the largest percentage reduction in average fare paid per trip. Similarly, the younger and older age groups, who are more transit dependent, increase their overall trip consumption and substantially reduce their average fare per trip compared to the current zone structure. As for impact by municipality, mainly riders from municipalities north of the Fraser river are able to increase their trips and reduce their average fare per trip ranging from an 0.4 percent reduction in Port Moody to as high as 14.6 percent in Vancouver. On the other hand riders travelling from municipalities south of the Fraser end up paying a much higher fare per trip; for some this is as high as 23 percent.

Time-of-day pricing generally results in an overall reduction in trips by only 0.8 percent while fare revenues increase by 3.3 percent. Also the number of trips in peak periods decreases by 3.6 percent while off-peak trips increase by 2.6 percent. In this scenario I apply a 20 percent increase to regular fares during peak periods from 6:00 to 9:00 am and from 3:00 to 6:00 pm, while applying concession fares for the rest of the day. The 20 percent increase in fares results in all income and age groups being affected by an average increase in fare per trip. However the increase is less for the lower income groups and transit dependent riders than the rest. The time-of-day structure does not seem to impact riders based on where they are located geographically since for riders from most municipalities the average fare per trip has increased except for three municipalities where it decreased. Riders from these municipalities make more trips during off-peak periods.

In conclusion the study makes three recommendations for TransLink to consider in getting ready to review it fare structure:

- Develop a fare policy to improve decision making on fare structure and price changes by avoiding reactionary decisions. Fare increases are a sensitive issue and without guidance on how the fare structure complements and advances the transit agency's service and financial goals, then it would be left to shifting public opinion and politics of the day to determine the outcome of fare reviews.

- The fare structure review should be done along with a review of service offerings. TransLink should evaluate its current and potential service offerings with respect to the fare price and structure. For example if the agency decides to pursue distance-based pricing, it could face significant political and public opposition from municipalities south of the Fraser River. But if the fare structure change is accompanied by substantial improvements to the quality of the service especially in terms of the frequency and speed, then the change could be more acceptable. A fare structure change on its own is likely to be met with suspicion that the agency's goal is to raise more revenue and not to improve the service and equity among riders.

- Improve forecasting model**:**

It is important for a transit agency to have a robust model to forecast ridership changes with respect to the factors that affect it. TransLink currently uses a constant elasticity value when predicting ridership changes due to fare increase. Riders' response to fare changes is affected by many variables, and the use of one value to capture all these different variations is less likely to produce an accurate forecast. It is important for TransLink to develop its own forecast model with own elasticity values that capture the unique characteristics of its riders, system, and regional economic conditions.

# Chapter 1. Introduction: The Quest for Greater Efficiency and Equity in Public Transit Pricing

Transit authorities across North America are examining their fare structures as they introduce electronic fare card technology. These 'smart cards' enable authorities to more accurately track ridership by time of day, location, and distance traveled. TransLink, metropolitan Vancouver's transit authority, intends to review its fare policy in 2016, two years after full implementation of its new smart card fare technology called "Compass" card. The two-year window gives TransLink time to compile information on users' travel patterns to help inform the policy review. Compass card technology will provide the data that enables TransLink to:

1- Set prices that encourage efficient use of the system and more closely reflect the cost of providing the service which varies considerably by distance travelled, time of day or by mode of transit used;

2- Reduce inequities due to cross-subsidies between the different groups using the system and thus increase ridership

Transportation pricing is one of several strategies TransLink intends to use to achieve its transportation targets made in the 2013 Regional Transportation Strategy. Two important targets are set for 2045:

- Half of all trips to be made by walking, cycling and transit;
- Reduce the distances people drive by one-third

Pricing policies that encourage users to efficiently use the region's network of roads and transit are identified in the strategy document. Three types of pricing strategies are considered: "road pricing; transit pricing with time-of-day, location or distance-travelled variations; and parking pricing" (TransLink, 2013c). Transit riders normally pay a portion of the cost of providing transit services, which typically leads to arbitrary and inefficient use of the system (TransLink, 2013c). For example by not surcharging transit users for some of the extra cost of using transit during peak times, many low priority trips will be made during this time while crowding other commuters who have no choice but to use transit at peak times. Similarly car trips taken during peak periods clog the roads unnecessarily and increase the cost and inconvenience to other users. The lack of signaling the right price to consumers leads to inefficient use of the system.

Although the main purpose of smart card technology is to improve fare buying and collection methods, and reduce fare evasion, it has the potential to generate a large amount of data on “how customers use the transit network” (TransLink, 2009; Pelletier et al., 2011). This information can be used to improve transit routes and schedules and to match fleet ridership and travel times with fleet size and frequency. It can also facilitate flexible fare structures tailored to different users’ needs such as differentiated and concessionary fares, and streamline partnerships with other agencies such as universities, employers and social service agencies (Fleishman et al., 1996; Pelletier et al., 2011).

A transit agency’s fare policy and structure affects almost all aspects of its administration and operations, therefore it is very important to assess the potential impacts of any proposed changes to fare structures. For example in 2012, fare revenue constituted 51.4 percent of total annual revenue for TransLink and therefore affected operating budgets and funding required from others sources (TransLink, 2012). The fare structure affects ridership levels, and fare collection technology affects boarding time on buses (Fleishman, 2010). When increasing fares it is also imperative to assess the impact on riders who are transit dependent, low income, or with disabilities.

TransLink currently uses a three zone fare system for all its bus, rapid transit “SkyTrain”, and passenger ferry “SeaBus” routes, five zones for its commuter rail – the West Coast Express[2], and an extra airport zone over its 1800 km service area that spans 21 municipalities, one electoral area and one treaty First Nation that make up the

[2] The West Coast Express is a commuter train that runs during the morning and afternoon rush hours to transport commuters into and out of downtown Vancouver. Trips by West Coast Express are excluded from my analysis since it has a different fare structure and fare prices than the rest of the system.

Metro Vancouver region (Figure 1). The zone system is considered one form of differentiated pricing where users pay for extra distances travelled (Cervero, 1990; Fleishman, 2003). This structure does create some inequities, especially for short distance travellers. For example a one-zone user could travel the same distance or more as someone traveling between two zones and pay much less per kilometer traveled depending on where they are within the zone's boundaries. Also as can be observed from the map below given the area that TransLink services, for large parts of the region transit travel is more or less flat fare based.

Transit scholars have argued that flat fares impose inefficiencies on the transit system and inequities among users, because long distance and peak period trips impose higher operating costs on the system than short distance and off-peak trips. This results in short-trip and off-peak transit users paying much more per distance travelled than long-distance and peak time travellers (Cervero, 1980; Ballou and Mohan, 1981; Yoh et al., 2012). Cervero (1981) suggests that differentiated pricing is more efficient and equitable than uniform or flat fare pricing because users pay for the actual distance travelled.

As noted above, in 2012 fare revenues contributed 51.4 percent of TransLink's operations budget. While this farebox recovery ratio, which is the fare revenue divided by the transit's operating cost ratio, falls within the Canadian average (Calgary Transit, 2014), it has dropped from 56 percent in 2006 (TransLink, 2012b). Some attribute this to the fact that increases in most of the fares TransLink offers are limited by legislation to 2 percent annually, a rate that does not necessarily equal the annual rate of increase in operating cost. Wages, labour, and material costs can rise at a rate higher than a general inflation rate, and increased ridership also leads to higher costs due to expansion of the system (Calgary Transit, 2014; Anderson et al., 2012). I explore differentiated fare pricing structures which have the potential to increase farebox recovery while improving the efficient use of the transit system. I examine the impacts of differentiated pricing on TransLink's operations, ridership, and affordability if fare prices are set according to actual distances travelled or by time of day travelled. I will be exploring the effectiveness, equity, and affordability of a differentiated fare structure in Metro Vancouver.

I use raw unpublished data from the latest regional trip diary survey to evaluate the impacts of changing the current fare structure to distance-based, and to time-of-day pricing, on ridership, equity among riders and affordability, and on transit revenues. In the following chapters, I provide a review of the literature on fare policies, fare structures, riders' response to fare changes, and equity issues in transit policy. Following that, I present the policy options considered for this research which have been gleaned from the literature review. I then provide a description of the quantitative and qualitative methodologies used for this research. The quantitative methodology follows a method established in the literature to calculate/forecast change in ridership using elasticity of demand. The qualitative review involves case study/interviews of transit agencies that use differentiated pricing followed by the results that show that distance-based pricing has the potential to increase ridership and revenues, while time-of-day pricing can increase total revenues with minimal reduction to ridership, while shifting some of peak ridership to off-peak times. The policy options are then evaluated using a multi-criteria matrix to show the trade-offs between the different policy options, but not necessarily to recommend one option over the others. I conclude the paper with a few recommendations that would facilitate a fare review process, and improve forecasting modeling.

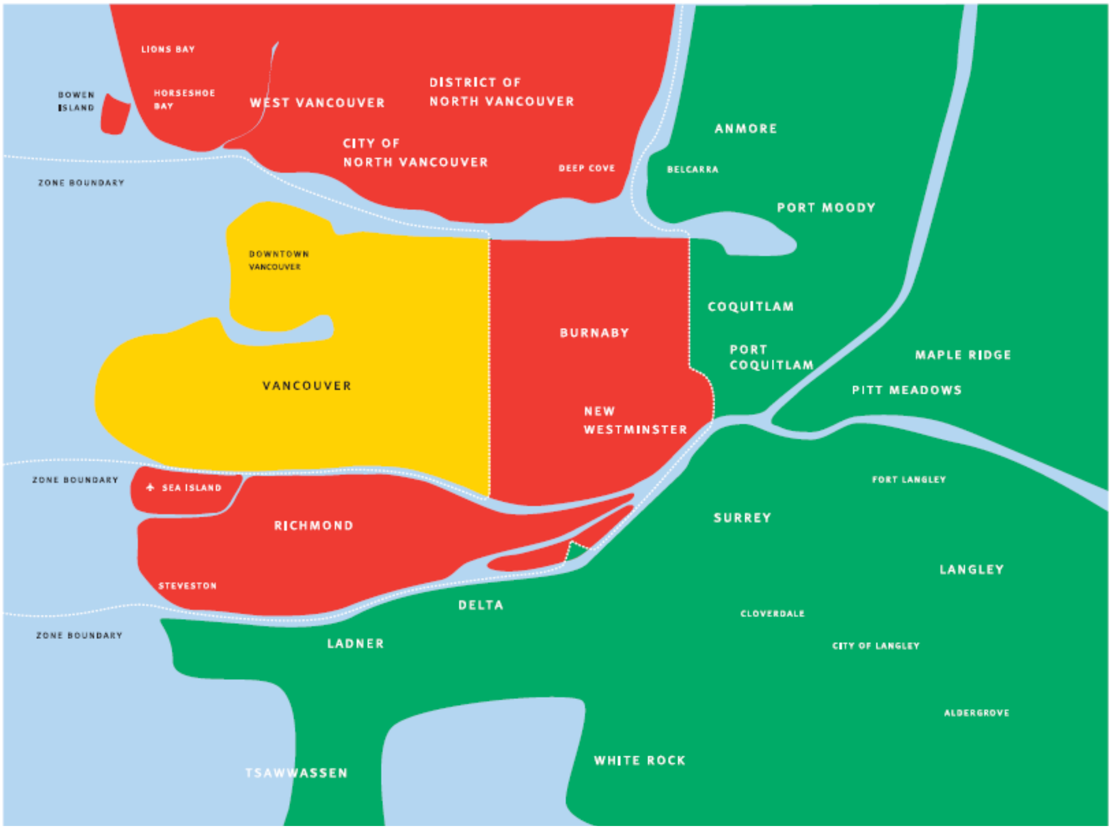


**Figure 1.1. Fare Zone Map**
Reprinted with the permission of TransLink (August 14, 2014)

# Chapter 2. Background: A Review of Fare Policy

This chapter provides a brief overview of the current Metro Vancouver transit system and fare structure. It also provides a review of the literature on the elements that constitute a transit fare system with a focus on fare policy, structure, revenue and pricing. The effects of a fare structure and price change on ridership, equity and efficiency are also reviewed.

## 2.1. Metro Vancouver Regional Transit System

1- Area covered, services, and modal split

TransLink's service area covers 1800 square kilometers that spans the 23 local governments that make up the Metro Vancouver region, as well as one municipality in the Fraser Valley Regional District that is served by one station of the commuter train West Coast Express. The network is composed of buses, three light rail lines "SkyTrain", passenger-only commuter ferries "SeaBus", and the commuter train "West Coast Express".

- Modal split and average trip lengths

Residents of Metro Vancouver made 6.06 million trips per day in 2011. The mode split and average trip length for those trips is as follows (TransLink, 2013a):

**Table 2.1. Mode Split in Metro Vancouver**

| | | |
|---|---|---|
| Auto Driver | 57% | 9.9 Km |
| Auto Passenger | 16% | 7.4 Km |
| Transit | 14% | 12.6 Km |
| Walk | 11% | 1.1 Km |
| Cycle | 1.8% | 4.7 Km |

2- TransLink Fare Structure

Revenues from transit fares totalled over $461million in 2012 (TransLink, 2012). The fare structure is as follows:

**Table 2.2. TransLink Fare Structure**

| Fare Media | | **Peak*** | | | **Off-peak**** | | |
|---|---|---|---|---|---|---|---|
| | | 1-zone | 2-zone | 3-zone | 1-zone | 2-zone | 3-zone |
| Concession | | | | | | | |
| Monthly FareCard | | $52.00 | | | | | |
| FareSaver (book of 10 tickets) | $17.5per book | One ticket $1.75 | One ticket + $1.00 add fare | One ticket + $2.00 add fare | $1.75 | $1.75 | $1.75 |
| Cash | | $1.75 | $2.75 | $3.75 | $1.75 | $1.75 | $1.75 |
| Regular | | | | | | | |
| Monthly FareCard | | $91 | $124.00 | $170.00 | | | |
| FareSaver (book of 10 tickets) | | $21.00 | $31.50 | $42.00 | 1-zone ticket | | |
| Cash | | $2.75 | $4.00 | $5.50 | $2.75 | $2.75 | $2.75 |
| Day Pass | | $9.75 | | | $7.50 | | |
| U-Pass* | | $36.75 | | | | | |

*Weekdays from start of service to 6:30 p.m.

**Weekdays after 6:30 p.m. and all day Saturday, Sunday and Holidays.

Source: TransLink website at http://www.translink.ca/

- FareCard Monthly Pass

FareCards allow unlimited travel anytime and any day of the week within the selected zone. Add fares can also be purchased to upgrade the pass to a different zone.

- FareSaver Tickets - Book of 10 Tickets

The FareSaver tickets offer savings over cash fares and are appropriate for infrequent transit users since they have no expiry or time period limitations. As cash fares they are limited to 90 minutes of travel after which they expire. An add fare can be purchased to allow travel beyond 1 zone.

- Cash Fares

These fares apply to all buses, SeaBus and SkyTrain lines except West Coast Express and the additional $5 add fare from the airport. This ticket allows travellers 90 minute travel time within the fare zone of the ticket.

- Day Pass

Allows travel on all transit modes and across all zones for one day. It is a good option for tourists.

- U-Pass and GoCard

The U-Pass is a subsidized pass for students enrolled in any post-secondary institution in Metro Vancouver. It is a universal pass which means that every student has to participate in the program regardless of whether they use it or not. The price reduction was offered to students based on universal participation in the program. The fare is charged automatically to students as part of their fees. The current rate of U-Pass is $36.75 per month. This allows travel on any of TransLink services in all zones in Metro Vancouver except the West Coast Express that has a different discount rate structure for students. Similarly high school students from age 14 to 19 can pay concession fares on all TransLink modes if they show their GoCard.

## 2.2. Description of a Transit Fare System

A fare system consists of a fare policy, fare structure, and fare collection/payment technology where all three aspects are highly interconnected and interdependent. A fare policy sets out the goals and objectives of the agency to guide its decisions regarding the fare structure and technology used and any future changes (Fleishman et al., 1996; Fleishman, 2003). The fare structure which is the focus of this paper, consists of four aspects: (1) a pricing strategy which could be flat or differentiated; (2) payment options which could be cash, multi-ride tickets, monthly passes, etc; (3) a transfer policy which determines if transfers between different transit lines or modes is free, for a charge or time limited, and (4) the pricing level which is the actual amount charged for a fare. Lastly the fare technology which consists of the fare payment media used such as cash, magnetic strip tickets, tokens or smart cards and the equipment used to sell and collect the fare (Fleishman et al., 1996; Fleishman, 2003).

### 2.2.1. Transit Fare Policy

Although few transit agencies adopt a stand-alone fare policy statement to regulate its fare-related decisions, most changes are made in response to either a problem such as revenue losses or system changes such as adding a new transit mode or changing fare collection technology (Fleishman, 2003). Most often fare policy objectives, goals and decisions are found/derived either implicitly or explicitly from an agency's strategic plan or other formal policies (Fleishman et al., 1996). Research on fare setting policy concludes that the goals and objectives of many transit authorities are often conflicting and contradicting (Cervero, 1990; Fleishman et al., 1996; Streeting and Charles, 2006; Yoh et al., 2012). This in turn complicates the process of making efficient and equitable fare policy decisions. For example it is very difficult to be cost effective while providing transit access to everyone. Usually, transit agencies attempt to improve cost efficiency[3] by providing more services to high utilization routes, which are usually short-distance trips in higher density areas, and reducing services to low-density and long-distance routes. Yoh et al. (2012) attribute the problem of competing goals to the competing interests and expectations of the many stakeholders (e.g. elected officials, transit riders, taxpayers, business community, etc), involved in or influencing shaping of the transit policy agenda. Some of the most commonly cited agency objectives and goals include:

- Maximize ridership
- Improve quality of service
- Encourage modal shift from private cars to transit mostly to ease congestion and reduce air emissions
- Improve mobility and access for everyone especially transit dependent groups such as seniors, low income and disabled.
- Provide affordable alternative to the private car and help shape transit-oriented communities
- Provide a cost-effective and efficient service
- Achieve a certain fare recovery ratio or meet a certain ridership or revenue target

Fleishman et al. (1996) suggest that when a transit agency is making a fare related decision, it is important to first identify fare policy goals, group related goals and prioritize them. The authors suggest that most fare policy goals fall into one of four categories; "customer-related, financial, management-related, and/or political". Although some of the goals might overlap between categories or be classified differently this

[3] Cost efficiency as defined in transit studies is a measure of the ratio of passenger revenues and operating costs. Efficient operations aim to reduce the gap between costs and revenues.

classification helps clarify how goals relate to one another and impact the different operation, administration and service aspects of a transit agency. Table 2.3 provides a summary of some common fare policy goals organized by category and identifies their impact on fare structure and/or technology.

**Table 2.3. Fare Policy Goals by Category**

| Policy Goal | Goal Applies to | |
|---|---|---|
| | Structure* | System/technology** |
| Customer-related | | |
| Increase ridership/minimize revenue loss | X | |
| Maximize social equity | X | X |
| Increase fare options | X | X |
| Reduce complexity | X | X |
| Financial | | |
| Increase revenue/minimize ridership loss | X | |
| Reduce fare abuse and evasion | X | X |
| Improve revenues control | | X |
| Reduce fare collection costs | X | X |
| Increase pre-payment/reduce use of cash | X | X |
| Management-related | | |
| Improve data collection | | X |
| Improve modal integration | X | X |
| Increase pricing flexibility | X | X |
| Maximize ease of implementation | X | X |
| Improve fleet/demand management | X | X |
| Improve reliability of fare equipment | | X |
| Improve operations (i.e. maximize throughput) | X | X |
| Political | | |
| Maximize political acceptability | X | |
| Achieve recovery ratio goal/requirement | X | |

*Structure: Flat or differentiated fare structure
**System/Technology: Fare payment and collection media
Source: Fleishman et al., 1996, p. 16

### 2.2.2. Transit Fare Structure

A fare structure generally encompasses decisions about the strategy, payment option, transfer policy and pricing level. Fare strategies are either flat or differentiated. Flat structure charge riders the same price regardless of the distance they travel, time of day or quality or speed of the transit mode used. Alternatively, differentiated pricing structures charge riders based on distance travelled either by zone or actual kilometers, by time of day (higher charge for peak times), by speed, or quality of transit mode (Fleishman et al., 1996; Fleishman, 2003). The use of flat versus differentiated fares by transit agencies varies around the world, with many of the large Asian cities using distance-based fares while the majority of North American cities using flat fares ("Farebox recovery ratio", n.d.). Table 2.4 summarizes the advantages and disadvantages of the different fare structures.

Transit scholars have been advocating for decades for differentiated instead of flat transit fares on the basis that they improve economic efficiency (Cervero, 1981; Cervero, 1990; Fleishman et al., 1996; Fleishman, 2003). Economic efficiency is thought to be achieved by charging riders the relative cost of their trip which means that long-distance and peak time riders pay a relatively higher fare to cover the higher cost of their trips (Streeting and Charles, 2006). Efficiency in transit economics is often measured in terms of the ratio of the revenue from fares relative to the operating cost of transit; this is referred to as farebox recovery (fare revenue/cost of operations) (Cervero, 1981; Taylor and Norton, 2009). A ratio of 1 means that riders cover the full operating cost of their trip while a ratio less than one means that they are subsidized for part of the trip cost, and over one means that they pay more than the operating cost of a trip, and thus contribute to capital infrastructure costs (Taylor and Norton, 2009).

To understand the impact of the flat fare system on equity among riders, a study of the Los Angeles transit system analysing the proportion of operating costs covered by users' fares found riders during peak times to be covering 37 percent of the operating cost of their travel versus 56 percent recovery for off-peak travellers.[4] The study also showed that short distance travellers were covering more of their trip costs than long distance travellers. The revenue per mile (RPM) to cost per mile (CPM) ratio ranged from 2.2 for less than a mile distance, to 0.48 for the 1 to 2 mile trips, and to as low as 0.06 for trips over 20 miles. Moreover the analysis showed that the relationship of RPM/CPM ratio to distance traveled followed a non-linear pattern, where the decline in RPM/CPM ratio was much higher between low and medium distance trips than between medium and long distance trips. The research demonstrates that the subsidies were similar for trips of six miles or longer and suggest that a potential measure to eliminate this discrepancy could be a fare system with "low basic prices and surcharges tapered logarithmically with distance" (Cervero, 1981).

Differentiated pricing structures tend to generate higher revenues and higher farebox recovery because riders are charged according to the costs they impose on the system. Scholars advocate for a regular review of fare prices to reflect transit operating cost changes to prevent revenue shortfalls and service cuts (Yoh et al., 2012). It is argued that transit fares are a more reliable source of revenue because they are affected by the level of ridership especially if they reflect the marginal cost of the service. This can help stimulate more efficient behaviour by riders for example by consuming more short distance trips, combining trips and using transit at off-peak times. On the other hand non-fare revenues such as fuel and sales taxes and subsidies from higher levels of government tend to vary depending on economic conditions and do nothing to stimulate efficient behaviour since those who contribute to the tax are not all transit users (Watts, 2006; Yoh et al., 2012).

[4] Note that the focus in this paper is on operating costs relative to fare revenues. It should be noted that any pricing framework that also reduces peak loads will reduce infrastructure investment needs. If some of the peak ridership can be diverted to other times of the day (and not shifted to private vehicle travel), then less transit infrastructure will need to be constructed. My research takes the level of infrastructure as a given and has as its goal, to use that infrastructure more efficiently, i.e., obtain a better balance between cost of service and fare revenue paid.

**Table 2.4. Advantages and Disadvantages by Type of Fare Structure**

| | Fare Strategy Options | | | | |
|---|---|---|---|---|---|
| | **Flat fare** | **Market -based*** | **Distance-based** | **Time of day-based** | **Service quality based** |
| **Advantages** | • Easiest to understand<br>• Simplest and least expensive to implement and administer<br>• Lowest level of fare abuse | • Generally considered equitable<br>• Can make fare increase politically acceptable<br>• Can minimize ridership loss with fare increase<br>• Maximizes prepayment<br>• Most convenient option | • Should produce greatest revenue<br>• Considered equitable; longer trip has higher cost<br>• | • Should increase ridership<br>• Allows management of fleet usage through shift to off-peak<br>• Considered equitable; commuter pay more | • Relatively easy to understand<br>• Considered equitable; higher quality service has higher cost<br>• High revenue potential; low fare abuse<br>• Allows management of fleet usage through shift between services |
| **Disadvantages** | • Places inequitable burden on those making short trips<br>• Increase will cause greatest loss of riders | • Generally produces least revenue<br>• Potentially high level of fare abuse<br>• Requires extensive marketing to maximize ridership<br>• Highest media production and distribution cost | • Difficult to use<br>• Difficult to implement and administer; may require special equipment<br>• Potentially high level of fare abuse<br>• May be unpopular with long trips | • Potential for conflicts with drivers<br>• Potential for fraud (agents on rail)<br>• May require equipment modifications (or new equipment) | • May be unpopular among users of higher cost service<br>• Complicates transfers (e.g. may require payment of “upgrade” fare in transferring) |

*Market-based: Offering a range of fares and payment methods targeted to different market segments

Source: Fleishman et al., 1996

## 2.3. Travel Demand and Riders Response to Price Changes

This section explores the underlying factors that affect riders' demand for transit in response to fare pricing changes and summarizes information from the literature on fare elasticity values and transferability of those values. As with any other consumer product or service, change in prices usually affects consumers' demand for that product or service. Similarly transit fare changes affect riders travel demand. However the change in demand is more difficult to predict than consumer products and services, because travel is "derived demand". This means that travel is not an activity that is taken for its own sake but that is undertaken as a means to other activities such as getting to work, shopping, and entertainment. The traveller is affected by many aspects and has to consider many factors when making a travel related decision.

The amount and type of travel that people choose depends on many "demographic, geographic and economic factors". Some of these factors include trip purpose, income, travel options available and price of travel. Models have been developed to understand the relationship between travel demand and these different factors, including the effect of prices (Litman, 2013a). These models that use "techniques as simple as before-and-after comparisons and as advanced as econometric statistical modeling" (Cervero, 1990) help transit planners predict the effect of policy changes or economic and/or market trend changes on ridership. The price of travel includes direct monetary costs (i.e. bus fare, parking, airline ticket) and indirect costs such as travel time, inconveniences and risks which are all factors considered when people make travel related choices (Litman, 2013a). The extent to which people change their consumption of a service or product in response to a price change is called price elasticity. In the case of changing transit fare prices or structures this is referred to as fare elasticity which explains the extent of change in ridership in response to change in transit fares.

**Fare Elasticity**

It is an important variable in forecasting ridership change in response to many changes including fare structure and price changes. Fare elasticity values indicate how sensitive riders are to price changes; in general a value of one is referred to as unit elastic meaning that a one per cent change in price causes an equal change (one percent) in ridership. Values less than one are called inelastic because the relative change in ridership is less than the change in price (i.e. one percent change in price causes less one percent change in consumption) which also means an increase in revenue; and values more than one are called elastic because the relative change in ridership is more than the change in price while causing a decrease in revenues.

Elasticity values are measured using several methods such as through stated preference surveys, shrinkage analysis which is a method that measures the effect on ridership before and after a fare change, or through complex econometric models.

Fare elasticities are affected by many factors that are usually region dependant. These factors include:

- Trip type e.g. work, school, shopping, etc
- Household Income
- City size and density
- Trip length
- Car ownership
- Time since price change (short term or long term)

Appendix A provides a detailed summary on different ways to measure transit demand elasticities, the impact of different factors on demand, and transferability of elasticity values.

## 2.4. Equity

Equity, also referred to as justice or fairness, is one of the main reasons for providing and subsidizing public transit. Other than the arguments about the benefits of public transit in improving urban mobility, reducing road congestion and improving environmental conditions, elected officials justify subsidies to public transit because it provides the disadvantaged (e.g. people with disabilities, seniors, youth and low income) with an affordable mean to get to essential destinations such as work, school, shopping and medical appointments (Taylor and Norton, 2009). Transportation equity is "in the eye of the beholder"; therefore there are many ways to define transportation equity, to categorize those affected, and to measure the impacts, all depending on the stakeholder (TRB, 2011). Since this paper is focused on fare structures, I will be discussing equity in transit pricing and financing.

Although most transit agencies and elected officials are concerned with the impacts of their decisions on equity; most do not clearly define the term or apply consistent criteria and measures to objectively assess the impact of their policies on equity. As Taylor and Norton (2009, p.22) explain "Equity gets defined differently by different interests at different times. Disagreements over equity in transportation pricing and finance arise from the competing and contradictory ways that equity is both framed and evaluated." Hence, I will briefly explain the variability in defining equity concepts in transit pricing and finance, how those who are impacted are categorized and impacts on and measurement of equity.

### 2.4.1. Types of Equity

The literature has more than 25 different definitions for equity related to public infrastructure finance and service delivery (TRB, 2011) each stemming from how justice is perceived from different points of view. Taylor and Norton (2009) attribute this myriad of definitions and the disagreements about what equity means to the different philosophical interpretations of the concept of "distributive justice". Distributive justice is concerned with the way limited resources are allocated to individuals in a society. There are many philosophical frameworks that define the principles of distributive justice mostly according "to unit of distribution – be it geographic areas, groups, and individuals—and the logic of distribution—such as the rationales of need, merit, and fortune" (Taylor and Norton, 2009). Five theories are presented by Taylor and Norton as reflected in Table 2.5 that they argue constitute the roots of the competing equity definitions. For each theory Taylor and Norton show the relationship of the theory to public finance and corresponding equity type. The authors state that most public transportation finance and pricing arguments are derived from these theories, but since the public and elected officials are mostly not aware or not directly relating their argument to these theories, the arguments made about transit equity can be illogical and contradictory. In fact public opinion research has demonstrated that most people's definition or idea about justice is variable and changes according to different situations.

**Table 2.5. Relating Theories of Justice to Public Finance**

| Theory of Justice | Conception of Justice in Relation to Public Finance | Type of Equity |
|---|---|---|
| Strict egalitarianism | Each individual in society receives the same magnitude of goods and services irrespective of contribution | Outcome equity |
| Difference principles | Individuals have equality in basic rights and liberties, but society is better off when individual success is cultivated and allowed to benefit individuals directly | Opportunity equity |
| Resource-based principles | Goods and services are equally distributed to individuals at the outset, but there is little or no societal cross-subsidization from that point forward | Opportunity equity |
| Desert-based theories | Individuals who increase wealth in society are entitled to benefit directly from that wealth | Market equity |
| Libertarianism | Consensual transfers of goods and services between individuals within a society are just by definition | Market equity |

Source: Taylor and Norton, 2009, p.25

There are also many ways that equity is categorized/conceptualized in the literature. The most commonly used categories of equity include horizontal equity that measures the distribution of costs and benefits among equal individuals or groups and vertical equity that measures distribution of costs and benefits among people in unequal circumstances (Litman, 2013b). Other scholars contend that there are five equity concepts commonly used in debates around transportation according to: 1- Benefits received, 2- Ability to pay, 3- Return to source, 4- Costs imposed, and 5- Process (or participation. Table 2.6 gives a brief definition to each concept and an example of how it is applied in transportation (TRB, 2011). Additionally Taylor and Norton (2009) propose another way to categorize equity based on the five theories of justice. They suggest that strict egalitarianism emphasizes equality in outcome, while difference principles and resource-based principles value providing equal opportunities and desert-based theories and libertarianism emphasize equity based on market.

**Table 2.6. Equity Concepts in Transportation Finance**

| Type of Equity | Simple Definition | Transportation Example |
|---|---|---|
| Benefits received | I get what I pay for | People who use a facility the most pay the most |
| Ability to pay | I pay more because I have more money | A project is financed through a progressive tax that is disproportionately paid by higher income people |
| Return to source | We get back what we put in | Transit investment in each county is matched to that county's share of metropolitan tax revenues used for transit |
| Costs imposed | I pay for the burden I impose on others | Extra expense required to provide express bus service for suburb-to-city commuters is recovered through fares on this service |
| Process (or participation) | I had a voice when the decision was made | Public outreach regarding proposed new high-occupancy toll lanes provides transparent information and seeks to involve all affected parties in public hearings and workshops |

Source: TRB, 2011

## 2.4.2. Categories of Individuals in Equity Assessment

Adding to the complexity of properly defining and analysing equity impacts in transportation pricing and finance is the presence of many "units of analysis" or ways to categorize people. Taylor and Norton (2009) suggest that most social scientists are concerned with individual equity, while activists are concerned with group equity (e.g. low income, disabled individuals and seniors), and elected officials with geographical equity (i.e. voters). And since most often it is elected officials who make decisions about transit pricing and finance, usually geographical equity is at the centre of the discussion (Taylor and Norton, 2009; TRB 2011). Other scholars propose a somewhat similar but expanded system for categorizing people when analysing equity, it is suggested that people could be grouped according to:

- Geographic location
- Economic status
- Generation (i.e. present or future generations)
- Other demographic characteristics (e.g., sex, age, race or ethnicity, physical limitations)
- Use of the transportation system (e.g., drivers, rail commuters, bicyclists) (TRB, 2011)

### 2.4.3. Equity Assessment

The above sections briefly discuss the roots of the tension in the debate about transit pricing and finance fairness and define how those impacted are grouped. This foundation work is important prior to assessing equity of proposed pricing or finance policies. Since equity is one of several criteria considered when assessing policies it is important to understand how it interacts with other criteria, measurement methods, and issues to consider when assessing and analysing equity.

Most often transit projects and policies are assessed using several criteria, including efficiency, effectiveness[5] and equity. Many scholars though find that equity could be (or perceived to be) in tension with efficiency and effectiveness (Murray and Davis, 2001; TRB, 2011; Taylor and Norton, 2009). In essence efficiency is about an optimum economic allocation of benefits and costs, regardless of how and who is impacted by this allocation (Murray and Davis, 2001). For example an efficient allocation of transportation funding might be to increase services between high density and high income residential areas and busy business districts at peak times, while the most equitable allocation would be to improve services during off-peak times to areas where low-income and transit dependent riders live. Taylor and Norton (2009) however find that this tension is unwarranted most of the time if decision makers and analysts are able to get past unsubstantiated popular beliefs. Distance or time-of-day based fare pricing provides a good example of how this perception of tension between efficiency and equity

[5] Effectiveness in this paper is used to measure how well a policy change achieves goal. For example, the goal could be to increase ridership at off-peak times while keeping revenue constant.

is not what it appears to be. Many advocates and decision makers argue against distance or time-of-day based pricing because it increases transportation costs for low-income/transit dependent riders. And since low income riders are more sensitive to price increase than higher income ones, then they will avoid making these trips which might hinder their accessibility and mobility. While this claim can't be refuted, similarly a large body of research has shown that most long-distance and peak time travel is taken by higher income individuals. So in reality distance-based and time-of-day pricing may shift the burden of higher cost trips from low income to high income people. The issue of ways to deal with the inequity caused to transit dependent riders will be discussed later in the policy options chapter.

It is also important to consider units of measurement when analysing equity impacts. Transportation impacts can be measured in many different "reference units" each implying an assumption. Units used such as per capita imply that each rider should receive an equal benefit, revenue or cost per kilometer imply that benefits received should match cost to system, while per trip implies that more travel warrants more resources (Litman, 2013b).

Other issues to consider when assessing equity is the distribution of benefits and costs among different groups of people and how these might change in the long-term based on how those affected may shift the cost onto others. Individuals and businesses most sensitive to cost increases will most probably avoid the burden by shifting it away from them. This could be in the form of avoiding making trips, relocating or travelling in other less costly ways. Hence it is very important to assess the non-economic impacts to ensure that the behaviour change that resulted in less travel has not increased the social burden by preventing individuals from getting to jobs, shopping, medical appointments or other necessary trips (TRB, 2011).

In summary, these are some of the takeaways from the literature review on fare structures, riders' response to fare changes, and equity issues with transit financing:

- Fare policies with clear objectives and goals can facilitate the process of setting fares while minimizing confusion and disagreement.
- Riders' demand for transit depends on many factors that are region specific. Riders' demand for transit is measured using elasticity values which are

important in forecasting change in demand in response to fare price changes. There are several ways to measure elasticity values depending on the transit agencies available resources.

- Equity is defined differently by different people. This is because there are many ways society thinks limited resources should be distributed. The public and transit scholars are usually concerned with individual equity, interest groups with group equity, while elected officials with geographic equity. Units of assessment and ways to categorize people are also different and it is important to acknowledge these differences in how equity is defined in order to objectively assess equity of transportation financing policies.

# Chapter 3. Policy Options

The policy options examined illustrate the potential to improve the efficiency, effectiveness, and equity of transit services provided in Metro Vancouver using different fare structures and to support Metro Vancouver's Regional Growth Strategy (RGS). One of the goals of the RGS is to promote compact transit-oriented development where residents are in close proximity to employment, services, and leisurely activities (Metro Vancouver, 2011). Refer back to Table 2.4 that describes the different fare structures used by transit agencies; Flat fare, market-based, distance-based, time-based and service-based. I focus on distance and time-based fare structures because they are the most commonly used differentiated fare structures by transit agencies and researched by transit scholars. Through their application in different parts of the world, they have demonstrated their potential in improving efficiency and equity.

Although service-based fare structures are fairly used, I chose not to explore it here since TransLink already uses this structure for the West Coast Express commuter train and HandyDART service. I will not be exploring flat fare structures as they would be a move in the wrong direction; they are less efficient in a system as large and complex as Metro Vancouver's. They contribute to inequity and promote inefficient land use due to the large subsidy to those traveling the longest distances.

## 3.1. Status-quo

TransLink currently uses a zone fare structure which is considered one form of distance-based pricing however it is a coarse version. Zone fare structures are easy to understand for the user while establishing a relationship between distances travelled and fare price.  In Chapter 4, Figure 4.2 shows the number of trips by distance interval in Metro Vancouver. For example, the distance interval 0-5 km is mostly a 1-zone fare, but there are some travelers who pay a 2-zone fare because they are crossing a zone boundary although traveling a fairly short distance. Similarly, there are riders who pay a 1-zone fare for trip distances over 20 km even though for this distance most riders are paying a 2 or 3-zone fare. This creates inequity between riders and discourages short-distance trips which are generally more cost-effective. However despite these issues TransLink has an average farebox recovery rate comparable to other North American transit agencies (Lindquist et al., 2009) and has increased its ridership over the years (TransLink 2013a). Therefore the status-quo option will be evaluated along with the other two options.

## 3.2. Distance- based Fare Structure

Distance-based fares establish a clear connection between distance travelled and fare paid. It encourages short-distance trips while discouraging very long ones which would have the likely consequence of increasing travel by the private car. This strategy however works well for Metro Vancouver since the direction of the regional growth strategy and transit strategy is to encourage and support high density development close to public transit and the creation of compact and complete communities. In its truest form distance based pricing charges users according to exact distance travelled. Some other variations include dividing a service area into equal distance zones, for example a zone every 5km, to simplify the fare calculation for the user. In this paper I am proposing a distance-based structure that is based on the actual distance travelled in kilometers. I am proposing a minimum base charge up-to 3 kilometer distances and then a fare per kilometer for distances over 3 kilometers. The rationale for charging a minimum base charge is to continue to encourage very short trips to be made by walking or cycling, and to account for a minimum average cost to have a rider board the system. The structure is meant to be illustrative of the sort of distance-based pricing that might be implemented by TransLink. Changing the minimum distance fare and/or the charge per kilometre can be readily simulated using the methodology in this paper.

Any transit authority needs to consider two issues when contemplating distance-based pricing. One is the method used to calculate trip distance, and the other is instituting a “Best Fare” policy that provides transit-dependent riders with pricing options that reduce the impact of a distance-based fare (Taylor and Jones, 2012). These two issues can be easily addressed with smart card technology that provides data on every trip's origin and destination for every customer. The approaches are explained below.

Transit trips are rarely as straightforward as a straight line distance between the trip origin and destination. Many bus lines especially local ones have circuitous routes. This means that riders would be travelling and paying for a much longer trip distance than a more straightforward route between the two points. One way to overcome this problem is used by the Washington Metropolitan Area Transit Authority (WMATA) when calculating fares. They use "composite" mileage between the two transit points. The composite mileage is the average of the miles between any two stations and the straight line distance on a map (PlanItMetro, 2012). For example if the distance between two stations is 15 kilometers and the straight line distance between trip origin and destination on the map is 9 kilometers then the composite average is (15km+9km)/2= 12 kilometers. This would then be the distance the rider is charged. I do not use this method in my methodology since I do not have exact trip origin and destination information, but this could be done once data are available from the smart cards.

The second issue is instituting a "Best Fare" policy to reduce the impact of fare increase on riders, especially on low-income and transit dependent riders. The "Best Fare" policy ensures that riders pay the lowest possible fare. For low-income and/or transit-dependent riders, the policy guarantees that if they make a certain number of trips whose aggregate fare is equal to the cost of a pass they do not pay any extra charges on additional trips, regardless if they pre-purchased a monthly pass or not. The high price of a monthly pass might be unaffordable for many low-income travelers. This might push them to pay as they go for higher fare products such as cash. The "Best Fare" guarantees that once they reach a certain number of trips per month they get the monthly pass savings (TRB, 2001; Taylor and Jones, 2012). Again, this is feasible with a smart card technology in place.

The "Best Fare" policy could also be extended to all riders on the system to relieve the rider from having to decide in advance which product they might need. It encourages riders to take unforeseen trips that they weren't planning for without worrying about paying the highest fare product because they failed to plan for it (Taylor and Jones, 2012).

## 3.3. Time-of-day Fare Structure

In this option, fare prices are differentiated based on the time-of-day when most trips are taken on the system. Generally time-of-day fare differentiation is done by either applying a surcharge during peak hours or a discount during off-peak hours, or by doing both (Cervero, 1986). This differentiation makes the connection between the cost differential of providing services during peak and off-peak times. In the option used here, I chose to apply a surcharge to peak hours and apply concession fares to off-peak hours. Most utility and road infrastructure service providers face peak-time demands that exceed supply and therefore install capacity to meet the peak demand while their systems are not being utilized to full-capacity at other times. Depending on how high the peak demand is and the ratio of peak to base demand, the cost of maintaining a system for peak demand rises.

Transit systems face the same dilemma of designing a transit system to meet peak demand. While originally transit systems were designed to meet different demands at different times, they morphed to serve mostly professionals and students making work and school related trips at certain times of the day, and mostly in one-direction. The increase in demand during rush hours causes transit agencies to purchase, operate, and maintain additional vehicles and services just to meet this demand (Smith, 2009). Cervero (1986) notes that studies in Europe and the US have consistently shown that the ratio of marginal cost of peak to off-peak hours can be as much as three to one. Most transit agencies in the US have an average of 25 to 30 percent differential between peak and off-peak fares, which is less than the differential in marginal cost. However this surcharge captures some of this higher marginal cost and can stimulate some degree of shift in ridership from peak to off-peak hours.

Cervero (1986) has found from his assessment of US agencies that applied time-of-day pricing that for most systems the shift from peak to off-peak ridership was minimal. The explanatory factors are as follows:

- Peak riders are less sensitive to price than off-peak riders.
- The price differential between peak and off-peak periods is not large enough to induce the required behaviour change.
- The designated peak hour bands were too lengthy and did not encourage much shift to off-peak hours.

However some agencies managed to achieve substantial efficiencies and ridership shifts. The reasons cited include: the targeting of congested transit routes and directions of travel, and very aggressive marketing and public education campaigns to inform the public about the purpose and benefits of the policy.

# Chapter 4. Methodology

## 4.1. Quantitative Methodology

In this part of the methodology I analyse data from the most recent TransLink regional trip diary survey to determine how changes to the fare structure will impact riders and transit revenues. I use raw unpublished data from the 2011 TransLink regional trip diary survey. This survey is conducted every few years to understand the travel pattern behaviours and socio-demographic characteristics of Metro Vancouver residents. This information is crucial for transit and regional planning purposes. The survey records the travel patterns of individuals during a 24-hour period on a weekday during the fall of 2011[6] (TransLink, 2013b).

The database contains information on households, persons and all trips made by the individual persons during the one day they record their trip information. The database contains 21,851 household surveys[7], 52,175 person surveys and 146,026 individual trips by all modes of transportation – personal vehicles, cycling, walking, and public transit (TransLink, 2013b). I obtained the raw data from TransLink in Microsoft Access format. I extracted information regarding transit trips and related person surveys. Each household, person and trip survey has an identification number to remove personal information and protect privacy of individuals. Household surveys though have different identification numbers than person and trip surveys. Therefore I was able to extract transit trip information linked to persons' survey information only since they are linked by the same identification number.

[6] Each household is assigned a different weekday to complete the survey in the period between September 15 and December 12, 2011 (TransLink, 2013b)

[7] This represents just over 2% of all households in the Metro Vancouver region according to 2006 Census data (TransLink 2013b)

The total number of transit trips contained in the database is 18,722 including all trips made by transit bus, SkyTrain, SeaBus, West Coast Express, and HandyDart. For the purposes of this study I am only interested in trips made by bus, SeaBus and SkyTrain since they have the same fare structure and fare pricing. West Coast Express and HandyDart are special services with different fare structures and price levels. I also eliminated trips that did not contain information on transit pay method or fare used, and for the time-of-day analysis trips that did not have start time information were also not included (they were included in the distance-based analysis, hence the discrepancy in the number of trips between the two analyses). All trips that have small municipalities as origin or destination were also eliminated because it is not possible to determine what zone fare to assign to them since some of these municipalities are in 2-zone fare and some are in 3-zone fare. Lastly all trips made from and to areas outside the Metro Vancouver region were also not included. As a result the total number of trips analysed are 17,224 trips for distance-based and 17,049 for time-of-day.

First, I exported transit trips and associated persons' data from Microsoft Access to Microsoft Excel to perform the analysis. The survey collects a large amount of data, at the person and trip level. At the person level information such as gender, age, household size, income, method of pay for transit, and employment status are collected. And at the trip level information such as trip purpose, trip origin and destination, trip distance, and start and end times are gathered.

The purpose of obtaining and analysing this data is to calculate the following:

- The impact on ridership due to change in fare prices and the response of riders to that change. Fare increases usually induce reduction in demand for transit trips and fare decreases will do the opposite, although the effects are typically not symmetric in magnitude. Every rider will respond differently to the change in price depending on percent change in price, direction of change, trip purpose, availability of alternatives, and other factors. From the survey data I will be able to predict the extent of change for every rider and then determine the impact on different rider groups based on income, location, age group, and captive versus choice riders.
- Calculate the change in TransLink fare revenue based on change in transit trips taken.

### 4.1.1. Process for Calculating Fare per Trip for Peak and Off-peak Riders

In order to calculate the fare per trip and subsequently fare per kilometer, I needed information about zone travelled, age group, fare product used (monthly Farecard, cash, Faresaver tickets, etc), and trip distance. Age group and trip distance information are available but information about fare product used for each trip and zone traveled is not available. In the person survey there is a question about how a person usually pays for transit. I used this information as a proxy to the fare product used for each trip related to that person. To estimate the trip zone I used the trip origin and destination information (see Table 4.1). The first step was to assign a zone, 1, 2, or 3 to each trip. Once a zone was assigned I was able to assign a fare to each trip based on the rider's age group (concession or regular), method of payment and time-of-day (peak or off-peak fare) (see Table 4.2).

For riders who pay using cash, their trips were assigned the cost of a cash ticket for the specific zone. Riders who pay using FareSavers their trip cost is equal to the price of the Faresaver book divided by 10. While for riders using any type of a monthly pass such as a regular or concession FareCard, annual pass or U-pass, I calculate the average price of a trip based on minimum expected use of a pass. So for example it is estimated that a monthly pass user would at least use the card for 40 one-way trips to make it viable to purchase a pass (TransLink, n.d.). To verify this assumption I calculated the number of individuals in three different categories and their respective total trips to find out the average number of trips made by each individual. FareCard users comprise a total of 2850 persons in the survey who have made 6023 trips in one day. This is an average of 2.1 trips per person per day. For the senior age groups 65 years and over, there are 775 individuals that have taken a total 1759 trips. This is an average of 2.3 trips per person per weekday. For U-Pass users there are 1450 people who took a total of 3064 trips; an average of 2.1 trips per person per weekday. Therefore the total number of trips made per month, based on 20 working days, is just over 40 trips per individual.

**Table 4.1. Zone Fare between Municipalities**

| | |
|---|---|
| 1 Zone fare | Travel in the same municipality<br>Travel in the same zone (with exceptions) |
| 2 Zone fare | Travel between zones 2 and 1<br>Travel between zones 3 and 2 (with exceptions)<br>Exceptions for 1 zone fare:<br>Travel between Burnaby and Richmond, District of North Vancouver, City of North Vancouver, and West Vancouver<br>Travel between Richmond and District of North Vancouver, City of North Vancouver, and West Vancouver<br>Travel between New Westminster and District of North Vancouver, City of North Vancouver, and West Vancouver |
| 3 Zone fare | Travel between zones 3 and 1<br>Exceptions for 2 zone fare<br>Travel between all municipalities in Zone 3 (Delta, Surrey, Langley Township, Langley City, White Rock, Maple Ridge, Pitt Meadows, Port Coquitlam, Port Moody, Coquitlam) and District of North Vancouver, City of North Vancouver, and West Vancouver |

As mentioned before, concession/off-peak fares apply to all trips after 6:30pm on weekdays and all day on Saturday, Sunday and holidays. Therefore for off-peak fares I use the following values to calculate the cost per trip for every individual based on their method of pay for transit.

**Table 4.2. Fare per Trip Based on Payment Method and Age Group for Peak and Off-peak Hours**

| Fare Media | | Peak | | | Off-peak | | |
|---|---|---|---|---|---|---|---|
| | | 1-zone | 2-zone | 3-zone | 1-zone | 2-zone | 3-zone |
| Concession | | | | | | | |
| Monthly pass/Employer paid pass* | Per month | $52.00 | | | $52 | | |
| | Per trip | $1.30 | $1.30 | $1.30 | $1.30 | | |
| FareSaver (book of 10 tickets) | $17.5 per book | $1.75 | $1.75+ $1.00 add fare | $1.75+ $2.00 add fare | $1.75 | | |
| Cash | | $1.75 | $2.75 | $3.75 | $1.75 | | |
| Regular | | | | | | | |
| Monthly FareCard/Employer paid pass* | Per month | $91.00 | $124.00 | $170.00 | $91.00 | | |
| | Per trip | $2.28 | $3.10 | $4.25 | $2.28 | | |
| FareSaver (book of 10 tickets) | Per book | $21.00 | $31.50 | $42.00 | $21.00 | | |
| | Per trip | $2.10 | $3.15 | $4.20 | $2.10 | | |
| Annual Pass* | Per month | $79.25 | $106.75 | $146.25 | $79.25 | | |
| | Per trip | $1.98 | $2.67 | $3.66 | $1.98 | $1.98 | $1.98 |
| Cash | | $2.75 | $4.00 | $5.50 | $2.75 | | |
| U-Pass* | Per month | $36.75 | | | | | |
| | Per trip | $0.91 | | | | | |
| Subsidized annual pass*&** | Per year | $45.00 | | | | | |
| | Per trip | $0.09 | | | | | |

*The price per trip is based on 40 one-way trips per month.
** This is a BC Government subsidized annual pass for low-income seniors and people with disabilities (http://www.sd.gov.bc.ca/programs/bus-pass.html)

## 4.1.2. Time-of-Day Calculations

This scenario is based on charging riders higher fares during peak time use of the system to reflect the higher cost of providing transit services during peak times. According to the 2011 Metro Vancouver Regional Trip Diary Survey - Analysis Report (2012) and my own analysis of the trip diary data (see Figure 4.1), the highest number of trips in general and transit trips in particular are made during two periods: from 6:00am to 9:00am and in the afternoon from 3:00pm to 6:00pm. A review of the literature and of pricing structures of transit agencies that use time-of-day pricing reveals that peak fare surcharges are in the range of 15 percent to 30 percent of off-peak fares (Cervero, 1986; Smith, 2009). Based on this I chose to apply a 20 percent fare surcharge on current regular fares for peak times. Therefore the regular fare on any trip that has a start time between 6:00 and 8:59am and 3:00 and 5:59pm was increased by 20 percent. I did not apply the increase to concession or deeply discounted passes such as the U-Pass or low-income annual pass, only to regular fare products. All trips that start in off-peak times, which are between 9:00am to 2:59pm and after 6:00pm, are assigned current off-peak fares.

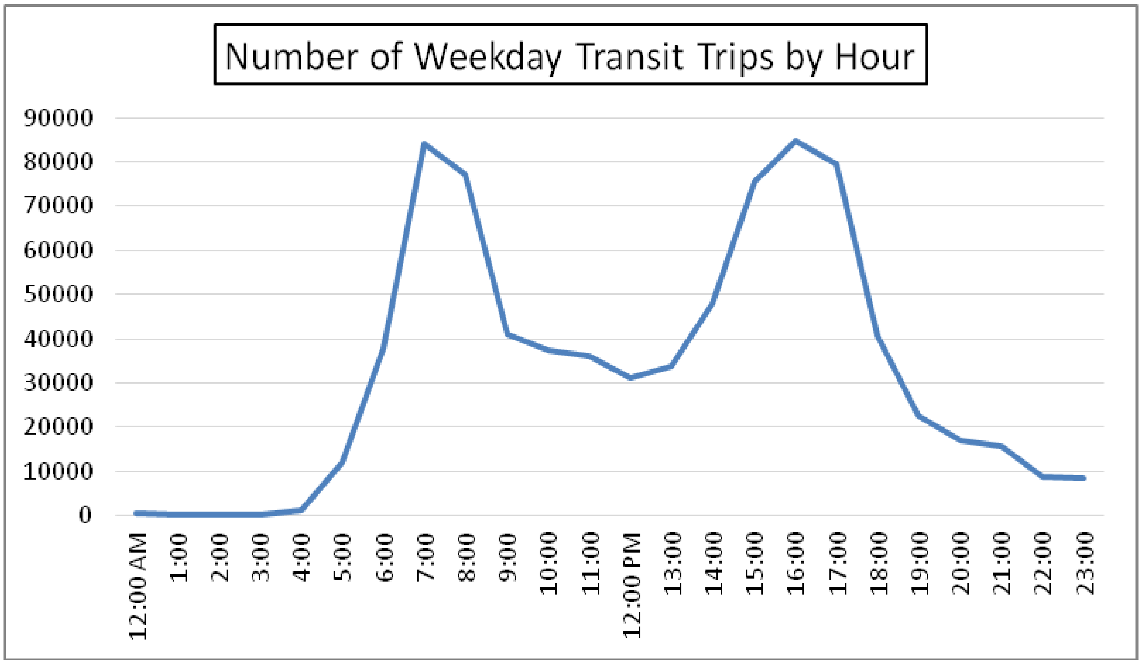


**Figure 4.1. Number of Weekday Transit Trips by Hour**

### 4.1.3. Distance-based Calculations

In order to assign a fare per kilometer, I analysed the current fare paid by kilometer based on trip distance travelled in 5 kilometer intervals up to 20 kilometers and then 10 kilometer interval for the 20 – 30 km category and the last category is over 30 kilometers. Distance intervals used are: 0-5km/5-10km/10-15km/15-20km/20-30km/Over30km. I used this method mainly because I did not have access to operating cost information or a fare structure proposal by the regional transit agency. I calculated a system average based on distance traveled and current fare paid as explained hereafter.

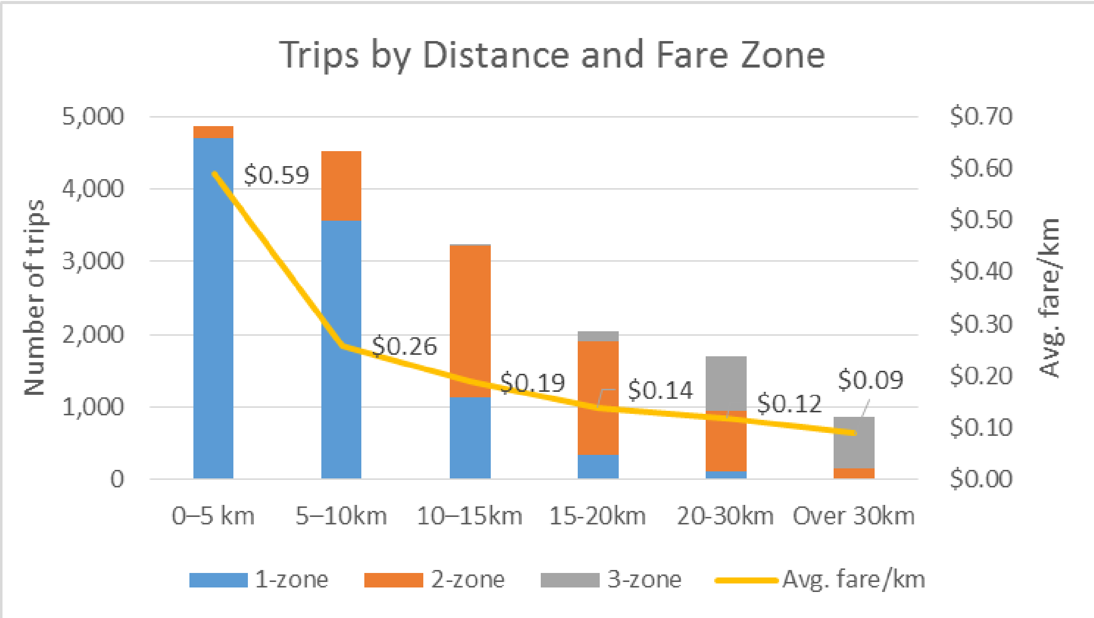


**Figure 4.2. Trips by Distance and Fare Zone**
Data for this figure is listed in Table B 1 in Appendix B

I analysed fare per kilometer paid based on pay method and fare category (regular and off-peak) (Table 4.3). I calculated the number of trips by distance interval and fare category and then summed the total fares paid and total distance travelled for each of the fare and distance interval category. From this information I calculated fare paid by kilometer travelled for the distance interval by fare category. I then summed up fares paid and trip distance across all fare categories for each distance interval, and calculated an average fare per kilometer for each distance interval. Following this step I summed up all fares paid and trip distances across all fare categories and all distance intervals and calculated the system fare per kilometer paid which is $0.19. This value coincides with the average fare per kilometer for the distance interval 10-15 km.

Since the average fare per kilometer is higher than $0.19 (the average fare per kilometer system-wide) for the distance intervals 0-5 km and 5-10 km, I tried to balance prices around the 10-15 km distance average fares, so that the new fares will be equal to or slightly higher than a 2-zone fare. Hence trips from 0-15 km would cost either less or around the same as before the change, since trips less than 15 kilometers are charged a much higher fare per kilometer than longer distance trips.

I first calculated the average across all distance intervals for each fare media as in table 4.4. Then I calculated the average rate for trips between the intervals 5-10 km and 20-30 km to eliminate the very high and very low average rates for short and very long-distance trips.

**Table 4.3 Trips by Distance Interval and Fare Category**

| | 0 - 5 km | | | | 5 - 10 km | | | | 10 - 15 km | | | | 15 - 20 km | | | | 20 - 30 km | | | | Over 30 km | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #Trips | Sum fares | Sum tripkm | Avg fare/km | #Trips | Sum fares | Sum tripkm | Avg fare/km | #Trips | Sum fares | Sum tripkm | Avg fare/km | #Trips | Sum fares | Sum tripkm | Avg fare/km | #Trips | Sum fares | Sum tripkm | Avg fare/km | #Trips | Sum fares | Sum tripkm | Avg fare/km |
| Concession FareCard | 719 | 935 | 2,206 | 0.42 | 378 | 491 | 2,672 | 0.18 | 113 | 147 | 1,374 | 0.11 | 50 | 65 | 877 | 0.07 | 40 | 52 | 953 | 0.05 | 30 | 39 | 1,167 | 0.03 |
| Concession FareSavers | 349 | 614 | 1,038 | 0.59 | 209 | 380 | 1,448 | 0.26 | 81 | 188 | 959 | 0.20 | 23 | 54 | 400 | 0.14 | 25 | 70 | 581 | 0.12 | 18 | 58 | 728 | 0.08 |
| Concession Cash | 139 | 246 | 401 | 0.61 | 89 | 167 | 661 | 0.25 | 58 | 139 | 696 | 0.20 | 32 | 85 | 567 | 0.15 | 31 | 92 | 754 | 0.12 | 21 | 69 | 854 | 0.08 |
| Regular FareCard | 1,190 | 2,747 | 3,775 | 0.73 | 1,546 | 3,818 | 11,645 | 0.33 | 1,194 | 3,418 | 14,488 | 0.24 | 754 | 2,343 | 13,133 | 0.18 | 620 | 2,242 | 15,155 | 0.15 | 296 | 1,211 | 10,655 | 0.11 |
| Regular FareSavers | 935 | 2,001 | 2,979 | 0.67 | 788 | 1,781 | 5,727 | 0.31 | 604 | 1,656 | 7,365 | 0.22 | 326 | 973 | 5,640 | 0.17 | 266 | 902 | 6,583 | 0.14 | 149 | 560 | 5,561 | 0.10 |
| Regular Annual Pass | 343 | 685 | 1,016 | 0.67 | 267 | 572 | 1,980 | 0.29 | 210 | 508 | 2,556 | 0.20 | 155 | 412 | 2,671 | 0.15 | 122 | 397 | 3,008 | 0.13 | 76 | 273 | 2,801 | 0.10 |
| Regular Cash | 429 | 1,195 | 1,321 | 0.90 | 293 | 878 | 2,181 | 0.40 | 231 | 832 | 2,824 | 0.29 | 132 | 479 | 2,247 | 0.21 | 144 | 647 | 3,566 | 0.18 | 71 | 333 | 2,614 | 0.13 |
| U-Pass | 441 | 406 | 1,415 | 0.29 | 808 | 743 | 6,136 | 0.12 | 654 | 602 | 8,173 | 0.07 | 531 | 489 | 9,247 | 0.05 | 428 | 394 | 10,314 | 0.04 | 202 | 186 | 7,398 | 0.03 |
| Low-income Annual Pass | 307 | 28 | 825 | 0.03 | 145 | 13 | 1,030 | 0.01 | 87 | 8 | 1,059 | 0.01 | 42 | 4 | 734 | 0.01 | 26 | 2 | 618 | 0.004 | 4 | 0 | 152 | 0.002 |
| Total | 4,852 | 8,856 | 14,977 | 0.59 | 4,523 | 8,843 | 33,479 | 0.26 | 3,232 | 7,496 | 39,494 | 0.19 | 2,045 | 4,904 | 35,518 | 0.14 | 1,702 | 4,798 | 41,531 | 0.12 | 867 | 2,728 | 31,931 | 0.09 |

**Monthly FareCards**

- **Regular FareCard**

For the regular monthly pass the average fare per kilometer across all distance intervals is $0.23, and the average fare per kilometer paid by users making 10-15 km distance trips is $0.19. For this distance riders could be paying 1 or 2 zone fare (see Figure 4.2). The split is 2 to 1 in terms of the 2 to 1-zone fares for that distance. A 2-zone monthly pass rider pays $3.10 for such trip. The average trip distance travelled for this category is 12.2 km/trip, therefore if I set the price at $0.23 with a minimum $1.3 for any trip up to 3 kilometer, then the fare would be $3.40 and for a 15 kilometer trip which is the maximum trip distance for this category the fare would be $4.10. I decided to set the fare at $0.21 which is the average fare per kilometer for trip distances between 5 and 30 kilometer, and also because the price for an average trip distance 12.2 km is $3.20 which is close to the price for a 2-zone trip fare.

I have set the maximum fare at $5.50 for a monthly pass which corresponds to a 23 kilometer trip. Therefore any trips over 23 kilometers will be capped at $5.50 per trip. When calculating new fares based on distance travelled, I amalgamated annual pass, employer paid pass, monthly FareCards, and FareSavers under one category which is monthly pass rate. Therefore any trip fare that was calculated based on these payment methods gets assigned a monthly pass rate in calculating the new fare.

**Table 4.4. Averages of Trips across Distance Intervals**

| | Average of trips 0-5 km to over 30 km | | | | Average of trips 5-10 km to 20-30 km | | | |
|---|---|---|---|---|---|---|---|---|
| | #Trips | Sum fares | Sum trip km | Avg fare/km | #Trips | Sum fares | Sum trip km | Avg fare/km |
| Concession FareCard | 1,330 | 1,729 | 9,248 | 0.19 | 581 | 755 | 5,876 | 0.13 |
| Concession FareSavers | 705 | 1,363 | 5,154 | 0.26 | 338 | 692 | 3,388 | 0.20 |
| Concession Cash | 370 | 798 | 3,933 | 0.20 | 210 | 483 | 2,678 | 0.18 |
| Regular FareCard | 5,600 | 15,778 | 68,851 | 0.23 | 4,114 | 11,820 | 54,421 | 0.22 |
| Regular FareSavers | 3,068 | 7,873 | 33,855 | 0.23 | 1,984 | 5,312 | 25,315 | 0.21 |

| | Average of trips 0-5 km to over 30 km | | | | Average of trips 5-10 km to 20-30 km | | | |
|---|---|---|---|---|---|---|---|---|
| | #Trips | Sum fares | Sum trip km | Avg fare/km | #Trips | Sum fares | Sum trip km | Avg fare/km |
| Regular Annual Pass | 1,173 | 2,848 | 14,033 | 0.20 | 754 | 1,890 | 10,215 | 0.19 |
| Regular Cash | 1,300 | 4,364 | 14,753 | 0.30 | 800 | 2,836 | 10,818 | 0.26 |
| U-Pass | 3,064 | 2,819 | 42,683 | 0.07 | 2,421 | 2,227 | 33,870 | 0.07 |
| Subsidized Annual Pass | 611 | 55 | 4,419 | 0.01 | 300 | 27 | 3,441 | 0.01 |
| Total | 17,221 | 37,625 | 196,930 | 0.19 | 11,502 | 26,041 | 150,022 | 0.17 |

- **Concession FareCard**

Currently concession passes have a single rate of $52 for all zones and all times of the day. From the preliminary analysis of the data it can be seen that over 80 percent of concession FareCard trips are in the range of 0-10 km. The overall average fare per kilometer for this category is $0.19 per kilometer while the rate for 0-5 km is $0.42 per kilometer and 5-10 km is $0.18 per kilometer. The overall average rate is very close to regular fare rate and would make the trip cost increase for all trips over 5 kilometer distance. I have therefore decided to take the average rate for trips between the intervals 5-10 km and 20-30 km. The average for this range as can be seen in Table 4.4 is $0.13. This rate is more reasonable since it is about 40 percent less than the regular fare rate and it falls between the averages of the 5-10 km and10-15 km distance intervals. I used this as the rate per kilometer for this fare category. With this rate a 5 kilometer trip would cost $1.06 ($0.80 minimum fare for 3 kilometer ride + $0.13* 2 kilometers) for a monthly cost of $42.40 based on 40 one-way trips per month. A 10 kilometer trip would cost $1.71 for a total monthly cost of $68.40 based on 40 trips per month. The maximum trip fare for this category is set at $2.30 which is the fare for a 15 kilometer trip and would cost $94 monthly. I did not keep the ratio of 60:40 between the maximum regular and concession fares which would result in a rate of $3.30 per trip. The monthly fare for such rate would be $132 which is 2.5 times more than the current monthly fare.

- **Deep-discount Monthly Fares**

I have not attempted to vary the fares of the U-Pass and low-income annual pass since the policies and subsidies for these passes are set in cooperation with the province of British Columbia. However other transit agencies such as Go Transit have distance-based rates for student passes. Go Transit offers discounts that start from 17 percent from regular adult fares if students are using the smart card “Presto” (Go Transit, n.d.b).

**Cash fares**

- **Regular cash fares**

Currently cash fares are about 30 percent more than the estimated fare per trip for a monthly pass. So for example estimated fare per trip for a 2-zone pass is $3.10 and the cash fare for the same zone is $4.00. For a 3-zone pass the estimated fare per trip is $4.25 and the cash fare is $5.50.

If I set the cash fare at 30 percent it will be $0.27/km when calculating the new fare for a 15 kilometer trip the new fare would be $4.54. I decided to set it at $0.25 to keep the fare for a 15 kilometer trip, $4.30, close to the current 2-zone cash fare which is $4.00. I have set the maximum cash fare at $6.50 which is equivalent to a 25 kilometer trip. So any trips over 25 kilometers will not cost more than $6.50.

- **Concession cash fares**

Fares are set at the average fare per kilometer for the distances between 5 and 30 kilometers which is $0.18 per kilometer. The maximum fare paid for this category is $4.25 which is for a trip distance of 22 kilometers. The current ratio between regular and concession cash fares is about 65 to 35, and with $4.25 as the maximum the ratio stays the same.

**Table 4.5. Peak Concession and Regular Distance-based Fares**

| | Per km Rate | Min. Fare | Max. Fare |
|---|---|---|---|
| Concession monthly pass | $ 0.13 | $ 0.75 | $ 2.30 |
| Concession cash | $ 0.18 | $ 0.75 | $ 4.25 |
| Regular monthly pass | $ 0.21 | $ 1.30 | $ 5.50 |
| Regular cash | $ 0.25 | $ 1.30 | $ 6.25 |

**Off-peak Fares**

The current off-peak fare pricing is the same as 1-zone regular or concession fare. So it was not possible to devise it in the same manner as I did with peak pricing, therefore I followed the Washington Metropolitan Area Transit Authority (WMATA) ratio between off-peak to peak fares which is between 35/25 percent to 65/75 percent (WMATA, 2012). I attempted to keep the same ratio with the rate per kilometer and maximum and minimum fares as in Table 4.6.

**Table 4.6. Off-Peak Concession and Regular Distance-based Fares**

| | Per km Rate | Min. Fare | Max. Fare |
|---|---|---|---|
| Concession monthly pass | $0.10 | $0.50 | $1.65 |
| Concession cash | $0.13 | $0.50 | $3.00 |
| Regular monthly pass | $0.14 | $0.80 | $3.50 |
| regular cash | $0.17 | $0.80 | $4.00 |

### 4.1.4. Calculating New Demand and New Fare Revenue

Once the new fare structure has been determined, then the new demand for transit trips and new fare revenue can be calculated. I use a methodology developed by Ballou and Mohan (1981) and followed by several other studies (Cervero, 1981; Nuworsoo et al., 2009) to estimate the effect of fare changes at the individual trip level. Ballou and Mohan (1981) use a disaggregate method to calculate the change at the individual level to capture the unique characteristics of each individual rider and/or trip. This model assumes that other factors that affect travel demand such as frequency of transit service, walking distance to transit station/bus stop are held constant since the rider has already made the decision to use transit. Therefore the model is focused on measuring the change in the frequency of using transit due to a fare structure and price change (Ballou and Mohan, 1981).

I use the "arc elasticity" formula as follows to measure the change in demand:

$$Q_a = Q_b \ (F_a/F_b)^{\varepsilon}$$

$Q_a$ = Forecast demand under the proposed fare policy

$Q_b$ = Present transit demand

$F_b$ = Current fare paid by trip

$F_a$ = Fare that will be paid for the same trip under new fare structure

$\varepsilon$ = fare elasticity appropriate for trip (exponent)

This methodology allows the application of different fare elasticities depending on the individual rider or trip characteristics. One important factor to note about this method is that forecast in demand is concerned with current riders' travel consumption and trip types only. The method does not predict change in demand based on any new trip types that the existing rider might take or increases in demand from new riders.

After calculating demand predicted from the pricing change, I calculate revenue generated under new fare policy as follows:

$$\text{Revenue} = Q_a * F_a$$

### 4.1.5. Elasticity Values Used

I use two elasticity values for sensitivity analysis; a constant which is -0.2 which is the value used by TransLink to predict change in demand due to an increase in fare. I also use a variable elasticity value derived from combining and weighting three elasticity values that are dependent on the unique characteristics of each trip, namely trip type, trip distance, and auto availability. For each trip a matrix of three columns indicates: 1-

the length of the trip which is denoted as short, medium, or long; 2- if a car was available or not for the trip, and 3- trip type. An elasticity value is assigned based on each variable.

I use the following elasticity values:

1- Trip distance
   - Short distances from 0 – 5km: -0.55,
   - Medium distances from 5 – 20km: -0.29
   - Long distance over 20km: -0.42

   The long distance value is a calculated average since the study that the values were borrowed from did not have a value for long distance trips (Litman, 2012). It is the average of the short and medium distance elasticities. It is believed that long distance trips have higher elasticity than medium distance trips however it is most probably lower than the elasticity for short trips that can be substituted by walking or cycling (Balcombe et al., 2004).
2- Car availability: There is a question in the survey that asks if a car is available for the trip, however the response rate for that question is low. So I used a proxy of two other variables to deduce an answer. I assumed that if a rider has a driver's licence and the household has 1 or more cars then there is a car available. And if the person does not have a driver's licence or a car, then they do not have a car available for the trip.
   - Car available: -0.41
   - No car available: -0.1 (Litman, 2012)
3- Trip Type
   - Work/Post secondary and Grade school trips: -0.23
   - All other trips: -0.42 (Linsalata and Pham, 1991)

It is important to note here that the elasticity values used in this methodology are obviously borrowed from other regions that are not necessarily comparable in many aspects to the Metro Vancouver region. Unfortunately it was not possible to find recent elasticity values from comparable regions. However using these values still demonstrates the effect of the different elasticity values on the forecast and also highlights the importance of using region specific elasticity values to reflect the unique characteristics of the riders, of the transit and transport system, and regional socio-economic factors. Many variables affect the rider's decision in using transit that can't be captured by a constant elasticity value.

## 4.2. Qualitative Methodology

This part involves a case study review of two transit authorities: the Washington Metropolitan Area Transit Authority in Washington, DC, and GO Transit in Toronto, Ontario. Both agencies use distance-based and/or time-of-day pricing. I have supplemented the case study review with interviews with officials from these agencies. The purpose of the case study review is to understand issues with implementation of these policies, and public and political attitude, acceptance, and perception of these fare structures.

The case studies selected for this project are of transit agencies that use distance-base or time-of-day pricing structure. Since this strategy is not very widely used by transit agencies around the world and to a much lesser extent in North America, I have focused on Canadian and/or US examples because of the similarity in economic and social conditions and policies as well as the ability to communicate in English.

The case study analysis and interviews examine the following issues:

- Governance structure
- Funding sources
- Demographic information such as population, density, car ownership, etc
- Agency's overall objectives and goals  and specific fare policy goals
- Ridership changes with respect to fare changes (if available)
- Fare structure and collection system used
- Farebox recovery
- Extent and brief description of transit network
- Pricing strategies for car travel and parking
- Affordability of transit (taking into account average income, housing prices and other relevant economic indicators)

- Understand impact of fare policy on administration, finance, customer service, operations and planning.

# Chapter 5. Quantitative Results

In this chapter I present the results of the simulation done to model the effects of changing the transit fare structure to distance-based and time-of-day pricing. The effects on demand for transit and revenues, and ridership equity is analysed for status quo and the two proposed fare structures.

## 5.1. General Information about the Data

With the current system the following tables summarize information about total trips, fares collected, income and trip purpose profile, and method of payment. The calculated fares are based on the price per trip assumptions in Table 4.2.

**Table 5.1. Trips and Fares Collected by Peak and Off-Peak Travel**

| | Peak (4:00 am - 18:29 pm) | Off-peak (18:30 pm till end of service) | No start time trips | Total |
|---|---|---|---|---|
| #trips | 705,608 | 87,327 | 9,033 | 801,968 |
| Fares collected | $1,540,768 | $164,616 | $15,897 | $ 1,721,282 |

**Table 5.2. Income Groups by Peak/Off-peak**

| Income group | Peak trips | | Off-peak trips | |
|---|---|---|---|---|
| | #trips | % total trips | #trips | % total trips |
| < $25,000 | 78,056 | 13% | 10,490 | 14% |
| 25,000 - $50,000 | 135,630 | 22% | 18,416 | 24% |
| $50,000 - $75,000 | 128,008 | 21% | 15,985 | 21% |
| $75,000 - $100,000 | 115,178 | 19% | 13,782 | 18% |
| $100,000 - $150,000 | 100,454 | 17% | 10,915 | 14% |
| >$150,000 | 50,081 | 8% | 6,387 | 8% |
| Total | 607,407 | 100% | 75,976 | 100% |

**Table 5.3. Trip Purpose by Peak/Off-peak**

| Trip Purpose | Peak trips | | Off-peak trips | |
|---|---|---|---|---|
| | #trips | % total trips | #trips | % total trips |
| Work / Post-Secondary | 444,044 | 62.9% | 42,624 | 48.8% |
| Escort (drop-off / pick-up) | 10,737 | 1.5% | 995 | 1.1% |
| Grade School | 48,319 | 6.8% | 468 | 0.5% |
| Shopping / Personal Business | 122,408 | 17.3% | 12,604 | 14.4% |
| Social / Recreational / Dining | 80,100 | 11.4% | 30,635 | 35.1% |
| Total | 705,608 | 100% | 87,327 | 100% |

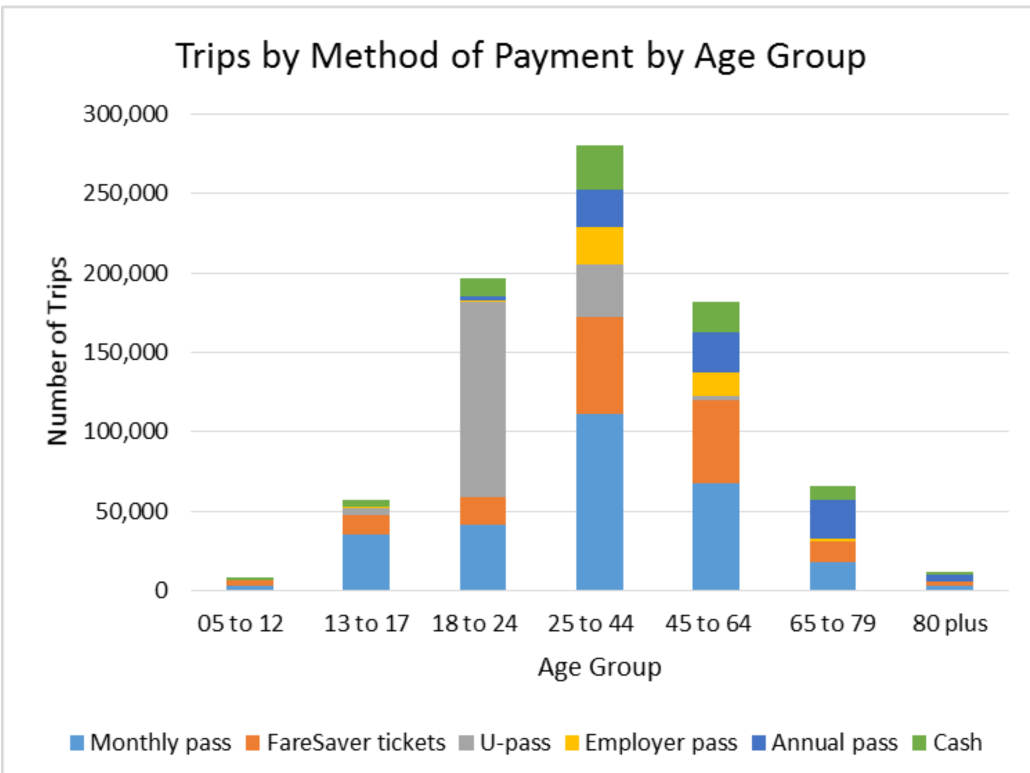


**Figure 5.1. Number of Trips by Payment Method and Age Group**
Data for this figure is listed in Table B 2 in Appendix B

## 5.2. Distance-Based Results

In this section I present data and results on number of trips by distance travelled by income group, by age group, by municipality, and by car availability to rider. These results are presented for the status-quo or the zone system, and for the simulation done for distance-based fare structure.

### 5.2.1. Status-Quo

- Number of trips by distance

As can be observed in Table 5.4 about 70 percent of trips are short and medium distance trips falling in the range from 0 to 15 kilometers.

**Table 5.4. Total trips by distance**

| Distance | Trips | % of total trips |
|---|---|---|
| 0-5 km | 210,159 | 26% |
| 5-10 km | 202,220 | 25% |
| 10-15 km | 153,261 | 19% |
| 15-20 km | 99,657 | 12% |
| 20-30 km | 89,232 | 11% |
| Over 30 km | 47,438 | 6% |
| Total | 801,968 | 100% |

- Distance travelled by income group

In Table 5.5, it can be seen that 65 percent of trips for riders with incomes less than $25,000, are short distance trips ranging between 0 and 10 kilometers. This percentage of trips between 0 and 10 kilometers decreases slightly across income groups, and then rises again for income group "> $150,000". The opposite is true for longer distance trips over 20 kilometers. Only 10 percent of trips for the income group "less than $25,000" are long distance or over 20 kilometers, while this percentage increases across income groups and then slightly decreases for the highest income group.

**Table 5.5. Trips Taken by Distance and by Income Level**

| | < $25,000 | | $25,000 - $50,000 | | $50,000 - $75,000 | | $75,000 - $100,000 | | $100,000 - $150,000 | | > $150,000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Trips | % of total | Trips | % of total | Trips | % of total | Trips | % of total | Trips | % of total | Trips | % of total |
| **0-5Km** | 32,700 | 37% | 45,628 | 29% | 38,560 | 26% | 28,816 | 22% | 27,270 | 24% | 13,095 | 23% |
| **5-10Km** | 22,983 | 26% | 40,771 | 26% | 34,655 | 24% | 32,938 | 25% | 23,139 | 21% | 16,370 | 29% |
| **10-15Km** | 14,703 | 16% | 31,232 | 20% | 27,418 | 19% | 25,694 | 20% | 22,764 | 20% | 11,153 | 20% |
| **15-20Km** | 10,160 | 11% | 17,051 | 11% | 18,194 | 12% | 16,740 | 13% | 15,364 | 14% | 6,863 | 12% |
| **20-30Km** | 6,314 | 7% | 15,155 | 10% | 19,386 | 13% | 16,625 | 13% | 15,786 | 14% | 4,523 | 8% |
| **Over 30Km** | 2,569 | 3% | 6,020 | 4% | 8,139 | 6% | 9,629 | 7% | 8,249 | 7% | 4,948 | 9% |
| **Total** | 89,430 | | 155,857 | | 146,352 | | 130,444 | | 112,570 | | 56,951 | |

- Distance Travelled by Age Group

Figure 5.2 shows the number of trips traveled by distance interval by each age group. Most of the trips made by the younger (05 to 17 years) and older age groups (65 and over) are short distance trips between 0 and 10 kilometers.

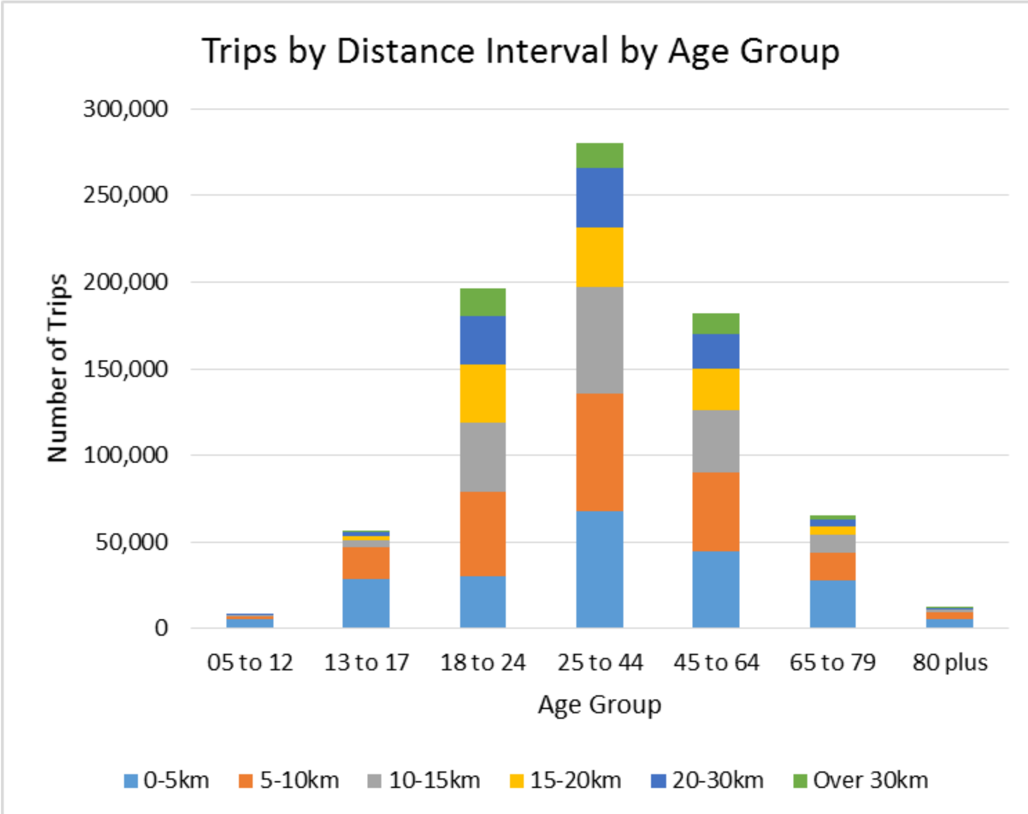


**Figure 5.2. Trips by Distance Interval and by Age Group**
Data for this figure is listed in Table B 3 in Appendix B

- Trips by Municipality

Table 5.6 shows that close to 42 percent of transit trips are made by Vancouver residents, followed by 14 percent for each of Burnaby and Surrey residents. Figure 5.3 shows the variation in trip distance across municipalities where over 90 percent of Vancouver residents take trips that range from 0 to 15 kilometers, while in White Rock about 70 percent of trips are over 30 kilometers long. Just over 75 percent of Burnaby residents' trips are in the range from 0 to 15 kilometers, while this number drops to just below 40 percent for Surrey residents, with the remaining 60 percent of Surrey riders' trips being over 15 kilometers in length.

**Table 5.6. Total Trips by Release Region**[8]

| Municipality | Total trips | % of Total |
|---|---|---|
| Burnaby | 113,398 | 14.2% |
| Coquitlam | 29,143 | 3.6% |
| Delta | 23,659 | 3.0% |
| Langley City | 2,694 | 0.3% |
| Langley Township | 7,937 | 1.0% |
| Maple Ridge | 8,348 | 1.0% |
| New Westminster | 34,752 | 4.3% |
| North Vancouver City | 19,240 | 2.4% |
| North Vancouver District | 21,625 | 2.7% |
| Pitt Meadows | 2,180 | 0.3% |
| Port Coquitlam | 9,942 | 1.2% |
| Port Moody | 6,746 | 0.8% |
| Richmond | 54,817 | 6.8% |
| Small Municipalities | 545 | 0.1% |
| Surrey | 111,068 | 13.9% |
| UEL | 4,877 | 0.6% |
| Vancouver | 335,046 | 41.8% |
| West Vancouver | 12,362 | 1.5% |
| White Rock | 2,624 | 0.3% |
| **Total** | **801,003** | **100.0%** |

[8] Release region is the municipality associated with the person's household

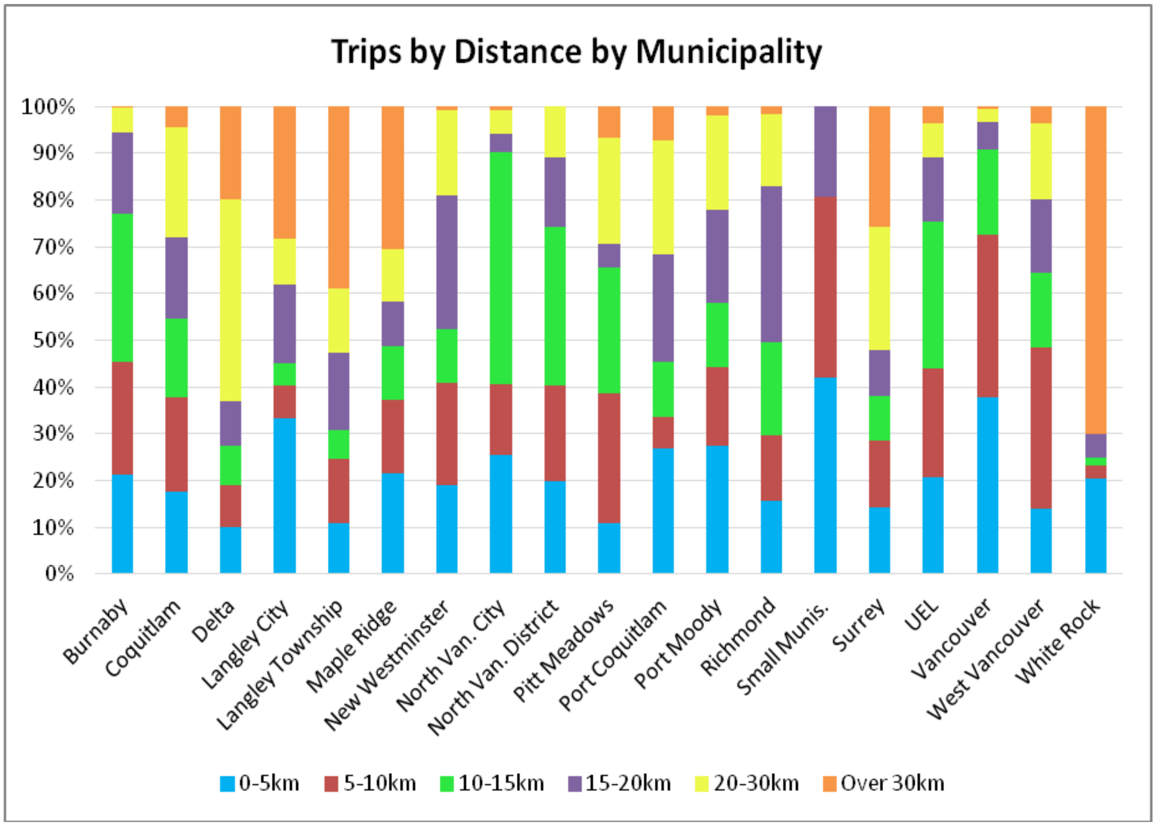


**Figure 5.3. Trips Taken by Distance and by Municipality**

### 5.2.2. Distance-based

The number of trips and total fares increase for both elasticity values: the constant -0.2, and the variable elasticity calculated for each trip based on its own characteristics (as explained in the Methodology section). The increase in trips with the variable elasticity is more than double the increase using constant elasticity; this is likely due to the fact that the -0.2 value underestimates the response of riders to the change with fare decreases, while the variable elasticity might be overestimating the response for fare decreases. Hence the increase in revenue is higher for the constant elasticity because the increase in the number of short distance trips is less than with variable elasticity. Similarly the reduction in the number of long distance trips is less with the constant elasticity.

**Table 5.7. Summary of Results for Distance-based Pricing**

| | Status quo | Distance-based with -0.2 elasticity | Distance-based with variable elasticity |
|---|---|---|---|
| Total trips | 801,968 | 811,754 | 824,679 |
| Total fares | $1,721,282 | $1,767,087 | $1,757,125 |
| Change in total trips (from status quo) | - | 1.2% | 2.8% |
| Change in total fares | - | 2.7% | 2.1% |
| Average fare/trip | $2.15 | $2.18 | $2.13 |

- Effects by Income Group

All income groups increase their trip consumption; however the fare per trip for the three lowest income groups and the highest income group decreases. Alternatively, the fare per trip for income groups, "$75,000 to $100,000" and "$100,000 to $150,000", increases. This is because riders from these income groups make a higher proportion of the longer distance trips i.e. 20 kilometers and over, while the other four groups have a higher share of short distance trips from 0 to 10 kilometers.

**Table 5.8. Summary of Results for Distance-based by Income Group**

| | < $25,000 | $25,000 - $50,000 | $50,000 - $75,000 | $75,000 - $100,000 | $100,000 - $150,000 | >$150,000 |
|---|---|---|---|---|---|---|
| Total trips before | 89,430 | 155,857 | 146,352 | 130,444 | 112,570 | 56,951 |
| Total trips after | 92,978 | 162,556 | 150,986 | 132,504 | 114,385 | 58,703 |
| Total fares before | $151,500 | $327,525 | $333,438 | $296,507 | $255,669 | $129,690 |
| Total fares after | $146,783 | $322,323 | $343,411 | $310,932 | $269,457 | $131,290 |
| Change in total trips | 3.97% | 4.30% | 3.17% | 1.58% | 1.61% | 3.08% |
| Change in total fares | -3.1% | -1.6% | 3.0% | 4.9% | 5.4% | 1.2% |
| Average fare/trip before | $1.69 | $2.10 | $2.28 | $2.27 | $2.27 | $2.28 |
| Average fare/trip after | $1.58 | $1.98 | $2.27 | $2.35 | $2.36 | $2.24 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Change in fare/trip | -6.8% | -5.6% | -0.2% | 3.2% | 3.7% | -1.8% |

- Effects by Age Group

All age groups are able to increase their trips with distance-based pricing, however transit riders below the ages of 18 and over 65 years benefit from the highest percent increase. The average fare per trip is either reduced or remains constant for most groups except for age group 18-24 where it increases by 1 percent. The fare per trip is substantially reduced for the younger and older age groups.

**Table 5.9. Summary of Results for Distance-based by Age Group**

| | **05 - 12** | **13- 17** | **18 - 24** | **25 - 44** | **45 - 64** | **65 - 79** | **80 and up** |
|---|---|---|---|---|---|---|---|
| Total trips before | 8,212 | 56,854 | 196,685 | 280,627 | 181,809 | 65,672 | 12,109 |
| Total trips after | 9,399 | 61,547 | 198,188 | 287,577 | 186,214 | 68,819 | 12,935 |
| Total fares before | $13,843 | $81,317 | $321,357 | $717,598 | $500,052 | $73,539 | $13,576 |
| Total fares after | $10,752 | $71,639 | $331,164 | $740,968 | $519,328 | $70,964 | $12,310 |
| Change in trips | 14.4% | 8.3% | 0.8% | 2.5% | 2.4% | 4.8% | 6.8% |
| Change in fares | -22.3% | -11.9% | 3.1% | 3.3% | 3.9% | -3.5% | -9.3% |
| Average fare/trip before | $1.69 | $1.43 | $1.63 | $2.56 | $2.75 | $1.12 | $1.12 |
| Average fare/trip after | $1.14 | $1.16 | $1.67 | $2.58 | $2.79 | $1.03 | $0.95 |
| Change in fare/trip | -32.1% | -18.6% | 2.3% | 0.8% | 1.4% | -7.9% | -15.1% |

- Change in Trips and Fares by Municipality

For 10 municipalities as can be seen in Table 5.10 the total number of trips will increase; this includes Vancouver, Burnaby, Maple Ridge, small municipalities, the three North Shore municipalities, and tri-cities municipalities. Most trips in these municipalities are shorter distance trips i.e. between 0 and 15 kilometers. For the other 7 municipalities mostly south of the Fraser River, the total number of trips decreases.

The fare per trip decreases for seven municipalities with the highest decrease for riders from Vancouver and small municipalities. On the other hand the fare per trip increases for all other municipalities with the highest increase at 27.4 percent for riders from the Township of Langley, followed by 25.1 percent for riders from White Rock. This could be explained by the fact that 67 percent of trips from the Township of Langley, and 76 percent of trips from White Rock are 15 kilometers and over.

**Table 5.10. Summary of Results for Distance-based by Municipality**

| | Burnaby | Coquitlam | Delta | Langley City | Langley Township | Maple Ridge | New Westminster | North Vancouver City | North Vancouver District | Pitt Meadows | Port Coquitlam | Port Moody | Richmond | Small Municipalities | Surrey | UEL | Vancouver | West Vancouver | White Rock |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total trips before | 113,398 | 29,143 | 23,659 | 2,694 | 7,937 | 8,348 | 34,752 | 19,240 | 21,625 | 2,180 | 9,942 | 6,746 | 54,817 | 545 | 111,068 | 4,877 | 335,046 | 12,362 | 2,624 |
| Total trips after | 115,837 | 29,238 | 22,855 | 2,678 | 7,514 | 8,362 | 34,496 | 20,121 | 22,070 | 2,113 | 10,033 | 6,943 | 54,253 | 593 | 107,686 | 4,821 | 358,982 | 12,593 | 2,528 |
| Total fares before | 245,958 | 68,679 | 58,573 | 5,987 | 20,429 | 16,371 | 80,688 | 46,949 | 45,982 | 4,718 | 22,648 | 15,699 | 117,696 | 952 | 278,047 | 8,026 | 647,570 | 26,882 | 7,280 |
| Total fares after | 249,345 | 73,193 | 67,203 | 6,891 | 24,689 | 18,097 | 90,183 | 44,929 | 46,405 | 5,460 | 24,916 | 16,099 | 130,258 | 884 | 319,079 | 8,916 | 592,478 | 27,097 | 8,680 |
| Change in trips | **2.2%** | **0.3%** | -3.4% | -0.6% | -5.3% | **0.2%** | -0.7% | **4.6%** | **2.1%** | -3.1% | **0.9%** | **2.9%** | -1.0% | **8.8%** | -3.0% | -1.2% | **7.1%** | **1.9%** | -3.7% |
| Change in fares | 1.4% | 6.6% | 14.7% | 15.1% | 20.9% | 10.5% | 11.8% | -4.3% | 0.9% | 15.7% | 10.0% | 2.5% | 10.7% | -7.1% | 14.8% | 11.1% | -8.5% | 0.8% | 19.2% |
| Average fare per trip before | $2.17 | $2.36 | $2.48 | $2.22 | $2.57 | $1.96 | $2.32 | $2.44 | $2.13 | $2.16 | $2.28 | $2.33 | $2.15 | $1.74 | $2.50 | $ 1.65 | $1.93 | $2.17 | $2.77 |
| Average fare per trip after | $2.15 | $2.50 | $2.94 | $2.57 | $3.29 | $2.16 | $2.61 | $2.23 | $2.10 | $2.58 | $2.48 | $2.32 | $2.40 | $1.49 | $2.96 | $1.85 | $1.65 | $2.15 | $3.43 |
| Change in fare/trip | **-0.8%** | 6.2% | 18.8% | 15.8% | 27.7% | 10.3% | 12.6% | **-8.5%** | **-1.1%** | 19.4% | 9.0% | **-0.4%** | 11.8% | **-14.6%** | 18.4% | 12.4% | **-14.6%** | **-1.0%** | 23.8% |

- Change in Trips and Fares for Captive versus Choice Riders

Riders' reaction to a fare change is affected by whether they have access to or own a car or not. Riders who can drive and have access to a vehicle are often referred to as choice riders; while riders who can't drive because they do not have a driver's licence or have no access to a car are called captive riders (TCRP, 95). I used this variable as one of the criteria that affect riders' transit commute decision when fares change. It was included as one of the variables in the weighted variable elasticity. The following table shows that captive riders are able to consume more trips and pay less fare per trip than with zone fares, while the fare per trip for choice riders increases. This is mostly due to the fact that captive riders take shorter distance trips more often than choice riders.

**Table 5.11. Summary of Results for Distance-based by Captive versus Choice Riders**

| | Captive riders | Choice riders |
|---|---|---|
| Total trips before | 367,091 | 434,877 |
| Total trips after | 385,975 | 438,704 |
| Total fares before | $723,978 | $997,303 |
| Total fares after | $697,412 | $1,059,712 |
| Change in trips | 5.1% | 0.9% |
| Change in fares | -3.7% | 6.3% |
| Fare/trip before | $1.97 | $2.29 |
| Fare/trip after | $1.81 | $2.42 |
| %Change fare/trip | -8.4% | 5.3% |

**Table 5.12. Captive/Choice Riders by Distance Travelled**

| | Captive riders | Choice riders |
|---|---|---|
| 0-5km | 36% | 18% |
| 5-10km | 28% | 23% |
| 10-15km | 16% | 21% |
| 15-20km | 9% | 15% |
| 20-30km | 7% | 15% |
| Over 30km | 3% | 8% |
| Total | 100% | 100% |

**Table 5.13. Captive/Choice Riders by Income Group**

| | Captive riders | Choice riders |
|---|---|---|
| > $25,000 | 20% | 6% |
| $25,000 - $50,000 | 28% | 18% |
| $50,000 - $75,000 | 20% | 22% |
| $75,000 - $100,000 | 16% | 21% |
| $100,000 - $150,000 | 11% | 21% |
| >$150,000 | 4% | 12% |
| Total | 100% | 100% |

## 5.3. Time-of-Day Results

In this section I present data and results for total and type of transit trips by hour of day. I compare status-quo or the zone system with time-of-day scenario where transit trips starting on peak times, which are 6:00 to 9:00am and 3:00 to 6:00pm, are surcharged 20 percent on current regular fares. Meanwhile trips between peak times are assigned current off-peak fares. The data in this section shows trips by hour by income group, age group, and car availability.

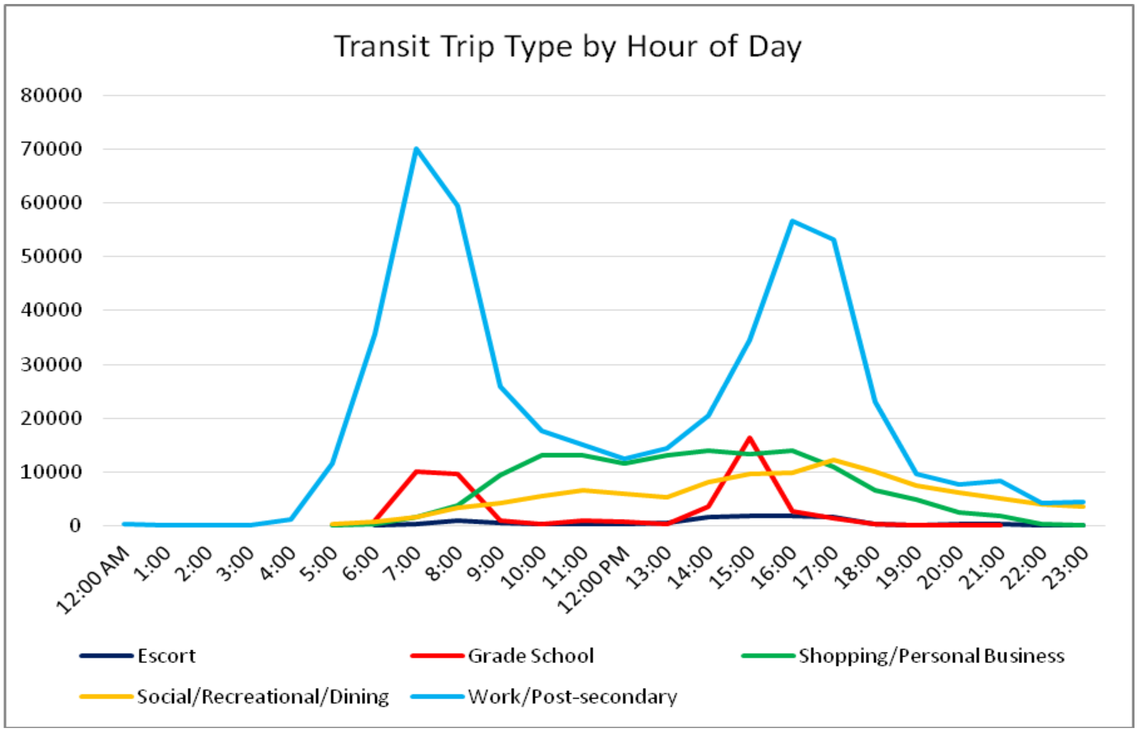


**Figure 5.4. Trip type by Hour of Day**

### 5.3.1. Status Quo

- Current trips by Income Group by Hour of Day

Figure 5.5 shows the pattern of trips for transit riders by income group. It can be observed that the “less than $25,000” income group makes most of its trips in the off-peak period between 9:00am and 3:00pm followed in descending order by the next 4 income groups. The highest income group does not exactly follow that pattern and it seems to have a small peak during off-peak hours, around noon time.

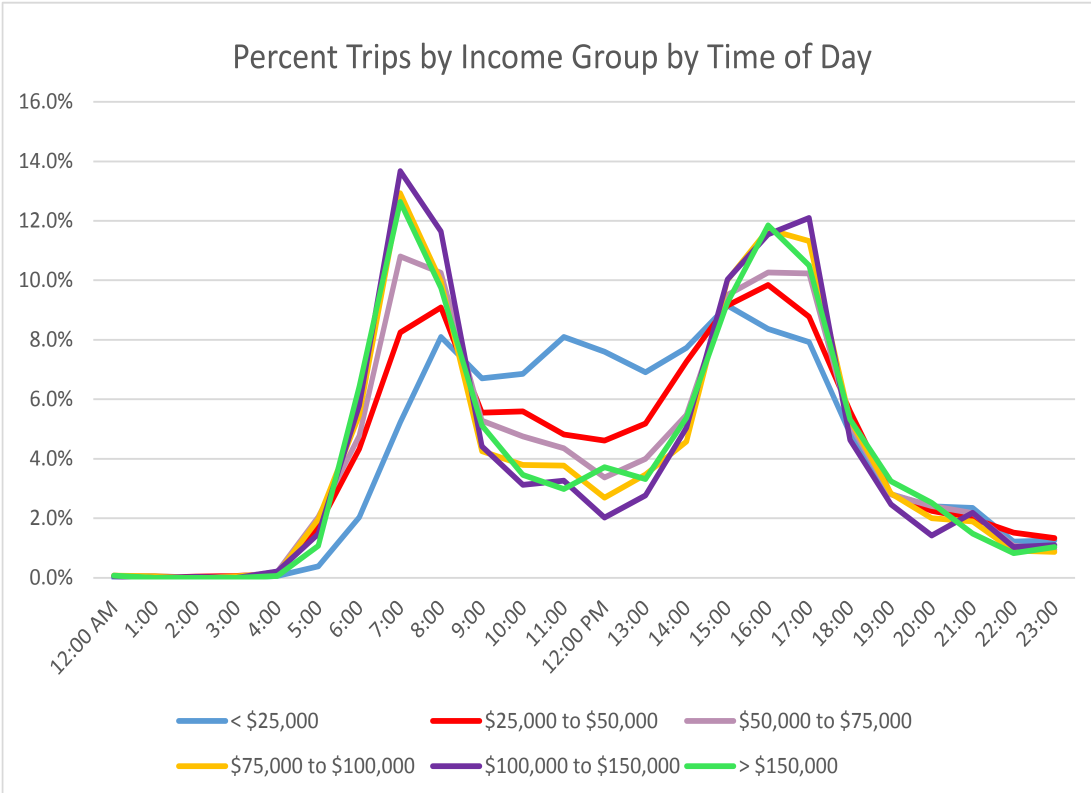


**Figure 5.5. .Percent Trips by Income Group by Time of day**

The next graph shows the types of trips taken by different income groups. Work and post-secondary trips constitute most of trips for all income groups, however the two lower income groups use transit much more than other income groups for personal/private business and social/recreational/dining trips. These types of trips are usually taken during off-peak hours.

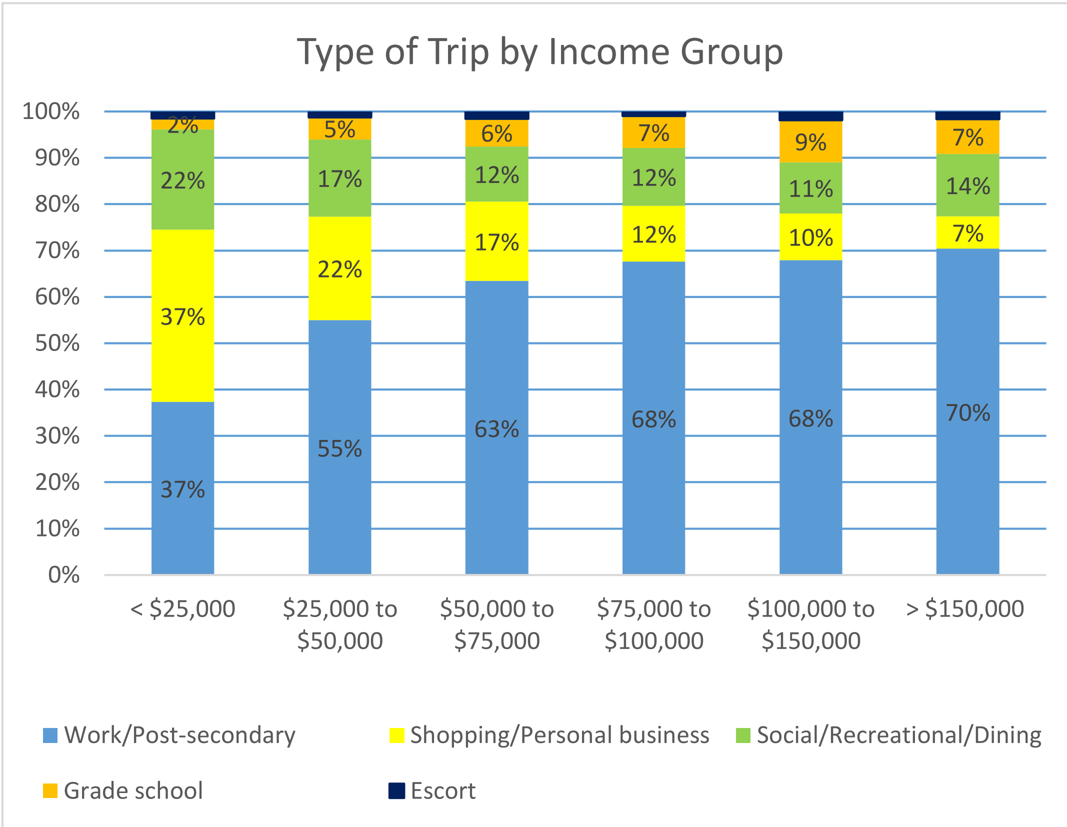


**Figure 5.6. Trip Type by Income Group**

- **Transit Trips by Hour by Age Group**

As the graph shows all age groups, except “65 plus”, have a higher use of transit during peak times as demonstrated by the two peaks in the graph lines. Their use is steady between the peaks and tapers off beyond that. All groups use transit at almost the same rate in the time period between 9:00 am and 2:00 pm except age group 05 to 17 since they are at grade school during this time. Age group “65 plus” uses transit mostly during the midday off-peak hours between 9:00 and 3:00 since most people in that group are retired.

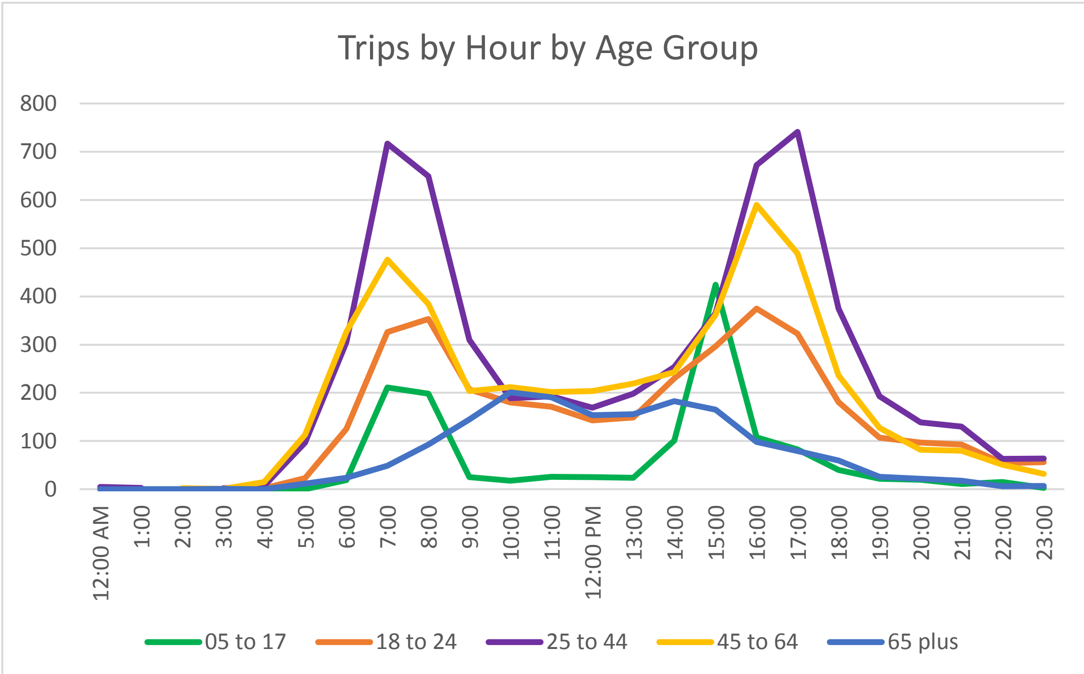


**Figure 5.7.	Trips by Hour by Age Group**

- **Captive and Choice Riders Trips by Hour**

Captive and choice riders' graphs display the same pattern as previous time-of-day graphs where their trips are higher at the two peak times of the day while having a plateau of constant trips between those times. However captive riders have a higher rate of off-peak trips while their afternoon peak starts about an hour earlier than choice riders. This is consistent with lower income groups since captive riders have a higher percentage of low-income riders compared with choice riders (see Table 5.13).

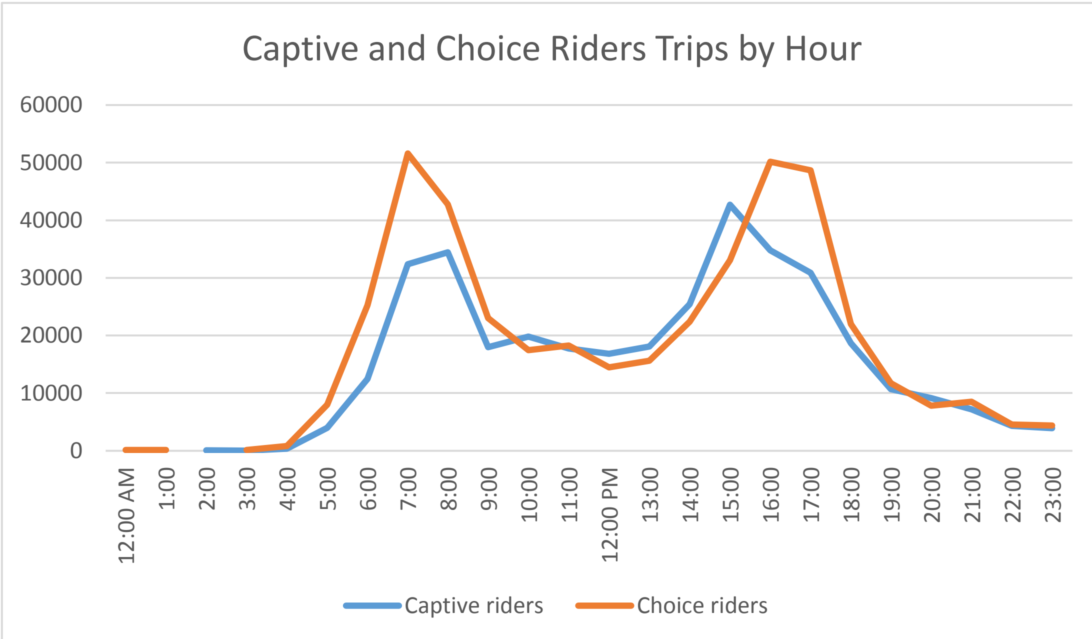


**Figure 5.8. Captive versus Choice Riders Trips by Hour**

### 5.3.2. Time-of-Day

The results of the simulation of a 20 percent surcharge on regular fares during peak time resulted in a reduction in the number of total trips by less than 0.6 percent and 0.8 percent, respectively, for the constant and the variable elasticities. The total fares and fare per trip increase almost equally for both elasticity values. Also the peak trips decrease by 2.5 percent and 3.8 percent for the constant and variable elasticity respectively. These results are expected with a time-of-day fare structure where peak trips decrease, off-peak trips increase, and revenues and fare per trip increase. The purpose of time-of-day pricing is to reflect the higher cost of providing transit services at peak times, which results in shifting some of the ridership from peak to off-peak hours, while increasing revenues (Cervero, 1986). However as can be seen the shifts in ridership are not substantial as concluded by Cervero of his analysis of US and international experiences on time-of-day pricing (1986).

**Table 5.14. Summary of Results for time-of-day Pricing**

| | Status quo | Time-of-day with -0.2 elasticity | Time-of-day with variable elasticity |
|---|---|---|---|
| Total trips | 793,081 | 788,243 | 786,411 |
| Peak trips | 439,198 | 428,855 | 423,352 |
| Off-peak trips | 353,883 | 359,388 | 363,058 |
| Change in peak trips | - | -2.4% | -3.6% |
| Change in off-peak trips | - | 1.6% | 2.6% |
| Total fares | $1,705,574 | $1,772,251 | $1,761,324 |
| Avg. fare/trip | $2.15 | $2.25 | $2.24 |
| % change in total trips (from status quo) | - | -0.6% | -0.8% |
| % change in total fares | - | 3.9% | 3.3% |
| % change in average fare/trip | - | 4.5% | 4.1% |

- Effects by Income Group

The overall fares and fare per trip increase for all income groups. However the lowest three income groups experience a smaller fare per trip increase than the income groups over $75,000. This is due to the fact that higher income groups use transit more during peak times and hence they are affected the most by the fare surcharge. This finding is consistent with the literature.

**Table 5.15. Summary of Results for Time-of-day by Income Group**

| | < $25,000 | $25,000 - $50,000 | $50,000 - $75,000 | $75,000 - $100,000 | $100,000 - $150,000 | >$150,000 |
|---|---|---|---|---|---|---|
| Total trips before | 88,546 | 154,046 | 143,993 | 129,106 | 111,370 | 56,468 |
| Total trips after | 88,190 | 153,415 | 142,951 | 127,659 | 109,737 | 55,651 |
| Total fares before | $150,382 | $324,457 | $328,500 | $294,014 | $253,759 | $129,014 |
| Total fares after | $152,687 | $331,676 | $337,709 | $305,955 | $265,994 | $135,069 |
| %Change in total trips | -0.4% | -0.4% | -0.7% | -1.1% | -1.5% | -1.4% |
| %Change in total fares | 1.5% | 2.2% | 2.8% | 4.1% | 4.8% | 4.7% |
| Average fare/trip before | $1.70 | $2.11 | $2.28 | $2.28 | $2.28 | $2.28 |

| | < $25,000 | $25,000 - $50,000 | $50,000 - $75,000 | $75,000 - $100,000 | $100,000 - $150,000 | >$150,000 |
|---|---|---|---|---|---|---|
| Average fare/trip after | $1.73 | $2.16 | $2.36 | $2.40 | $2.42 | $2.43 |
| % Change in fare/trip | 1.9% | 2.6% | 3.6% | 5.2% | 6.4% | 6.2% |

- Effects by Age Group

There is small effect on age group 5 to 17 and some change for riders over 65 years where their total trips increase and their fare per trip decreases. This is mostly due to the fact that the surcharge has not been applied to concession fares. There is a small change to age group 18 to 24 since many of the riders in that age group have a U-pass, which also is not affected by the price increase. The age groups affected the most are riders between the ages of 25 and 64 who mostly use transit for commuting during peak times.

**Table 5.16. Summary of Results for Time-of-Day by Age Group**

| | 05 to 17 | 18 to 24 | 25 to 44 | 45 to 64 | Over 65 |
|---|---|---|---|---|---|
| Total trips before | 64,179 | 193,817 | 278,153 | 180,709 | 76,222 |
| Total trips after | 64,300 | 193,038 | 273,507 | 178,278 | 77,287 |
| Total fares before | $93,818 | $317,320 | $711,962 | $496,978 | $85,496 |
| Total fares after | $93,134 | $324,384 | $746,533 | $516,117 | $81,155 |
| %Change in total trips | 0.2% | -0.4% | -1.7% | -1.3% | 1.4% |
| %Change in total fares | -0.7% | 2.2% | 4.9% | 3.9% | -5.1% |
| Average fare/trip before | $1.46 | $1.64 | $2.56 | $2.75 | $1.12 |
| Average fare/trip after | $1.45 | $1.68 | $2.73 | $2.90 | $1.05 |
| % Change in fare/trip | -0.9% | 2.6% | 6.6% | 5.3% | -6.4% |

- Effects on Captive and Choice Riders

The effect on captive and choice riders is very similar, albeit the increase in total fares and fare per trip is a bit lower for captive riders.

**Table 5.17. Summary of Results for Time-of-day by Captive versus Choice Riders**

| | Captive Riders | Choice Riders |
|---|---|---|
| Total trips before | 362,256 | 430,825 |
| Total trips after | 359,635 | 426,776 |
| Total fares before | $715,880 | $989,694 |
| Total fares after | $738,713 | $1,022,611 |
| %Change in total trips | -0.7% | -0.9% |
| %Change in total fares | 3.2% | 3.3% |
| Average fare/trip before | $1.98 | $2.30 |
| Average fare/trip after | $2.05 | $2.40 |
| % Change in fare/trip | 3.9% | 4.3% |

- Effect by Municipality

The effect of time-of-day fare by municipality in not highly variable. As can be seen in Table 5.18 the percent change in total trips varies between -2.5% and 1.4% while the percent change in total fares varies between -1.4% and 4.5%. This small variation reflects the ratio of peak to off-peak trips made by riders from the different municipalities. This slight variation by municipality shows that a time-of-day fare structure would not affect riders based on their geographical location.

**Table 5.18. Summary of Results for Time-of-Day by Municipality**

| | Burnaby | Coquitlam | Delta | Langley City | Langley Township | Maple Ridge | New Westminster | North Van. City | North Van. District | Pitt Meadows | Port Coquitlam | Port Moody | Richmond | Small Municipalities | Surrey | UEL | Vancouver | West Vancouver | White Rock |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total trips before | 111,828 | 28,847 | 23,371 | 2,694 | 7,841 | 8,191 | 34,401 | 19,069 | 21,513 | 2,180 | 9,795 | 6,746 | 54,079 | 545 | 110,038 | 4,877 | 331,340 | 12,136 | 2,624 |
| Total trips after | 110,863 | 28,947 | 23,376 | 2,683 | 7,807 | 8,252 | 34,029 | 18,990 | 21,290 | 2,160 | 9,791 | 6,773 | 53,628 | 545 | 110,203 | 4,825 | 326,442 | 12,171 | 2,688 |
| Total fares before | $243,136 | $68,262 | $58,095 | $5,987 | $20,231 | $16,145 | $80,195 | $46,554 | $45,776 | $4,718 | $22,027 | $15,699 | $116,406 | $952 | $276,278 | $8,026 | $641,161 | $26,498 | $7,280 |
| Total fares after | $251,853 | $69,093 | $59,283 | $6,059 | $20,957 | $15,937 | $83,163 | $47,716 | $47,774 | $4,833 | $22,421 | $15,670 | $120,711 | $952 | $280,257 | $8,319 | $670,171 | $26,703 | $7,178 |
| %Change in total trips | -0.9% | 0.3% | 0.0% | -0.4% | -0.4% | 0.7% | -1.1% | -0.4% | -1.0% | -0.9% | 0.0% | 0.4% | -0.8% | 0.0% | 0.1% | -1.1% | -1.5% | 0.3% | 2.4% |
| %Change in total fares | 3.6% | 1.2% | 2.0% | 1.2% | 3.6% | -1.3% | 3.7% | 2.5% | 4.4% | 2.4% | 1.8% | -0.2% | 3.7% | 0.0% | 1.4% | 3.7% | 4.5% | 0.8% | -1.4% |
| Average fare/trip before | 2.17 | 2.37 | 2.49 | 2.22 | 2.58 | 1.97 | 2.33 | 2.44 | 2.13 | 2.16 | 2.25 | 2.33 | 2.15 | 1.74 | 2.51 | 1.65 | 1.94 | 2.18 | 2.77 |
| Average fare/trip after | 2.27 | 2.39 | 2.54 | 2.26 | 2.68 | 1.93 | 2.44 | 2.51 | 2.24 | 2.24 | 2.29 | 2.31 | 2.25 | 1.74 | 2.54 | 1.72 | 2.05 | 2.19 | 2.67 |
| % Change in fare/trip | 4.5% | 0.9% | 2.0% | 1.6% | 4.0% | -2.0% | 4.8% | 2.9% | 5.5% | 3.4% | 1.8% | -0.6% | 4.6% | 0.0% | 1.3% | 4.8% | 6.1% | 0.5% | -3.7% |

## 5.4. Affordability

In this section I calculate the annual cost of transit for low-income people based on a monthly pass, for all three fare structures. I use Statistics Canada, low-income cut-offs (LICO) figures for metropolitan areas with a population over 500,000. LICO is "an income threshold below which a family will likely devote a larger share of its income on the necessities of food, shelter and clothing than the average family" (Statistics Canada, 2009). Statistics Canada produces before and after-tax figures and they recommend using after tax figures since people make purchases with after-tax income and hence it is a better reflection of their economic well-being (Statistics Canada, 2009). However, I am constrained to use before-tax income figures since the household incomes reported in the trip diary survey are before-tax household incomes and I have no way to compute their after-tax income.

Assumptions used to calculate costs

- Two-person households are assumed to be two adults therefore the cost is based on two regular monthly passes.
- Three-person households are calculated based on two adults and one child i.e. two regular monthly passes and one concession pass.
- Four-person households are assumed to be two adults and two children i.e. two regular monthly passes and two concession passes.
- The annual cost of a monthly pass is calculated as follows:
- Current zone structure = Cost of a monthly pass by zone * 12 months/year
- Distance-based = 12 months/year * 40 trips/month * cost per trip ($1.30 boarding minimum + ((average distance - 3km) * ($0.21/Km)). The average distance for each distance interval is calculated in Table 4.3.
- Time-of-day = Cost of a monthly pass by zone * 1.20 (20 percent surcharge only on regular fares)* 12 months/year.

The results for total annual cost and in proportion to income are presented in Table 5.19

**Table 5.19. Annual cost of Transit Based on the Cost of a Monthly Pass for Low-Income Individuals/Households**

| | | Cost of Current Zone Structure | | | Cost of Distance-based | | | | | Cost of Time-of-day | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| House-hold size | LICO | 1-Zone | 2-Zone | 3-Zone | 0-5 km (3.1 km) | 5-10 km (7.4km) | 10-15km (12.2km) | 15-20km (17.4km) | 20km and over | 1-Zone | 2-Zone | 3-Zone |
| 1 person | $23,298 | 1,092 | 1,488 | 2,040 | 634 | 1,068 | 1,551 | 2,072 | 2,640 | 1,310 | 1,786 | 2,448 |
| | % of income | 4.7% | 6.4% | 8.8% | 2.7% | 4.6% | 6.7% | 8.9% | 11.3% | 5.6% | 7.7% | 10.5% |
| 2 persons | $29,004 | 2,184 | 2,976 | 4,080 | 1,268 | 2,135 | 3,103 | 4,145 | 5,280 | 2,621 | 3,571 | 4,896 |
| | % of income | 7.5% | 10.3% | 14.1% | 4.4% | 7.4% | 10.7% | 14.3% | 18.2% | 9.0% | 12.3% | 16.9% |
| 3 persons | $35,657 | 2,808 | 3,600 | 4,704 | 1,658 | 2,794 | 4,061 | 5,779 | 6,384 | 3,245 | 4,195 | 5,520 |
| | % of income | 7.9% | 10.1% | 13.2% | 4.7% | 7.8% | 11.4% | 16.2% | 17.9% | 9.1% | 11.8% | 15.5% |
| 4 persons | $43,292 | 3,432 | 4,224 | 5,328 | 2,049 | 3,452 | 5,019 | 6,883 | 7,488 | 4,493 | 5,443 | 6,768 |
| | % of income | 7.9% | 9.8% | 12.3% | 4.7% | 8.0% | 11.6% | 15.9% | 17.3% | 10.4% | 12.6% | 15.6% |
| | | 3,294 | 1,665 | 335 | 1,786 | 1,420 | 965 | 560 | 63 | 3,294 | 1,665 | 335 |

# Chapter 6. Qualitative Results

The case study review and interviews with agencies that use distance-based and/or time-of-day pricing provide insights into issues of implementation complexity, and public and political perception of the fare structure and pricing. As mentioned in chapter 4, I have selected North American transit agencies that use differentiated pricing because of the similarity in social, political, and economic conditions. However these agencies have had their existing fare structures since their inception so I was not able to get information on the process of and reaction to a change in fare structure. Nonetheless, GO Transit in Toronto is in the process of reviewing its fare structure as part of a wider review of a regional fare and service integration study. It helped shed some light into their process/plan for public and political stakeholder participation in the review, and potential fare structure change.

The information presented hereafter is mostly based on personal communication[9] with representatives from WMATA and GO Transit, and on information from the agencies' websites. Information from websites and other studies are appropriately cited in the next sections.

## 6.1. Washington Metropolitan Area Transit Agency (WMATA), Washington, District of Columbia

### Key statistics

[9] Interviews were conducted with:

Mark Schofield, Director of Financial Planning and Analysis, Washington Metropolitan Area Transit Agency

Chris Burke, Manager, GO Planning, Metrolinx

**Table 6.1. WMATA Key Statistics for 2012**

| Mode | Ridership | Size | Farebox Recovery |
|---|---|---|---|
| Rail (Metrorail) | 212,188,640 trips | 86 stations<br>170 Km | 66.5% |
| Bus (Metrobus) | 131,780,990 | 325 routes on 169 lines<br>11,490 bus stops | 22.1% |
| System wide | | | 49.6% |

Source: WMATA (n.d.a)

**Governance:** WMATA was created in 1967 by the US congress, as an interstate compact (which is an agreement between two or more states consented by the US congress) between the District of Columbia, the state of Maryland, and the state of Virginia. Its mandate is to build and operate transit services in the National Capital area. WMATA provides rail, bus, and para-transit services, and has its own police force.

WMATA is served by a Board of Directors that consists of sixteen members; 8 voting members and 8 alternate members. Each one of the states and the federal government appoints two voting and two alternate members (WMATA, n.d.b)

**Service Area:** Metrorail and Metrobus serve a population of 5 million within a 1,500 (3880 km2) square-mile area (WMATA, n.d.a)

**Funding Sources:** WMATA has no independent taxation authority and depends on its member jurisdictions for capital investments and operating subsidies. The federal government contributes roughly 56 percent of the capital costs. Fares and other revenue currently fund 55.3 percent of the daily operations, while state and local governments fund the remaining 44.7 percent (WMATA, n.d.a)

**Fare structure:** WMATA uses a mix of fare structures for the different modes. Metrorail uses both distance-based and time-of-day fare structure, while Metrobus uses a flat fare structure, and the express buses use a service-based structure (WMATA, n.d.a; WMATA, n.d.b). WMATA has always used differentiated fare structure since its inception (interview). The boarding charge and maximum fare are determined based on the agency’s financial situation, board direction, and economic conditions. The agency is careful when setting the maximum fares to ensure that riders who commute very long distances will not be priced out of transit. WMATA long distance and peak rail riders are usually higher income and own more cars (Smith, 2009). Therefore if the cost of using transit is comparable to driving and parking a car at their place of work then riders will switch to their car. Currently the cost to use transit for some of long distance trips is about $15 per day (this includes cost of parking at rail station), hence WMATA planners have to be cognisant of these costs and trade-offs, when increasing the maximum fare.

**Table 6.2. WMATA Fare Structure**

| | Metrorail | | Metrobus | Express bus | Airport bus |
|---|---|---|---|---|---|
| | Peak | Off-peak | | | |
| Boarding charge (0-3 miles) | $2.10 | $1.70 | $ 1.60 | $3.65 | $6.00 |
| 1st Tier(3-6 Miles) | $ 0.32 | $ 0.24 | | | |
| 2nd Tier (6+ Miles) | $ 0.28 | $ 0.21 | | | |
| Maximum Fare | $ 5.75 | $ 3.50 | | | |
| Cash surcharge | $1.00 | | $0.20 | $0.35 | |

Source: WMATA n.d.a; WMATA, n.d.b

Seniors and people with disabilities pay half the fares of peak Metrorail and Metrobus regular and express services.

**Fare policy:** WMATA has a fare policy that sets out seven principles that guide the board's decisions on fare level and structure changes as follows:

1. Ensure and enhance customer satisfaction
2. Establish a mechanism to allow customers to determine their fares easily
3. Optimize the use of existing capacity
4. Establish equitable fares and ensure compliance with federal regulations
5. Facilitate movement between modes and operators throughout the region
6. Encourage the use of cost-effective media
7. Generate adequate revenue while maximizing ridership

The policy also stipulates a regular biennial review and adjustment of fares to match the consumer price index (WMATA, 2010)

**Equity issues:** The board has made an intentional policy decision to keep bus fares artificially low because bus riders tend to be lower income than rail riders. Also as the rail system expanded, the buses tended to act as a feeder service to the rail network (Smith, 2009). Therefore bus routes that are replaced with a rail line would terminate at the rail station and riders would transfer to Metrorail to continue on with their trip, hence there would be no parallel bus and rail service. However in recent years, as the rail system has gotten more congested that policy has been loosened because there is a need for more capacity especially going to the downtown core. So there are currently some bus routes that parallel the rail.

The agency does not have a system wide program for low-income riders but specific programs are targeted at certain populations which are sponsored by one of the states or counties. For example, the latest rail line opened in 2004 and the parallel bus lines were cancelled. Residents in one of the lower income areas were the line traversed complained about being forced to use rail and pay double the fare. The agency instituted special transfer discounts at a couple of those rail stations to compensate those riders. The discounts were subsidized by the District of Columbia. The District also subsidizes all school children to ride the bus for free. The agency is reimbursed for the loss in revenue by the district.

**Fare affordability:** Transit agencies are required by federal regulations to ensure that fare changes do not negatively impact low-income and minority groups, so the agency has to do this analysis for those groups whenever a fare increase is considered.

**Complexity of system (Implementation):** The WMATA rail fare structure is distance based. The agency uses a unique distance calculation to overcome problems of rail lines being indirect and circuitous. They use an average of the actual distance between the origin and destination stations and the straight line distance or “as the crow flies” between the two points. This deals with the concern that some riders have about having to pay for travelling unnecessary long distances because of the system design.

**Political Acceptance and geographical equity:** About three years ago, the board requested that staff investigate and evaluate other fare structures in hopes of finding a simpler and more user friendly structure. Staff looked at flat and zone fares and presented results to the board (WMATA, 2011). In evaluating and debating the merits of each option the board members ran into geographic inequity issues. For example with a flat fare which could be an average between the current minimum and maximum fares, riders travelling long distances would be reaping a large benefit while riders traveling short distances or living in the downtown core would be paying much more.

**Fare elasticity and riders response to fare changes:** The agency uses an econometric model to project ridership based on variables such as employment, population forecast, and gas prices. The model uses an average fare elasticity value but it is a rough estimate. In general ridership has been fairly inelastic to fare changes because most federal government employees and many private sector employees get a discounted fare. However the agency feels that riders might be getting a bit more responsive to fare increases and hence their elasticity will rise; the agency will monitor the situation going forward.

**Type of ridership:** In the last 10 years, there has been an increase in riders in their twenties and thirties who are consciously making the decision to use transit because they do not own a car. This is quite a paradigm shift from when transit was considered “a travel option of last resort”.

It is interesting to note that a 2006 WMATA survey found that 80 percent of daily rail riders have a car available, and hence they are choice riders. WMATA notes in that report that service quality is a “significant factor influencing” these riders and hence improving service quality is vital to retaining and growing this ridership (WMATA, 2006).

## 6.2. GO Transit, Toronto, Ontario

### Key Statistics

**Table 6.3. GO Transit Key Statistics 2010/2011**

| Mode | Ridership* (Annual boardings) | Size | Farebox recovery |
|---|---|---|---|
| Rail | 43.7 million | 63 stations<br>450 Km | 82.2% |
| Bus | 14.2 million | 15 terminals<br>2760 Km | |

Source: Metrolinx, 2011

**Governance:** GO Transit is a regional public transit system that serves the greater Toronto and Hamilton area. It is a division of Metrolinx, which is an agency of the provincial government of Ontario. Metrolinx was created in 2006 to manage, develop and coordinate an integrated transportation network for the greater Toronto and Hamilton area.

Metrolinx is governed by a board made up of 15 members who are mostly private sector executives. Elected officials or public sector employees can't serve on the board. The board members are appointed by the Lieutenant Governor upon recommendation from the provincial minister of transportation (Metrolinx Act, 2006).

**Service area and system description:** GO Transit service area covers 11,000 km and serves a population of 7 million. The agency operates rail and bus systems. The rail lines are designed as a radial system that brings commuters into and out of downtown Toronto. Six of the 7 train lines operate during morning and afternoon peak hours bringing travellers to the Toronto downtown core and again moving them outbound in the afternoon. Only the Lake Shore rail line operates an all-day two-way service every day. Between the peak hours coach buses otherwise called "train buses" fill in the gaps in the train timetable and they run from downtown Toronto to the different rail stations in order to provide a two way all day service (GO Transit, n.d.a)

The agency also provides express bus services across major corridors that are not served well by rail lines. The bus network covers corridors in-between the rail lines and then east west across the city that follow the express highways 401, 403 and 407. GO Transit also connects with all 17 municipal transit systems in its service area.

**Funding:** GO transit recovers 85 percent or more of its operating costs from fare and sundry revenues. The Provincial government subsidizes any operating costs that are not recovered through revenue, and provides capital funding for rehabilitation, replacement, and expansion. The federal and municipal governments have in recent years contributed as well to capital funding for expansion (GO Transit, n.d.c)

**Fare structure:** GO Transit uses distance-based pricing for all its trains and buses; Fares are calculated from on a base amount and a distance amount added on top of that. The minimum fare would be travel that occurs within one-fare zone and the cost of travelling across each zone is added to the base fare. Every rail station is in a separate fare zone. The agency introduced the smart card "Presto" fare card much like many other transit agencies around the world. "Presto" is an electronic fare payment system that replaces other payment methods such as cash, tickets, and cards. The fare card has been adopted by all municipal transit agencies, where Go Transit services are offered, except in Milton, Ontario. The Toronto Transit Commission (TTC) is in the process of adopting the fare card and over the next 2 to 3 years Toronto will be shifting entirely to "Presto".

The fare zone system was established based on the rail's radial design where each station has its own fare zone. But when the bus system network was created and the grid was overlaid on top of the radial system, it made the fare calculation complicated and created some problems. The agency had to fix some anomalies, for example, where the trip would cost more by bus than train because the bus route crosses more zones. The other drawback with the fare structure is that it is difficult for customers to understand.

**Fare policy:** The agency does not have a stand-alone fare policy however some fare policy goals are stated in the strategic plan under one of its six objectives.

Objective: GO Transit's operations will be economically sustainable

Goals:

- GO Transit to maintain a cost-recovery ratio of 75 percent
- Ensuring that fares are competitive with the cost of driving, while doing annual adjustments to reflect service deliver costs.
- Fares should be easily understood, and reflect the value of services to the travellers.
- Charges for special services will be introduced where appropriate
- Sustainable recovery of costs from fares (Go Transit, n.d.c)

**Fare policy and fare structure and service integration review:** GO Transit is currently in the process of reviewing its fare structure and exploring alternative structures such as time-of-day and service-based to optimize the use of its existing assets. The agency is exploring the possibility of improving the use of the system by shifting ridership from peak to off-peak and hence increasing off-peak ridership, and reducing some of the peak demand. This review is also being done concurrently with another study that is exploring regional fare structure and service integration between GO Transit and all other municipal transit agencies.

The purpose of the fare and service integration study is motivated by the regional transportation plan "The Big Move" to develop a more integrated regional transit network that is better coordinated and hence more customer friendly. The possibility of using a single fare system for the entire region is being explored and although this would have major financial and governance implications, it would be simpler to administer since all transit agencies are using the smart card "Presto" and would be customer friendly. The review is also exploring the hierarchy of services offered. It is developing a typology of different services based on speed and frequency and the value aspect for the customer. This would allow a better integration between services offered and price charged, and would allow the opportunity to offer customers a wider range of services and prices that would fit their needs and ability to pay.

**Public acceptance and consultation:** Although GO Transit is still in the process of doing these two major studies they have already engaged their customers and stakeholders, and are developing a public consultation plan.

The agency has a big focus on customer service and has made considerable progress over the last 5 years to institutionalize this commitment. They developed the Passenger Charter, which includes 5 commitments to their customers. Progress on these commitments is tracked. They also have two customer service related committees; one is a board committee chaired by a board member who is a customer service executive with a major private corporation. The other group is a customer service advisory committee made up of actual customers from all different parts of the system. The group meets regularly to discuss customer service related topics. Some of the early results of the studies and ideas have been presented to them to get their feedback. This committee provides GO Transit planners with a good sounding board to some of the issues and problems that might arise before they consult on their plans and ideas with a larger riders group.

Prior to starting the fare policy review, the first phase involved reviewing the agency's goals and objectives. This step was essential to ensure that the review was guided by a clear mandate, especially knowing that they had some contradicting goals and objectives. In this process all internal stakeholders had the opportunity to participate and provide feedback and to raise issues that they were dealing with or were anticipating in the future. This proved to be a useful exercise in terms of bridging the gap between operational issues and goals and objectives.

As part of the fare and service integration study, they have formed a technical advisory committee made up of representatives from all municipal transit agencies, and planning departments. The group meets regularly to discuss the progress of the study. At this point the involvement is at the staff level only but GO Transit planning has started to engage their stakeholder relations department to plan for the wider stakeholder engagement process. The direction of the department is to do this in a phased approach were the public is involved in developing the solutions. They are envisioning holding events where they bring thought leaders, decision makers, the public, and representatives from other jurisdictions to start brainstorming ideas and solutions.

**On the issue of dealing with contradicting goals and objectives:** The main reason the agency decided on reviewing fare and service integration together is to avoid contradict goals and objectives. If the agency was to review the fare structure on its own without considering services, most people would be comparing fares based on what they currently pay without consideration to services offered or value for money. By reviewing services and fares together, it would provide a more complete picture of the services received by customers compared to what they pay. One of the criteria they use to evaluate options is value for money for the customer. A review of the fare structure on its own might raise concerns that the agency is only trying to improve its revenues, regardless of other benefits.

**Issues to consider when evaluating alternative fare structures:** In looking at an alternate fare structure it is necessary to be clear on the problem being addressed by changing the fare structure. There are always trade-offs with any fare structure and therefore being clear about the issues you are addressing will minimize the creation of new unanticipated problems. For GO Transit having many service providers sometimes with parallel services, it is important to identify how the services complement each other. And also to create a consistent and seamless fare structure that facilitates travel and transfer for the region’s riders.

# Chapter 7. Criteria and Measures

This chapter outlines and explains the criteria and measures used to evaluate the policy options discussed in Chapter 3. The criteria suggested here are used most often to evaluate transit policies, and have been mainly informed through the literature and case studies.

**Table 7.1. Criteria and Measures Evaluation Matrix**

| Criteria | Description | Measure | Scale |
|---|---|---|---|
| Equity | Vertical equity:<br>- Impact on different income groups<br>- Impact on mobility disadvantaged groups (seniors, youth, disabled) | Change in ridership<br>Change in fare paid/trip | - Increase/ Decrease<br>- Low/Medium/ High |
| | Geographical equity:<br>- Impact on people in different municipalities/regions | Change in ridership<br>Change in fare paid/trip | - Increase/ Decrease<br>- Low/Medium/ High |
| Effectiveness | Increase in ridership and/or increase of revenues | Percent of ridership change<br>Percent of revenue change | % Change |
| Implementation Complexity | Impact on TransLink to implement policies | Based on case studies and in-depth interviews with other transit agencies who have implemented similar policies | Low/Medium/ High |
| Community responses/ Acceptability | Political | Based on case studies and in-depth interviews with other transit agencies who have implemented similar policies | Low/Medium/ High |
| | Commuters | | |
| Affordability | For riders it would be how much of their income they spend on transit fares | % Cost of transit/income compared to status-quo | Lower/No change/Higher |

## 7.1. Equity

As mentioned earlier, equity along with efficiency are the two criteria that are said to substantially improve with more fine-grained differentiated pricing structures such as distance-based and time-of-day. I appraise vertical and geographical equity to evaluate the policy options as most transit debates are focused on these aspects. Vertical equity assesses the impact of the policy change on groups of people in different income categories as well as people who are transit dependent. Geographical equity on the other hand determines impacts on people living in different parts of Metro Vancouver. The measures that I use to assess these impacts are the change in the number of riders in the corresponding income or transit dependent group. The other measure is the change in fare paid by trip as a result of change in the fare structure and price.

The income categories used are total household income categories used in the 2011 TransLink Regional Trip Diary survey

- Less than $25,000
- $25,000 to less than $50,000
- $50,000 to less than $75,000
- $75,000 to less than $100,000
- $100,000 to less than $150,000
- $150,000 or more

Transit dependent groups

- Seniors - people over 65 years
- Has no driver’s licence - people under 16 years old, disabled, or have any other barriers that prevent them from getting a driver’s licence
- Households with no private vehicles

Geographical groups are based on the 23 local governments that make up the Metro Vancouver region and as identified in the 2011 TransLink Regional Trip Diary Survey.

## 7.2. Effectiveness

Effectiveness measures the change in ridership and revenues. The effectiveness criterion is often used as a measure of the ability of a transit agency to maximize its ridership while keeping its revenue to cost ratio stable (Talley and Anderson, 1981). TransLink also uses effectiveness as a performance measure for change in ridership and revenues (TransLink, 2012). Therefore ridership and revenue changes with the two different fare structures evaluated are compared with status-quo. An increase in ridership and/or revenues is considered an effective policy.

## 7.3. Implementation Complexity

This criterion measures the extent of effort required to implement a fare structure change. A change in the fundamental structure of any public program entails a lot of administrative and outreach efforts. A change in the structure of transit fares will probably impact all aspects of TransLink. Impacts such as reconfiguring and reprogramming all fare vending machines with new fare structure, matching the accounting system to the new structure, developing new communication and outreach material to inform riders of the new structure, and so on.

I derive information about implementation complexity from interviews with other transit authorities who have implemented these types of fare structures to understand the level of detail involved in implementation.

## 7.4. Acceptability

Acceptability differs across the different groups' usually affected by or representing those affected by the policy change. The groups most engaged in the discussion are politicians, and transit commuters. Acceptability is usually affected by how equity is perceived and assessed by each group. Hence, as noted, politicians will be mostly concerned about geographical equity which means that their transit benefit is roughly equivalent to their tax contribution. And commuters are most concerned with affordability, accessibility and reliability of the system. This criterion assesses the level of acceptability by these two groups. I derive information about acceptability from interviews with other transit agencies and from any available news articles that might present any of the groups' opinions on the issue.

## 7.5. Affordability

Transit fare affordability is an important criterion by which users and politicians will perceive the fairness of the fare structure. Although transit fares represent a small portion of travel cost for most people, it is often scrutinized by users and politicians because it is an out of pocket expense that is visible, unlike monthly recurring costs such as car insurance and monthly car payments. Transit affordability is a measure of the portion of an individual or household income spent on transit. It indicates the ability of an individual to make a trip based on the financial cost imposed by transit relative to their income (Carruthers et al., 2005). In Canada according to Statistics Canada' Survey of Household Spending, 2012 (2014), the average household spending on transportation was $11,216 of which $10,087 was spent on private transportation (which includes spending on the purchase of cars, trucks and vans and their operating costs). The remaining $1,128 was spent on public transportation (this covers spending on public transit, taxis and air and train fares).

The issue of transit affordability is a separate topic though, and it is not the objective of this research to explore it. However I am using it here in order to assess how the different fare structures impact affordability when compared to status-quo or the zone structure. The impact on affordability is assessed by calculating how much low-income riders spend on transit under the different fare structures. The following formula is used to assess change in affordability for the different income categories as outlined in the equity criterion.

Affordability = Number of trips x Average cost per trip / Per capita income (expressed as a percent) (Carruthers et al., 2005)

# Chapter 8. Evaluation of Policy Options

The policy options explored in my research represent a small sample of the many fare structure options and combinations available to improve the efficiency of the transit system, and equity among riders. It is important to note that these options are not mutually exclusive, and hence this evaluation does not attempt to illustrate the superiority of one fare structure over the others. The options presented here in this research can be used on their own, or combined in many different ways depending on the transit system service offerings, and its goals and objectives. Nonetheless, I still evaluate all three options based on the criteria and measures presented in the previous chapter to demonstrate the effects and merits of each fare structure on the evaluation criteria separately.

**Table 8.1. Policy Options Evaluation Matrix**

| | | Policy options | | |
|---|---|---|---|---|
| Criteria | Measure | Status-quo | Distance-based | Time-of-day |
| Equity | | | | |
| Vertical equity | | | | |
| Impact on different income groups | Change in ridership | No-change | Increase for all groups | Decrease for all groups |
| | Variability in fare paid/trip across groups | Low | High | Low |
| Impact on mobility disadvantaged groups (those with no access to a private car) | Change in ridership | No-change | Increase | Increase |
| | Variability in fare paid/trip across groups | Medium | High | Medium |
| Geographical equity | | | | |
| Impact on people in different municipalities/ regions | Change in ridership | No-change | Increase for some & decrease for others | Mostly Decrease |

| | | | | |
|---|---|---|---|---|
| | Variability in fare paid/trip across municipalities | Medium | high | Low |
| Effectiveness | Change in total trips | No-change | 2.80% | -0.8% |
| | Change in revenue | No-change | 2.10% | 3.3% |
| Implementation Complexity | Low/Medium/High | Low | High | Medium |
| Community responses/Acceptability | | | | |
| Political | Low/Medium/High | High | Low | Medium |
| Commuters | Low/Medium/High | High | Medium | Low |
| Affordability | Lower/No-change/Higher than status-quo | No-change | Higher | Higher |

## 8.1. Equity

### 8.1.1. Vertical equity

- Impact on different income groups

1- Status Quo

About 60 percent of the trips made by the lowest two income groups are short distance between 0 and 10 kilometers. Earlier in Chapter 4 in Figure 4.2 it can be seen that the calculated average fare per kilometer for trips 0 to 5 kilometer is $0.59, while for trips 5 to 10 kilometers it is $0.26. The average fare per kilometer decreases substantially to $0.09 per kilometer for trips over 30 kilometers which are mostly made by riders from higher income groups. Nonetheless the average fare per trip for the lowest two income groups is lower than the other four groups. The fare per trip is constant though for incomes from $50,000 and up. This demonstrates the low effect of zone fares in creating variability in the average fare per trip across income groups.

2- Distance-based

This fare structure results in an increase in the trips consumed by all income groups since riders in all income groups make trips of all different distances. However because close to 60 percent of the two lower income groups trips are shorter distance trips (0-10 km), and they have the smallest percentage of longer distance trips (over 20

Kilometers), they tend to gain the most in terms of reduction in average fare per trip. It is interesting to note that riders from the highest income group are also able to reduce their average fare per trip. This group also has a higher percentage of shorter distance trips and a lower percentage of long distance trips. This is a unique characteristic to Metro Vancouver because of its regional growth strategy and planning decisions that made the Vancouver downtown core and many other town centres desirable places to live, and hence more expensive in terms of real estate. It is possible that many high income individuals can afford to live closer to their place of work including expensive real estate locations such as in downtown Vancouver or areas surrounding it.

3- Time-of-day

The overall fares and fare per trip increase for all income groups, however the three lowest income groups experience a smaller increase in fare per trip, and a slight reduction in overall trips compared to higher income groups. Riders from these income groups tend to do most of their trips during the midday off peak period. They would therefore tend to benefit from the fare structure proposed in the policy options that reduces fares during midday to concession fares.

- Impact on mobility disadvantaged groups by age

1- Status quo

The zone fare structure might seem equitable to the younger and older age groups since most of their trips are shorter in distance i.e. paying mostly one zone fare, however a closer look at the data does not support that conclusion. For FareCard users where the price is the same for all zones, and where long distance riders tend to have a much larger subsidy, it is still fairly affordable for these age groups. However the inequity is more apparent when riders from these age groups pay using cash or FareSaver tickets. Their fare per kilometer is much higher for shorter distances as can be seen in Table 4.3. For example the fare per kilometer for a trip distance up to 5 kilometers is $0.59 per kilometer, and for subsequent trip distances 5-10 km it is $0.26 per kilometer, and for 10-15 km it is $0.20 per kilometer, therefore the fare per kilometer for 0-5 km is three times as much as that for 10-15 km.

2- Distance-based

With distance-based fare structure, the younger 5-17 years, and older age groups 65 years and older can increase their overall trips while substantially reducing the average fare per trip. Riders from these age groups travel the shortest distances on average out of all other age groups and as a result benefit the most from distance-based pricing.

3- Time-of-day

The peak surcharge mostly affects age groups 25-44 years and 45-64 years, since riders in these age groups use transit mostly during peak times. There is a slight improvement in terms of increase in total trips and decrease in fare paid for age group “Over 65”.

- Impact on mobility disadvantaged groups by captive versus choice riders

1. Status quo

Captive riders pay about 14 percent less in average fare per trip than choice riders, which is due to the fact that they make shorter distance trips and hence pay for the lower fare zones.

2. Distance-based

The average fare per trip for captive riders is reduced by 8.4 percent, while choice riders pay 5.3 percent more than with status quo. With distance-based fares captive riders pay 25 percent less than choice riders while increasing their total trips by 5 percent.

3. Time-of-day

For both groups, there is a slight reduction in total trips, and just over 3 percent increase in fare per trip. Time-of-day fare structure impacts both captive and choice riders similarly.

### 8.1.2. Geographical equity:

1- Status Quo

The average fare per trip varies across municipalities which reflect the proportion of different zone trips taken by riders in each municipality. So for example the average fare per trip in Vancouver is $1.93 while it is $2.50 in Surrey. This reflects the fact that Vancouver residents make a higher number of shorter distance trips which require a one-zone fare, while Surrey residents make higher number of longer distance trips that require 2 and 3-zone fare.

2- Distance-based

The same variation in average fare per trip is observed with distance-based pricing, however the differences are larger. Taking Vancouver and Surrey as an example once more, it can been seen that the fare per trip decreases for Vancouver to $1.65 while the fare per trip for Surrey riders increases to $2.96, which is a more accurate reflection of the difference between the ratio of short to long trips in both municipalities.

Distance-based pricing also results in an increase in trips and reduction in fare per trip for riders from the three north shore municipalities. Riders from these municipalities if travelling outside the North Shore immediately cross a fare zone border and have to pay a 2-zone fare even if the distance they are travelling is short. Similarly riders from Vancouver see a large decrease in fare per trip because currently once they leave the city of Vancouver they cross a fare zone boundary and are charged the next fare zone, even if their trip is short.

3- Time-of-day

The percent change in trips across municipalities is either slightly lower or slightly higher than 0 percent. The fare per trip increases for all municipalities except three; Maple Ridge, Port Moody, and White Rock which could be due to a higher proportion of trips being made during off-peak periods. The fare per trip increase varies from 0.5 percent in West Vancouver to 6.1 percent in Vancouver. Again the high percentage increase in Vancouver could be due to a higher proportion of peak to off-peak trips.

## 8.2. Effectiveness

1. Status-quo

The zone structure or status-quo is used as a benchmark to measure the effectiveness of the other two policies. It is important to note again that the results of the analysis show change in ridership and revenue for existing riders only. Earlier in the methodology section it was explained that the model used to estimate change in demand only predicts change for existing riders and for the types of trips they are currently making. The model does not take into account any change in ridership due to new riders or existing riders making other trip types than the ones they already make.

2. Distance-based

Both ridership and revenues increase with distance-based pricing. With the variable elasticity value the percent increase in ridership is higher than the percent increase in revenues. The constant elasticity value -0.2 however results in a higher increase in revenues than ridership. It was mentioned earlier that using the variable elasticity value overestimates the response of riders for fare reduction, while the constant elasticity value underestimates it. This leads to predicting more short distance trips and less long distance trips with the variable elasticity, and vice versa with the constant elasticity. These results demonstrate the importance of developing accurate agency specific elasticity measures in order to improve forecasting exercises. Another reason for the variable relative impact on revenues and ridership could be due to the requirement I imposed of revenue neutrality when devising a new fare structure. Nonetheless, from the two case studies examined for this research it is obvious that cost recovery can be very high with this fare structure while also attracting a high percentage of choice riders.

3. Time-of-day

While ridership decreases slightly with time-of-day pricing overall revenues increase by more than 3 percent and the fare per trip by more than 4 percent. There is also a shift in the number of trips from peak to off-peak, where peak trips are reduced by close to 3 percent and off-peak trips increase by just below 3 percent. This policy achieves two goals; one it raises overall revenues which recovers some of the extra costs incurred during peak period, and it shaves off a bit of the peak period ridership. Although the reduction is only 3 percent it can help delay capital expenditure to expand the current system to accommodate peak period ridership. Time-of-day or peak pricing can be applied on its own or combined with other strategies such as distance-based pricing, depending on what the transit agency's goals and objectives are.

## 8.3. Implementation Complexity

1. Status-quo

   There is no administrative or public education effort required with this option.

2. Distance-based

This fare-structure is quite complex in terms of administration and public education. In doing the simulation work for this research, I went through many steps analysing the current fare structure and determining average fare paid by different groups of riders in order to determine a new set of distance-based fare structure. This exercise is an indication of the complexity of adopting distance-based pricing with the consequences of changing all of TransLink's accounting system, fare vending and collection, and public education. However the use of the smart-card technology "Compass" should facilitate gathering and analysing trip detail information that is not available through the on-board trip survey.

The two transit agencies interviewed for this research, have at some point evaluated other fare structures in hopes of finding a simpler and more user-friendly structure. However both attempts did not result in any change due to the inherent inequity with the other fare structures namely flat and zone structures.

3. Time-of-day

This fare structure still requires administration changes, in terms of all the changes required to fare vending and collection equipment, accounting systems, and public education. However it is less complex than distance-based pricing. One of the biggest challenges with time-of-day pricing is the problem of delays in transit service delivery caused by system breakdowns for Skytrain or SeaBus, traffic congestion affecting bus schedules, and other factors. If the delay spills over from an off-peak to peak period, the challenge is how to avoid charging customers who fully intended to reach their destination before the peak fare applied (Smith, 2009).

## 8.4. Community Response/Acceptability

1- Distance-based

**Political response**: from the geographical equity results it would be hard to imagine that there would be strong support for distance-based pricing especially from municipalities where the average fare per trip could increase by close to 25 percent. Transit services in most of these municipalities are not extensive and/or frequent, and the existing sentiment in suburban municipalities is that the system is inequitable because of the lack of sufficient transit infrastructure and service. In a recent report prepared by the city of Surrey for the TransLink's Mayors' Council, the large gap in infrastructure and services between the North and South of the Fraser municipalities was emphasized. The report highlights that 56 percent of Metro Vancouver population lives north of the Fraser, namely in Burnaby, Vancouver, tri-cities, Richmond, and New Westminster, and gets 68 percent of bus funding. While 31 percent live south of the Fraser and get only 19 percent of the bus funding. Similarly the north has 68 kilometers of rapid transit tracks, while the south has 6 km only (Ferguson, 2014).

In an article appearing in the Georgia Straight in October 2013, opinions were divided on the acceptance of the fare structure. One politician believed that distance-based fares might disproportionately affect low-income riders more than other groups. While another finds it more equitable since it improves some of the issues with the current system such as paying for an extra zone even if travelling short distances (Pablo, 2013). Most likely politicians from North of the Fraser and North Shore municipalities would be more supportive of distance-based pricing.

**Commuters:** Most riders would probably be receptive to distance-based pricing since most trips in the region are short distance trips. Market research of transit users around the world has shown that riders prefer fare structures that reflect actual distance travelled over flat fares since they find them more equitable (Streeting and Charles, 2006). Riders whose fares will decrease as result of the policy will be very supportive while riders whose fares will increase will not be supportive. Riders whose fares will increase will be long distance travellers probably travelling from areas where the service is indirect i.e. requires more than one exchange, and infrequent. It is unlikely that riders in these areas, which are mostly south of the Fraser, will support distance-based pricing especially if it is not complemented with a substantial improvement in service. As one Vancouver councillor pointed out that riders might pay more for long distance trips “if they get there quickly and it’s a quality experience, but if they have to pay more to stand for 45 minutes or an hour on a jammed bus that’s only coming every 20 minutes, they probably won’t continue” (Pablo, 2013).

2 Time-of-day

Politicians are usually supportive of this strategy since it results in increase in transit revenues with minimal reduction in ridership. It also shifts some of the peak ridership to off-peak which would delay the need to expand the system to accommodate the increase in peak trips (Cervero, 1986)

Most commuters would likely oppose this strategy since most trips are made during peak periods. This strategy would raise the fare for anyone making a trip during this time. Many people don’t like the idea that publicly provided services should be “allocated on the ability to pay” (Smith, 2009).

## 8.5. Affordability

1. Status-quo

The costs of monthly passes with the current zone structure are used as a benchmark to compare how the other fare structures increase or decrease transit cost for low-income households. I do not attempt here to evaluate or score the affordability of the current fare structure; it is just used for comparison.

2. Distance-based

The cost of a monthly transit pass in proportion to the income of a low-income household is shown in Table 5.19. With distance-based fares, trips up-to 10 kilometers in distance are paying either less or the same as the cost of a 1-zone fare. Households making 10 to 15 kilometer trips are paying close to the cost of a 2-zone fare. While 1 and 2-person households making 15 to 20 kilometers trips are paying the same cost of a 3-zone fare, but for 3 and 4-person households this cost is 15 percent more than a 3-zone fare. Households making trips over 20 kilometers are paying substantially more than the current cost of a 3-zone fare; between 30 percent and 40 percent more. The cost of a monthly pass increases substantially for 2, 3, and 4 person households to the extent of costing them about 18 percent of their annual income. However looking at Table 5.5 we see that 65 percent and 55 percent of the trips made by the lowest two income groups are between 0 and 10 kilometers. The cost for these groups is either reduced or remains the same as a one-zone fare. So although a number of households are highly disadvantaged by this fare structure, a greater number benefit from it; and this has been demonstrated earlier. An important point would be that it is more cost-effective to offer low-income groups who are disadvantaged by this price change a subsidy, than subsidize all riders to avoid increasing the price for a small sector of riders.

3. Time-of-day

The cost increases for all households with time-of-day fares, since a 20 percent surcharge is applied to all regular fares at peak times. The increase is 20 percent for one and two person households, and less for three and four person households because the 20 percent increase is not applied to concession fares. The scenario used to calculate the change in fare for time-of-day pricing is probably the maximum increase that a household would experience with this fare structure, because it assumes that all persons in the household are making 40 trips per month all during peak-time period. From earlier results, it was shown that the two lowest income groups make more trips during the midday time than any other group. Therefore the overall increase in fare per trip for these two income groups is much smaller than other groups. However for comparison reasons the same scenario is used for all fare structures.

In conclusion, the results from this analysis reinforce information that differentiated fares improve equity and efficiency. Although I was not able to assess efficiency because of the lack of detailed cost information, I was able to assess effectiveness by evaluating change in ridership and revenues. The regional trip diary survey data provided a lot of detail in order to run the simulation; however some key pieces of information were missing; Information such as zone travelled, cost per trip, and method of payment. Nonetheless, I was able to make certain assumptions and use other pieces of data to resolve these issues. In the future, these problems should be overcome with the introduction of the smart card “Compass”. In the next chapter I present some recommendations based on the results of this analysis and the qualitative review, to guide a fare policy review process.

# Chapter 9. Assessment and Recommendations

The results of this project reinforce findings by transit scholars and economists, and results from other regions that differentiated pricing improves equity and efficiency. The simulation done on distance-based pricing shows a considerable improvement in equity by income, age, and transit-dependency, as well as an increase in revenues. Geographical equity is probably the only measure that does not improve for all municipalities which is mostly due to the extent and frequency of transit services offered across the different parts of Metro Vancouver; and because downtown Vancouver and the Broadway corridor[10] still remain the largest business centres in the region. The time-of-day pricing simulation shows a potential of improving cost recovery and shifting some peak ridership to off-peak periods, with minor reduction in overall ridership.

Changing the fare structure to a more differentiated form has the potential of improving many operational, financial, and service aspects. Also the advancement in fare collection technology with the use of smart cards can certainly facilitate the use of complex fare structures. However, Canadian and US transit agencies have been reluctant to adopt differentiated fare structures for many reasons. A study conducted in the US in 2013 investigated transit agencies reasons for fare restructuring, and their fare policy goals. Two interesting findings emerged from this study; 1- fare changes are usually done in reaction to budgetary crisis and there is rarely time to review the fare structure or fare policy objectives. The underlying cause for this problem seems to be the agency's contradictory goals and objectives that hinder the ability to have a clear direction to base decisions on. 2- Transit agency executives and decision makers are "risk averse" and will try to avoid any changes that might attract public scrutiny or inquiry

[10] The Broadway corridor is the second largest office district in the province of BC, after downtown Vancouver. It is an area that stretches from the east side to the west side of Vancouver around Broadway.

for two main reasons; one is because fare restructuring is a substantial change from the status-quo, and two because they are worried about ridership losses. Interestingly transit agencies often do not consider ridership that they might gain because of implementing differentiated fare structures, or have conducted market research to gauge the public's view and preference for differentiated fares (Yoh et al., 2012).

Based on these considerations, in the next few paragraphs I make a few recommendations to help improve the process of setting fares and forecasting ridership changes, while minimizing stakeholder opposition in the Metro Vancouver region.

**Fare Policy**

TransLink should consider developing a fare policy with clear objectives and goals that complement the Regional Transportation Strategy. The fare policy will help improve decision making on fare structure and price changes by avoiding reactionary decisions whether it is due to budgetary shortfalls or to stakeholder opposition. It is also important to be clear on what specific problems with the current fare structure that the agency hopes to address with a new fare structure.

When setting objectives and goals the agency needs to be realistic about what the fare structure can achieve, and avoid contradicting objectives. Contradicting objectives might include keeping fares low to improve affordability for low-income people and to encourage non-riders to switch mode, while improving coverage to low transit demand areas. These types of contradicting objectives are problematic because in order to keep transit affordable, fares have to be kept low which could be achieved by increasing low-cost transit services. However to improve coverage in low-demand areas, it means providing high cost services. It is contradictory objectives such as these that make achieving financial and operational efficiency elusive. Yoh et al. (2012), in "Does Transit Mean Business" acknowledges the difficulty of a public transit agency to overcome the problem of contradictory and unaligned goals of the multiple stakeholders involved in or influencing decision making. Public transit is thus unlike its private counterparts who can orient all parts of their business towards increasing profits. Regardless of how complicated it is to align goals, it is essential for the long-term financial sustainability of the agency and services provided, to ensure there is an efficient and equitable fare structure in place.

**TransLink should consider differentiated pricing along with service offerings**

As mentioned earlier, there are many forms of differentiated fare structures that transit agencies can use. The choice depends on what the agency is trying to achieve. Overall, Metro Vancouver riders and TransLink can both gain by switching to distance-based and/or time-of-day pricing. I have examined each separately and have illustrated the effect of each on ridership and the agency revenues and operations. There could be however more efficiencies to be gained by combining the two structures or exploring other fare structures such as service-based. Regardless of the fare structure that TransLink is interested in pursuing, it would be beneficial if the agency evaluated its current and potential service offerings with respect to the fare price and structure. For example if the agency decides to pursue distance-based pricing, it could face significant political and public opposition from municipalities south of the Fraser River, as explained in the policy analysis chapter. But if the fare structure change is accompanied by substantial improvements to the quality of the service especially in terms of the frequency and speed, then the change could be more acceptable. A fare structure change on its own is likely to be met with suspicion that the agency's goal is to raise more revenue and not to improve the service and equity among riders. TransLink would likely benefit from pursuing a process similar to what Go Transit is currently undertaking, which is an integrated review of fare structure and service integration.

Another important issue to consider when dealing with geographical and income inequities is to offer concessions through targeted programs, but not by keeping financially unsustainable low fare levels to benefit a few. Low fares subsidize wealthier riders unless they can be targeted to low-income people. The greater the subsidy, the more the pressure on the transit authority to find means of taxing residents to make up the difference between fare revenue and cost of service. For example by offering targeted subsidies to low-income individuals, similar to programs offered to post-secondary students or low-income seniors, the regular fares could be adjusted to signal a more accurate reflection of the variability in cost in providing transit services, while keeping fares affordable to low-income individuals. This sort of initiative would require considerable research and outreach to designate who is eligible as well as cooperation from the provincial government in identifying the target individuals.

Similarly geographical inequity can be dealt with by improving service offerings. Most riders would pay the extra costs of travelling long distance trips if it is a good quality service i.e. fast and comfortable. Research has shown that generally riders are twice as sensitive to service changes versus fare changes (Cervero, 1990). For most choice riders who can make the trip by car, it is a matter of whether they can achieve any time savings by transit that warrant foregoing driving (Vancouver Sun, 2013). For most car owners the price of the car and insurance are sunk costs, they usually make their decision on whether to use transit or not, by evaluating the difference between the price of gas and parking versus the fare price and the trip time. The fare price is certainly competitive with the high gas and parking prices in Metro Vancouver. But the trip time and service quality is often weighted more heavily than these costs. According to the latest Statistics Canada's latest National Household survey, the average commute to work is still shorter by car, 26.4 minutes versus 40.9 minutes by transit (Vancouver Sun, 2013).

**Improve forecasting model**

As demonstrated by the data analysis done for this research, it is important for a transit agency to have a robust model to forecast ridership changes with respect to the factors that affect it. The use of two different elasticity variables in the simulation work produced different results, which reiterates the importance that TransLink develop its own elasticity values. Riders' response to fare changes is affected by many variables as discussed in chapter 2, and the use of one value to capture all these different variations might not produce an accurate forecast. Riders' response is affected by many other factors some internal to transit such as extent and type of service, trip time, frequency, etc. and some are external to transit such as gas prices, employment rate, and other economic indicators. It is important for TransLink to develop its own forecast model with own elasticity values that capture the unique characteristics of its riders, system, and regional economic conditions.

The model developed for this research also did not project the potential new ridership, which could add a few thousand trips more per day. Conducting market research to understand the motivations of potential new riders that the system could gain is necessary in order to get a full-picture of all the gains and losses that could be expected. TransLink needs to also get a deeper understanding of how its costs vary by different modes, routes, directions, time-of-day, etc. in order to assess the efficiency of the current fare structure, and potential new ones.

**Conclusion**

In summary, this research has demonstrated that variable/differentiated fare structures could substantially improve the efficiency and effectiveness of the Metro Vancouver transit system and equity among its riders. Therefore, as TransLink is preparing to review its fare policy it is recommended that they consider differentiated pricing, specifically distance-based pricing for two important reasons:1- because it reinforces regional growth plans in promoting complete communities where people are in close proximity to work, play and essential services and 2- it has the potential to improve cost-recovery and hence reduce the uncertainty with revenue generation, especially as gas tax revenues are decreasing and other services are competing for the same tax sources.

A fare policy with well-defined objectives and goals that is politically and publicly endorsed is essential to improve and guide future fare setting. Fare increases are a sensitive issue and without guidance on how the fare structure complements and advances the transit agency's service and financial goals, then it would be left to shifting public opinion and politics of the day to determine the outcome of fare reviews.

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# Appendix A. Fare Elasticities

### How are Fare Elasticities Measured?

Fare elasticity is a measure used to represent the extent of change in transit ridership in response to a fare change. It is defined as the percent change in transit ridership due to a one percent change in the price of the fare. The sign of the elasticity value determines the direction of the change; a negative value means that the price change caused a decrease in ridership while a positive sign means an increase. Also the elasticity value determines how sensitive people are to the change. Hence a value of one is referred to as unit elastic meaning that a one per cent price change causes an equal change (one percent) in ridership. Values less than one are called inelastic because the relative change in ridership is less than the change in price (i.e. one percent change in price causes less one percent change in consumption) which also means an increase in revenue; and values more than one are called elastic because the relative change in ridership is more than the change in price while causing a decrease in revenues.

According to Pham and Linsalata (1991), transit fare elasticity can be determined using one of the following three methods:

1- Stated preference surveys where users are directly asked about how they would react to a fare change either by changing their mode or frequency of travel.
2- Shrinkage analysis is a method that measures the effect on ridership before and after a fare change. This method is widely used because of its simplicity. However its major disadvantage is that it does not take into account all factors that affect travel demand, such as trip purpose, time of day, gas prices or unemployment rates that might occur simultaneously to a fare change. When using this method to predict ridership change in response to a fare change, the analyst has to assume that all other factors that affect travel demand are constant.
3- Econometric methods are a more preferable because they overcome the disadvantage of the before and after methodology by determining travel demand with respect to all its explanatory factors. Many factors are considered by

travelers when they make a decision about a trip, these factors include purpose of trip, time of day, price of alternative travel modes (e.g. gasoline price, transit fare, etc) and many others. Using statistical methods the relationship between historical ridership data and travel demand explanatory factor can be determined. From the travel demand function the effect of the transit fare could then be "isolated" to determine the fare elasticity.

Although econometric methods provide a more accurate estimation of elasticity values, many analyst and transit agencies do not have the time and means to conduct such analyses. Therefore a more simple approach such as before and after measure is usually used with imputed elasticity values taken from studies that have done the econometric analysis. Several mathematical formulas can be used to calculate elasticity depending on the shape of the demand curve (Pham and Linsalata, 1991). These are point elasticity, arc elasticity, and mid-point arc elasticity. Point elasticity (equation 1), which is the most simplistic approach to calculate elasticity if we only have two data points, assumes a linear demand relationship between the two data points i.e. straight line with constant slope. The problem with this approach is that it assumes the direction of change does not matter to the level of the demand, just the sign differs (Cervero, 1982). We know from literature that the demand curve is not linear and that demand tends to be more sensitive to fare increases than fare decreases (Cervero, 1990).

Therefore if the shape of the demand curve is not known then Arc and mid-point arc elasticities are better measures for elasticity. Both methods establish a hyperbolic relationship between two points. Arc elasticity measures the change in consumption incrementally for each 1 percent change in price (equation 2). On the other hand, mid-point arc elasticity expresses change "in relation to the arithmetic average of the "before" and "after" price and consumption level."(Equation 3) (Cervero, 1982; Litman, 2013a).

$$\text{Point elasticity} = \frac{Qa-Qb}{Qb} \div \frac{Pa-Pb}{Pb} \qquad \text{Equation 1}$$

Qb and Qa are quantities before and after price change and Pb and Pa are prices before and after

Arc elasticity = $\frac{\log Qa - \log Qb}{\log Pa - \log Pb}$ Equation 2

Mid-point arc elasticity = $\frac{Qb - Qa}{1/2(Qa+Qb)} \div \frac{Pb - Pa}{1/2(Pb+Pa)}$ Equation 3

So which method is the most appropriate to use? Cervero (1982) suggests that for very small price changes all three equations yield similar demand results. However for large price changes the results will be different depending on whether the price change is an increase or a decrease. For example point elasticity yields larger ridership losses with price increase than the arc or mid-point arc elasticities. Balcomb et al. (2004) recommends using arc elasticity because it generates a convex demand function which supports empirical evidence that fare-demand functions are actually convex.

**Determinants of Transit Fare Elasticity and Values**

The first comprehensive study to compile fare elasticities from a large number of cases produced the industry standard or rule-of-thumb called Simpson-Curtin rule. The study analysed elasticities from 77 cases of transit fare increases over 20 years. The study evaluated the percent change in ridership over the three months period following an increase in fare; and concluded that demand for transit "declines by one-third of one percent for every one percent increase in fare" meaning that the price elasticity rate is -0.33 (Cervero, 1990)

Many studies have been published since then looking at specific cities, factors that influence elasticity, short-run and long-run, revealed and stated preferences, etc and hence a large body of research on the effect of fare changes on transit demand/ridership is available.

The information on factors that affect fare elasticity and the values summarized hereafter is from US, UK and/or Australian studies (Cervero, 1990; Litman, 2012; Litman, 2013a; TRL, 2004, TCRP 95). Most of these studies are based on "revealed preference" i.e. observed behaviour data and less on "stated preference" method i.e. a sample of users are asked a set of hypothetical questions on the proposed change in order to estimate potential demand change.

**Trip Type:** Work and school trips tend to be less price sensitive than “choice” trips like shopping and leisure. Riders commuting to work or school have little choice in whether to make the trip or not or the trip time, therefore their price sensitivity is much less than choice riders who could forgo the trip all-together if the price is too high for them.

**Peak/off-peak:** This factor is sometimes considered as a subset of trip type since most work and school travel is during peak times while leisurely travel tends to be during off-peak times. It is found that elasticity for off-peak travel is generally 1.5 to 2 times higher than peak travel.

**Table A.1. Bus Fare Elasticity: Peak and Off-Peak Travel for Select US Cities**

| | Peak | Off-Peak | Population |
|---|---|---|---|
| Spokane, Washington | -0.32 | -0.73 | 266,709 |
| Grand Rapids, Michigan | -0.29 | -0.49 | 374,744 |
| Sacramento, CA | -0.22 | -0.14 | 792,266 |
| Group I Average | -0.27 | -0.45 | 1 million and less |
| Portland, OR | -0.20 | -0.58 | 1,026,144 |
| San Francisco, CA | -0.14 | -0.31 | 3,190,698 |
| Los Angeles, CA | -0.21 | -0.29 | 9,479,436 |
| Group II Average | -0.18 | -0.39 | 1 million and more |
| All Systems Average | -0.23 | -0.42 | |

Source: Adapted from Pham and Linsalata (1991)

**Access to a car:** captive riders who have no access to a car tend to be less sensitive to price change than choice riders (those who have access to a car), simply because their travel choices are limited. Off-peak fare elasticities for riders in Denver showed that captive riders have a (-0.25) elasticity versus (-0.31) for choice riders. Similarly a study of work related trips on buses in London revealed that the elasticity of choice riders was (-0.41) and that of captive riders was (-0.1).

**Household Income:** The general belief is that people with high incomes tend to be more price-sensitive because they probably own a car and hence have an alternative to public transport. On the other hand low income people are less sensitive to price change because they most likely do not own a car. However some argue that higher income people should be able to tolerate a fare increase because the share of transport cost to their income is much smaller than a low income individual. And low income individuals can probably substitute transit with walking. This argument would be more applicable to short distance trips since it is feasible to walk.

Some studies have found that income elasticities vary by city size. A study in Manhattan found the opposite of the general belief; low income riders were found to be more sensitive to fare increases than higher income riders. This is attributed mainly to the fact that in dense urban areas low income people can walk to their destination while higher income riders mostly commuting from outside the city are willing to pay the higher transit fare which is still less expensive than commuting in congested traffic and finding and paying for expensive parking.

**Age:** the effect of age on price elasticity is debated. Generally it is believed that price sensitivity declines with age because the elderly are to some extent captive riders since they are less likely to be able to drive.

**Table A.2. Transit Fare Elasticities by Age Group**

| Age Group | Elasticity |
|---|---|
| Riders under 16 years old | -0.32 |
| Riders aged 17-64 | -0.22 |
| Riders over 64 years old | -0.14 |

Source: Adapted from Litman, 2012 p.9

**Transit Mode and Routes:** Fare elasticities vary depending on the transit mode used. Usually bus riders are the most sensitive to price changes followed by train then rapid rail riders. This is attributed mostly to the advantage of rapid rail being a faster and more reliable option than the bus. The bus is subject to road congestion and delay and hence is less predictable and less reliable. A study of the Chicago Transportation Authority bus and rail riders found that peak bus riders have an elasticity of (-0.30), and off-peak riders( -0.46), while rail riders have a peak elasticity of (-0.1) and off-peak riders (-0.46). Moreover, fare elasticities are found to be lower on routes that serve transit dependent riders and higher on routes where riders have different alternatives.

**City Size and Density:** City size tends to have an effect on elasticity where large cities have lower price elasticities than smaller one. This is probably reflecting the higher quality and more extensive transit service that can be offered in large cities. Research has also shown that price elasticities are inversely related to densities. In low-density suburban settings where transit services are less frequent and more inconvenient and where most people use their car small, any increases in fares usually have higher impact on ridership. In higher density and mixed-use areas people are less sensitive to price increases because transit is probably more convenient to use and car ownership might be less prevalent.

**Trip length**: Price elasticity is also affected by the length of the trip where short trips (2 km or less) have the highest elasticity which decreases for medium distance trips and then increases again for longer distance trips. The high elasticity for short trips reflects the possibility of substituting transit with walking or cycling while travel choices are limited as distance increases

**Time interval since Change:** fare elasticities are not static by any means they change with time and conditions. When a fare change is first introduced some people might be able to easily change their travel patterns to conform to the change while others will need more time due to difficulty in changing habits or due to economic or location constraints. For example over the longer term people might relocate, buy a car, etc. The effect of that delayed response causes elasticity to increase over the long-term, making long-run elasticities to be 2 to 3 as large as short-run elasticities. Therefore most of the research done distinguishes between short-run and long-run elasticities and sometimes medium-run. Short-run is usually defined as 1 to 2 years, medium-run from 5 to 10 years and long-run over 10 years.

**Transferability of Elasticities**

It is best to measure a region-specific elasticity to accurately reflect the dynamic interaction between variables that affect transit demand. However this is not always feasible and hence researchers seek out elasticity values for studies of other regions from the literature. It is crucial though when using elasticities from other regions and other times to carefully consider the situations in which these values were developed and the properties of the elasticities. As mentioned before elasticities are dynamic since they change over time due to changes in preferences and economic conditions, so it is important to consider the conditions in which elasticities were measured. The following list of factors should be considered when using “transferred” elasticity values (Balcombe et al., 2004; Litman, 2013a)

1- Socio-economic information  such as household income, transit spending relative to income, car ownership, extent of transit use/spit by mode
2- Regional characteristics such as employment rate, population, density, transit service area, modes of transit available
3- The time period over which demand was measured and if the elasticity represents the short or long-run
4- Magnitude, type and direction of fare change
5- Determine if elasticity was measured for groups of people or individuals
6- Purpose of the journey (work versus leisure)
7- The functional form of the demand function from which the elasticity is derived.

# Appendix B. Tables for Figures from Chapters 4 & 5

**Table B.1 - Trips by distance and Fare Zone**

| | #Trips | 1-zone | 2-zone | 3-zone | Avg. trip km | Total km | Total fare ($) | Avg. fare ($/km) |
|---|---|---|---|---|---|---|---|---|
| 0–5 km | 4,855 | 4,696 | 159 | - | 3.09 | 14,983 | 8,856 | 0.59 |
| 5–10 km | 4,523 | 3,575 | 948 | - | 7.40 | 33,479 | 8,843 | 0.26 |
| 10–15 km | 3,232 | 1,133 | 2,088 | 11 | 12.22 | 39,494 | 7,496 | 0.19 |
| 15-20 km | 2,045 | 333 | 1,578 | 134 | 17.37 | 35,518 | 4,904 | 0.14 |
| 20-30 km | 1,702 | 127 | 825 | 750 | 24.40 | 41,531 | 4,798 | 0.12 |
| Over 30 km | 867 | 21 | 139 | 707 | 36.83 | 31,931 | 2,728 | 0.09 |
| Total | 17,224 | 9,885 | 5,737 | 1,602 | 16.88 | 196,936 | 37,625 | 0.19 |

**Table B.2: Trips Taken by Method of Payment by Age Group**

| Method of payment | 05 to 12 | 13 to 17 | 18 to 24 | 25 to 44 | 45 to 64 | 65 to 79 | 80 plus | Total |
|---|---|---|---|---|---|---|---|---|
| Monthly pass | 2,916 | 35,501 | 41,248 | 111,354 | 67,445 | 18,284 | 3,044 | 279,792 |
| FareSaver tickets | 3,708 | 12,116 | 17,630 | 60,967 | 52,512 | 12,493 | 2,371 | 161,796 |
| U-pass | - | 4,632 | 122,564 | 32,743 | 2,371 | - | 142 | 162,451 |
| Employer pass | - | 173 | 797 | 23,815 | 14,891 | 1,530 | 79 | 41,287 |
| Annual pass | - | - | 2,733 | 23,002 | 25,069 | 24,485 | 4,709 | 79,999 |
| Cash | 1,588 | 4,432 | 11,712 | 28,746 | 19,522 | 8,879 | 1,764 | 76,643 |
| Total | 8,212 | 56,854 | 196,685 | 280,627 | 181,809 | 65,672 | 12,109 | 801,968 |

**Table B.3: Trips Taken by Distance by Age Group**

| | 05 to 12 | 13 to 17 | 18 to 24 | 25 to 44 | 45 to 64 | 65 to 79 | 80 plus |
|---|---|---|---|---|---|---|---|
| 0-5km | 5,378 | 28,405 | 30,470 | 68,047 | 44,284 | 28,147 | 5,428 |
| 5-10km | 1,937 | 18,409 | 48,392 | 67,527 | 46,181 | 15,629 | 4,145 |
| 10-15km | 643 | 4,084 | 39,944 | 61,394 | 35,964 | 10,082 | 1,150 |
| 15-20km | 60 | 2,568 | 33,705 | 34,895 | 23,192 | 4,672 | 565 |
| 20-30km | 194 | 2,309 | 27,795 | 33,998 | 20,212 | 4,287 | 437 |
| Over 30km | - | 1,079 | 16,379 | 14,765 | 11,975 | 2,855 | 384 |
| Total | 8,212 | 56,854 | 196,685 | 280,627 | 181,809 | 65,672 | 12,109 |