CUSTOMER RESPONSES TO DUAL MODE PERSONAL RAPID TRANSIT

by

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ABSTRACT

Since the 1960s the personal rapid transit field (PRT) has been building momentum as an exciting alternative to both the automobile and the bus. Work within the PRT field has been primarily engineering or scientific in nature. Little work has been done using the tools of marketing to validate customer expectations or desires around personal rapid transit.

This study focuses on dual mode PRT systems, which means vehicles that can switch from the PRT network to the normal road network at on/off ramps. Hypothetical dual mode PRT systems based on current knowledge are developed and conjoint analysis used to measure customer responses to the variable attributes of the potential systems. The attributes studied are the type of vehicle (electric, ultra-compact smart car and compact car), the price per month for access to the network and the distance from an on-ramp. The results suggest that dual-mode PRT is acceptable to customers and could be implemented using a toll road business model given a corridor of suitable density as show in chapter 5.3.1.

DEDICATION

To my wife Julia, without whose support and proof reading this would not have been possible.

ACKNOWLEDGEMENTS

I would like to acknowledge the enthusiastic support of Colleen Collins-Dodd, my thesis supervisor, who offered expertise, and encouragement, the support of my mother who helped me stay focused and moving, and the excellent MBA team at SFU.

Finally I would like to acknowledge Richard Prutton for introducing me to the PRT concept and acting as an engaged thesis sponsor.

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GLOSSARY

APM	Automatic People Mover. A computer controlled train, car or bus that moves people in a driverless fashion.
PRT	Personal Rapid Transit. A type of APM whereby people commute in their own vehicles without making intermediate station stops to their final destination.
Dual Mode	A form of PRT where the vehicles operate in two modes: a track-attached APM mode and driver controlled mode.
Headway	Space between cars. A greater headway implies a lower capacity.
Bogey	Device that connects the vehicle to the track (wheels, suspension and a frame). The term was appropriated from carts used in mines where a wood box sits on the bogey.
P3	Public Private Partnership

1 INTRODUCTION

When asked what brought him from retirement to run Day4 Energy[1] at his advanced age, Dr. John S. MacDonald (co-founder and former CEO and Chairman of MacDonald Dettwiler & Associates Ltd., one of Canada's leading aerospace firms) responded that *"the chance to make the world a better place only comes along once in a lifetime."*

Personal Rapid Transit (PRT) technically represents an opportunity to make the kind of difference that MacDonald is referring to. A PRT system is one where each commuter drives a special car on ordinary roads to an on-ramp, at which point the car is connected to a high speed track that takes the user to an off-ramp near their destination.

The contribution of PRT involves several dimensions of the commute to work, one of Canada's biggest polluters and time wasters. The gains are along the lines of:

- Reduction in energy consumed by commuters;
- Use of more efficient energy (electricity vs. gas);
- Increase in safety;
- Reduction in chemical and noise pollution.
- Gains in quality of life of commuters by increasing safety and reducing the amount of time of their commute.

Day 4 Energy is a company that is working to make cost effective solar energy,

1.1 Aim of research

The user element to PRT remains very much under-researched in comparison with the technical side. This thesis investigates whether there is a base of interest and support for such systems among commuters, and whether any gains need to be traded off against a lower standard of living, as is the case with high density living and public transit. Issues include reduced travel costs, longer possible commute distances, and increased personal velocity. While antagonists argue that technologies such as these will increase urban sprawl, it must remembered that people continue to "vote" for urban sprawl as they continue to move further and further from the downtown core.

The PRT field has been evolving incrementally but has not yet achieved success. In this research, a literature review is conducted of the PRT industry (chapter 2) in comparison with automobile and public transit. This research serves to gain an overview of PRT and determine what can be considered as a given and what can still could be influenced by commuter preferences aiding the adoption of the system. In chapter 3 this information is used to create and conduct a survey, the results of which appear in chapter 4. Given these adoption rates and customer preferences, chapter 5 shows the relationship infrastructure costs and revenue for a business using a "toll road business model,[2]" which is is the closest model to how a PRT system could operate as a business.

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[2] A major Canadian toll road is the 407ETR which has been a private toll road since the mid 1990's. http://www.southbendtribune.com/apps/pbcs.dll/article?AID=/20060123/News01/601230334/-1/NEWS01/CAT=News01

[4] Jon Bell grants permission to reproduce at: http://web.presby.edu/~jtbell/transit/usage.html

2 PERSONAL RAPID TRANSIT

This chapter introduces PRT and compares it with the dominance of the automobile and the downward spiral in the use of public transport. This integration, combined with the green issues of transportation, barriers to the adoption of PRT and the possible configurations of PRT, leads to an understanding of what remains under-investigated and hence what needs to be understood of PRT if it is to have a chance of becoming a serious player.

2.1 What is PRT

In his paper "Some Lessons from the History of PRT," Anderson (1996) has traced the evolution of the dream of PRT back to 1953, and reports that the field has been continuously evolving since then in fits and starts. Anderson introduces us to the PRT dream in very charitable terms when he says *"The development of automated urban transportation systems, among which PRT is considered to be the goal, has been a highly interactive process among a wide variety of professionals, politicians, and dedicated citizens. In examining the writings, it is clear that these people saw the need for a viable complement to the automobile, and they understood that such a complement could not be just more conventional transit. They were willing and able to invest freely of their own time and treasure to realize a dream."*

To fully understand Anderson's PRT world, we must understand the full PRT dream. Komerska (2002) defined a PRT system as one that should have 7 features.

1. *Fully automated vehicles capable of operation without human drivers.*

2. *Vehicles captive to a reserved guideway.*

3. *Small vehicles available for exclusive use by an individual or a small group, typically 1 to 6 passengers, travelling together by choice, and available 24 hours a day.*

4. *Small guideways that can be located above ground, at ground level or underground.*

5. *Vehicles able to use all guideways and stations on a fully coupled PRT network.*

6. *Direct origin to destination service, without a necessity to transfer or stop at intervening stations.*

7. *Service available on demand rather than on fixed schedules.*

The PRT experience is one where we join to the network at a time and location of our preference, and exit at or near our destination, without the waiting characteristic of a public transit system. The system serves us in a personal way by picking us up and dropping us off – at our convenience. We need not share our space with strangers, but can travel with whomever we prefer.

For many this vision is compelling, however, substantial barriers to adoption exist. These barriers have limited PRT development to concepts, test tracks, and airport systems. The leading PRT vendors are enumerated in Appendix A.

PRT systems come in two flavours, "dual mode" and "single mode." In a dual mode system (such as the one proposed in this paper) the cars operate on normal roads and on the PRT track. In a single mode system, commuters walk to micro stations spaced about one mile apart throughout the service corridor.

2.2 Brief History of PRT

Anderson (1996 p. 1) shows that from the 1950's to the 1970's PRT systems were competing with street-cars. *"Others, however, dreamed of a return to the glory days of the streetcar, the use of which had peaked in 1917 [1] and, due to preference for and availability of the automobile, declined in the 30 years thereafter as rapidly as it rose in the 30 years before. Many in the later group saw that if the concept of PRT matured, the hope of return to the streetcar, even under a new name, would be gone forever. The resulting clash between the new and the old was severe and must be understood if the history of PRT is to be fully appreciated."* Today people talk about the glory of light rail as that which we should return to, with Light Rail Now (2004), for example, publishing titles like "*Personal Rapid Transit – Cyberspace Dream Keeps Colliding with Reality*"

Since 1953 numerous configurations have been proposed. Anderson (1996) estimated, based on 46 design categories, that there are ten quadrillion possible PRT system configurations.

Commercially, the PRT field has not progressed far beyond its 1953 level. Many companies have build test PRT tracks. The only operational PRT system is located in Morgantown, West Virginia.

2.2.1 Morgantown Single Mode PRT

Operated by West Virginia University, the Morgantown PRT system connects the university's two campuses with downtown Morgantown. The line which opened in 1979 is 3.6 miles long and has 5 stations.

The cars run on rubber tires in a U shaped guideway, and seat up to 8 passengers. The stations in the system are off-line, which means that you board a car and it may carry you directly to your destination without stopping at intermediate stations (the stations are "off-line").

Figure 2.1 Photos of Morgantown PRT System

Pictures courtesy of Dr. Jon Bell, Presbyterian College, Clinton SC[4]

Dr. Jon Bell (2005) describes clearly how the system may be accessed in an almost PRT like fashion.

"During low-traffic periods, all cars stop at all stations. During high-traffic periods, cars bypass stations so that any station can be reached non-stop from any other station. When entering a station, passengers press a button on the entry turnstile that signals where they want to go, then proceed to a specific platform to wait for the next car to that station. Different platforms serve different destinations; some platforms "share" destinations, and use an overhead electric sign to indicate the destination of the next car. The PRT vision has not yet been achieved."

2.3 Public Transit and Transportation

PRT exists within the field of transportation, which is split between public transportation and automobile based transportation. Therefore these systems serve as the best basis of comparison when considering a PRT system. Public transportation includes rail, light rail, elevated light rail, bus, express bus, and subway systems. The automobile based system comprises cars, trucks, vans, commercial vehicles, alleys, streets, highways and freeways.

Jensen (1996) has concisely enumerated the key drivers of demand for transportation, and how they have been changing. The factors he identifies as putting increasing pressure on both the automobile and public transportation systems are:

- All big cities are growing (in population and area)
- The structure of the cities is changing (move towards suburbs)
- The traditional Central Business District is becoming less important and new suburban centres are created.

- The traditional family pattern is changing. Previously, the wife stayed at home taking care of the children. Now she is often working and the children are placed in some kind of child care centre.

- Shopping is often done at big shopping centres attracting customers from remote areas.

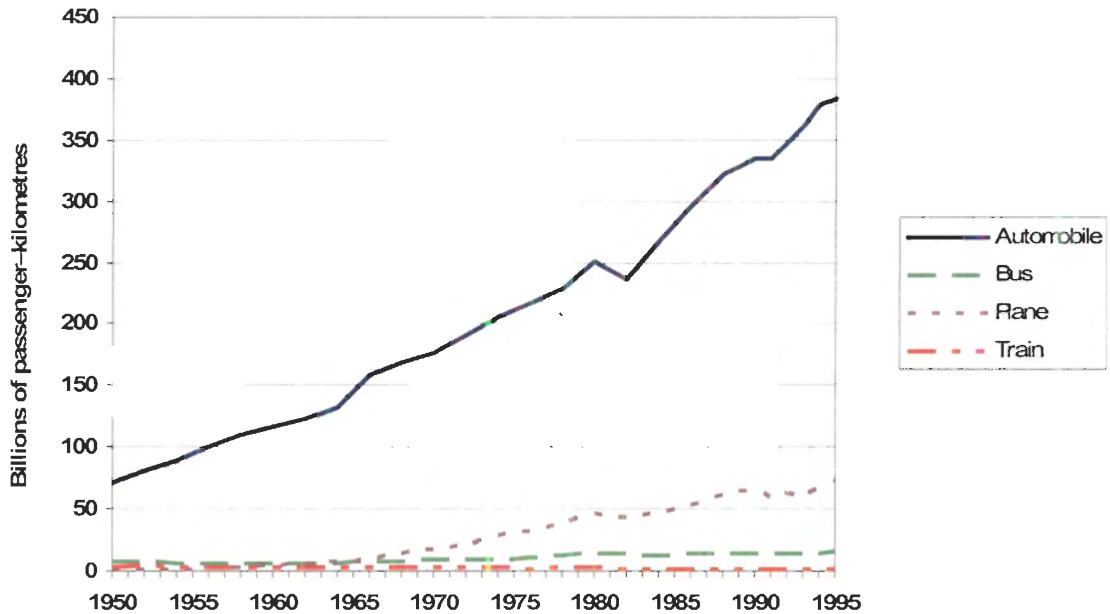
- The pace of modern life is faster than ever

- The modern family seems to be more actively involved in activities outside the home than ever before. The time schedule of a modern citizen is very tight. The activities are rarely common activities for the whole family, but each family member has its own rhythm.

2.3.1 Dominance of Automobile Transportation

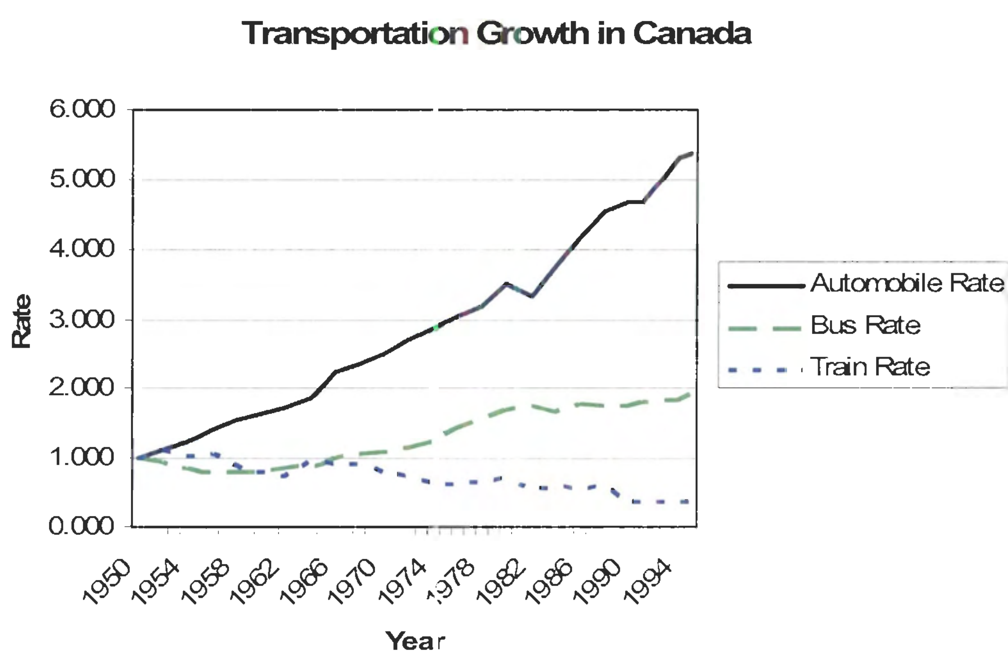
The automobile is characterized by a "feeling of safety and freedom". The Ottawa Citizen (1989) further suggests that "*Canadians [...] still have a deepseated love affair with their freedom machines.*" Drivers may come and go when they please, and once they are in their car it is safe for them to drive through questionable neighbourhoods or unfavourable weather conditions in "comfort and style." We can leave our personal belongings in our car in the off chance that we will need them, we can allow people into our car and give them a ride, or ride alone at our discretion. As shown in Figure 2.3 Canadian consumers have been overwhelmingly "voting" for automobiles with passenger-kilometres for busses in 1995 accounting for 4% of the automobile total. The number of automobile commutes has been growing at 2.5 times the rate of bus commutes, with the vast majority of all trips in Canada occurring in an automobile, as shown in Figure 2.3 and Figure 2.2 (Environment Canada (1995)).

Figure 2.2 Transportation in Canada by Type



Created using data provided by Environment Canada (1995).

Figure 2.3 Transportation Growth Rate in Canada by Type



Created using data provided by Environment Canada (1995). Planes excluded[5].

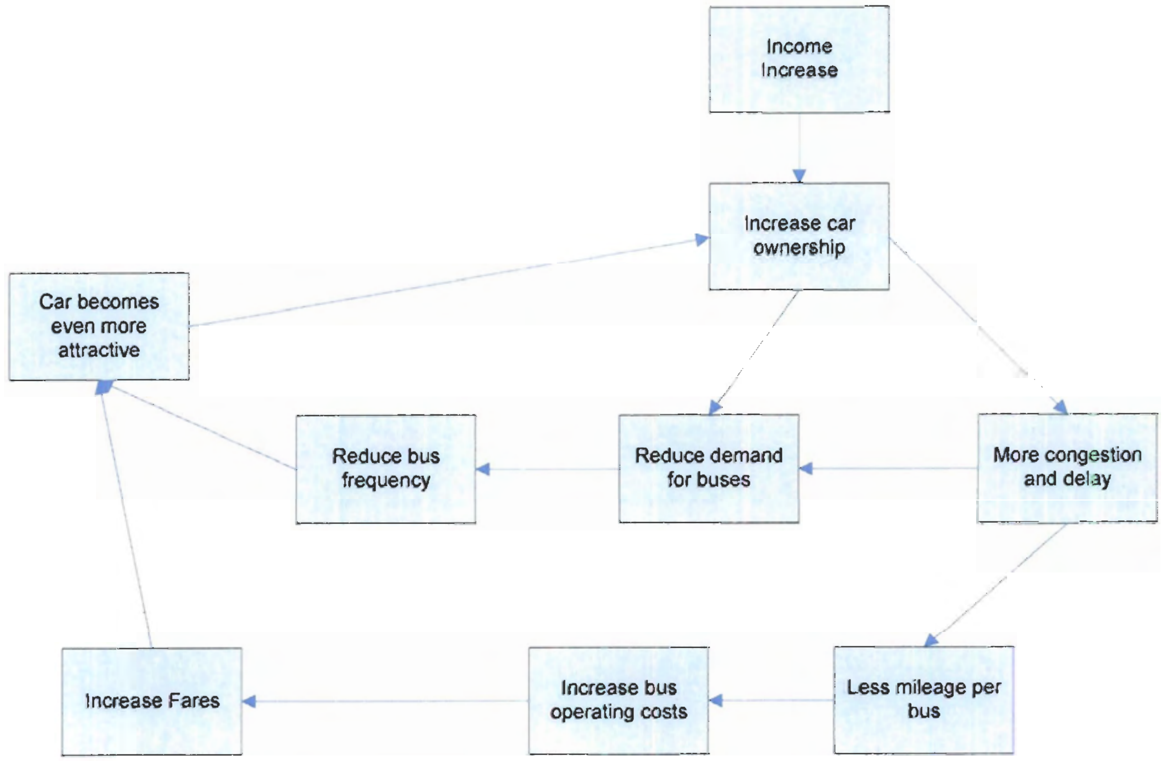
Criticisms of the personal automobile revolve around their externalities in the areas of congestion, pollution, fatalities, and land use.

2.3.1.1 Downward Spiral of Public Transit

The issue of transit is highly polarized, with many transit planners favouring public transit systems such as buses and trains, while consumers continue to adopt cars at higher and higher rates. In *"Modelling Transport,"* Orituzar and Willumsen (2001), a "downward spiral" is re-presented that leads customers away from the adoption of public transit and towards adoption of the automobile, as shown in Figure 2.4. As automobile adoption levels increase, service levels of bus systems decrease, thus increasing the incentive to adopt automobiles.

[5] Planes reach a relative growth rate of 90x during this time period.

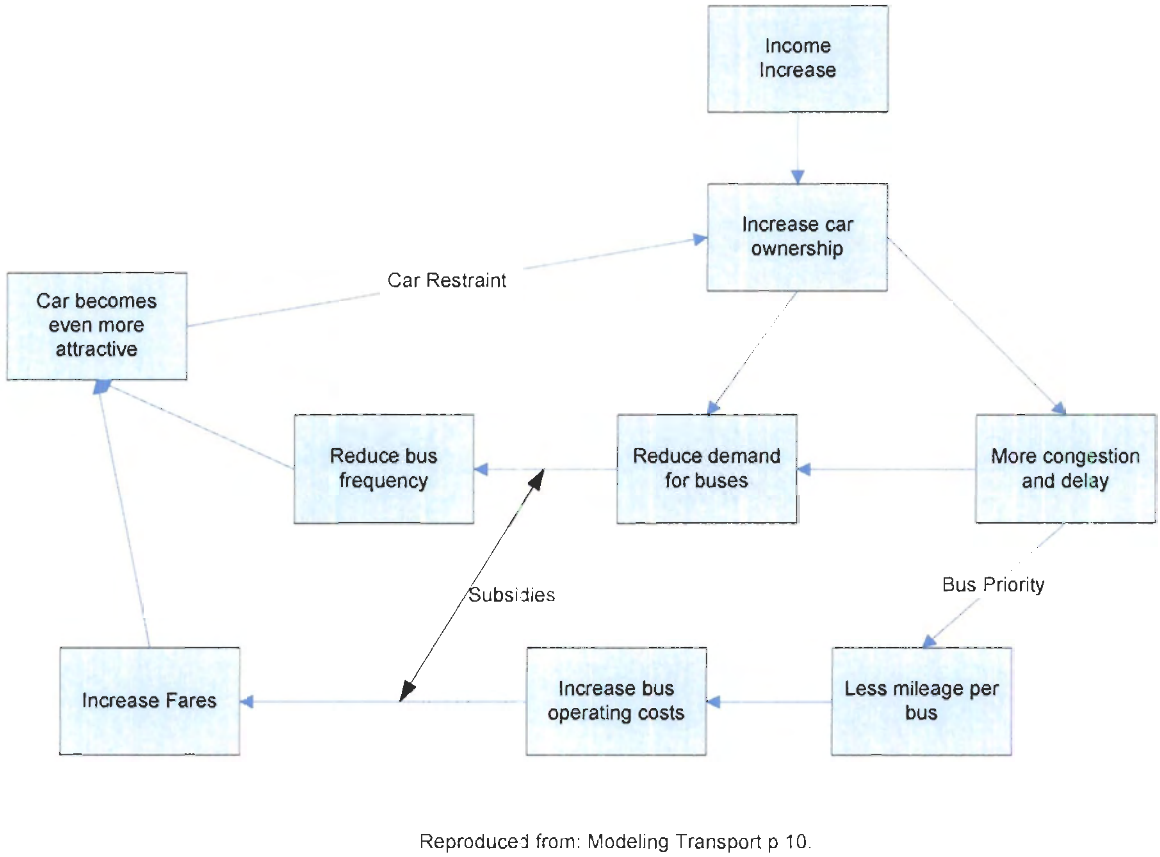
Figure 2.4 Downward Spiral of Public Transit



Adapted from Orituzar 2001.

The escape route from this spiral from the perspective of a city planner is to create bus priority lanes, and support the bus system with subsidies, as shown in Figure 2.5.

Figure 2.5 Downward Spiral of Public Transit – The Case for Subsidies



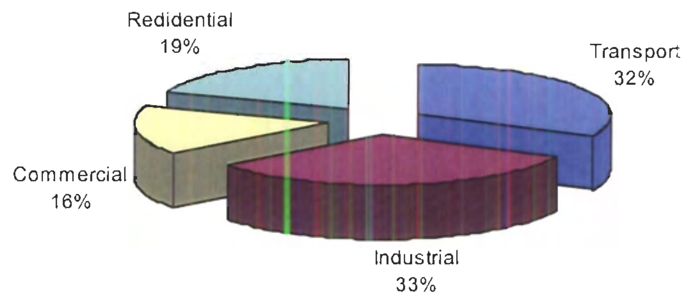
Adapted from Orituzar 2001.

This then has the effect of stimulating public transport above the market demanded levels. Orituzar then goes on to say "*special measures such as bus lanes must be provided to restrain cars more while providing priority to buses in situations of congestion.*" ... "*Public transport subsidies have strong advocates and detractors; they may reduce the need for fare increases, at least in the short term, but tend to generate large deficits and protect poor management from the consequences of their own inefficiency*" (Orituzar 2001, p. 9)

2.3.2 Green Aspect

Pollution from automobiles is viewed as a major source of global warming and in 1997 the U.S. Energy Information Administration (1998) reported, as shown in Figure 2.6, that 32% of emissions of green house gases are related to transportation. We may remember from Figure 2.2 that in terms of passenger kilometres automobiles dominate.

Figure 2.6 Energy End-Use Sector Sources of Carbon Dioxide Emission

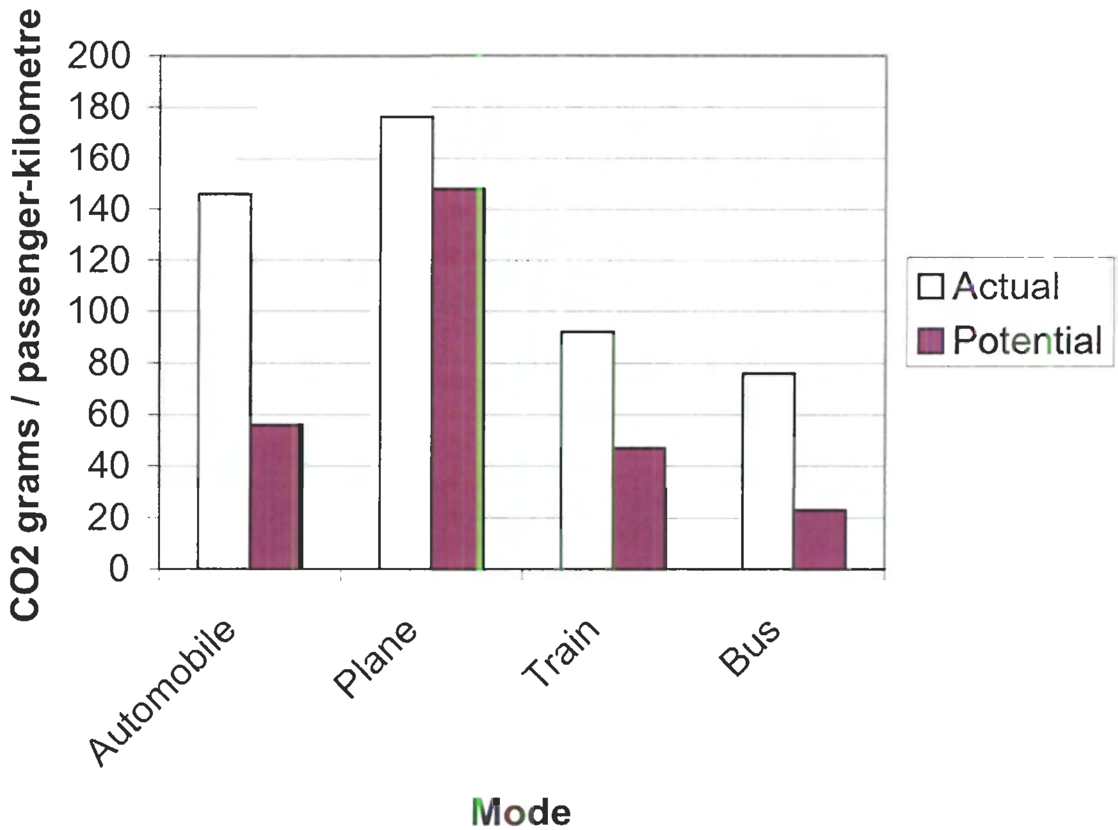


Adapted from US Energy Information Administration (1998).

Assumptions that buses are far more efficient from an environmental perspective are not sound. In Canada, the efficiency is not an order of magnitude, but only a factor of two (Using data provided by Environment Canada (1995))! However other studies cited in the Ottawa Citizen (1989) suggest that they produce *"one-sixth the amount of hydrocarbons produced by cars on a per-passenger basis."*

The real pollution difference between bus and automobile transportation is not clear, but we can consider two ratios above. The data provided by Environment Canada (1995) shows that a fully laden bus can produce as little as 23 grams of CO_2 per passenger kilometre, however, in practice it produces 76, which is half of that produced by a car (146) as shown in Figure 2.7. We can connect the Environment Canada data with other studies if we instead assume that buses are producing the optimal 23 grams and that cars are producing the actual 146, then we find a ratio of 6:1 which is consistent with what was reported to the Ottawa Citizen (1989).

Figure 2.7 CO2 Emissions per Passenger Ki ometre Type



Adapted from Environment Canada (1995).

2.3.3 Automobile Safety

In 2004 the US the National Centre for Statistics and Analysis and the National Highway Traffic Safety Administration (NHTSA) reported that there were 42,636 fatalities related to motor vehicle accidents and that the economic cost of these collisions was $230.568 billion. Subramanian (2004) puts this into the context of total deaths in the US when he reports on behalf of the NHTSA that from age 3 to 33 the leading cause of death is automobile accidents, and that for all ages automobile deaths rank third behind cancer and heart disease.

2.3.4 Creating Barriers to Reduce Congestion

Another tool used by city planners to reduce congestion is to create barriers to commuting. These barriers lead people to combine trips and cancel optional trips. These barriers occur naturally within bus transportation and can be induced into automobile transportation using tolls, taxes and allowing congestion to build.

A disadvantage of bus transport is that convenience is lower so this acts as an incentive to combine trips. The combining of trips leads to a smaller number of passenger trips and thus reduces congestion.

The addition of tolls generates a similar effect in automobile transportation. Planners of the Gateway Project in BC tout the proposed toll as a benefit that will further reduce congestion on the new bridge, and extend the amount of time before congestion occurs on the bridge. Congestion also acts as a barrier to commuting. As congestion increases commute times the more people will look to combine trips or cancel trips as it extends travel times.

2.4 PRT and Transportation

At present city planners are making trade-offs between public transit and the automobile. Greater Vancouver, BC under the auspices of the Gateway Project is planning new bridge infrastructure which includes tolls. While attending the Gateway Project open house, I learned that they were applying a toll for 2 reasons. The first was to raise money, and the second was to reduce demand for crossing the bridge. This is illustrative of the bind faced by city planners when they want to increase capacity, but doing so releases latent demand leading to further congestion. Therefore they seek to reduce congestion by increasing capacity and in addition they seek to create barriers to automobile trips to decrease demand for car transportation and further reduce congestion.

Dual mode PRT offers another solution to this problem through a few key features:

1. It offers the benefits of a car, which people are clearly voting for through their behaviour.

2. PRT cars are computer controlled and as such may operate at much shorter headways than cars on a freeway. This increases the capacity per lane and reduces commute time.

3. It is tightly coupled with a "greener" infrastructure.

    a. Electric motors are more efficient than gas.[6] Electric motors are 50 to 95% efficient, whereas gas engines are around 25% efficient, with diesel engines' efficiency at 40%.

    b. At small headways such as those proposed later in this document, wind resistance is substantially reduced as vehicles "draft" off each other.

    c. Reducing the vehicle weight increases efficiency, as less mass needs to be accelerated and decelerated at stops.

    d. Electric vehicles considered here use regenerative braking, further enhancing energy efficiency.

A PRT enabled car may produce less pollution per passenger kilometre than riding the bus! And if very short headways are achieved, then this will be accomplished with a relatively small footprint in terms of land use and infrastructure per passenger kilometre.

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[6] Source: http://cipco.apogee.net/mnd/mfgeovr.asp

Dual mode PRT is not a panacea, however. Substantial negative consequences exist in terms of:

1. Parking the vehicles in urban centres.
2. Increased personal velocity leading to greater urban sprawl.
3. PRT systems in the event of underinvestment, like freeways, will become congested.
4. Failure on the elevated guideway may lead to wide system failures.
5. Dependence on large quantities of electricity.

2.4.1 Public Goods and Free Riders

In 1954 Samuelson introduced the concept that "free-riders" and high transaction costs lead to an undersupply of public goods under market based supply arrangements. Samuelson argued that government was needed to force payment on such goods so as to cut through the prohibitive transaction costs hampering private production. Within the context of PRT, the free rider ship problem is alleviated, as computers can collect tolls when users enter the network. Whereas in the case of road networks pay for use is more difficult to implement.

Both road and public transit infrastructure are "public goods" in Canada and are owned and operated by government and crown corporations with the support of private contractors. As such these organizations are responsible for determining the appropriate level of supply and investing in further infrastructure.

Today in Canadian urban centers roads are typically severely congested during peak periods. PRT may offer relief for public planners, if it were to operate as a private road system. This private road system could address peak usage considerations and transportation through corridors, freeing city planners to focus more on suburban travel. This leads to a situation where PRT operators, like toll road operators, have incentives to reduce congestion so that profit is maximized.

The issue here is that government is trying to balance the needs of everyone while toll road operators are primarily interested in congested corridors.

2.5 Barriers to PRT Adoption

PRT must be adopted by 2 groups. The first group is the governmental body or toll road operator, who is introducing the product to end users. The second group are commuters who must change their behaviour.

My assumption is that there are two scenarios of adoption of PRT for the first group. The first scenario is one where the public body is adopting PRT as an owner/operator, and the second is where right-of-ways (ROW) are being granted to a private company in a P3-type arrangement.

The reason we consider government as adopting a system is that this is the model proposed by major PRT proponents such as SkyTran, TriTrack and RUF. Their adoption strategy is to develop their system to late concept or early proof-of-concept stage, then secure a contract with government to pay for the remaining development and installation of the system. Within this model the, body that chooses the first system is left exposed to the financial risk and to being left to operate or scrap the system if it fails.

In the following section PRT adoption for both groups is analyzed using Rogers' ACCORD model (2003). This model identifies 6 critical factors that affect adoption.

2.5.1 Relative Advantage

Relative advantage is the advantage of the system relative to other options. The key question is how the adopters value the benefits. This also includes the switching costs to the new technology, which for commuters includes having their car modified and the immediacy of the benefits.

For politicians considering PRT, the benefits of this system are not clear relative to light rail or road infrastructure. In the case of a government granting ROW, there is an advantage in that less or no government revenue is required. Political benefits accrue if constituents value the benefits of PRT.

Commuter's evaluation of relative advantage compared to transit or private vehicle is an empirical question that will be addressed by the research presented in section 5.1.

2.5.2 Compatibility

This factor has to do with how compatible the new technology is with users' existing behaviours and knowledge. Will they need to learn anything new? Is it compatible with current social norms?

For commuters, the experience is akin to driving on a toll road, with the new experience being that the car is elevated and computer-controlled for a portion of the journey. So there will be some learning required to plan a new route and understand how to use it. There may also be negative social implications, as many high status vehicles may not be compatible with the PRT track.

For governments adopting the technology it has low compatibility. For a politician compatibility it is low as it will require new behaviours in terms of city layout and design as a new element of elevated high speed PRT corridors enters the mix.

In the case of granting a P3, the government may stick with one of its frequently filled roles, acting as regulators while being seen as promoting innovation. However, there may be some concerns about being stuck with the system if it fails.

2.5.3 Complexity

This factor has to do with whether it is possible to communicate the benefits, and whether people can understand them. Ease of use is also part of complexity.

The complexity of PRT from the perspective of a commuter is low; a picture and a short description was enough for respondents in the study to understand the concept. The complexity of adopting and creating such a system is high. For a government granting a P3, the complexity of doing so is relatively low, as they frequently do this.

2.5.4 Observability

Observability has to do with whether the public can observe the benefits – can they be communicated and demonstrated? Observability is quite different before and after construction. Demonstrating benefits to taxpayers before (and during construction) can be quite difficult (see the RAV line discussion).

However, from the perspective of a commuter stuck in traffic who views another commuter "zooming by" on a PRT track parallel to the congested roadway, this represents a highly observable moment. Some of the benefits around safety and reduced emissions are not visible, however.

From the perspective of a government, the observability of benefits is unclear. The observability of air quality improvements and changing the cost structure of transportation infrastructure is low.

2.5.5 Risk Factor

The risk factor has to do with the fear of adopting too early or too late. Wait and see if there are sunk costs, uncertain technology, limited information or negative network externalities.

As the commuter only considers adopting the system after it is built and the price, speed and congestion are known, the risk is low. However, as a taxpayer, the risk is seen be much higher.

For a government investing in the first project, the risk is very high. For the same body granting ROWs to a P3, risk is reduced as the P3 absorbs risk.

2.5.6 Divisibility / trial

Can the technology be tried out at low risk? Is a free trial, trial period, leasing option or demo version available? Can it be incrementally adopted?

In the case of a commuter adopting the system, both leasing and free trials are possible. One example method of trial could be to ride along with someone in their car on the system.

For the perspective of a government body, because the system does not exist anywhere, and it not trial able until millions have been spent and years passed trial is unavailable. The firm engaging the P3 may build the system incrementally and survey users as the design continues, to create the effect of incremental trial in order to mitigate this factor, but benefits are not achieved until some critical distance is built.

Table 2.1 ACCORD Factors Summary

Factor	Commuter	Government Adopting	Government granting ROW to P3
Relative Advantage	High (+)	Low (-)	Med
Compatibility	Med High (+)	Low	High (+)
Complexity	Low (+)	High (-)	Med
Observability	High (+)	Low (-)	Low (-)
Risk	Low (+)	Very High (--)	Med
Divisibility / Trial	High (+)	Low (-)	Med

A '+' indicates increased likelihood of adoption and '-' is unfavourable.

To conclude, the ACCORD factors indicate that users are likely to adopt the system if the price and infrastructure is right, while the government as an implementer of the system will be much less likely to adopt such a system without pressure from commuters.

I expect that the situation above is very similar to the one that faced initial passenger railway pioneers when railways were competing with carriages. Like initial rail infrastructure (Mumbles in 1807[7]), PRT infrastructure may need to enter the world as a private venture which will later be adopted by public planners.

2.6 Major Design Criteria

The PRT field currently contains hundreds of different visions for how PRT may eventually work.

Features that all PRT visions share are:

- Cars travel on a special track.

[7] http://www.welshwales.co.uk/mumbles_railway_swansea.htm

- Cars are controlled automatically while on the track.
- Cars are packed tightly together while on the track, to increase throughput.

After this, the visions divide along several key attributes that affect all aspects of the system design.

- Single / Dual Mode
  - Single-mode cars operate only on the track, and users must walk/drive/bus to the track to board the train.
  - Dual-mode systems have cars that drive on and off the track. This thesis is studying customer response to a dual mode system.
- Speed
  - PRT systems such as SkyWeb Express (http://www.skywebexpress.com/150a_performance.shtml) operate at a low speed – from 20 mph to 60 mph.
  - Tri-Track (http://www.tritrack.net) operates at a high speed of 180 mph.
- Headway
  - A conventional freeway lane carries 1,800 to 2,200 vehicles per hour during peak conditions, regardless of the speed that vehicles travel. The reason that speed does not matter is that as drivers increase their speed their headway (space between the cars) also increases. PRT designers project peak throughputs from 2,000 to 20,000 vehicles per hour on a single PRT track/lane, depending on the headway selected. At very short

headways proposed the effect of drafting may have as much impact as 20% as show in Table 2.2. However these gains only materialize at very short headways.

Table 2.2 Headway and Efficiency from Drafting

Cars/hr	Speed (km)	Space (sec)	Energy Delta Leader	Energy Delta Follower	Net Benefit
1800	161	2.00	100%	100%	0%
3600	161	1.00	100%	100%	0%
5400	161	0.67	100%	100%	0%
7200	161	0.50	100%	100%	0%
9000	161	0.40	100%	100%	0%
10800	161	0.33	97%	84%	19%
20000	161	0.18	58%	110[8]%	32%

Calculated using tables and formulae from Hucho (1998).

There are also non-key, system specific attributes which are significant but not useful when comparing or contrasting different PRT systems.

- Track system
- Car weight/style
- Power system (electric/gas/battery)
- Switching system
- Control system

[8] This is not an error. For a small window of separation there is an advantage to the follower. Once the cars get too close then all the benefits are transferred to the leader.

2.7 Proposed PRT System Configuration Design Choices

On the basis of the above and in order to measure demand for a potential PRT system it is important to select design criteria that represent differences in systems that would make a difference to commuters (determinant attributes) while keeping the size of the survey instrument manageable for respondents. Therefore certain decisions about what to survey need to be made. The following section describes what is chosen as fixed design criteria because it is claimed that commuter opinions of these are harmonious. Criteria around what it is thought commuters might well not share the same view are deemed variable design criteria and these formed the basis of the survey.

2.7.1 Fixed Design Criteria

2.7.1.1 Dual Mode

The decision to create a dual-mode system represents a departure from the majority of PRT thinking. The advantage of dual-mode is that the technology adoption is much more likely, as the technology then is more acceptable to existing car owners. This kind of PRT does not represent as great a departure from the existing method of transport, where people get into their cars and drive to work; this basic process is left unchanged with the exception that their car is on a computer-controlled guideway for the majority of the commute.

An additional benefit of dual mode is that people drive a short distance to and from the track, thus increasing the width of the corridor. This means that a higher throughput may be achieved in lower density suburban area, which has positive effects for cost-justifying the system.

2.7.1.2 Car Velocity

The velocity of the cars while on the track has been fixed at 160 km/h with the objective of being possible yet, fast. This speed represents an improvement of approximately 1.5x over existing freeway speeds, while being within the speeds available to cars and rail today.

A second objective of this high speed was to introduce a compelling benefit to users of the system. At these speeds, users can travel from Langley to the downtown core in less than 20 minutes, instead of the 60 minutes by car or 90 minutes by bus available today.

2.7.1.3 Headway / Guideway Capacity

We have fixed this at 22 metres measured from front bumper to front bumper. This translates to 0.33 seconds at 160 km/h yielding a throughput of 10,800 vehicles per hour[9]. Achieving a throughput this high represents an "engineering challenge;" however this is offset by having higher capacity to support the massive demand for transportation and, to provide sharing of infrastructure costs over a greater number of users. Another benefit to a short headway is that the cars may then "draft" off of each other, improving system efficiency.

2.7.1.4 Commute time

We fixed the length of the commute to 15 minutes on the track for the purposes of the conjoint analysis, which allows commuters to travel for 40 kilometres or 25 miles. We expect that on average, commuters will travel a shorter distance, but wanted users to understand that long-distance commutes were convenient using the system.

2.7.1.5 Control System

The system is modelled after a freeway, where cars join the network at on-ramps and exit at off-ramps. While on the network, the car travels non-stop and is controlled by a computer

[9] 10,800 vehicles per hour is the equivalent of 5 freeway lanes.

system, which safely pilots the car to its destination. Once at the off-ramp the driver (human) resumes control of the vehicle and drives to his destination.

2.7.2 Design Criteria Studied Within the Survey

2.7.2.1 Vehicle Weight

Vehicle weight is a major design criterion for an elevated system, as engineering rules of thumb tell us that doubling the weight increases the construction cost by a factor of four. However, consumers generally prefer larger vehicles for added convenience and capacity—up to some limits (often based on cost per mile of operation). In the survey, we model vehicle weight by allowing the users to choose vehicles with different weights within limits consistent with a PRT system.

Weight affects the operation of vehicles in three ways that are relevant to this study. In a collision, the heavier vehicle has an advantage. However before a collision, a lighter vehicle has the advantage of being able to stop and start more quickly (though heavier vehicles "handle better" at high speeds). Finally, a heavier vehicle consumes more energy as it drives -- the extra weight needs to be started and stopped.

When designing the dual mode PRT, we wanted to choose vehicles that look and worked like "regular cars," to ease customer adoption and to leverage existing technology. However, we also wanted to choose cars that had a light weight, to reduce infrastructure costs.

Table 2.3 Vehicle Weights

Car Weights/Economies	Economy (l / 100km)	Curb Weight (kg)
Toyota Prius	4.0/4.2	1,335
Toyota Echo	**7.1/5.8**	**1,064**
Toyota Camrey	10.0/6.4	1,515
Smart Car	**3.0/8.0**	**730**
Zap Zebra	**Electric**	**640**

Compiled from manufacturers specifications published on the web. Selected vehicles are bolded.

We chose the three lightest cars with the objective of discovering which one is most acceptable to customers. Using engineering rules of thumb, we expect it to cost in the order of 4 times as much or more to build a track to suspend an Echo than for a Zap Zebra.

One of our objectives for the survey was to find the optimal vehicle weight, by considering both constructions costs and adoption rate. Since the infrastructure costs are shared by all users, more users results in lower infrastructure costs per user. This means that if more than four times the number of users will adopt a vehicle that is twice as heavy it makes more sense to build the more expensive system. The optimal point from an earnings perspective is an optimization of the following two functions.

Capital Cost = 4 * Weight * K

Earnings = Price * Number of Users – Capital Cost

The variables "weight" and "number of users" are related through commuter preference for heavier vehicles discovered within the survey results.

2.7.2.2 Price

A major objective of the survey was to detect what level of price the users find acceptable. As such, we wanted to ensure that the prices we asked about were in the right range and did not skew our survey results.

We use the West Coast Express[10] as a close comparable upon which to base prices in the survey. The West Coast Express is a commuter rail corridor that runs between Vancouver, BC and Mission. Fares vary from $152.50 to $255.00 for a monthly pass. The West Coast Express carries just over 8,000 commuters per day. Using this as a base point, we have decided the customer may be willing to pay more than the West Coast Express rate for shorter commutes and greater convenience. So the top price we have surveyed is $300. The bottom price we chose was just below the price of riding the bus for an equivalent trip, or $100. Then we took $200 as a mid-point price.

Using this price range and a length of 40 kilometres, we see that this will allow for an infrastructure cost in the range of 2 to 8 million per kilometre (3 to 10 million per mile[11]) which is feasible.

2.7.2.3 Accessibility

The final key variable that we surveyed was distance to the nearest on-ramp. This variable affects the width of the corridor from which commuters may be drawn. The wider this corridor, the lower are the densities required to cost-justify this infrastructure is. We chose 5, 10 and 15 minutes from the on ramp, as lengths longer than 15 minutes began to negate any time savings of using the system.

[10] http://www.westcoastexpress.com/

[11] PRT systems are frequently quoted in cost per mile so I include these numbers here.

3 THE INSTRUMENT

In this chapter the details of the survey incorporating the fixed and variable design criteria chosen in the previous section are described. These variable criteria are vehicle weight, price and accessibility. How the survey was run and analysed is defended. Results of the survey appear in the following chapter.

3.1 Choice Based Conjoint Analysis

When asked directly what their preferences are for product attributes, many people are unable to determine the relative importance of product attributes. For example when asked whether flavour (chocolate chip or oatmeal) is more important than price (1.29, 2.29) for cookies, consumers may respond that they are all important. Consumers want the yummiest cookies at the best price. Conjoint analysis is a tool used within the marketing field, specifically in the area of new product development, whereby consumers are presented with bundles of goods for which they must state their preferences.

This instrument is a type of conjoint analysis called a discrete choice analysis. In this analysis users are asked to state their preference by either rejecting or accepting the bundle of goods.

The general process to complete a discrete choice conjoint analysis is:

- Select attributes
- Prepare a survey showing the combinations (the instrument here shows all combinations)

- Respondents choose to either accept or reject each bundle. In this instrument they choose either the bundle (accept) or drive (reject) or bus/sky train (reject).

- Data is inputted into statistical software to perform the regression analysis.

- Regressed data is "segmented" or "clustered" to determine the groups within the data.

- The most preferred features are emphasized in the product design targeted at the different groups identified.

Some disadvantages of a conjoint analysis are that only a limited set of attributes may be tested (otherwise the number of questions grows enormously), information gathering is complex, and respondents are limited to the bundles presented and have no opportunity to create new solutions.

The reasons why a conjoint analysis is appropriate for the purpose of identifying an optimal PRT configuration are:

1. The number of attributes we are testing is within the number that is easily testable using conjoint analysis

2. Conjoint analysis will allow us to ascertain the tradeoffs between the different bundles at intermediate levels.

3. Since cost information is available and price sensitivity is surveyed an "optimal product" can be designed.

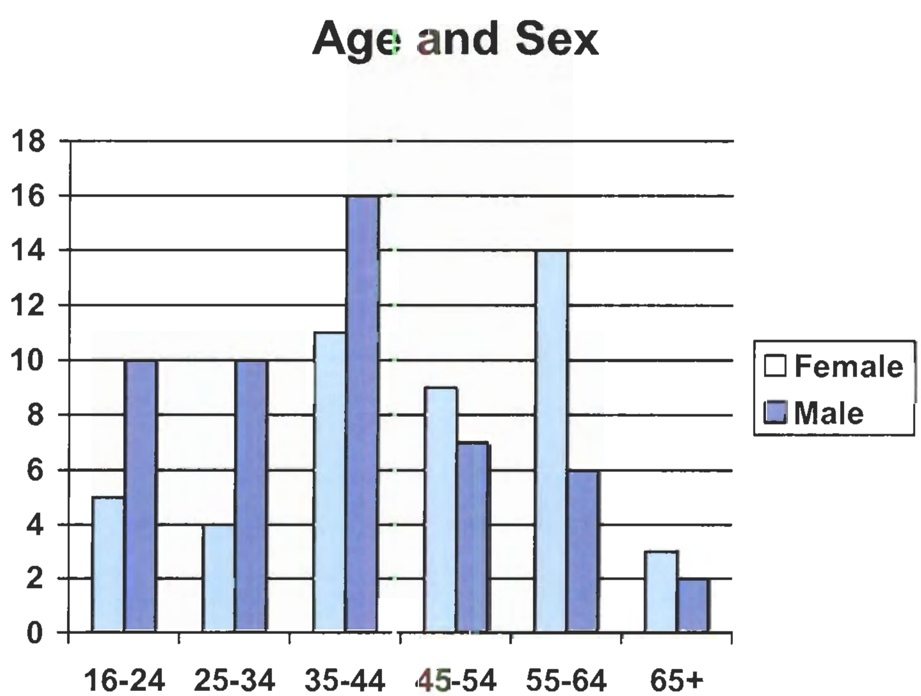
4. The "bundle" nature of commuting fits very well with conjoint analysis. Time, price, comfort and convenience are variables that we all want to maximize for

our commuting pleasure. However, in practice many difficult tradeoffs are made by consumers. This fits very well with the conjoint methodology.

3.2 Subjects

A convenient sample of relevant consumers was surveyed between Feb 26 and March 8 2006. A total of 101 people were surveyed and 6 were excluded from the results for choosing both Skytrain and drive options in the survey. The age and sex of all respondents are shown Figure 3.1.

Figure 3.1 Basic Demographics of Respondents



3.3 Survey Sections

The following section presents a summary what went into each section. The full survey instrument is included in Appendix B.

3.3.1 Introduction Section

The introduction section was 8 pages long and described in detail each of the PRT variables (Vehicle, Price and On-ramp distance).

After the survey instructions PRT was described in detail as:

> *In a PRT system you will drive a special car on normal roads to an "on- ramp." Upon entering the on-ramp, the car will be attached to a track that will move the vehicle and control it by a computer until you reach the selected off ramp. At the off ramp you will regain control of your car, turn on the motor and drive to your final destination.*
>
> *While on the track your car will travel at a speed of 160 km/h and there will be no stops as the track works like a free-way system with on-ramps and off ramps. The computer system takes care of speeding the car up to full speed on the on-ramp, merging with traffic, and slowing the car down on the off ramp so all cars on the track travel at full speed.*

The vehicles were described in a high level of detail as the electric vehicle is unfamiliar to respondents. Pictures of all of the vehicles were included so that they could see that the electric vehicles looked like regular cars. This was important as the PRT track option may seem futuristic that the electric vehicles not appear this way as well.

3.3.2 Conjoint Discrete Choices

This section asked the user to choose between a PRT option in the centre and Drive or Skytrain/Bus on either side as shown in Table 3.1. The expectation was that respondents would either choose between drive and PRT or Skytrain/Bus and PRT as these two options were held constant. The PRT variables varied as discussed in both the introduction to the survey and in chapter 2.7.2.

6 respondents who chose both Drive and Skytrain/Bus and these were excluded from the results.

Table 3.1 Sample Choice

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

3.3.3 Demographics

After completing the conjoint questions respondents were asked 10 questions focusing in on their demographics. These questions included the number of days per week that the commuted to work, their age, sex, details of their commute, technology adoption profile and their opinions about the biggest reason to adopt and biggest barrier to adopt a PRT system.

4 SURVEY RESULTS

The results of the conjoint analysis are segmented into series based on collection location. Interesting series created are;

- "All" includes all responses.
- "Bus" includes all responses taken from commuters on the bus (41 respondents).
- "Not Bus" includes the remaining 48 respondents which included Langley, BC residents and workers at two high tech firms.

The coefficients from the multinomial logit estimation of the conjoint data are shown in Table 4.1. (Pr(Z>|T|)) is shown under each coefficient and indicates whether the result is statistically different from zero. For the purposes of this study a value less than 0.1 indicates that the coefficient is statically different from zero. That is, the level of the attribute is significantly different from its base level, given the use of dummy variable coding in the analysis.

Table 4.1 Coefficients

	Parameter Est. (Pr(Z>|T|) [12]	Parameter Est. (Pr(Z>|T|)	Parameter Est. (Pr(Z>|T|)
Series	**All**	**Not Bus**	**Bus**
PRT	-0.6779 (0.0000)	-0.6618 (0.0316)	-0.6199 (0.0031)
Vehicle Electric	-0.2408 (0.1848)	-0.4925 (0.2274)	-0.1060 (0.6933)
Vehicle Smart	-0.1125 (0.5300)	0.0000 (1.0000)	0.0251 (0.9246)
Price $100	2.0888 (0.0000)	1.9774 (0.0000)	2.2425 (0.0000)
Price $200	1.1427 (0.0000)	1.0827 (0.0054)	1.0395 (0.0001)
On-ramp distance 5 min.	0.1870 (0.0797)	0.3064 (0.1952)	0.1751 (0.2796)
On-ramp distance 10 min.	0.0504 (0.6358)	0.0553 (0.8142)	0.0321 (0.8422)
Interaction between $100 price and electric	-0.5001 (0.0652)	-0.6237 (0.2930)	-0.6849 (0.1014)
Interaction between $100 price and smart car	0.0514 (0.8550)	0.1171 (0.8505)	-0.0759 (0.8627)
Interaction between $200 price and electric	-0.3749 (0.1354)	-0.2967 (0.5963)	-0.3818 (0.3078)
Interaction between $200 price and smart car	-0.0436 (0.8617)	0.2351 (0.6722)	-0.0461 (0.9021)

The data collected within the survey show that the model was statistically significant as shown in Table 4.1.

[12] If PR(Z>|T|) is less than or equal to 0.1 then the result is treated as statistically significant.

Table 4.2 Statistical Significance

Series	All	Not Bus	Bus
McFadden's RhoSq	0.7515 (Good fit)	0.4886 (Ok fit)	0.6361 (Ok fit)

Table 4.3 Predictions for series All

Question[13]	Price	Vehicle	On Ramp Distance	Share PRT	Share Other
2	$300.00	Smart	10	30%	70%
3	$200.00	Electric	5	47%	53%
4	$100.00	Compact	10	75%	25%
5	$100.00	Electric	10	62%	38%
6	$200.00	Compact	5	61%	39%
7	$300.00	Electric	10	27%	73%
8	$300.00	Compact	15	31%	69%
9	$200.00	Smart	15	54%	46%
10	$200.00	Smart	5	58%	42%
11	$300.00	Electric	15	26%	74%
12	$300.00	Compact	10	32%	68%
13	$100.00	Electric	5	65%	35%
14	$300.00	Compact	5	35%	65%
15	$100.00	Smart	15	74%	26%
16	$300.00	Smart	5	33%	67%
17	$200.00	Smart	10	54%	46%
18	$300.00	Smart	15	28%	72%
19	$200.00	Compact	15	56%	44%
20	$300.00	Electric	5	30%	70%
21	$100.00	Compact	15	73%	27%
22	$200.00	Compact	10	57%	43%
23	$100.00	Compact	5	77%	23%
24	$200.00	Electric	10	44%	56%
25	$100.00	Electric	15	62%	38%
26	$100.00	Smart	5	77%	23%
27	$200.00	Electric	15	43%	57%
28	$100.00	Smart	10	75%	25%

[13] Question 1 is a duplicate question and was included as a sample and was excluded from the calculations so is correctly omitted from this table.

5 DISCUSSION

In this discussion, first the results highlighting key variables are interpreted and interactions shown. Then recommendations of an optimal PRT system using the data gathered and the three variables of weight, price and on-ramp distance are provided.

5.1 Interpretation of Results

From the survey people indicate reasons to adopt. The top four reasons to adopt the system identified by respondents are found in Figure 5.1. Time savings is most significant followed by a belief that the system would be better for the environment and in some cases convenience. When drivers were asked why they did not take public transit their response indicated that time, convenience and not being served were the main reasons why they drove as indicated in Figure 5.2. Taken together this shows that the proposed PRT system will be adoptable by drivers where public transit is not as it meets their needs for speed and convenience which are sacrificed by public transit based on stated barriers and reasons adopt.

Figure 5.1 Count of Stated Reasons for Adoption

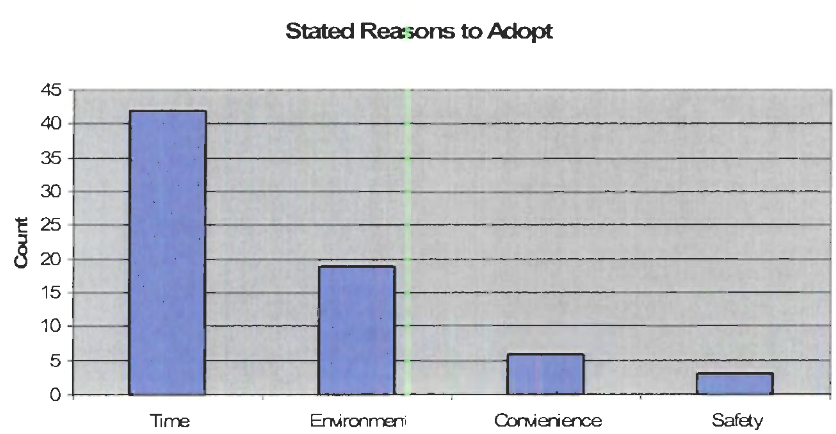
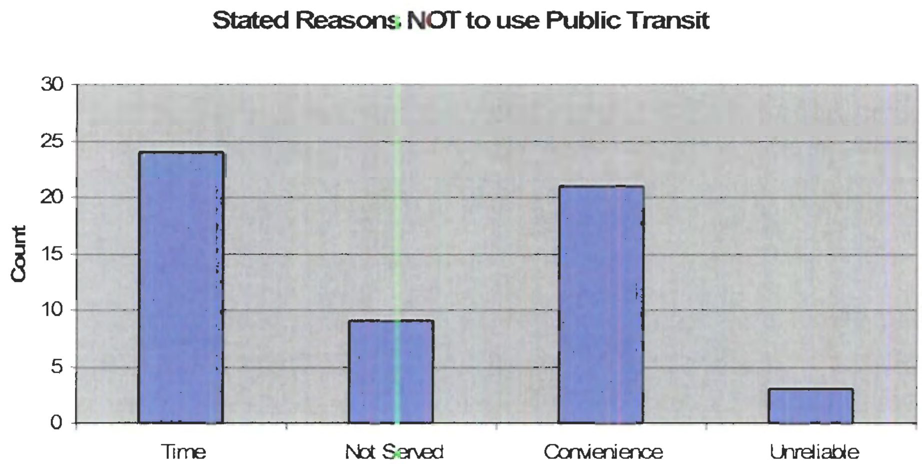


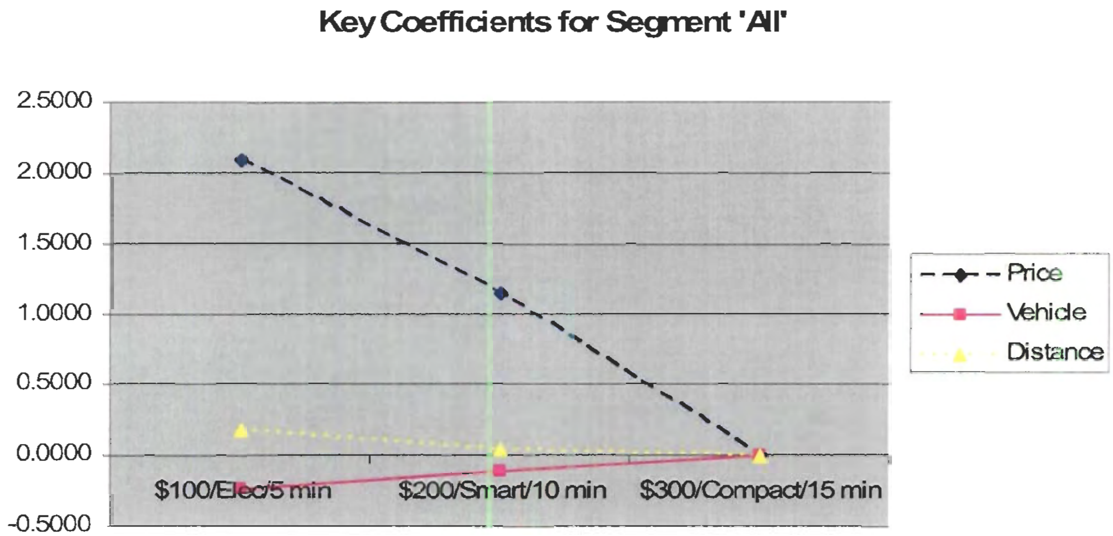
Figure 5.2 Count of Stated Reasons not to use Public Transit



5.1.1 Conjoint Results: Relative Importance of the Coefficients

Of the three variables studied (price, vehicle, and on-ramp distance) price dominated respondents choices as shown in Figure 5.3 Price has a range from 0 to 2.08 while vehicle type only had a range of 0 to -0.24 indicating that price carries more weight than vehicle selection. Moreover price was clearly statistically significant while differences in vehicle type and station distance were not statistically significantly different from 0.

Figure 5.3 Relative Significance of Coefficients Studied



5.1.2 Differences in Demography

Respondents who were surveyed on the bus differed from the survey group as whole in two ways. They exhibited slightly more price sensitivity which was expressed in the data as "liked low price more" as shown in Figure 5.4. People surveyed on the bus did not dislike the electric vehicle as much as those who were not surveyed on the bus, as shown in Figure 5.5 (though these results are not significantly different from 0.) Differences between the two groups were greater for vehicle type than price. Respondents surveyed on the bus were more amenable to the electric car, whereas the "drivers" wanted something more similar to what they were currently driving.

Figure 5.4 Different Demographics Response to Price

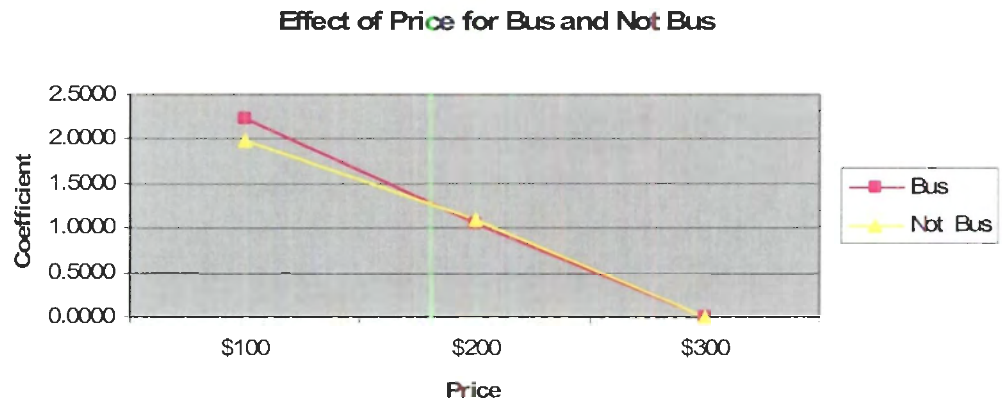
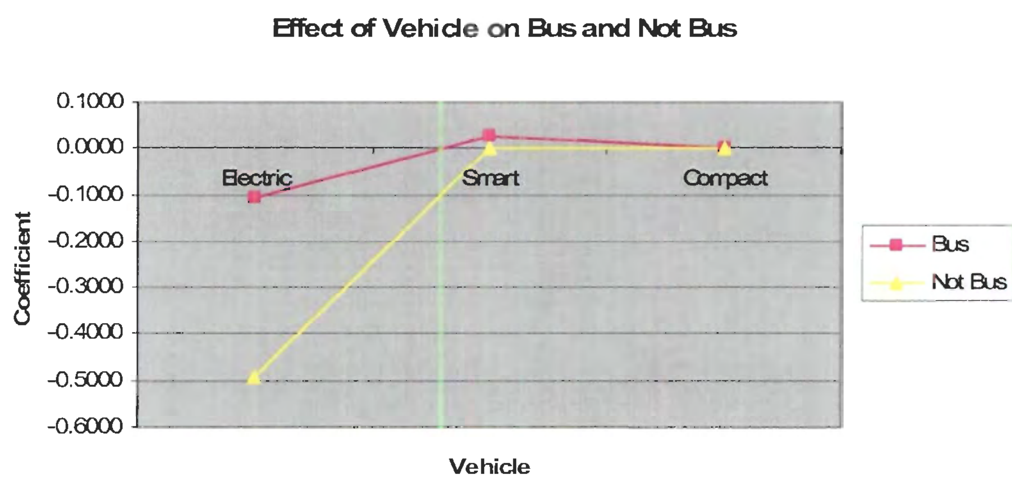


Figure 5.5 Different Demographics Response to Vehicle



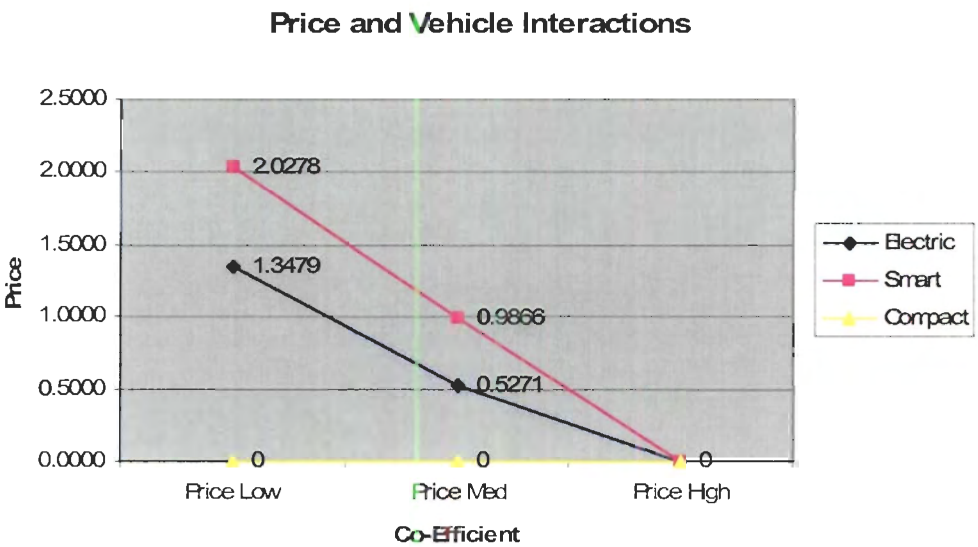
This table is based on data that is not statistically different from 0 and is illustrative only.

5.1.3 Price Interactions with Vehicle Type

Price interactions showed that a low price is less desirable for the electric car as shown in Figure 5.6. Price differences make a bigger difference for smart cars than electric cars, and an even smaller difference for compact cars. Respondents did not prefer the electric car, but when they chose the electric car they exhibited less price sensitivity.

This lower price sensitivity means that a greater number of users will adopt at a given price than if their sensitivity was higher. As revenue is calculated as price * number of users this means that we may generate higher revenues from the electric car relative to the smart car.

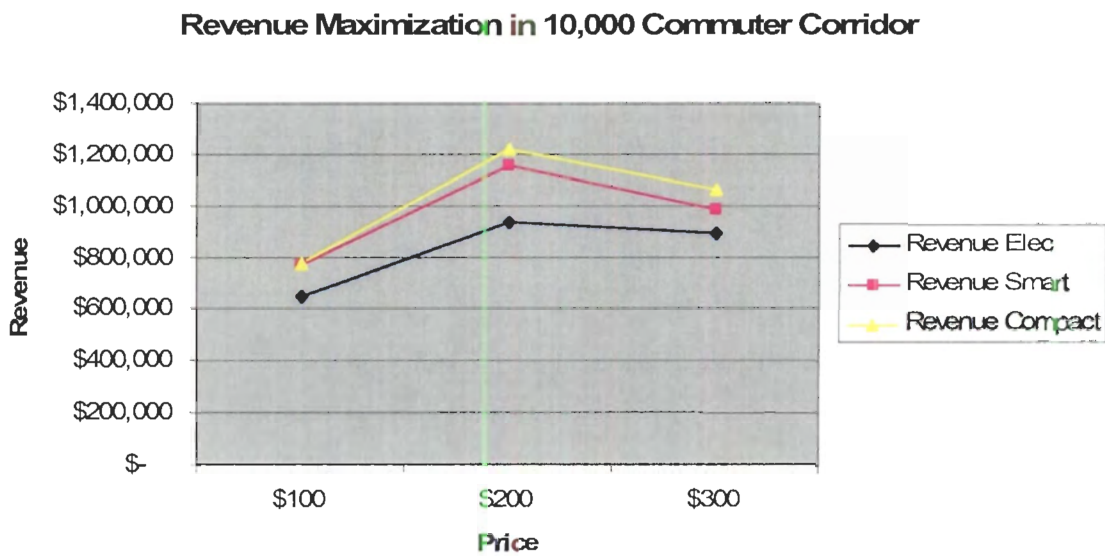
Figure 5.6 Price and Vehicle Interactions for All respondents



5.2 Revenue and Costs

Graphing the predicted shares from the model, and assuming a relevant population of 10,000, the revenue maximizing price is $200 per month as shown in Figure 5.7. This graph was built by using the predicted adoption rates and multiplying them by 10,000 to compute hypothetical monthly revenue from the system. Fixed costs are excluded as they are constant to capacity and variable costs are also excluded as they vary directly with ridership. The table also shows the lower price sensitivity (discussed in Section 5.1.3) for people who select the electric car as revenue falls less for the electric car as the price moves from $200 to $300. However the price does still decrease within this range indicating that the profit maximizing price is still $200 regardless of the difference in price sensitivity.

Figure 5.7 Revenue Maximization

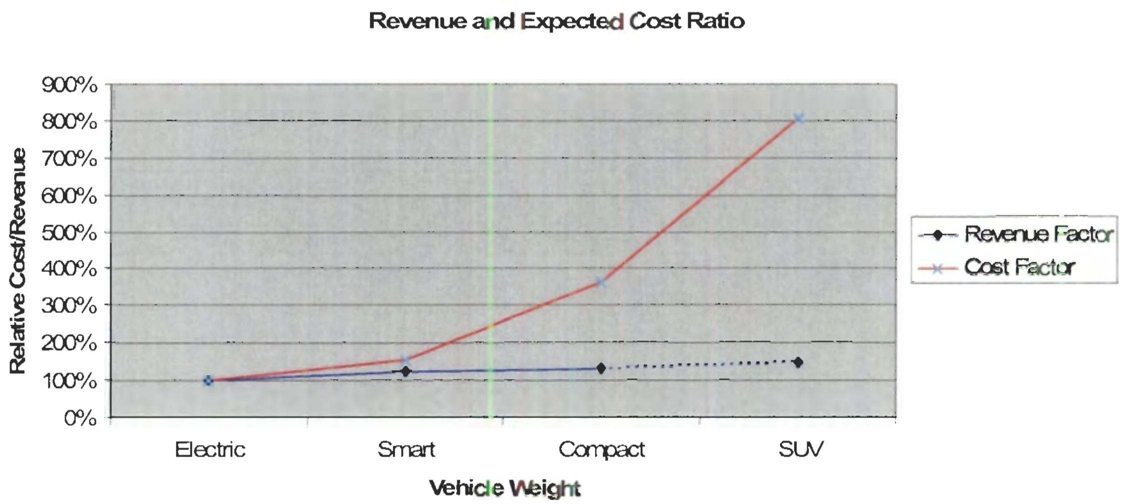


Having established the revenue maximising price of $200 for all vehicles we must next consider vehicle weight and how it impacts costs. As we are approaching the problem from a marketing standpoint where we are back-engineering the system from customer responses, we do not use an absolute system cost. Rather we analyse the relative change in cost and adoption rates.

Using the engineering rule of thumb (introduced in Section 2.7.2.1) that doubling the weight quadruples the cost we can determine the relation between revenue gains of sharing the fixed costs over a greater number of users against the disadvantage of higher costs. For the cost factor we multiple the weight difference by 4 and for the revenue factor we multiple the revenue maximizing price of $200 by the number of users projected to adopt from Table 4.3 (SUV is estimated through linear best fit).

The relationship between the cost factor and the revenue factor inform us about the relative profitability of the system. Increasing the weight of the vehicle has strong negative consequences on profitability as the slope of the cost line is far greater than the slope of the revenue factor line as shown in Figure 5.8.

Figure 5.8 Infrastructure Cost against Revenue



5.3 Recommendations

The three main conclusions that allow us to determine whether a dual mode PRT infrastructure could be viable are:

- The support in the literature that, as income increases people move away from public transport to private transport.
- The survey instrument showed that these same people would be interested in adoption of a PRT system.
- Predicted adoption rates are high enough to generate substantial revenue from reasonably dense corridors.

A PRT infrastructure could be created as a business that would serve customers by reducing their commute time, increasing the convince while at the same time generating environmental spin-off benefits in terms of reduced pollution, congestion and land use.

Given that the sensitivity to price is much higher than the sensitivity to vehicle or station distance, PRT designers are free to consider light weight electric vehicles and long on-ramp distances within their configuration. Using the engineering rule of thumb, doubling the price increases the cost by a factor of 4 and predictions from the statistical model, the most feasible dual mode PRT configuration has a cost of $200 per month and allows only the lightweight electric vehicle.

This conclusion is supported by the lower price sensitivity for electric cars show in Figure 5.6, the revenue maximizing price shown in Figure 5.7 and the infrastructure costs calculated in Figure 5.8. However, the PRT designer must consider carefully the costs of the system that he is proposing and how the costs actually increase with weight (as opposed to a rule of thumb for bridge builders). In practice, other factors may dominate these costs leading to a different optimal choice.

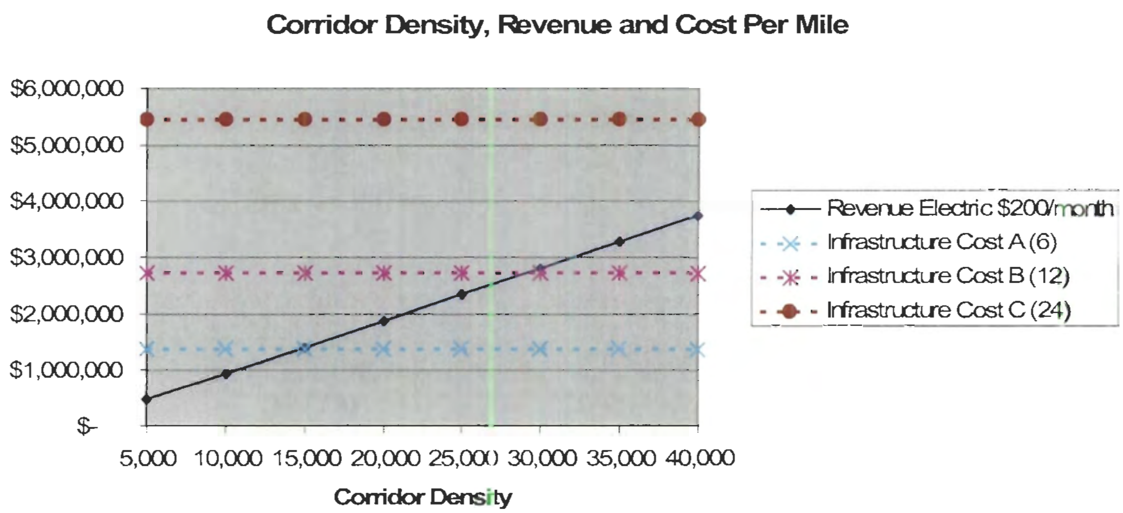
This study did not include the possible benefits of converting an existing compact car and the effect that this would have on the rate of adoption. It seems reasonable to speculate that if existing cars could be easily upgraded to enter the track that the rate of adoption would be accelerated as any car purchasing and updating cycle could then be bypassed.

5.3.1 Optimal System

Using the electric car and a price of $200 per month we can draw a chart that allows one to determine the feasibility of a PRT system based on the density of the corridor in question and the cost per mile. Using Figure 5.9 one can determine that for a PRT system with a cost of 6 million per mile (Infrastructure Cost A) the corridor density must exceed 15,000 in order for the adoption rate to lead to profitable operation. As the density increases above 15,000 the profitability of the system will improve until it becomes congested.

The PRT designer must work closely with a civil engineer and a transportation engineer to ensure that the density of the corridor and the infrastructure costs are balanced in such as way that a P3 or toll road business is feasible.

Figure 5.9 Relative Significance of Coefficients Studied



Based on predicted adoption rates and estimated infrastructure costs from Table 5.1. Cost per mile estimates are based on the costs of other elevated rail systems and estimates provided by PRT vendors and selected to show the relevant range.

Table 5.1 Cost per Mile as Expense

Financing Cost	Million per Mile	# Miles	Rate	Infrastructure Cost
A	6	25	10%	$1,363,051
B	12	25	10%	$2,726,102
C	24	25	10%	$5,452,204

Estimated monthly financing cost of carrying 25 miles of infrastructure at various costs per mile.

5.4 Overall Conclusion

This research set out to determine commuter preferences around key variables in the development and implementation of PRT. Analysing the variables of price, vehicle weight and on-ramp distance it was determined that a PRT system would be feasible given a corridor of suitable density. Infrastructure costs should be reduced by using light weight electric vehicles within the system. The future of PRT therefore looks hopeful if these user factors are taken into consideration as PRT could then make a contribution in the form of reduced energy consumption, noise and sound pollution in the presence of longer and safer commutes.

APPENDICES

Appendix A: PRT Vendors

http://SkyTran.net

http://TriTrack.net

http://www.skywebexpress.com/

http://www.atsltd.co.uk/

http://www.postech.ac.kr/~wing/

http://www.ruf.dk/

http://www.vectusprt.com/

http://www.megarail.com/

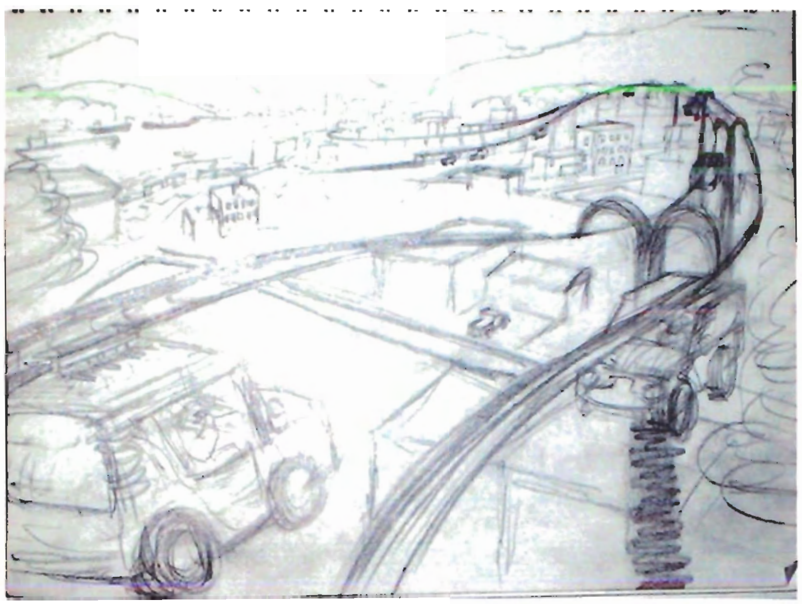
Appendix B: The Instrument

The actual survey used is presented in landscape on the following pages.

Commuting Alternatives:
A Survey of Commuter Preferences

The ever increasing congestion on our road systems coupled with increasing energy prices and concerns about pollution are creating an environment where new transportation alternatives may be considered.

While engineering work has been done to develop possible alternatives, no one really knows how commuters like you will react to these systems.



Yonas Jongkind
SFU MOT MBA Student
Simon Fraser University

Dear commuter:

Thank you for taking 15 minutes to participate in this important research into transportation options being conducted as part of my thesis project.

The survey methods used in this questionnaire may be very different from anything used in the past. Because we believe that your decisions can be quite complex, it is important to capture the "it depends" part of your decision making. Therefore we ask you to respond to all of the items – they may seem quite similar, but they do vary in important ways.

The questionnaire has two parts. Part one asks about your relative preference for transportation options and part two asks some general questions about how you "get around."

This survey has nothing to do with twinning highway 1 over the Port Mann Bridge or the "gateway project."

The survey is confidential and anonymous and your participation is voluntary. You will not be contacted again and no sales solicitation is involved. The results will be available at the SFU library within 6 months. Any complaints or concerns may be addressed to Bernie Love, Dean of SFU Business.

Survey Instructions

I am measuring whether people would like to use a Personal Rapid Transit System (PRT) and, if so, what their preferred configuration would be.

What is PRT

In a PRT system you will drive a special car on normal roads to an "on- ramp." Upon entering the on-ramp, the car will be attached to a track that will move the vehicle and control it by a computer until you reach the selected off ramp. At the off ramp you will regain control of your car, turn on the motor and drive to your final destination.

While on the track your car will travel at a speed of 160 km/h and there will be no stops as the track works like a free-way system with on-ramps and off ramps. The computer system takes care of speeding the car up to full speed on the on-ramp, merging with traffic, and slowing the car down on the off ramp so all cars on the track travel at full speed.

Part one

In this part of the survey we are going to ask you to choose between driving your car, riding the Sky Train, or taking a new PRT system with varying options.

The Sky Train option is always the same:

Commute Time:	60 minutes + 10 minute bus ride.
Cost:	$130 per month (3 zone pass)

The driving option is always the same:

Commute Time:	50 – 90 minutes depending on traffic.
Cost:	Gas costs and car ownership costs.

The PRT system has varied options:

Commute Time:	Always 15 minutes (+ distance to on-ramp).
Car:	
	Low Speed Electric Car
	Smart Car
	Compact Car
Price:	$100 to $300 per month for access to the track (not including vehicle costs)
On-ramp Distance:	5 to 15 minutes.

About the car:

Three different types of car are offered electric, Smart and compact. We chose the cars for their weights and efficiency in the system.

Electric Car

This is an electric car that is very economical to run, **but its speed limited to 65 km/h (hence it is not allowed on freeways)**. Aside from being limited to 65 km/h it looks and drives like a normal car, although the electric motor is quiet. The Electric Car is also very energy efficient, consuming $10 worth electricity where a car might consume $100 worth of gas. These cars would retail for $11,995 and would have all the normal financing options.

Zap Zebra

REVA

- Price: $11,995.
- Speed: Up to 65 km/h
- Range: Up to 65 km
- Motor: Electric
- Seating: Up to 4

Smart Car

Daimler-Chrysler has been selling the Smart car for several years. It is a light weight two seater which you may be familiar with.

- Price: $16,890
- Maximum speed: 135 km/h
- Range: 500 km
- Seating: 2
- Fuel Economy: 6 litres / 100 km or 47 MPG

Compact Car
This could be a Toyota Echo, Ford Focus or some similar car. Compact cars are small and light weight.

Ford Focus **Toyota Echo**

Price: $16,799 Price: $13,580

- Maximum Speed: 200 km/hr
- Range: 500 km
- Seating: 4
- Fuel Economy: 7 litres / 100 km or 40 MPG

About the commute time:

For this survey we have fixed the on-track commuting time to 15 minutes while on the track. While on the track your car travels non-stop at 160 km/hr, so it is possible to commute from a Langley on-ramp to Downtown Vancouver within 15 minutes.

About the price:

The prices offered in the survey are $100, $200 and $300 per month. This price covers the use of the track and energy consumption while on the track. It does NOT include the purchase price of the vehicle or the cost of gas to drive to the nearest on-ramp.

About the on-ramp distance:

The on-ramp distance is the driving distance from your home to the nearest on-ramp. In the survey we offer 5, 10 and 15 minutes as options.

We are assuming that it takes you 15 minutes to get to work once on the track, this distance can add substantially to the total commute time (It could double the total time to 30 minutes, with 15 minutes spent on the track and 15 minutes getting to the track).

When you answer the questions assume that you are choosing from the commute options (Drive, PRT, Skytrain): NOT your actual commute.

1

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Smart Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

Choose 1 of the 3 options for the next 27 questions.
The PRT option in the centre is the only one that changes.

2

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Smart Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

3

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	5 minutes		
Total Time	60-90 minutes	Total Time	20 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

4

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Compact Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

5

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

6

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Compact Car		
		On-ramp Distance	5 minutes		
Total Time	60-90 minutes	Total Time	20 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

7

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 Minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

8

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Compact Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 Minutes	Total Time	70 minutes
□ I Choose		□ I Choose		□ I Choose	

9

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Smart Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 minutes	Total Time	70 minutes
□ I Choose		□ I Choose		□ I Choose	

10

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Smart Car		
		On-ramp Distance	5 minutes		
Total Time	60-90 minutes	Total Time	20 minutes	Total Time	70 minutes
□ I Choose		□ I Choose		□ I Choose	

11

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 minutes	Total Time	70 minutes
□ I Choose		□ I Choose		□ I Choose	

12

Drive	PRT	Skytrain/Bus
	Price: $300/month	
	Vehicle: Compact Car	
	On-ramp Distance: 10 minutes	
Total Time: 60-90 minutes	Total Time: 25 minutes	Total Time: 70 minutes
□ **I Choose**	□ **I Choose**	□ **I Choose**

13

Drive	PRT	Skytrain/Bus
	Price: $100/month	
	Vehicle: Low Speed Electric Car	
	On-ramp Distance: 5 minutes	
Total Time: 60-90 minutes	Total Time: 20 minutes	Total Time: 70 minutes
□ **I Choose**	□ **I Choose**	□ **I Choose**

14

Drive	PRT	Skytrain/Bus
	Price: $300/month	
	Vehicle: Compact Car	
	On-ramp Distance: 5 minutes	
Total Time: 60-90 minutes	Total Time: 20 minutes	Total Time: 70 minutes
□ **I Choose**	□ **I Choose**	□ **I Choose**

15

Drive	PRT	Skytrain/Bus
	Price: $100/month	
	Vehicle: Smart Car	
	On-ramp Distance: 15 minutes	
Total Time: 60-90 minutes	Total Time: 30 minutes	Total Time: 70 minutes
□ **I Choose**	□ **I Choose**	□ **I Choose**

16

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Smart Car		
		On-ramp Distance	5 minutes		
Total Time	60-90 minutes	Total Time	20 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

17

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Smart Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

18

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Smart Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

19

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Compact Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

20

Drive		PRT		Skytrain/Bus	
		Price	$300/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	5 minutes		
Total Time	60-90 minutes	Total Time	20 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

21

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Compact Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

22

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Compact Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

23

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Compact Car		
		On-ramp Distance	5 minutes		
Total Time	60-90 minutes	Total Time	20 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

24

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

25

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

26

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Smart Car		
		On-ramp Distance	5 minutes		
Total Time	60-90 minutes	Total Time	20 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

27

Drive		PRT		Skytrain/Bus	
		Price	$200/month		
		Vehicle	Low Speed Electric Car		
		On-ramp Distance	15 minutes		
Total Time	60-90 minutes	Total Time	30 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

28

Drive		PRT		Skytrain/Bus	
		Price	$100/month		
		Vehicle	Smart Car		
		On-ramp Distance	10 minutes		
Total Time	60-90 minutes	Total Time	25 minutes	Total Time	70 minutes
□ **I Choose**		□ **I Choose**		□ **I Choose**	

Part 2: Profile questions

1. How many days per week do you commute to work? ______

2a. Age (Circle one): 16—24 25—34 35—44 45—54 55—64 65+

2b. Sex (Circle one): Male / Female

3. Where do you work (City/region): ______________

2. How do you commute to work (Number of minutes on each)

Drive ______ minutes
Bus ______ minutes
Skytrain ______ minutes
Walk ______ minutes
Cycle ______ minutes
Wait ______ minutes

3. How many vehicles in your household? ______

4. Would you be in the first

5% of users to adopt a PRT system like this? □ **I Choose**
10% of users to adopt a PRT system like this? □ **I Choose**
30% of users to adopt a PRT system like this? □ **I Choose**

5. When new technology is presented you are:

The first on the block with the technology □ **I Choose**
Wait until the bugs are worked out □ **I Choose**
Buy it when everyone has it □ **I Choose**
Buy it when I must □ **I Choose**

If you do not drive to work skip to question 10.

6. How much does driving to work cost per month? ___________

7. Do you carpool?

□ **Yes** / □ **No.**

8. Is one of your vehicles used mainly just for commuting to work?

□ **Yes** / □ **No.**

9. What is the reason why you do not take public transit?

10. How may people in your household commute to work and how?

12. What would be the biggest reason to adopt this type of PRT system?

13. What would be the biggest barrier to adopting this type of system?

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