Can BART Do Better? Sketch Modeling Alternate Fare Structures to Manage Demand

Matthew Schabas (corresponding author)
Department of City and Regional Planning
University of California, Berkeley
Berkeley, CA 94720, USA
Tel: +44-7790-141-129
Email: matthew.schabas@cantab.net

Ruth Miller
Department of City and Regional Planning
University of California, Berkeley
Berkeley, CA 94720, USA
Tel: +1-770-312-9295
Email: ruthm@berkeley.edu

Word Count: 243 Abstract + 5,181 Text and References + 3 Tables + 4 Figures = 7,174

Submitted for TRB 2013

ABSTRACT

This research paper applies sketch modeling to estimate how more complex fare structures could manage congestion and increase revenue on the Bay Area Rapid Transit (BART) system.

BART is an excellent case study because it already applies a relatively complex fare structure based on origin and destination. This exploration is motivated by an interest in making BART more efficient. BART experiences highly peaked ridership and is considering costly new investments to expand capacity. BART is also grappling with a substantial deferred maintenance deficit.

The literature review identifies fare structures used by comparable cities in OECD countries. An elasticity model simulates changes in ridership and revenue by fare structure. The model uses two different elasticities based on the literature and BART's 2010 Demand Management Study: commute trips (-0.15) and discretionary travel (-0.30).

The model suggests that BART could indeed manage peak ridership and increase revenue with a more complex fare structure. For example, introducing a $1.00 peak period and a $1.00 transbay peak-direction surcharge decreases peak ridership by 2.5% and increases weekday revenue by 19.5%. Other fare structures are explored. All scenarios consider a revenue neutral case where off-peak travel is discounted so that daily revenue remains at the existing level.

This exploration suggests that congestion pricing could increase ridership, revenue, or both while managing congestion. BART's existing technology allows these types of complexity. The policy recommendation is for BART and other systems with more simplified pricing to investigate peak-period, direction, and station pricing.

1 INTRODUCTION

Around the world, suburban rail networks and metro systems use different fare structures. Pricing trips carefully is important to cover operating costs and influence behavior. Transit agencies are often required to maximize conflicting goals: ridership, revenue, social, or environmental benefits (*1*). The chosen structure has implications about the fair balance between: farebox revenue and taxpayer subsidy; long and short trips; commuters and discretionary travelers; congestion; and different income groups. Understanding how alternative fare structures will impact the primary measures of a transit system – revenue and ridership – is essential for strategic planning in austere times.

This report models alternative fare structures for the Bay Area Rapid Transit (BART) suburban rail network serves the San Francisco Bay Area. Today, BART faces two major challenges: managing growing demand and renovating its aging infrastructure. BART will not serve the region's anticipated growth without major investment. Deferred maintenance, capital investments, and replacing the rolling stock remain underfunded (*3*). Maximizing value-for-money from existing BART infrastructure is necessary for the San Francisco Bay Area to meet its greenhouse gas reductions required under California State Bill 375 (SB375).

BART has used a distance based fare structure since opening in 1972 (*2*). Growing ridership during peak periods threatens to exceed capacity and compromise service quality. To manage capacity at key stations, BART is considering raising fares on trips during the peak commute periods (*4*). Using elasticity theory, this report considers the impact on ridership and revenue for several alternatives to the existing distance based fares.

2 LITERATURE REVIEW

The management of peak period ridership and revenue on commuter and urban rail with congestion pricing is extensively documented (*5*, *6*, *7*, *8*, *9*, *10*, *11*). This literature provided guidance for modeling methods. Predicting ridership change due to fare change using elasticity is a common method (*25*). Alternative methods include: the four-step transportation model, sophisticated behavioral modeling such as nested logit, and joint transportation and land use simulations (*13*, *14*, *15*, *16*). There is an argument that increasing model complexity does not improve the simulation of passenger choice. Elasticity was chosen because it offered a straightforward methodology for desktop sketch planning.

2.1 Choice of Elasticity Values for BART

Stated preference surveys suggest that for commute trips, a 25% price increase will reduce ridership by only 4% (*17*). In 2010, BART used elasticities of -0.15 for peak commute and -0.30 for off-peak trips for forecasting (*4*). Furthermore, the weekday average elasticity (-0.22) was estimated to be somewhere in between, but closer to the peak-commute price sensitivity.

Previous studies on urban rail gave wide variation in elasticity (*10*, *11*, *19*, *26*, *27*, *28*). Different public transit modes do not have the same demand elasticity (*10*, *23*). One study identified a kinked demand curve, where beyond some threshold any change in fare induces a major decrease in ridership. In 1990, this threshold was found to be $2 (*18*). This study assumes a linear demand curve instead of a kinked Simpson-Curtin Arc Elasticity (*19*). The range of elasticities from the literature (typically -0.1 to -0.5) support the elasticities used in this study.

2.2 Limitations of using Elasticity Theory

Using price elasticity is imperfect because behavior varies greatly by the passenger and exact trip. Fare policy is a complicated tool. Riders are more sensitive to fare increases than decreases (*18*). Smart card payment technologies allow riders to travel the system unaware of the precise cost. Lowering fares may not increase ridership as anticipated by elasticity theory because of information imperfections – non-transit riders are less likely to learn about the change (*5*). When large mode shifts to transit are observed, they often coincide with driving becoming much more expensive through cordon congestion pricing (*20*, *24*).

Availability of alternative modes is important (*20*, *19*). Research into the impact of London's Congestion Charging Zone revealed long-run car elasticity of -1.85 (*20*). This is much higher than typical long-run car travel elasticity of -0.3 (*21*) because of the availability of public transit (*25*). BART's elasticity is predicted to be higher than many commuter rail systems because it has strong competition from parallel freeways and express bus services (*19*).

Elasticity is not consistent across riders. Trips for commuting are less elastic than discretionary trips (*4*, *10*). Paradoxically, low-income riders are less sensitive to fare changes because they may be transit-dependent (*19*). High-income riders could be expected to be inelastic since fares make up a small portion of their disposable income.

The route also matters. BART found that transbay riders generally have much higher household income than local riders (*22*). The elasticity for each station pair will be different and vary by time of day.

This report assumes a homogeneous ridership for each time interval. A more detailed analysis would stratify ridership by income group, age, and trip purpose. This is beyond the scope of the available data. BART only has one price for a particular station pair. This means aggregate data can be used for modeling. A more complicated fare structure could not be modeled using elasticity because passengers may pay different amounts for the same trip. On other systems, day or season tickets can mean trips have zero marginal cost to the passenger.

2.3 Fare Structures

The three main fare structures used by urban public transit are:

- Flat fare – a fixed price paid to enter the system for a trip of unlimited length.
- Zoned fare – fare depends on number of zones travelled through and may vary with zone
- Distance fare – the direct or route mileage of the trip determines the fare. There will be a price per mile travelled and may be a minimum fare.

Some systems combine features of each. Peak and other surcharges are often used to manage demand for certain routes. Concessions are often available to seniors, schoolchildren, the disabled, and other vulnerable groups. Many systems also offer day, weekly, or monthly passes to encourage regular ridership. Transfers are sometimes free or discounted to simplify use of the whole transit network.

2.3.1 BART's Fare Structure

BART currently uses a distance-based fare system with surcharges. There is a minimum fare – currently $1.75 – and an additional fee per mile. Additional surcharges are added for trips through the Transbay Tube, to or from San Francisco Airport, and in San Mateo County (*2*). The fares do not vary by time of day or day of the week. BART's structure has remained unchanged since the system opened. Periodic fare increases have approximately matched inflation but there is no annual increase. Table 1TABLE 1 shows how fares were calculated in 2008. BART's farebox recovery was 71.6% in 2010 (*29*). This is high for an American urban public transportation agency.

TABLE 1 How BART Fares were calculated for each origin-destination station pair in 2008 (*2*)

Trip Length	Minimum Fare: Up to 6 miles	\$1.50
	Between 6 and 14 miles	\$1.70 + 12.4¢/mile
	Over 14 miles	\$2.69 + 7.5¢/mile
Surcharges	Transbay	\$0.83
	Daly City	\$0.96
	San Mateo County	\$1.20
	Capital	\$0.11
	SFO	\$1.50
Speed Differential	Charge differential for faster or slower than average trips, based on scheduled travel times.	±4.7¢/minute
Resulting Fares	Range	\$1.50 to \$8.00
	Average fare (before discount)	\$2.97
	Average fare paid (after discount)	\$2.77
Rail Fare Discounts and Special Fares	Children under 5	Free
	62.5% Discount:	
	Children 5 through 12	\$9 (\$24 ticket value)
	Persons 65 and over	
	Persons with a qualifying disability	
Semi-Monthly Rail/Bus Pass	BARTPlus (w/ \$15 to \$50 BART value) (6.25% discount, last ride bonus)	\$38 to \$71 (8 denominations)
Monthly Rail/Muni Pass	Fast Pass – (Within San Francisco, unlimited monthly use of BART & SF Muni)	\$45
One-Way Transfers From BART to	The County Connection	\$0.85 (\$1.75 base fare)
	Tri-Delta Transit	\$0.75 (\$1.25 base fare)
	Union City Transit	\$0.50 (\$1.50 base fare)
	VTA	Fare reduction equal to local credit
	WestCAT	\$1.00 (\$1.50 base fare)
	Wheels	\$0.60 (\$1.50 base fare)
Two-Way Transfers from BART to BART	AC Transit	\$1.50 (\$1.75 base fare)
	SF Muni, within San Francisco	\$1.25 (\$1.50 base fare)
	SF Muni, Daly City Station	Free (\$1.50 base fare)
ADA Service	East Bay Paratransit Consortium	\$3.00 to \$7.00
	All other areas	See ADA Paratransit Section

2.3.2 Case Studies

- London Underground's fare structure was described by Transport for London (TfL) Managing Director Jay Walder as "the most complicated in the world" (30). The exact fare varies by the zones travelled in, the route, method of payment and time of day. An off-peak single fare varies between £1.40 and £3.70. London has two peak periods: 06:30-09:30 and 16:00-19:00 when fares are increased by up to £2.70 (31). There is a substantial surcharge for paper tickets. The maximum daily fare charged to Oyster smart-card users is capped at the day pass price (31). Season tickets are also available.
- Washington DC's Metrorail divides the day into off-peak, regular, and peak-of-the-peak. It calculates fares based on distance and time of day (Smith 2009). There is a 20¢ surcharge on regular fares, which vary between \$1.95 and \$5.00, during the peak-of-the-peak (33).

Regular fares are reduced to between $1.60 and $2.75 in the off-peak. This encourages discretionary travelers to shift to less congested times of the day. As of 1st July 2012, new fares were introduced which removed the peak-of-the peak surcharge.

- The Toronto Transit Commission (TTC) uses a flat fare for all subway trips. This pricing structure is popular because it is simple (34). Toronto makes a sensible alternative scenario for BART because its farebox recovery rate (67%) is similar (35). TTC uses a flat fare on Toronto's entire multi-modal transit network of CAN$3.00 (36)
- New York City's Subway also uses one flat fare for all subway trips: $2.25 (37).
- Portland's MAX Light Rail divides its service area into four concentric zones (38). Trips across three zones are 30¢ more expensive than the $2.10 two-zone single fare (39). Within Portland's downtown zone, trips are free. Tri-Met's light rail cars permit boarding through all doors and use proof-of-payment fare enforcement.

2.4 Why BART Should Consider Different Fare Structures

Any pricing structure has inherent tradeoffs between consumption, revenue, equity, and the environment. Many argue that transit has an obligation to serve low income riders and offer alternative to greenhouse gas-emitting automobile trips. It must also cover some or all of its costs. Designing an enforceable fare system to balance these conflicting measures of success is challenging (*17*, *34*).

BART's technology is able to handle complex fare systems. The existing automatic fare gates check tickets on entry and exit. Trips are already priced by distance. The Bay Area's 'Clipper' smart-card allows passengers to pay complex fares based minimal confusion (*4*).

Estimates in the literature predict BART will need $513 million each year for the next 30 years to keep maintain a State of Good Repair (*3*). This estimate does not include earthquake safety, passenger security, or extensions. Budget shortfalls have led to a backlog of deferred maintenance and the rolling stock is approaching or beyond its design life. Without investment, passengers will experience declines in reliability and service quality. This will reduce BART's ridership and ability to serve the San Francisco Bay Area. Politically, BART may find it easier to request financial support from taxation or general funds if it can demonstrate it is charging users a substantial portion of the operating costs.

BART should consider a new fare structure to better manage its conflicting goals. Charging more for congested trips and travel times could spread peaks and reduce the need for expensive capacity expansions. Increasing off-peak ridership will generate additional revenue at little cost. Raising peak fares introduces some equity concerns, even if the increased revenue is used to discount off-peak travel.

3 MODELING RIDERSHIP WITH DIFFERENT FARE STRUCTURES

The Excel-based model analyzes existing ridership patterns for a weekday in fifteen-minute increments. The main calculation determines the ridership under the new fare structure. This uses a rearrangement of the normal elasticity of demand equation:

$$New\ Ridership = \left(1 + \left(Elasticity \times \left(\frac{Proposed\ Fare}{Existing\ Fare} - 1\right)\right)\right) \times Baseline\ Ridership$$

The model assumes that 50% of riders ‘lost’ from the peak period will choose to make the same BART trip outside the peak period. Weekends, existing discounts and other deviations from the published fares are not modeled. Elasticity is assumed to include the impacts of imperfect information.

Only using elasticity may seem simplistic. BART’s fare structure is relatively simple – there are no daily, weekly or monthly passes or discounts for advance purchases or use of different payment mechanism. This makes elasticity a valid method (*25*).

The model is designed to handle two different elasticities: commute trips and non-commute discretionary travel. This allows off-peak travel times to be more sensitive to price changes. Elasticity comes from BART publications. The peak-period elasticity of -0.15 has been taken as the commute elasticity and used for trips during 07:00-09:30 and 17:00-19:30 and -0.30 at other times (*4*).

3.1 Data Sources

BART’s Planning Department provided ridership data by origin-destination (O-D) pair for nine days spread through 2011 – all Tuesdays, Wednesdays and Thursdays. The data reports station exits in 15-minute increments. The average of these nine days is used as the baseline ridership scenario. Except between Daly City and West Oakland, BART services operate at frequencies similar to the 15-minute resolution of the data.

BART records passenger exits from the system. A more refined model would use journey times and the BART system schedule to estimate passenger entry times. The additional calculations would have little influence on the relative outcomes.

3.2 Assumptions

- BART’s demand elasticity captures all aspects of mode and trip choice. This includes the ability to shift trips to different times.
- Demand elasticity only varies with time of day. There is no attempt to model different elasticities for certain O-D trips based on estimates about trip purpose and rider wealth. It assumes that passengers have the same level of information after changes as when the elasticities were measured.
- The average of the nine days is representative of a typical weekday.
- BART daily operations and level of service are unchanged from the 2011 sample days.
- All passengers are assumed to pay the full published fare. Any existing discounts and other benefits (e.g. inexpensive BART parking and free transfers) are ignored.

3.3 Limitations

- The model assumes that all trips in the peak period have an elasticity typical for a suburban rail commuter.
- The model takes a blunt approach to reassigning riders lost due to fare increases. The model assumes that 50% of lost riders will choose to make the same BART trip outside the peak period. The remainder do not make the trip or make the trip without BART. Without finding clear guidance in the literature, the decision to split the riders evenly is a helpful approximation.
- In some cases, a rider may choose to enter or exit from another station to avoid the new fares. The model does not account for shifts in origin or destination when a trip is still taken by BART.

- The ridership data only records station exits. The model assumes anybody who exits after the peak period will have entered after the peak period. This is incorrect for trips arriving in San Francisco from the East Bay a few minutes after the end of the morning peak.
- The trip distribution is unchanged from the baseline case. There is no attempt to capture future land use changes, BART extensions or external factors influencing the decision to use BART.
- The model only considers weekday trips. When subsidies are given to off-peak trips for a revenue-neutral outcome, these off-peak trips do not include weekends.

3.4 Chosen Fare Structures

This study modeled five alternative scenarios based on the case studies and two suggested in BART's 2010 Demand Management Study:

- London – Complex expensive peak-period pricing
- Washington, D.C. – Peak-period pricing
- Toronto and New York – Flat fares for all trips
- Portland – Zone-based pricing
- Morning peak only
- Surcharges on busiest stations only

For each case, a revenue-neutral scenario is included. All additional revenue is applied directly to subsidize off-peak trips. Discounting like this is used extensively around the world to smooth peaks and improve efficiency (*9*).

4 RESULTS AND ANALYSIS

Aggregate outputs are shown in Table 2 and Figure 1. The scenarios are not systematic. Table 2 shows the changes to BART's existing fare structure used in each alternative scenario. The peak surcharge is applied to the time periods used by the case study.

Two scenarios use a peak direction surcharge. 16.9% of weekday trips begin or end at Embarcadero and Montgomery Street in San Francisco's financial district. This is considered the morning peak destination/evening peak origin for determining the 'peak direction'.

4.1 Peak Pricing

The complex London-based structure delivers an impressive 19.5% increase in revenue for a 1.1% loss in ridership. In the revenue neutral case, ridership is 6.1% higher than the baseline. This needs to be treated cautiously because of the large discount: $1.65. Elasticity models are vulnerable to misleading results for extreme price changes (*42*).

Introducing a 50¢ surcharge delivers a small decrease in ridership (-0.6%) for a significant increase in revenue (5.5%). In the revenue neutral case, ridership is only increased 2.1% through off-peak discounts of $0.45. Metrorail used a peak-of-the-peak 20¢ but subsequently concluded it was too low to cause behavioral change (*32*).

BART's 2010 Demand Management Study suggested a $2.00 surcharge to all trips during a narrow morning peak period (8:00-9:00 AM). The scenario produces a 5.8% increase in revenue with a small 0.3% fall in ridership. When revenue neutral, there is a 1.8% overall increase in ridership and $0.29 discount for off-peak travel. Long-distance commuters will not see an improvement on their return trip because whilst they are certain of a seat in the morning, they must still compete with local travelers in the evening commute period (*9*).

BART has studied charging an entry and exit surcharge for the busiest stations to shift demand away from the congested stations of Embarcadero and Montgomery Street (*4*). This scenario models BART's proposed $2.95 peak surcharge for exiting in the morning (08:00-09:00) and entering in the evening (17:00-18:00) peaks. This surcharge produces 3.4% extra revenue for a 0.23% decrease in ridership. The extra revenue could be used to uniformly reduce fares outside the peak hours, raising ridership by 1.95%.

TABLE 2 Summary of Scenarios

Scenario	**Ridership**	**% Change**	**Revenue ($ millions)**	**% Change**	**Average Fare ($)**	**Base Fare ($)**	**Extras**	**Peak Surcharge**	**Off-Peak Discounts**
Baseline	369,940	0.0%	1.297	0.0%	3.51	1.75	Distance		
London Complex Fares	360,693	-2.5%	1.550	19.5%	4.30	1.75	Distance	0630-0930 and 1600-1900; $1.00 +$1.00 peak-direction Transbay	
London Complex Revenue Neutral	388,128	4.9%	1.297	0.0%	3.34	1.75			$1.65
Toronto Subway Flat Fare	352,544	-4.7%	1.237	-4.6%	3.51	3.51			
Toronto Subway Revenue Neutral Flat Fare	345,491	-6.6%	1.297	0.0%	3.76	3.76			
New York Subway Flat Fare	388,716	5.08%	0.875	-32.6%	2.25	2.25			
Narrow Morning Peak	367,771	-0.6%	1.370	5.6%	3.72	1.75	Distance	0800-0900; $2.00 Morning Only	
Narrow Morning Peak Revenue Neutral	375,184	1.4%	1.297	0.0%	3.46	1.75			$0.29
Washington DC	367,773	-0.6%	1.368	5.4%	3.72	1.75	Distance	0730-0900 and 1630-1900; $0.50	
Washington DC Revenue Neutral	376,369	1.7%	1.297	0.0%	3.45	1.75			$0.43
Portland Zones	386,229	4.4%	0.977	-24.7%	2.53	1.75	Zones - $0.50		
Portland Zones Revenue Neutral (change base)	354,128	-4.27%	1.298	0.0%	3.66	2.87	Zones $0.50		
Portland Zones Revenue Neutral (change zone fee)	362,819	-1.92%	1.297	0.0%	3.58	1.75	Zones - $1.20		
BART Proposed Station-Specific Surcharge	366,598	-0.9%	1.396	7.6%	3.81	1.75	Distance	0800-0900; $2.95 surcharge in peak direction at Embarcadero and Montgomery Street	
BART Proposed Station-Specific Surcharge – Revenue Neutral	377,170	2.0%	1.297	0.0%	3.44	1.75			$0.43

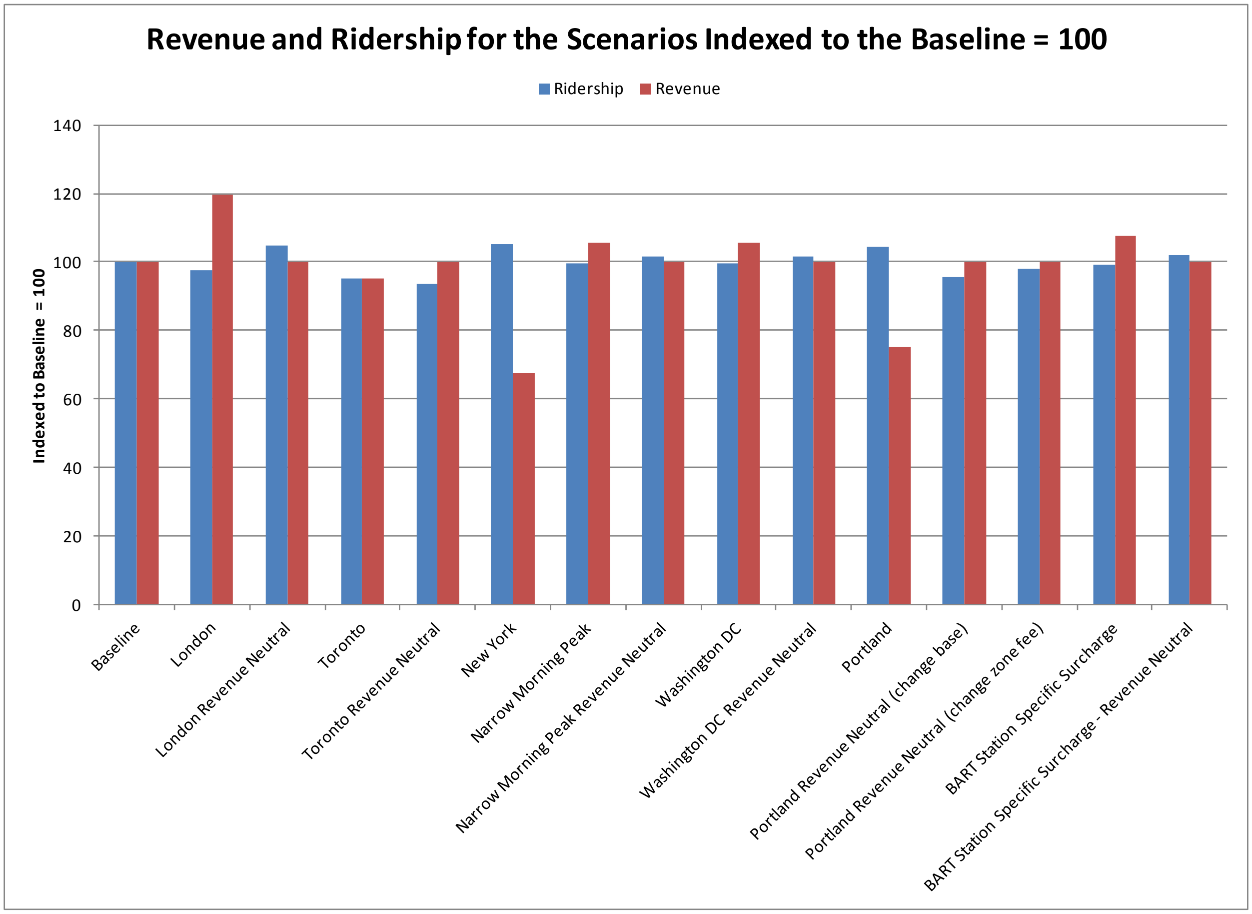


FIGURE 1 Ridership and Revenue Comparison between the Scenarios

4.2 Flat Fares

BART's current average fare is $3.51. If BART decided to charge $3.51 as a flat fare, the system would see a 4.7% weekday revenue decrease. To achieve revenue-neutrality, BART would have to increase its flat fare to $3.76. Implementing either flat fare would more than double the price for short trips, and total system ridership would decline by 4.6% and 6.6% respectively. These flat fares are similar to the Toronto TTC's CAN$3.00.

If BART adopted a lower flat fare, such as New York MTA's $2.25, ridership across the entire system would increase 5.1%. Considering the extreme discounts now given to longer trips – sometimes more than $6.00 – this scenario would reduce BART's weekday revenue by 32.6%.

4.3 Zone System

This scenario considers a new zone-based fare structure for BART to illustrate the alternative structure – see Figure 2. The zones are approximately matched to political boundaries (e.g. San Mateo County, the City of Oakland) and key destinations (e.g. San Francisco International Airport. There is a $1.75 base fare for travelling in a single zone and a 50¢ surcharge for each additional zone which approximates BART's distance fare structure.

With zone-based pricing, ridership increases 4.4%, but revenue decreases 24.7%. Revenue-neutral scenarios explore increasing either the base fare to $2.87 or the extra zone surcharge to $1.20. Ridership would be 4.27% and 1.92% below the baseline respectively.

FIGURE 2 Potential travel zones for BART

5 DISCUSSION OF RESULTS

The discussion of results will be restricted to the impact of different fare structures on ridership and revenue. A qualitative discussion of equity considerations is included to demonstrate that changing fares may not always benefit those who the changes aim to help.

5.1 Ridership

Ridership is a standard measure of performance for public transit. BART currently – and in all the scenarios – mainly serves commute travel in the morning and evening peaks – see Figure 4. There is ample off-peak capacity.

BART expects Embarcadero and Montgomery Street stations to reach capacity during peak periods in the near future (*4*). Effective congestion management shifts riders to less congested times. As it maximizes riders within existing capacity, congestion management is a more refined goal than ridership.

5.1.1 Total Daily Ridership

The model methodology assumes off-peak fare discounts result in ridership increases. Fare structures that generally reduced fares increased ridership. The low flat fare (New York) and zone-system (Portland) substantially reduce the cost of longer trips, and encourage many more people to ride BART (5.1% and 4.4%, respectively). The cost of using Portland's model is a 24.7% fall in revenue. All scenarios with peak surcharges reduced overall ridership.

For revenue-neutral cases, the London inspired scenario produced the highest ridership increase over the base case (4.92%); followed by the other peak surcharge scenarios. The revenue neutral cases show that it is possible to increase ridership without losing revenue. A warning with the validity of using London's revenue neutral case is that the discount effectively makes short off-peak trips free. Elasticity models are unrealistic at extreme prices (*42*).

The model shows that even major discounting will not increase total system ridership as much as introducing a complex peak fare structure and using the extra revenue to heavily discount off-peak travel. Simple fare structures (Toronto's Flat Fare and Revenue Neutral Portland Zones) actually decrease ridership if something close to the current average fare is maintained.

5.1.2 Congestion Management

BART is concerned about congestion at Embarcadero and Montgomery Street stations in downtown San Francisco (*4*). One measure for the proposed scenarios is how much they smooth the peak at Embarcadero and Montgomery Street stations. Figure 3 shows the passenger volume at Embarcadero during the morning peak for selected fare structures.

Peak pricing – in any form – has great potential to lower the high passenger volumes, although the model still projects ridership exceeding the station capacity of 2500 passengers per 15-minute interval.

The spikes at 09:00 and 09:30 for the London Revenue Neutral and Narrow Morning Peak Revenue Neutral are produced by the model's simple reallocation of lost riders to the off-peak period.

Fares influence travel behavior, and can be a tool of congestion management. The flat fare scenarios (Toronto, New York) show that some pricing structures can make peak periods more congested. Instead of a flat fare, BART should consider a plan that relieves congestion at peak periods and encourages trips in the off-peak periods.

Figure 4 reveals an important point about how the different scenarios increase ridership. New York and Portland gain riders during the peak with small off-peak gains. The London Revenue Neutral case reduces peak loading and gains riders during the off-peak period.

5.2 Revenue

The complex fare (London) is the overwhelming winner for revenue generation, increasing weekday revenue by 19.5%. This would improve farebox recovery to an impressive 86% (*29*). Other revenue-favorable scenarios include the station-specific surcharge (7.6%), narrow morning peak (5.6%), peak-of-peak from Washington D.C. (5.4%). All of these systems introduce a new level of specificity to BART's existing fare structure, either by time or station.

In all peak surcharge scenarios, the lost riders will be in the congested commute period. Losing riders relative to the baseline may actually be desirable. BART is concerned about capacity constraints at Embarcadero and Montgomery Street Station and crowding on trains using the TransBay Tube (*4*).

In every case, simpler structures decrease revenue. The low flat fare (New York) and zones (Portland) decrease revenue significantly (-32.6% and -24.7%, respectively), while the higher flat fares (Toronto-based) manages to lose both revenue (4.6%) and ridership.

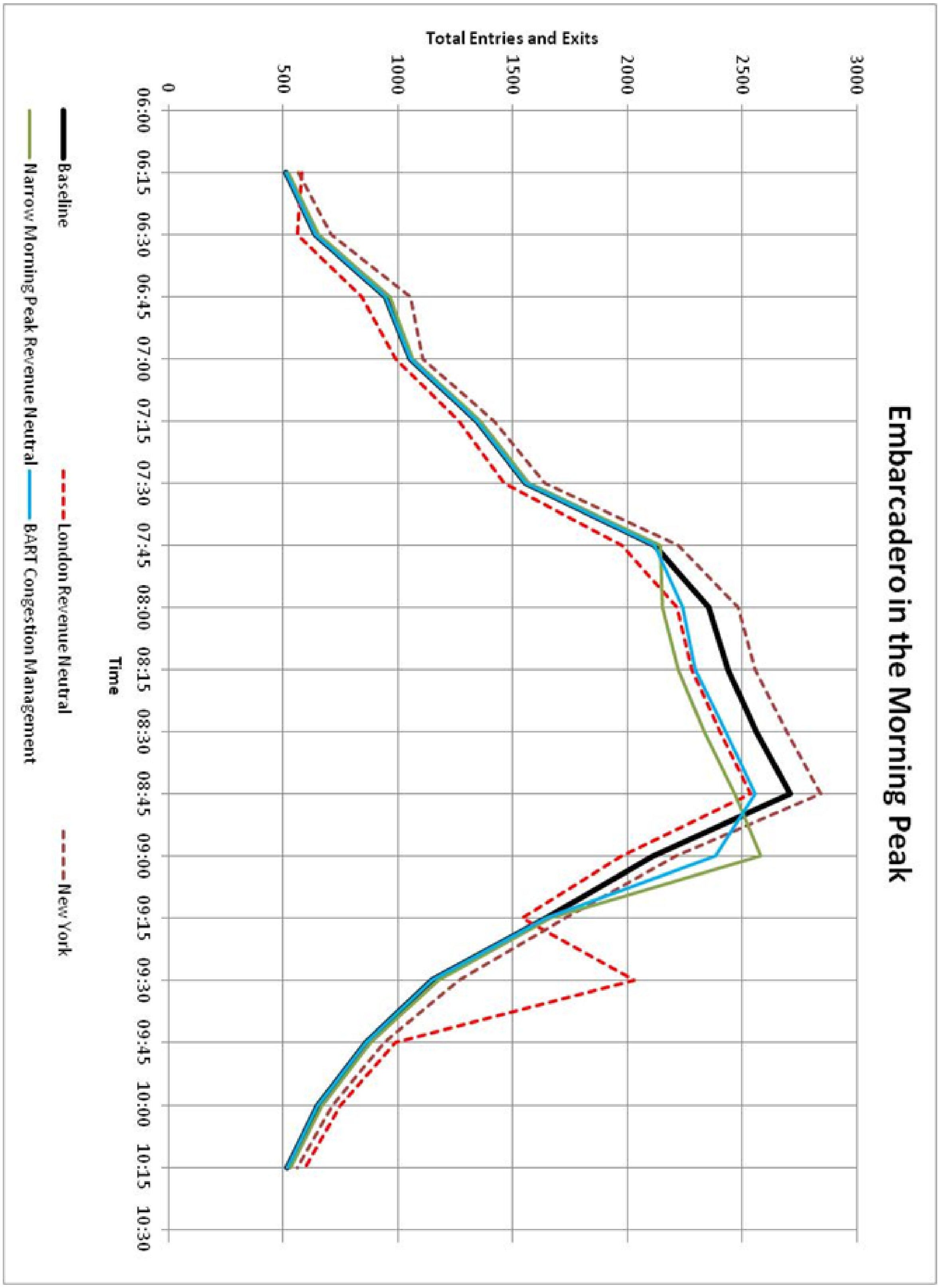
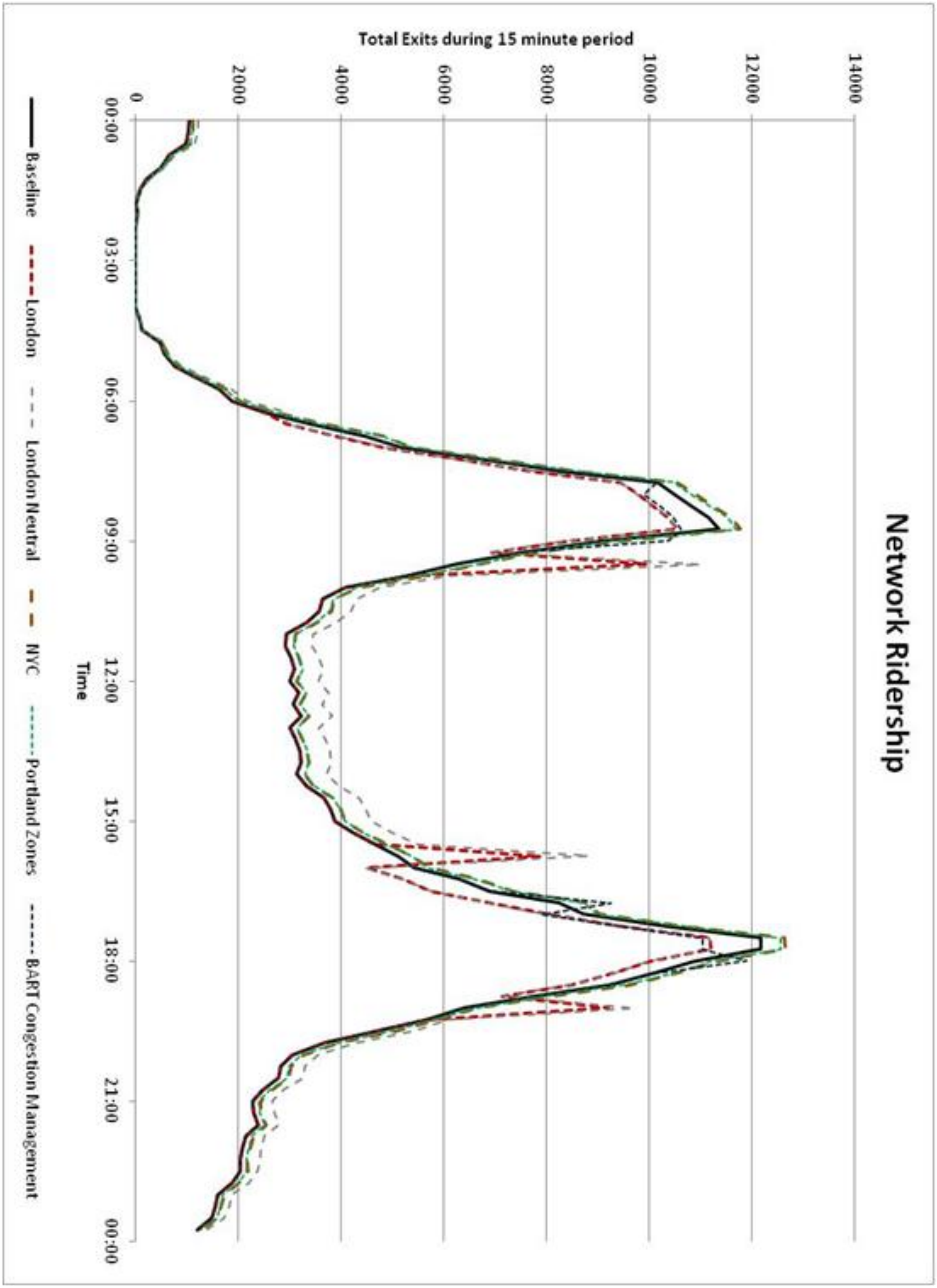


FIGURE 3 Embarcadero Total Entries and Exits by fifteen-minute interval during the Morning Commute Period



1 **FIGURE 4 Network Total Exits by fifteen-minute interval for selected scenarios**

5.3 Equity

BART is a public agency. While serving the entire population, any change to BART's service or pricing must be examined for its implications to low income users. Changes to BART's service must also be viable against the backdrop of the politically active Bay Area. This is further complicated by the increasingly antagonistic majority in the region who do not use BART and dislike paying the additional taxes which support it. Raising fares is never popular amongst riders even when backed with discounting and promises of capital investments.

The underlying principle of congestion pricing is that patrons impose a high negative congestion externality on each other during the peak period. A peak-period surcharge internalizes this externality, forcing riders to pay more of the full cost of their trip.

New fares that capitalize on the inelastic peak-period trips to Downtown San Francisco are bound to produce some concern. However, most people traveling in or out of Embarcadero station are relatively wealthy: 84% of riders aged 25-64 and 40% overall earn over $100,000 (*22*). Over half of riders taking the TransBay Tube on weekday mornings are from households earning over $100,000 (*22*). The revenue-neutral complex fare structure (London) and station-specific surcharges increase fares on wealthier passengers. Raising fares may not be as inequitable as most instinctively assume.

Though the flat fares are the most simple, they can be the least equitable. To offer a commuter from suburban Orinda to downtown San Francisco the same fare as someone traveling a single stop in Oakland would force the local trip to subsidize the longer. This proposal may be popular for its simplicity, and to the electorate in the remote regions of the BART system, but it would not improve equity. Table 4 gives an idea of the fares modeled in the revenue neutral scenarios for selected trips.

It is beyond the scope of this report to examine discounted season passes or concessions for particular vulnerable groups. A thorough consideration of exactly who will be paying more is an important step in analyzing a new fare structure but cannot be done using the aggregate dataset.

TABLE 3 Selected Fares for Several Revenue Neutral Scenarios

Trip		Fares in Revenue Neutral Scenario ($)					
		Baseline	London	Washington D.C.	Toronto	BART Station Specific Surcharge	Narrow Morning Peak
Peak Direction	Orinda-Embarcadero	**4.10**	6.10	3.67	3.76	7.05	6.10
	Daly City-Embarcadero	**2.95**	3.95	2.52	3.76	5.90	4.95
	Fruitvale-12th Street Oakland	**1.75**	2.75	1.32	3.76	1.75	3.75
	Richmond-12th Street Oakland	**2.6**	3.60	2.17	3.76	2.60	4.60
	Pittsburgh-SFO	**10.90**	12.90	10.47	3.76	10.90	12.90
Off-Peak Direction	Orinda-Embarcadero	**4.10**	2.45	3.67	3.76	3.67	3.81
	Daly City-Embarcadero	**2.95**	1.30	2.52	3.76	2.52	2.66
	Fruitvale-12th Street Oakland	**1.75**	0.10	1.32	3.76	1.32	1.46
	Richmond-12th Street Oakland	**2.6**	0.95	2.17	3.76	2.17	2.31
	Pittsburgh-SFO	**10.90**	9.25	10.47	3.76	10.47	10.61

6 FURTHER WORK

Further research is needed to form exact recommendations, but this study demonstrates that BART's fare structure could be changed to generate more ridership, revenue, or both. The model's response to fare changes is non-linear so a systematic analysis is necessary of different surcharges and discounts.

The dataset used in this report makes any equity or environmental analysis a large extension of the available facts. Analysis is needed to consider the consequences of a new fare structure. The model implemented here is not designed for this. Consideration of what modes BART would be competing with is important for both. If fare changes shift passengers for short trips to bikes and walking then there may be few negative consequences. If increases come at the expense of long distance car commutes then the changes may be very important.

7 CONCLUSIONS

The model suggests that BART has an opportunity to increase ridership and revenue whilst mitigating congestion through alternative fare strategies. A good fare policy will increase ridership in off-peak periods, increase revenue, provide equity to riders, and support larger plans to meet environmental goals.

Complex fares can perform better than either flat fares or BART's existing fares. A scenario with peak periods and peak direction surcharges increases BART's weekday revenue by 19.5%, providing funds that could reduce off-peak fares and fund modernization. A revenue-neutral version of this scenario increases BART's weekday ridership by 4.9%.

BART is facing unfunded deferred maintenance and needs new rolling stock. Finding ways to raise revenue from fares may make state and ballot measure funding politically acceptable because users are helping pay for improvements. Public transit offers essential mobility for low income groups. Like many suburban rail networks, BART's ridership has disproportionately high household incomes so increasing fares on inelastic commuter travel, though unpopular, may not be inequitable.

BART already has the technology for collecting more complex fares. Implementing complex fares may be a way to improve BART's value-for-money to both the regional taxpayer – through higher revenue – and its customers – with less congestion and cheaper off-peak travel – without major capital expenditure.

8 WORKS CITED

1. Deakin, E., G. Tal, and K. Frick. What Makes Public Transit a Success? Perspectives on Ridership in an Era of Uncertain Revenues and Climate Change. in *TRB 2010 Annual Meeting CD-ROM*, 2010.
2. BART. Short Range Transit Plan (FY08 through FY17) and Capital Improvement Program (FY08 through FY32). 2007.
3. Deakin, E., A. Reno, J. Rubin, S. Randolph, and M. Cunningham. BART State of Good Repair Report. *Transform*, Nov. 04, 2011. http://transformca.org/files/bart_sogr_regional_impacts_2011-11-04.pdf.
4. Nelson Nygaard. BART Demand Management Study. 2010.
5. Cervero, R. Flat Versus Differentiated Transit Pricing: What's a Fair Fare? *Transportation*, 1981, pp. 211-232.

6. Goodspeed, R. Evaluation of Alternative Fare Structures for Boston's Subway. 2011.
7. Grey, A., and D. Lewis. Public Transport Fares and the Public Interest. *The Town Planning Review*, July 1975, pp. 295-313.
8. Hale, C., and P. Charles. Practice Reviews in Peak Period Rail Network Management: Sydney & San Francisco Bay Area. 2009.
9. Henn, L., G. Karpouzis, and K. Sloan. A review of policy and economic instruments for peak demand management in commuter rail. in *The 33rd Australasian Transport Research Forum Conference*, 2010.
10. Hensher, D. A. Establishing a Fare Elasticity Regime for Urban Passenger Transport. *Journal of Transport Economics and Policy*, May 1998, pp. 221-246.
11. Paulley, N., R. Balcombe, R. Mackett, H. Titheridge, and J. Preston. The demand for public transport: The effects of fares, quality of service, income and car ownership. *Transport Policy*, no. 13, 2006, pp. 295–306.
12. de Rus, G. Public Transport Demand Elasticities in Spain. *Journal of Transport Economics and Policy, Vol. 24, No. 2*, 1990, pp. 189-201.
13. Bhat, C., and S. Castelar. A unified mixed logit framework for modeling revealed and stated preferences: formulation and application to congestion pricing analysis in the San Francisco Bay area. *Transportation Research Part B: Methodological*, Vol. 36, no. 7, August 2002, pp. 593-616.
14. McNally, M. G. The Four Step Model. 2007.
15. Waddell, P. UrbanSim: Modeling Urban Development for Land Use, Transportation and Environmental Planning. *Journal of the American Planning Association, Vol68. No.3*, 2002.
16. VTPI. Transport Model Improvements. February 22, 2012. http://www.vtpi.org/tdm/tdm125.htm. Accessed April 18, 2012.
17. Pratt, R. H. Traveler Response to Transportation System Changes. 2000.
18. Litman, T. Transit Price Elasticities and Cross-Elasticities. *Journal of Public Transportation*, Vol. 7, no. 2, 2011, pp. 37-58, Update to 2004 paper (Victoria Transport Policy Institute): http://www.vtpi.org/tranelas.pdf. http://www.vtpi.org/tranelas.pdf.
19. TCRP. Transit Pricing and Fares. *Transit Cooperative Research Program*, Vol. 95, 2004, pp. 1-58.
20. Reinke, D. Recent Changes in BART Patronage. Washington, DC, 1988.
21. Nuworsoo, C., A. Golub, and E. Deakin. Analyzing equity impacts of transit fare changes: Case study of Alameda–Contra Costa Transit, California. *Evaluation and Program Planning 32*, 2009, pp. 360-368.
22. Gordon, R. BART considers higher fares for peak hours. *San Francisco Chronicle*, September 2008, pp. A-1.
23. Mezghani, M. Study on electronic ticketing in public transport. 2008.
24. Cervero, R. Transit Pricing Research: A review and synthesis. *Transportation 17*, 1990, pp. 117-139.
25. Santos, G., and G. Fraser. Road Pricing: Lessons from London. 2005.
26. Franklin, J. P., J. Eliasson, and A. Karlstrom. Traveller Responses to Stockholm Congestion Pricing Trial, in *Travel Demand Management and Road User Pricing*., 2009.

27. Evans, R. Demand Elasticities for Car Trips to Central London as revealed by the Central London Congestion Charging Zone. 2008.
28. BART. 2008 Station Profile Report. 2008.
29. APTA. T26 2010 Pass Fare Recovery Ratio. *American Public Transportation Association*, 2012. http://www.apta.com/resources/statistics/Documents/NTD_Data/2010_NTD/T26_2010_Pass_Fare_Recovery_Ratio.xls. Accessed April 09, 2012.
30. Brierley, D. Tube fares 'the world's most complicated'. *This Is Local London*, November 12, 2004. http://www.thisislocallondon.co.uk/news/topstories/545661.0/. Accessed March 2, 2012.
31. TfL. *Tube, DLR and London Overground Fares*, 2012. http://www.tfl.gov.uk/tickets/14416.aspx.
32. Smith, M. Public Transit and the Time-Based Fare Structure. Chicago, 2009.
33. WMATA. Metrorail Fares. *WMATA*, 2012. http://www.wmata.com/fares/metrorail.cfm. Accessed April 10, 2012.
34. WMATA. Metrorail Fares. *WMATA*, 2012. http://www.wmata.com/fares/metrorail.cfm. Accessed July 6, 2012.
35. TTC. TTC Fare Collection Study. 2000.
36. TTC. 2010 Annual Report. 2011.
37. TTC. Prices. *Toronto Transit Commission*, 2012. http://www3.ttc.ca/Fares_and_passes/Prices/index.jsp. Accessed April 11, 2012.
38. New York MTA. Fares and Metrocard. 2012. http://www.mta.info/metrocard/mcgtreng.htm.
39. Tri-Met. Tri-Met Rail System. *Tri-Met*, 2012a. http://trimet.org/maps/railsystem.htm.
40. Tri-Met. Fares. *Tri-Met*, 2012b. http://trimet.org/fares/index.htm.
41. Deakin, E., G. Tal, and K. Frick. What Makes Public Transit a Success? Perspectives on Ridership in an Era of Uncertain Revenues and Climate Change. in *TRB Annual Meeting*, 2010.
42. FTA. Silicon Valley Berryessa Extension Project. 2010.
43. Goodwin, P. B., and H. C.W.L. Williams. Public Transport Demand Models and Elasticity Measures: An Overview of Recent British Experience. *Transportation Research Board vol. 19B*, 1985, pp. 253-259.

1