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Using Quantitative Methods in Equity and Demographic Analysis to Inform Transit Fare Restructuring Decisions

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ABSTRACT

New York City Transit (NYCT) and the Metropolitan Transportation Authority (MTA) have integrated race and income equity considerations into its extensive public outreach processes for fare changes. Responding to Federal Transit Administration's (FTA) Civil Rights/Title VI and Environmental Justice (EJ) requirements, NYCT developed two different quantitative and analytical approaches for forecasting equity impacts of fare restructuring decisions, in place of more traditional origin-destination surveys. The first approach uses standard aggregate fare elasticity models to estimate diversions between different fare classes and ridership losses resulting from fare adjustments. Average fare changes by fare media type are disaggregated with historical farecard usage patterns (consumption data) by subway station and bus route, and translated into demographic variables (minority/non-minority, and at or below/above poverty) based on Census data. Overall average fare changes are used to analyze equity impacts. A second, more experimental approach identifies user demographics by daily first swipe locations, and estimates daily average fares as actually experienced by each passenger using sequential transactions on discrete farecards. To meet ongoing requirements, methods were developed to analyze impacts separately for peak and off-peak time periods, and to demonstrate equity using statistical tests. Impact analyses results, and historical ridership, revenue, and market share data collected by the MetroCard Automated Fare Collection (AFC) system all inform fare structure design processes, with particular attention being devoted to distributing fare increase burdens equitably.

INTRODUCTION

The unprecedented global economic difficulties in late 2008 have led to a 2.7% decrease in subway ridership, 2.9% drop in bridge traffic, and about 40% fall in real estate transaction tax revenues that together finance the New York Metropolitan Transportation Authority (MTA). As MTA Financing Commission's final report (the Ravitch Report) states:

> "The effect of weakening economy has significantly eroded dedicated tax sources required to balance the Authority's budget while adversely impacting its cost of borrowing, pension contributions, and system generated revenues. In response to its statutory requirement to be self-sustaining and to submit a balanced budget, the MTA, in advance of this Commission's recommendations, has proposed service reductions that are unprecedented. Additionally, to fill the remainder of a 2009 budget shortfall that has doubled from $600 million to $1.2 billion, the Authority has proposed to increase fares and tolls by 23 percent, beginning June 1, 2009. The combination of these proposals will have a chilling effect on the 8 million riders that use the MTA system daily, as well as the Authority's workforce." (*1*)

As part of MTA's normal 2009 budget process, New York City Transit (NYCT) designed a Budget Gap Closing Program to cover the projected deficit. Unfortunately, feasible and realistic administrative savings and staffing reductions at that time didn't result in a balanced budget. Consequently, NYCT designed a program of service reductions, station changes, and fare increases (together "2009 Budget Balance Service Rationalization Package") that results in least pain for the smallest number of transit patrons. Furthermore, Federal law requires that NYCT change service and fares equitably with respect to income (poverty) and minority status.

FTA Environmental Justice (EJ) Requirements

Since 1972, Federal Transit Administration (FTA) has required recipients of Federal assistance to certify compliance with Title VI requirements during the grant approval process (*2*), achieved through data collection or existing data analysis, reporting, reviews, and remedial actions if necessary.

The applicable legislation is complex, including Federal regulations on Civil Rights, Environmental Impacts, Environmental Justice, and responsibilities to Limited English Proficient persons. The requirements are summarized in 2007 FTA Circular C4702.1A, Ch. 5, §4, "Requirement to Evaluate Service and Fare Changes":

> "[Recipients must] evaluate significant systemwide service and fare changes and proposed improvements at the planning and programming stages to determine whether these changes have a discriminatory impact." (*2*)

Specifically regarding fare changes, President Clinton issued Executive Order 12898 (*3*) in 1994 requiring Federal actions to address EJ in minority and low-income populations. The U.S. Department of Transportation (DOT) responded by issuing DOT Order 5610.2 (62 FR18377) in 1997 requiring development of a process within the framework of existing requirements (National Environmental Policy Act, Title VI of the Civil Rights Act of 1964). At the time, prevailing legal opinion was that the Order imposes no new statutory requirements for fare increases.

Beginning in 2004, FTA requested information from transit agencies relating to public hearings and fare increases analyses. NYCT already had an extensive public outreach process through its parent agency MTA. The 2009 fare increase hearings were conducted at eight locations, and comments were solicited via MTA's website and through regular mail. Responding to FTA request, NYCT developed methodologies for quantitatively analyzing fare change impacts to minority and low-income riders.

Statutory Impacts on Transit Fare Structure

Fare structure design processes should include predictive impact analyses. Prior to 2005, impacts to minority and low-income riders were not considered quantitatively. Comments received from public hearings included anecdotes of economic hardship and were available to the MTA Board prior to fare policy decisionmaking. However, without quantitative assessment of *how much* hardship and burden is endured by different socioeconomic groups, fare policy impacts cannot be known.

Outside New York, one state agency recently proposed a fare structure that eliminated a discounted "transfer", such that a subway-to-bus linked trip would require two full fares, rather than one full fare ($1.30) plus a transfer ($0.60). Transfers are required to reach economically disadvantaged outlying parts of the city. The constituents felt this proposal benefited suburbs with rail service at the expense of areas requiring transfers. The city government took the position that transfer fares elimination was inequitable, and invoked Federal Title VI provisions to protect the city residents' rights (*4*,*5*). After completing required analyses, the agency determined that an across-the-board fare increase was more appropriate instead of eliminating paper transfers. Importantly, statutory requirements of quantitative fare analyses prevented minority and low-income population from bearing larger shares of fare-increase burden.

In another case, one transit authority lowered cash fares from $1.35 to $1.25, and introduced day passes when 25-cent paper transfers were withdrawn in 2003. The $3 pass cost less than two single fares plus transfers, therefore "replaces need for transfers, makes multiple daily trips economical and convenient", and offered "best value for customers, especially those paying cash for daily tickets." (*6*) In New York, the "One City, One Fare" policy in effect since 1975, together with free MetroCard transfers instituted in 1997, helps to distribute transit fare burdens equitably between city residents.

Minority and Poverty Definitions

Circular Ch. 5, §1, "Requirement to Collect Demographic Data", defines minority and low-income areas as "Census tracts where minority and low-income resident percentages exceed the service area average". NYCT's service area includes New York City's five boroughs, where 2000 Census shows 65.02% are minority, and 21.25% below Federal poverty line.

Based on these definitions, subway stations and bus routes were classified as 'minority' or 'non-minority', and 'low-income (at or below poverty level)' or 'high-income (above poverty)'. Impact analyses are conducted at a station/route level, without identifying individual riders. Stations within or adjacent to minority tracts are 'minority' stations. A minority bus route has more than one-third of route length traversing minority tracts. Based on these criteria (first

promulgated by UMTA in 1972), 56% of stations and 67% of NYCT routes are minority; 54% of stations and 55% of routes are low-income.

DESIGNING FARE CHANGES

Historically, NYCT has enjoyed high farebox recovery ratios (69% subway, 39% bus) compared to other U.S. transit properties, by virtue of high development density and widespread adoption of rapid transit technology, which has lower operating costs per seat-mile. Due to high reliance on farebox revenues, NYCT has considerable experience in forecasting ridership and revenue trends (*7,8*), and has meticulously collected data going back to 1904 (*9*). The MetroCard Automated Fare Collection (AFC) system has given MTA more flexibility in restructuring fares to achieve policy goals. Thus, NYCT has a good understanding of how fare changes might affect ridership and trip patterns in aggregate (*10*).

Principal Assumptions

Disadvantaged customers (low-income and minorities) generally favour fare media with lower sales values due to less frequent travel, inability to pay higher amounts, and cultural attributes. Similar trends are observed in minority/non-minority comparisons.

Within each fare class (Figure 1, top), low-income population accounts for a larger share of subway boardings in low-value ($2.00), high fare-per-trip Pay-per-Ride (PPR) MetroCards. Conversely, high-income population accounts for a larger fraction of Monthly Unlimited ($81) boardings. In terms of shares of total (subway+bus) boardings and unique farecards in each income group (Figure 1, bottom), Cash fares, Non-Bonus PPR and Weekly Unlimited MetroCards are overwhelmingly preferred by low-income demographic, whereas opposite is true for Bonus PPR, Express Bus, and Monthly Unlimited MetroCards.

An inverse relationship exists between farecard value and average fare per trip. NYCT gives discounts to customers committing to riding transit frequently with Unlimited Passes. On aggregate, pass customers consume more rides per day than PPR customers, due to zero incremental cost of each ride. A side-effect of this fare structure is that someone with lower ability to pay (favouring low-value instruments) will pay more per trip than pass users.

Based on these observations, NYCT designs fare restructuring actions to minimize impacts to disadvantaged populations, encourage travel behaviours that help to fulfill policy goals, and generate revenues for system operations.

APPROACHES TO FARE CHANGE IMPACT ANALYSIS

Conventionally, an intercept survey is used to measure equity impacts. However, this approach has several specific limitations:

1. Marketing surveys identifying customers by demographic and income in a city diverse as New York raises potentially problematic sensitivities for a public agency.
2. Random samples are subject to biases relating to data collection processes. To properly administer a survey, a stratified sample with respect to fare media type, trip pattern, and

other demographic factors that might impact fare and travel decisions must be used. Gathering adequate and accurate samples can become very costly (*11*).
3. Even when correctly sampled, response bias limits fare change surveys' usefulness.
4. Typical origin-destination fare instrument surveys require analysts to determine what fare *would be* paid under proposed scenarios. Travel pattern and fare media changes resulting from fare increase are unaccounted for.
5. When properly designed to capture trip pattern and media substitutions with appropriate questions, it is a stated preference method. Customers are asked to 'pretend' under new fare structures. Recent research suggests many customers cannot do this accurately (*12*).

For these reasons, NYCT developed two independent approaches to perform required analyses. The first, more traditional approach disaggregates standard systemwide aggregate fare models (*7,10*) – calibrated using May 2003 and March 2005 Fare Increase data – that predict revenue, ridership, and average fares by media class. While it is a solid two-stage model able to account for diversion between transit and other modes and between different fare media, it does not disaggregate ridership changes by station/route or demographics. The disaggregation process weighs each station/route using observed fare media preferences at those locations, and computes average fares by demographics based on location profiles.

The second, more experimental approach follows recent trends toward treating a series of transactions on one farecard as sequential trips made by an individual (*11,14*), to study travel and purchasing characteristics (*15,16*). The discrete approach treats the day's first swipe location as proxy for user demographics, then follows farecards through the day's activities to determine daily average fares per trip *as actually experienced* by specific customers, and what fares would be paid assuming travel patterns and fare media preferences don't change. Figure 2 compares strengths and weaknesses of NYCT's two different approaches with classic surveys.

NYCT currently utilizes the disaggregation approach as standard fare impact analysis method, essentially assuming that demand elasticities within fare class and cross-elasticities between fare classes are independent of geography and demographics (even though market shares vary). While no evidence exists to suggest the contrary, an obvious area of future research is to disaggregate historical fare media sales data to separately calibrate demand elasticities. Factor analysis would reveal variables offering significant information about diversion behaviour, and model calibration would focus on relevant variables. Although not required by Title VI, NYCT more recently used the discrete approach to analyze proposed student fare increases, where no elasticity data was available.

MARCH 2008 FARE INCREASE PROPOSAL

For this fare increase, NYCT (in consultation with MTA) designed fare policies to leverage most social benefits from the transportation system while ensuring equity for protected demographic groups. Two options (Figure 3) were proposed:

1. **Option 6A** preserved the fare structure while encouraging riders to "buy-up" to an Unlimited pass. PPR fares (Single Ride Tickets and MetroCards) would see 12.5% increases ($2.00 to $2.25) while pass prices increase between 0% and 4.2%.

2. **Option CP5** mirrored the City's Congestion Charge proposal, offering new discounts to those travelling outside peak hours, while encouraging regular commuters to purchase passes. To induce off-peak travel, multi-ride MetroCard fares decrease by 10%~25% (to $1.50) after 10am, while remaining at $2.00 during peak hours. Pass prices increase between 6.6% and 8.3%, as passes are valid during peak periods.

In both options, a new 14-Day pass is introduced, priced at or below two 7-Day passes, allowing customers unable to afford Monthly passes access to larger discounts.

Analysis Method (Disaggregating Fare Media Elasticity Model)

Only the disaggregation approach was used for this fare increase. NYCT's aggregate fare model uses historical farecard data and contains two components calibrated from observations made before and after prior fare increases (*10*): 'revealed' diversion rates between different fare media (i.e. cross-elasticity) and trip attenuation rates (i.e. direct elasticity) as some passengers curtail discretionary trips due to higher fares. Although it accurately predicts fare change impacts on ridership and media choice, it is not sensitive to demographics; travel demand is treated as an aggregate citywide phenomenon and changes are not disaggregated geographically or otherwise.

Theoretically, the model could be calibrated for each demographic (or geographic area, which correlates with demographics) using historical farecard purchase and usage data. This entails substantial model development work and computation resource requirements. Instead, readily available "base case" station- and route-level boarding (i.e. farecard swipe) information was filtered by demographics (minority/non-minority; low-/high-income) and time periods (peak/off-peak). The aggregate model results were applied to this data (Figure 4), allowing comparisons of average fare changes by demographics. Potential disparities are then identified, and results used to inform fare design processes.

The disaggregation process (Figure 5) computes projected percentage-change in ridership and average fare by fare media and mode, then applies resulting percentages to base case data for each fare class, mode, and station/route. Having calculated predicted ridership and average fare, a simple ratio is used to 'back out' expected revenues. The overall average fare (by station, route, or demographics) is total revenue divided by total ridership.

Analysis Results

Option 6A (across-the-board adjustment) incurred a marginally larger increase (6.7%) in average fare for minorities during the peak (6am – 10am) compared with non-minorities (6.0%). However, minorities continue to pay lower average fares ($1.31) than non-minorities ($1.40). Conversely, Option CP5 imparts a generally larger increase during peak hours, but resulted in near equal impacts (11.3% versus 11.2%). As with 6A, minorities continue to pay lower average fares ($1.36 versus $1.47).

During off-peak (10am – 3pm), Option 6A raised fares for minorities more than non-minorities, but increases for both demographic are within 0.5%. Option CP5 lowered fares for minorities and non-minorities equally, with overall average fares decreasing about 1%.

Overall impacts of 6A and CP5 are basically equivalent (Figure 6). Both increase fares approximately 6%~7% systemwide. However, the fare increase burden's distribution is dramatically different. Option 6A essentially preserves the status quo, with each demographic and time-period bearing the burden approximately equally, with minorities subject to slightly higher percentage increases (up to 0.7% more) than non-minorities. Conversely, Option CP5 places burden entirely on peak riders, regardless of demographic. Peak fares increase by 11% while off-peak riders actually pay slightly less. More importantly, CP5 distributes burden more equally between minorities and non-minorities, with differences in increases remaining within 0.2%.

There is striking correspondence between income- and minority-based results, both telling the same story: 6A places marginally more burden on low-income stations/routes; CP5 disproportionately places burden on peak riders, but distributes it more equitably, with higher-income stations/routes paying slightly more.

Outcome

In December 2007, MTA Board approved 3.5% fare increases effective March 2008 (*17*). For reasons outside of agency's control, the Congestion Pricing proposal did not come to fruition. The redesigned fare adjustments combined best features of both proposals to reflect the new political reality, raising Monthly Pass prices by higher percentages than Weekly Pass (shifting burden somewhat towards the higher-income demographic), introduced new 14-Day Passes, and kept base fare at $2.00. Analysis shows that average fares increases by 3.5% for all groups. Minorities and low-income continue to pay lower average fares. As it turns out, March 2008 fare increase didn't solve all of the agency's financial problems.

JUNE 2009 FARE INCREASE PROPOSAL

Due to the ongoing economic crisis (*18*), June 2009 Fare Increase proposal was much more severe than 2008. System generated revenues, commercial property transfer and mortgage recording taxes, and payroll surcharges decreased while materials, pension, health coverage, and borrowing costs were actually increasing (*19*). Absent additional funding commitment or increases in tax-based subsidies, the Authority had no alternative except to increase fares and cut service to balance its 2009 budget.

This increase's primary purpose was to raise revenue, and not necessarily to induce changes in travel behaviour. Following 2008's increase, fares were increased 'across-the-board' with similar percentage increases for all fare media types as much as possible, resulting in approximately equal impacts for all groups.

Fare Structure Design

Four options were proposed at public hearings (Figure 7). Options 23A and 23B increases average fares by approximately 25% and revenues by 23% (due to reduced discretionary travel). Options 8A and 8B, contingent on "Ravitch Report" funding sources, increases average fares about 8%. In effect, it distributes system subsidy burdens more equitably on non-transit users through tolls on East River bridges and regional taxes, reflecting transit's contribution to local

economy and overall regional mobility by preventing traffic gridlock and providing better accessibility to the region's core.

Two 2009 proposals differentiate Cash and PPR fares by explicitly requiring a higher Cash fare, replacing the MetroCard Bonus in effect since 1998. In Option 23B, Cash fare is raised from $2.00 to $3.00 (50%), but MetroCard fare is $2.25, resulting in effective increases of only 29% to 13% (depending on whether Bonus fares were previously purchased). The 15% 2008 Bonus 'volume discount' requiring minimum $7.00 purchases (for $8.05 value awarded) is converted to 33% discount ($3.00 Cash vs. $2.25 MetroCard) for all farecard holders, with no minimum purchase requirement.

This change addresses longstanding criticisms that discounts aren't available to those who need it most – low-income occasional riders unable to pay up-front costs to 'buy in' to the program (the Bonus Threshold). Indeed, the MetroCard Bonus program has consistently reduced the threshold, from $15 (1998), to $10 (2003), then $7 (2007). These fare options effectively lower the threshold to $2.25, allowing disadvantaged population to benefit from Bonus discounts..

Further Development of Analysis Methods

Statistical Tests

Methods developed in 2008 (approved by FTA in the 2004-2007 Triennial Title VI submission) were used in 2009. However, concerns were raised about small differences in percent-change and absolute dollar-change, requiring judgment calls as to whether 0.1% or $0.01 differences constitute acceptable equity within error margins. Obviously, these projections are generated from models containing assumptions and inherent errors. Standard two-sample unpaired *t*-test (*20*) determines whether small differences between averages are *statistically significant*.

t-statistic is calculated from means and standard deviations of both samples, and compared to a *t*-critical value (dependent on standard deviations and observation counts). If sample *t*-statistic falls within *t*-critical range, two averages are sufficiently close and considered statistically equal.

NYCT conducted statistical analysis on the subway station/bus route level (separately for each mode) to verify equitable distribution of impacts. *Average change in fare paid* is used for *t*-tests, because tracking individual transit user's demographics isn't possible. Average change in fare is the average of all differences between current and new average fares on a station/route basis, weighted equally. If average changes are statistically equal between groups, the fare structure is not discriminatory. In other words, fare adjustments are independent of demographics – or "racially blind" – if impacting minority/non-minority equally.

Discrete Farecard Approach

Due to proposal's severity, alternative approaches were sought to understand effects of model's simplifying assumptions. The discrete farecard approach was developed to understand impacts as perceived by individual farecard holders. To understand the customer perspective, swipe-level data was used to track specific farecards and calculates average fares experienced by individual users over reasonable time horizons. NYCT doesn't track revenue passengers using personally identifiable information, but farecards are tracked using anonymous IDs.

Computer programs were developed to track transactions, actual fares paid, and future fares *that would be paid* throughout an entire day for all swipes. The program (Figure 8, top):

1. Sorts all swipes by Card ID.
2. For each farecard, attaches minority/income classifications using station/route indicated in the day's first swipe. Farecards with first swipes occurring outside NYCT service area (Westchester Bee-Line, Long Island Bus, PATH, MTA Bus) or at designated commuter hubs are discarded (Figure 8, bottom).
3. For each PPR farecard:
    a. Determine fare paid in each transaction (either $2.00 or $0.00 free transfer), and attach fare that *would be paid* for same trips under each fare scenario.
    b. Determine average daily customer cost per trip (total fares divided by total transactions) for that farecard.
4. For each Unlimited farecard:
    a. Determine daily transaction counts;
    b. Divide allocated daily pass cost by transaction counts to obtain average cost per trip. Pass cost is allocated on a six-day week basis.
5. Summary data for each farecard is written out to a flat file, by Card ID. Special farecards (half fares) are processed separately. Student, employee, and official passes are ignored.

While farecard users' actual demographics cannot be known, first swipe location/route (proxy for user's normal residence) may be a better indicator than to simply assign swipes to surrounding neighbourhoods. Average fares experienced by individual farecard users also better represents customer perceptions than the systemwide aggregate. Although customer perception is not a criterion under Title VI, NYCT conducted analysis to see if potential issues might arise where certain individuals would be impacted disproportionately *if* they chose not to change their traffic patterns and fare media preferences.

Results

Analysis was not conducted separately for peak/off-peak, because no time-of-day pricing options were sought. The 23% options (23A, 23B) essentially increase average fare by 25% for minorities and non-minorities (Figure 9, top), and for both high- and low-income riders. All increases show less than three-cent (0.5%) difference. Disadvantaged riders continue to pay substantially lower average fares.

Ravitch options (8A, 8B) also continue to maintain lower fares for minority/low-income groups, increasing by about 8%. Percentage-increases for disadvantaged groups are 0.1% more, due to essentially equal increases in dollar value (within one cent), which forms a greater percentage of lower base average fares. Overall impact raises average fares to approximately $1.43. NYCT carefully designed fare structures to distribute impacts equally amongst all groups, to within a few cents (or fractions of one percent).

Statistical Tests

t-tests (Figure 9, middle) were conducted for each mode because of different basic units for demographic classification (subway station/bus route). In this more detailed analysis, NYCT

found negligible (less than one cent) but statistically significant disparity under two options (23B, 8B). In each case non-minorities are more adversely affected than minorities, therefore no corrective action is necessary (*2*). Similar results are found for income; all significant disparities resulted in high-income populations being more adversely affected. No other statistically significant disparities were found.

Farecard Level Disaggregation

MetroCard data from Thursday 10/16/2008 (total 6.3 million transactions) was selected for farecard-level disaggreration. For all regular fare instruments under all options, without accounting for passengers changing fare instruments, average of individual farecard holders' perceived fares increased by larger amounts for non-minorities than minorities (Figure 9, bottom). Results were similar for income. All disadvantaged groups experienced smaller increases when service consumption data is analyzed at individual farecard level.

Outcome

In December 2008, MTA Board adopted its 2009 Final Proposed Budget amid a shoe-throwing protest by one transit rider (*21*). The budget projected deficits of $1.2 billion, due to the weakening economy and MTA's structural deficits (*22*). Concurrently, the Ravitch Commission made recommendations to provide new sources of revenues to MTA. On May 5, New York State Legislature approved a modified plan:

> "Fare increases will contribute $500 million… Fare rise 10% now, 7.5% in 2011 and another 7.5% in 2013. The proposal raises $1.5 billion from payroll taxes… [Taxi, car rental, vehicle registration] levies contribute $261 million… The agreement avoided [Harlem River bridge] tolls controversial with suburban commuters." (*23*)

Subsequently, the MTA approved a smaller 10.4% fare increase (*24*). Projections for payroll taxes proved optimistic, resulting in 2010 budget shortfalls of $800 million. While proposed service rationalizations were averted in 2009, revised "2010 NYCT Service Reductions" is pending implementation (*25*), together with lay-offs affecting both administration and labor.

METHODOLOGY DISCUSSION

Fare Model Disaggregation

NYCT used average fare data at the station/route level for significance testing, due to difficulty in disaggregating projections. This model architecture results in three interrelated logical consequences:

1. Each station/route is weighed equally; analysis for disparity is therefore at this level. Statistically significant findings indicate that impacts affect one group of stations more than another – not one population versus another.
2. *t*-tests on *average change in fare paid* at each station/route accounts only for variance between stations/routes – and thus not sensitive to differences between riders *at the same station*. However, since rider demographics are location-based, this isn't a huge area of concern.

3. Station/route aggregation processes already remove much of the variance in individual fares paid. Standard deviations are artificially low compared to approaches examining individual trips or passengers, resulting in *t*-tests extremely sensitive to small differences between groups. Even at this high sensitivity, NYCT found no significant adverse impacts to disadvantaged groups.

Statistical tests at lower disaggregation levels may be impossible, as accurate predictions of travel patterns changes by specific farecard holders is required. While models could be developed that explicitly analyze trip patterns for each farecard, calculate "breakeven" points, and automatically choose most economical fare instruments, such model may not accurately reflect customer behaviour. Prior research suggests some passengers have intrinsic preferences for certain fare plans (*15*). Some riders strongly prefer the freedom of passes despite higher costs per trip, whereas others choose PPR even though money could have been saved with passes.

Statistical tests can be conducted "after-the-fact" by comparing observed farecard usage patterns before and after fare changes, for an equivalent sample set of farecards randomly chosen to represent each demographic. London Underground has conducted some work using this fare panel concept (*16*), an interesting area of further research for NYCT.

Farecard Level Analysis

Of the two approaches, farecard-level analysis is more experimental and not routinely used because of certain shortcomings:

1. **PPR MetroCard Bonus:** Prior to 2009 fare adjustments, MetroCard purchases of $7.00 at point-of-sale (POS) are awarded $1.05 (or 15%) 'Bonus Value', resulting in $8.05 farecards good for four rides. At point-of-entry (POE), transactions are recorded as four $2.00 rides with $0.05 residual value. Because MetroCard Vending Machines (MVMs) allow addition of arbitrary amounts, a single farecard could contain both 'Bonus' and 'Non-Bonus' values concurrently (e.g. customers purchasing $7.00 cards ($8.05 value) subsequently adding $1.95 to complete five rides). Transaction records are not coded with initial card value or Bonus/Non-Bonus. Properly calculating effective fares paid by individual PPR passengers require complex programs joining POS to POE data. Forecasting this consistently under proposed fare structures is even more analytically challenging.
2. **Unlimited Pass Utilization and Average Fare:** Current design analyzes daily AFC files containing all transactions on a MetroCard Revenue Day. When calculating customers' average fares paid, crude assumptions are made about daily pass costs. More correctly assessing average fare per trip for one specific Unlimited farecard require counting all transactions throughout its validity period. Computationally, this entails sorting and processing 59 days' worth of data (approximately 430 million transactions, 29.2 gigabytes) per analysis day, well beyond NYCT's typical workstation processing capability. Stratified sampling techniques may be necessary to establish pass users' average fares per trip.
3. **Cash, Single Ride Ticket, and Paper Transfers:** MetroCard AFC doesn't track single ride tickets (SRT) and paper encoded transfers (PET). The cardboard SRT/PET ticket

stock has narrower magnetic strips and don't carry serial numbers. A counter is incremented every time SRT/PET is issued or used, but POS and POE cannot be associated for these tickets, making it impossible to disaggregate transfer rates for cash customers by route. SRT/PET accounts for small market shares (<5%), but nonetheless is important in fare policy discussions, because Cash fares are overwhelmingly used by minority/low-income occasional riders.

4. **Diversion Factors:** Designed to study *what if* riders retained same trip patterns and fare instruments after fare restructuring instead of predicting how customers actually behave, discrete analyses of base and proposed fares don't account for these changes.

LESSONS LEARNED

While Title VI analysis might be seen as a matter of code compliance, it should be integral to fare policy decisions and fare structure design. Models allowing ridership, revenue, and equity impacts under different fare structures to be studied are an important part of the transit agency's fare policy toolbox.

As AFC systems and ticket vending machines become ubiquitous at transit agencies and commuter railroads, valuable data streams are generated, allowing fare purchase decision analyses not only by location, time-of-day, media type, fare class, method of payment, but also variables inferred indirectly like demographics, trip purpose, trip length, and destination. Where available, fare change analyses should be conducted using automatically collected data, rather than surveys. Both NYCT approaches can be adapted for other properties, but further work is required depending on local AFC specifics.

For 2009 fare increase, NYCT used both approaches to analyze impacts to low-income/minority neighbourhoods. Differences in average fare increases were always less than 3 cents (or 0.5%, usually substantially less) between groups, with higher increases affecting high-income/non-minority populations. *t*-tests demonstrated statistically significant disparities in some cases, however, no corrective actions were required because disadvantaged neighbourhoods were less adversely affected. Farecard-level analysis, though experimental, confirmed that fare increases for disadvantaged farecard holders were always lower.

This should not be surprising: In New York, disadvantaged neighbourhoods are often more affordable because of lower transit accessibility, requiring long subway rides or bus-subway transfers. Since 1975, NYCT's "One City, One Fare" policy (and free MetroCard transfers introduced in 1997) has meant disadvantaged neighbourhoods tended to pay lower fares per trip (and lower fares per mile, even though this wasn't explicitly assessed). The main concern when designing fare options is to ensure that when adjusting relative prices of Passes and PPR MetroCards, situations aren't inadvertently created where average fare increases are higher for disadvantaged groups.

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REFERENCES

(1) Commission on Metropolitan Transportation Authority Financing (The Ravitch Commission). *Report to Governor David A. Paterson*, New York, N.Y., December 2, 2008.

(2) U.S. Department of Transportation, Federal Transit Administration. *Circular FTA C4702.1A: Title VI and Title VI-Dependent Guidelines for Federal Transit Administration Recipients*. File No. FTA-2005-23227-62. Washington, D.C., 2007.

(3) The White House. Executive Order 12898: Federal Actions to Address Environmental Justice in Minority and Low Income Populations. In *Federal Register*, February 11, Vol. 59, No.32. Washington, D.C., 1994.

(4) Larry Eichel. *FTA Letter Aids City's Fight to Keep 60-cent SEPTA Transfers*. The Philadelphia Inquirer, Philadelphia, Penn., August 6, 2007.

(5) Ashwin Shandilya. *SEPTA Raises Fares Again as Token Prices Go Up 15 Cents*. Daily Pennsylvanian, Philadelphia, Penn., October 1, 2007.

(6) Dave Sotero, M. Littman. *New Metro Day Pass to Provide Customers with Unbeatable Value for Daily Transit Needs*. Press Release, Los Angeles County Metropolitan Transportation Authority. Accessed at *http://metro.net/news_info/archives/2003/12_december/mta_205.htm* on October 10, 2007.

(7) Lawrence R. Hirsch, Jordan D., Hickey R.L., and Cravo V. Effects of Fare Incentives on New York City Transit Ridership. In *Transportation Research Record 1735*, Transportation Research Board of the National Academies, Washington D.C., 2000.

(8) Jennifer E. Cohen, Williams A., and Cravo V. The Impact of Weather on Transit Revenue in New York City, TRB Paper #09-3036. In *Proceedings of the 88th Annual Meeting of the Transportation Research Board*. CD-ROM. Transportation Research Board of the National Academies, Washington D.C., 2009.

(9) NYCT Office of Management and Budget. *Annual Subway & Bus Ridership Report, New York City Subway Centennial Edition: 1904-2004*. New York, N.Y., 2004.

(10) Robert L. Hickey. Ridership and Revenue Impact of May 2003 MTA New York City Transit Fare Increase, TRB Paper #05-2314. In *Transportation Research Record*, Transportation Research Board of the National Academies, Washington D.C., 2005.

(11) Alla Reddy, A. Lu, S. Kumar, V. Bashmakov, and S. Rudenko. Application of Entry-Only Automated Fare Collection (AFC) System Data to Infer Ridership, Rider Destinations, Unlinked Trips, and Passenger Miles. TRB Paper # 09-0809. In *Transportation Research Record 2110*, Transportation Research Board of the National Academies, Washington, D.C., 2009.

(12) Stephanie Hess, J. Shires, and P. Bonsall Treatment of Respondent Uncertainty in Stated-Choice Survey for Fare Simplification on Bus Journeys. TRB Paper #10-3006. In *Proceedings of the 89th Annual Meeting of the Transportation Research Board*. CD-ROM. Transportation Research Board of the National Academies, Washington D.C., 2010.

(14) James J. Barry, R. Newhouser, A. Rahbee, and S. Sayeda. Origin and Destination Estimation in New York City Using Automated Fare System Data. In *Transportation Research Record*, Transportation Research Board of the National Academies, Washington, D.C., 2002.

(15) Michael Frumin. *The Choice between Period Tickets and Pay As You Go on London's Public Transport System: Implications for Efficiency, Revenue, and Best Value*. Unpublished Manuscript, Massachusetts Institute of Technology, Submitted to Transport for London, Cambridge, Mass., 2008.

(16) Hazem Zureiqat, Wilson, N. H. M., and Attanucci, J. Fare Policy Analysis for Public Transport: A Discrete-Continuous Modeling Approach Using Panel Data, TRB Paper #09-1591. In *Proceedings of the 88th Annual Meeting of the Transportation Research Board*. CD-ROM. Transportation Research Board of the National Academies, Washington D.C., 2009.

(17) Metropolitan Transportation Authority. *MTA Board Approves 2008 Budget – Fare and Toll Increases to Take Effect in March.* Press Release #81, New York, N.Y., 2007. Accessed at *http://www.mta.info/mta/news/releases/?en=071219-HQ81* on February 5, 2009.

(18) Metropolitan Transportation Authority. *MTA Budget Deficit Grows by $621 Million*, April 27, 2009. Accessed at *http://www.mta.info/mta/news/releases/?en=090427-HQ12* on June 22, 2009.

(19) Aaron Stern. *Money and Myth: Financial Plan Review and the Origins of the Deficit*. Office of Management and Budget, Presentation to the NYCT Presidential Speaker Series, New York, N.Y., June 5, 2009.

(20) John E. Freund. *Modern Elementary Statistics, Tenth Edition, Chapter 12: Tests of Hypothesis*. Prentice Hall, Upper Saddle River, N.J., 2001.

(21) William Neuman. Say Whatever You Want, but No Throwing Shoes, *The New York Times*, New York Section, December 18, Page A37, New York, N.Y., 2009.

(22) Metropolitan Transportation Authority. *Fare, Toll, Service Facts – Changes in Fares and Tolls, Levels of Service, and Station Staffing*. Accessed at *http://www.mta.info/mta/09/overview5.pdf* on February 19, 2009.

(23) Metropolitan Transportation Authority. *MTA Board Approves Reduced Fare and Toll Increase*, May 11, 2009. Accessed at *http://www.mta.info/mta/news/releases/?en=090511-HQ15* on June 22, 2009.

(24) Valerie Bauman. MTA Bailout Resolved for $2.26 Billion in First Year. In *Newsday Long Island*, May 5, 2009. Accessed at *http://www.newsday.com/* on May 6, 2009.

(25) New York City Transit. *2010 Service Reductions*, January 27, 2010. Accessed at *http://mta.info/mta/news/books/pdf/100125_1031_service2010-nyct.pdf* on March 4, 2010.

LIST OF FIGURES

Subway Fare Media Choice by Originating Station Demographic

Fare Media Type	2008 Sales Value	% Share of Boardings within Fare Media Class (by Station)		Average Fare per Trip
		Low Income	High Income	
Monthly Unlimited	$81	38%	62%	$1.15
14-Day Unlimited	$47	50%	50%	$1.20
Weekly Unlimited	$25	51%	49%	$1.21
Pay-per-Ride MetroCard	$4 or more	58%	42%	$1.58

Systemwide Fare Media Market Shares by Income Demographic

Analysis Method (see notes below)	**Method 1:** ** Share of AM Boardings (6-10am)		**Method 2:** Share of Daily Swipes		**Method 3:** Share of Unique Farecards	
Fare Media Type	**Low Income**	**High Income**	**Low Income**	**High Income**	**Low Income**	**High Income**
Cash	7.6%	2.6%	Not known from farecard data*		Not known from farecard data*	
Single Ride Ticket	2.1%	2.1%				
Non-Bonus PPR MetroCard	8.8%	5.9%	44%	47%	55%	56%
Bonus PPR MetroCard	31%	39%				
Fun Pass (1 Day)	0.7%	1.0%	0.7%	0.7%	0.4%	0.4%
Weekly Pass	18%	13%	19%	12%	14%	8%
14 Day Pass	2.2%	1.6%	2.6%	1.4%	1.9%	1.1%
Monthly Pass	28%	35%	34%	39%	29%	34%
Express Bus Pass (7 Days)	0.1%	0.5%	0.1%	0.6%	0.1%	0.5%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

* **Note:** MetroCard swipe data does not include Cash and Single Ride Ticket data, and does not provide a mechanism for distinguishing between Bonus and Non-Bonus PPR cards.
** **Method 1:** Income shares of *total AM boardings* by fare media class, based on AM peak revenue data (6am-10am, May through October, 2008), income buckets identified based on station/route where transaction (card swipe/coin deposit) occurred.
Method 2: Market shares of *total swipes* (unlinked trips), based on MetroCard swipe data (October 16, 2008) disaggregated by income buckets identified using station/route characteristics where the first swipe of the day occurred.
Method 3: Market shares of *total unique farecards*, based on MetroCard swipe data (October 16, 2008) disaggregated by income buckets identified using station/route characteristics where the first swipe of the day occurred.

FIGURE 1 Analysis of passenger income demographics by fare media type (2008).

	Conventional Stated-Preference Marketing Survey	**Disaggregation of Fare Media Elasticity Model**	**Discrete Analysis of Individual Trip Itineraries and Fares Paid**
Accurately measure individual impacts	Accurate measurement depends on proper sampling	Fare increase impacts are represented as overall increases in average fares for a specific customer group	Fare increase impacts are measured for individual customers then aggregated to determine average
Captures trip attenuation and fare media diversion	Survey can be designed to capture rider expectations of future travel	Trip attenuation and diversion between different fare media are based on historical observed rates	Computes new average fares *assuming* that riders cannot change their travel patterns and fare media preferences
Properly determines passenger demographics	Relies on self-reporting by each survey respondent	Assumes customer demographics is a function of station location and analyzes morning and midday trips	Assumes customer demographics is a function of the location of the day's first swipe
Appropriately measure average fare for periodic passes	Assumes each customer pays the average fare for their chosen fare instrument	Disaggregates average fares by fare media on the basis of fare media market shares at each station	Assumes a "ownership cost per day" for periodic passes then divide by actual daily trip count
Provides a statistical distribution of average fares paid	Does not provide a distribution in a typical survey setup	Within each demographic, only an average fare is provided, not a standard deviation nor a distribution	A distribution of average fares can be provided for any level of aggregation higher than individual customers
Accounts for multi-ride "bonus fare" discounts	Bonus fare usage is self-reported by each respondent	At the aggregate level, average fares are allocated on the basis of past purchase patterns by station	Does not account for bonus fares because individual farecards can hold both bonus and non-bonus fares
Explicitly analyzes average fare impact for cash riders	Only if sufficient and representative cash customers are captured in the survey	Yes, on the basis of aggregated "cash, single ride ticket, and magnetic transfers" category	No, because demographics of cash riders cannot be inferred from farecard serial number
Ease of application of statistical tests	Standard methods may be used; treats each respondent as one observation	Level of aggregation at which the statistical tests are conducted can be debated and may affect results	Treats each customer's average fare as a single data point and is arguably the most accurate application of *t*-tests
Model can be recalibrated easily using new data	Each fare change proposal requires a time-consuming and expensive survey	Elasticities and cross-elasticities require time consuming manual matrix computation to derive	Program analyzes daily farecard data dumps automatically, but cannot yet handle multi-day analysis
Able to roll average fares up to the systemwide level	Average fare found in survey may not exactly match the systemwide average	Average fare within each group is always weighted based on trips, i.e. total revenue divided by total trips	Rolling up to the systemwide average fare requires appropriate weighting by farecard or by group
Uses revealed preference data	No, unless surveyor validates respondent's actual fare media	Yes – dataset reflects historical fare media *and travel* decisions made by customers	Yes – dataset reflects actual fare media choices made by *current* customers

FIGURE 2 Three approaches to analyzing fare change impacts by rider demographics.

Fare Instrument	2005 Base	Option 6A		Option CP5		
		All Day	% Change	Peak	Off-Peak	% Change
Local Bus or Subway						
Cash/Single Ride Ticket	$2.00	$2.25	13%	$2.25	$2.25	13%
Non-Bonus MetroCard™	$2.00	$2.25	13%	$2.00	$1.50	Varies
Bonus MetroCard	$1.67	$1.88	13%	$2.00	$1.50	Varies
One Day Fun Pass™	$7.00	$7.50	7%	$7.50	$7.50	7%
7-Day Pass	$24.00	$25.00	4%	$26.00	$26.00	8%
New 14-Day Pass	—	$45.00	—	$48.00	$48.00	—
Monthly Pass	$76.00	$79.00	4%	$81.00	$81.00	7%
Express Bus						
Non-Bonus MetroCard	$5.00	$5.25	5%	$5.00	$5.00	0%
Bonus MetroCard	$4.17	$4.38	5%	$5.00	$5.00	20%
7-Day Express Pass	$41.00	$41.00	0%	$40.00	$40.00	-2%

FIGURE 3 March 2008 proposed fare restructuring options, including a proposed peak/off-peak fare differential.

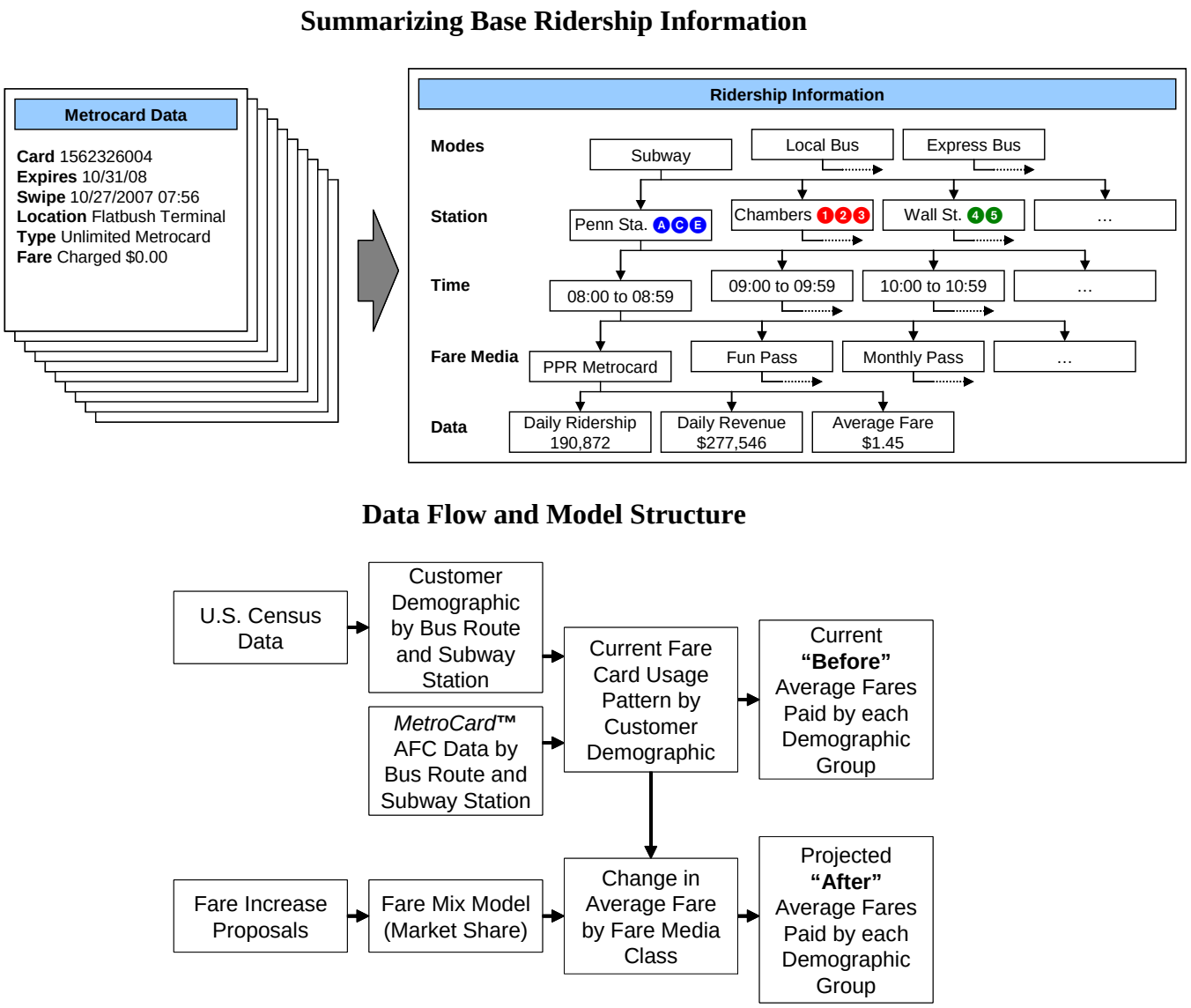


FIGURE 4 Data flow and structure of NYCT model for Title VI fare change analysis.

$$\Delta P_{FM} = \frac{P_{FM(\text{after})} - P_{FM(\text{before})}}{\sum_{\forall\, FM \text{ in } \{\text{Fare Media, Mode}\}} \left(P_{FM(\text{before})} \right)} \qquad \textit{(Equation 1)}$$

$$P_{FMG(\text{after})} = P_{FMG(\text{before})} \times (1 + \Delta P_{FM}) \qquad \textit{(Equation 2)}$$

where

ΔP_{FM} is the percentage-of-total change in ridership for each fare class in each mode
$P_{FM(\text{after})}$ is the ridership in that fare class and mode after fare change
$P_{FM(\text{before})}$ is the ridership in that fare class and mode prior to fare change
P_{FMG} is the ridership in that fare class and mode by geography (station/route)

$$\Delta f_{FM} = \frac{f_{FM(\text{after})} - f_{FM(\text{before})}}{f_{FM(\text{before})}} \qquad \textit{(Equation 3)}$$

$$f_{FMG(\text{after})} = f_{FMG(\text{before})} \times (1 + \Delta f_{FM}) \qquad \textit{(Equation 4)}$$

where

Δf_{FM} is the percentage-of-total change in average fare for each fare class in each mode
$f_{FM(\text{after})}$ is the average fare in that fare class and mode after fare change
$f_{FM(\text{before})}$ is the average fare in that fare class and mode prior to fare change
f_{FMG} is the average fare in that fare class and mode by geography (station/route)

$$R_{FMG(\text{after})} = f_{FMG(\text{after})} \times P_{FMG(\text{after})} \qquad \textit{(Equation 5)}$$

$$f_{MD(\text{after})} = \frac{\sum_{\substack{\forall\, FMG \text{ in } \{\text{Fare Media, Mode,} \\ \text{Station or Route in that Demographic Group}\}}} \left(R_{FMG(\text{after})} \right)}{\sum_{\substack{\forall\, FMG \text{ in } \{\text{Fare Media, Mode,} \\ \text{Station or Route in that Demographic Group}\}}} \left(P_{FMG(\text{after})} \right)} \qquad \textit{(Equation 6)}$$

where

$R_{FMG(\text{after})}$ is the projected revenue for that fare class, that mode, and the appropriate geography (station/route)
$f_{MD(\text{after})}$ is the projected average fare in that fare class for the demographic group represented by selected route and stations, after fare restructuring

FIGURE 5 Details of the fare model disaggregation process.

Time Period	Demographic	Base Case Average Fare	Option 6A Average Fare	Option 6A % Change	Option 6A $ Change	Option CP5 Average Fare	Option CP5 % Change	Option CP5 $ Change
Peak	Non-Minority	$1.32	$1.40	6.0%	$0.08	$1.47	11.3%	$0.15
	Minority	$1.22	$1.31	6.7%	$0.09	$1.36	11.2%	$0.14
Off-Peak	Non-Minority	$1.22	$1.31	6.9%	$0.09	$1.21	-1.4%	-$0.02
	Minority	$1.18	$1.26	7.4%	$0.08	$1.16	-1.2%	-$0.01
Total	Non-Minority	$1.29	$1.37	6.3%	$0.08	$1.38	7.1%	$0.09
	Minority	$1.20	$1.29	7.0%	$0.09	$1.28	6.3%	$0.08
Overall		**$1.23**	**$1.32**	**6.7%**	**$0.09**	**$1.32**	**6.6%**	**$0.09**

Note: NYCT used May 2006 data from all stations (except transfer hubs predominantly used by commuters from outside of New York City, like Penn Station, Grand Central, Port Authority Bus Terminal, Howard Beach, and Jamaica-Sutphin) to populate "base case" fare media preferences by demographic.

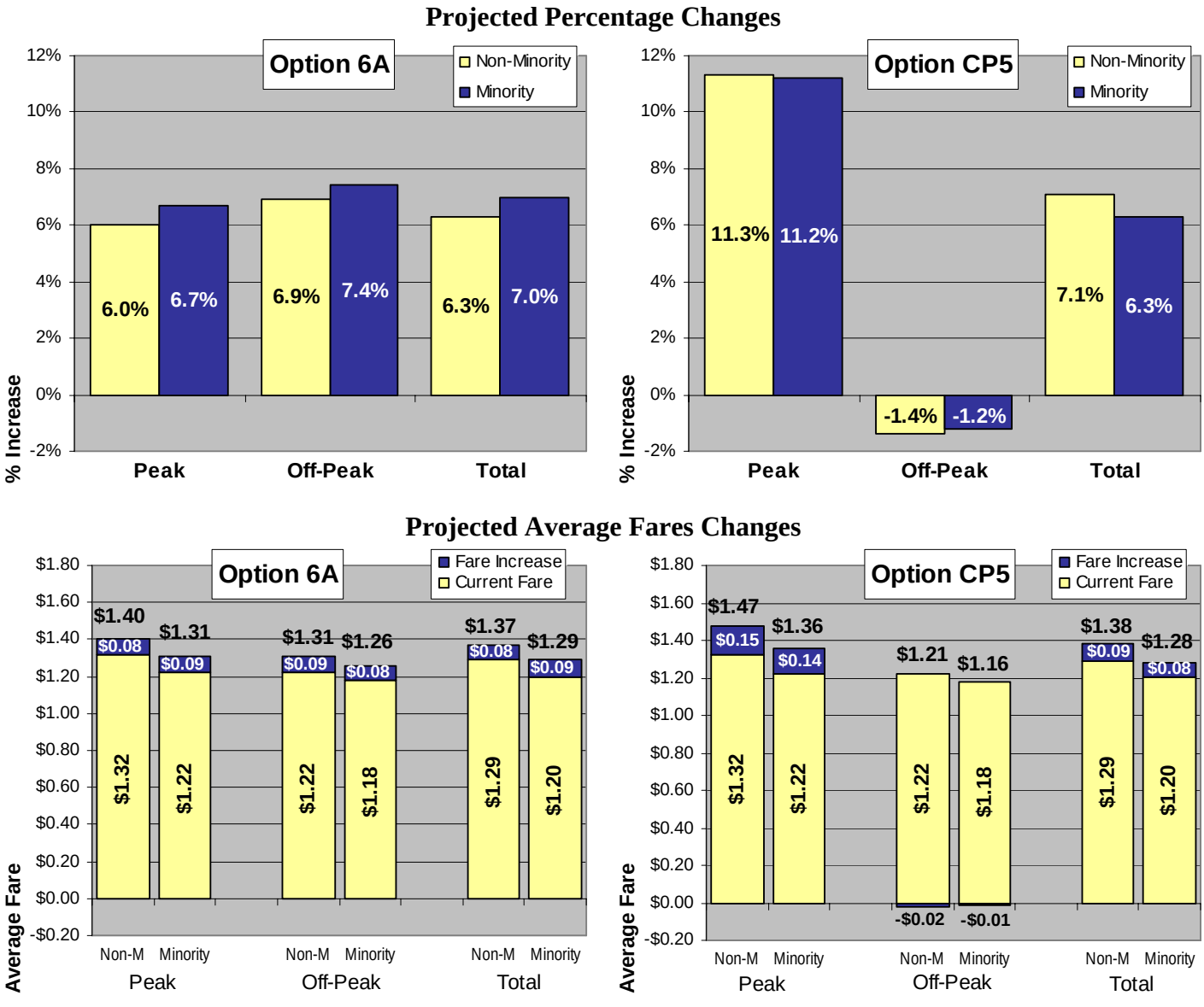
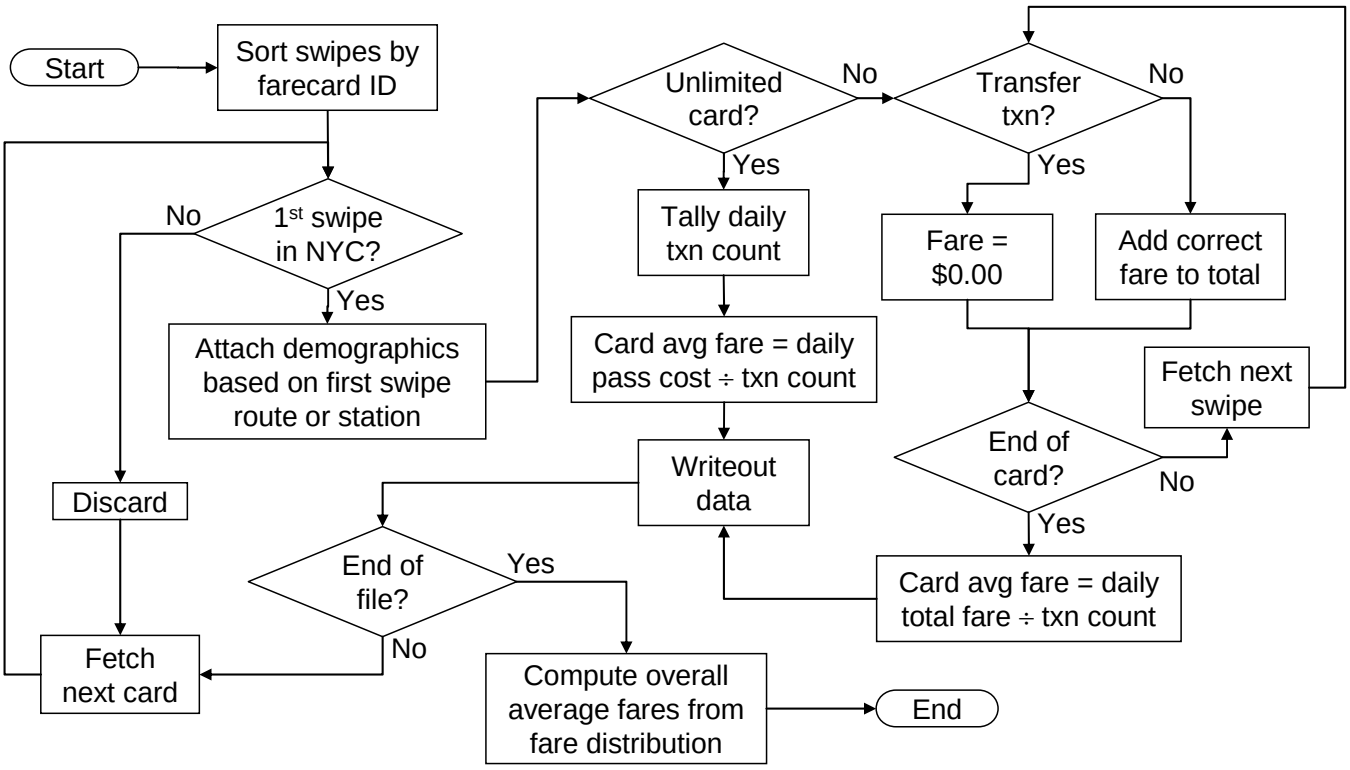


FIGURE 6 March 2008 projected average fare changes by minority/non-minority status.

Fare Instrument	2008 Base Sales Value	Option 23A Sales Value	Option 23A % Chg	Option 23B Sales Value	Option 23B % Chg	Option 8A Sales Value	Option 8A % Chg	Option 8B Sales Value	Option 8B % Chg
Local Bus or Subway									
Cash/Single Ride Ticket	$2.00	$2.50	25%	$3.00	50%	$2.25	13%	$2.25	13%
Non-Bonus MetroCard	$2.00	$2.50	25%	$2.25	13%	$2.25	13%	$2.00	0%
Bonus MetroCard	$1.74	$2.17	25%	$2.25	29%	$1.88	8%	$2.00	15%
1 Day Pass	$7.50	$9.50	27%	$9.50	27%	$8.00	7%	$8.00	7%
7 Day Pass	$25.00	$31.00	24%	$31.00	24%	$27.00	8%	$26.00	4%
14 Day Pass	$47.00	$59.00	26%	$57.00	21%	$49.00	4%	$49.00	4%
30 Day Pass	$81.00	$103.00	27%	$99.00	22%	$88.00	9%	$87.00	7%
Express Bus									
Cash	$5.00	$6.25	25%	$6.00	20%	$5.75	15%	$5.50	10%
Non-Bonus MetroCard	$5.00	$6.25	25%	$5.50	10%	$5.75	15%	$5.00	0%
Bonus MetroCard	$4.35	$5.43	25%	$5.50	27%	$4.79	10%	$5.00	15%
7 Day Express Pass	$41.00	$51.00	24%	$51.00	24%	$45.00	10%	$47.00	15%

FIGURE 7 June 2009 proposed fare restructuring options, including two 23% options, and two 'Ravitch' options contingent on additional funding mechanisms.



Sample Data

Poverty **Pay per Ride Fare Media**
Minority **Full Fare**

Forecast Fares

CARD_ID	DATE	TIME	TXN	POE	BOOTH		VALU	LOC	SEQ_NO	MP	MEDA	NOW	23B	23A	08A	08B
9585152873	20081016	51200	121	000 F014A5	2	R487	200	188	00206702	11	P P F	200	225	250	225	200
9585152873	20081016	51800	146	000 000000	R336	R145	0	2016	00206703	10	P P F	0	0	0	0	0
9585152873	20081016	150600	120	000 000305	R246	R177	200	1956	00206704	00	P P F	200	225	250	225	200
9585152873	20081016	160600	144	000 F01DD6	2	R494	0	172	00206705	11	P P F	0	0	0	0	0

MetroCard Transfer

Card_IDs have been obfuscated.

Full Fare
Unlimited 14 Day Pass

Fares per Day

CARD_ID	DATE	TIME	TXN	POE	BOOTH		VALU	LOC	SEQ_NO	MP	MEDA	NOW	23B	23A	08A	08B
9658632269	20081016	81800	157	026 F00E66	3	R517	0	610	00621937	22	U U14F	392	475	492	408	408
9658632269	20081016	83000	157	026 F01754	3	R517	0	609	00621938	22	U U14F	392	475	492	408	408
9658632269	20081016	85400	157	026 F01419	1	R481	0	381	00621939	10	U U14F	392	475	492	408	408
9658632269	20081016	104800	157	026 F00EB5	3	R520	0	711	00621940	22	U U14F	392	475	492	408	408
9658632269	20081016	111800	157	026 F02324	1	R481	0	311	00621941	10	U U14F	392	475	492	408	408

First swipe in MTA Bus Company service area; card ignored.

CARD_ID	MP	MEDA	TXNS	NOW	23B	23A	08A	08B
9598097605	00	P F	1	200	225	250	225	200
9598099015	10	P F	2	200	225	250	225	200
9598100098	00	P F	4	150	169	188	169	150
9598100406	01	P F	3	133	150	167	150	133
9598100514	00	U30F	2	158	193	201	171	169
9598100543	00	P F	1	200	225	250	225	200
9598100549	10	U07F	3	139	172	172	150	144
9598100550	01	P F	2	200	225	250	225	200
9598100555	00	P F	2	200	225	250	225	200
9598100556	00	U07X	2	342	425	425	375	392
9598100559	10	U07F	2	209	259	259	225	217
9598100560	00	U07F	3	139	172	172	150	144
9598100564	11	U07F	4	104	129	129	113	108
9598100570	00	U07F	2	209	259	259	225	217

Total daily transaction count

Minority/Poverty designations based on first swipe of the day

7 Day Express Bus Pass

Daily average fares based on:
- **individual transfer rates for Pay-per-Ride cards;**
- **actual daily usage for Unlimited Passes.**

FIGURE 8 Analytical model structure and sample data for discrete farecard analysis.

Projected Average Fare Changes by Demographic

Option	Base Case	23A		23B		8A		8B	
Demographic	Average Fare	Average Fare	$ Change (% Chg)	Average Fare	$ Change (% Chg)	Average Fare	$ Change (% Chg)	Average Fare	$ Change (% Chg)
Non-Minority	$1.39	$1.74	$0.35 (25.3%)	$1.72	$0.33 (24.2%)	$1.50	$0.11 (8.4%)	$1.49	$0.10 (7.7%)
Minority	$1.27	$1.59	$0.32 (25.2%)	$1.58	$0.31 (24.6%)	$1.38	$0.11 (8.5%)	$1.37	$0.10 (7.8%)
High Income	$1.37	$1.71	$0.34 (25.3%)	$1.70	$0.33 (24.2%)	$1.48	$0.11 (8.4%)	$1.48	$0.11 (7.8%)
Low Income	$1.27	$1.59	$0.32 (25.2%)	$1.58	$0.31 (24.7%)	$1.38	$0.11 (8.5%)	$1.37	$0.10 (7.9%)
Overall	**$1.32**	**$1.65**	**$0.33 (25.3%)**	**$1.64**	**$0.32 (24.4%)**	**$1.43**	**$0.11 (8.4%)**	**$1.42**	**$0.10 (7.8%)**

Note: Percentage changes shown are based on actual $ change values, not rounded to the nearest $0.01 as above.

Average Change in Fare Statistical Test Results

Mode	Demographic	23A Average Change in Fare	23A Station Level Variance	23A Result	23B Average Change in Fare	23B Station Level Variance	23B Result
Subway	Non-Minority	$0.35	0.0005	Not Significant	$0.34	0.0005	Larger Impact to Non-Minority
	Minority	$0.35	0.0003		$0.33	0.0003	
Bus (Local)	Non-Minority	$0.29	0.0005	Not Significant	$0.29	0.0010	Not Significant
	Minority	$0.29	0.0001		$0.29	0.0002	
Bus (Express)	Non-Minority	$0.98	0.0006	Not Significant	$0.92	0.0006	Not Significant
	Minority	$0.97	0.0006		$0.91	0.0006	

Mode	Demographic	8A Average Change in Fare	8A Station Level Variance	8A Result	8B Average Change in Fare	8B Station Level Variance	8B Result
Subway	Non-Minority	$0.12	0.0000	Not Significant	$0.11	0.0001	Larger Impact to Non-Minority
	Minority	$0.12	0.0000		$0.10	0.0000	
Bus (Local)	Non-Minority	$0.10	0.0001	Not Significant	$0.11	0.0001	Larger Impact to Non-Minority
	Minority	$0.10	0.0000		$0.10	0.0000	
Bus (Express)	Non-Minority	$0.43	0.0001	Not Significant	$0.51	0.0001	Not Significant
	Minority	$0.42	0.0001		$0.50	0.0001	

Change in Perceived Fare by Farecard Type and Demographic

Fare Media Type	Minority	Trans-action Count	Farecard Count	Farecard Perceived Fare	Average Farecard Perceived Fare ($ Change from Base Case)			
				Base	**23A**	**23B**	**8A**	**8B**
Pay-per-Ride	No	1,331,719	674,844	$1.95	$2.42 ($0.47)	$2.18 ($0.23)	$2.18 ($0.23)	$1.95 ($0.00)
	Yes	1,492,302	663,106	$1.73	$2.16 ($0.43)	$1.94 ($0.21)	$1.95 ($0.21)	$1.73 ($0.00)
One Day Fun Pass	No	22,933	5,569	$2.39	$3.02 ($0.64)	$3.02 ($0.64)	$2.55 ($0.16)	$2.55 ($0.16)
	Yes	23,641	4,742	$2.01	$2.54 ($0.54)	$2.54 ($0.54)	$2.14 ($0.13)	$2.14 ($0.13)
Weekly Pass	No	240,001	73,550	$1.72	$2.13 ($0.41)	$2.13 ($0.41)	$1.86 ($0.14)	$1.79 ($0.07)
	Yes	763,098	207,051	$1.50	$1.85 ($0.36)	$1.85 ($0.36)	$1.61 ($0.12)	$1.55 ($0.06)
14-Day Pass	No	31,849	10,356	$1.68	$2.10 ($0.43)	$2.03 ($0.36)	$1.75 ($0.07)	$1.75 ($0.07)
	Yes	98,013	26,939	$1.42	$1.78 ($0.36)	$1.72 ($0.30)	$1.48 ($0.06)	$1.48 ($0.06)
Monthly Pass	No	998,733	370,302	$1.44	$1.83 ($0.39)	$1.76 ($0.32)	$1.56 ($0.12)	$1.55 ($0.10)
	Yes	1,241,284	379,442	$1.22	$1.56 ($0.33)	$1.49 ($0.27)	$1.33 ($0.10)	$1.31 ($0.09)
Express Bus Pass	No	15,202	5,389	$3.12	$3.88 ($0.76)	$3.88 ($0.76)	$3.42 ($0.30)	$3.57 ($0.46)
	Yes	3,804	1,094	$2.56	$3.19 ($0.62)	$3.19 ($0.62)	$2.81 ($0.25)	$2.94 ($0.37)

Note: Full-fare farecards only and before bonus value adjustment, excluding all farecards whose first transaction of the day (proxy for place of residence) occurs outside the NYCT network. All-day 100% sample for Thursday, October 16, 2008.

FIGURE 9 June 2009 projected average fare changes by demographic, statistical test results, and changes in perceived fare by card type and demographic.