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Safeguarding Minority Civil Rights and Environmental Justice in Service Delivery and Reductions – New York City Transit Authority Title VI Program Case Study

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ABSTRACT

Federal Civil Rights and Environmental Justice (EJ) mandates require transit agencies to provide service without racial or income discrimination, and to ensure meaningful access by persons with Limited English Proficiency. EJ research generally focuses on long range planning and capital investment decisionmaking. However, for operating agencies, equity in scheduling, service planning, and tactical service delivery operations is critical to compliance with Title VI legislation and FTA Circular C4702.1A. In 2009, New York City Transit (NYCT) designed a service reductions package in response to economic downturn. EJ considerations were integral to its planning. Using ridership performance criteria for route selection resulted in fewer impacts to heavily minority/low-income routes. Quantitative analysis ensured protected demographics are not significantly adversely impacted by proposed service rationalizations. Route and frequency modifications and service span changes were evaluated with statistical *t*-tests during programming stages, resulting in proposals sensitive to equity concerns. Operationally, NYCT actively monitors service using U.S. Census, survey, and routine agency data. *t*- and *chi-squared* tests explicitly demonstrates racial and income equity in all aspects of agency operations based on service standards and policies. As an example, *t*-tests compared observed load factors to published guidelines; no significant differences in service delivery were found between demographic groups.

INTRODUCTION

One key event of modern U.S. Civil Rights movement in transportation took place aboard a public transit bus in Montgomery, Alabama. On December 1, 1955, Mrs. Rosa Parks, a seamstress by trade, refused to give up her seat to a Caucasian man on board National City Lines No. 2857 and was arrested for refusing to obey driver direction (*1*). The local women's political council organized a bus boycott by Montgomery's black community, which caused significant deficits in public transportation revenue. The ensuing struggle lasted 381 days, eventually leading to a U.S. Supreme Court decision (*Browder v. Gayle*) declaring laws requiring segregated buses unconstitutional (*2*).

The Montgomery Bus Boycott was preceded by a similar 1953 event in Baton Rouge (*3*) that abolished local laws requiring seat segregation, and subsequently inspired boycotts across the South, including Tallahassee, Miami, Tampa, Atlanta, Rock Hill (S.C.), Columbia (S.C.), and "Freedom Rides" onboard Greyhound Lines (*4*) designed to test the Supreme Court decision.

All U.S. transit agencies are today required not to discriminate against any persons based on race, color, religion, gender, or national origin. Federal Transit Administration (FTA) also requires agencies to identify and address adverse health, environmental, social, and economic effects of transit operations on minority and low-income populations, and to ensure meaningful access by persons with Limited English Proficiency (*5*), together termed "Environmental Justice" (EJ) requirements. These requirements are rooted in the Civil Rights Act of 1964 (*6*). First proposed by President John F. Kennedy but not passed until after his assassination, it became part of President Lyndon B. Johnson's "Great Society" initiatives that created many social programs, including Urban Mass Transportation Administration (UMTA), FTA's predecessor. As President Johnson remarked upon signing:

> Americans of every race and color have died in battle to protect our freedom […] Now our generation of Americans has been called on to continue the unending search for justice […] We believe that all [people] are created equal. Yet many are denied equal treatment […] it cannot continue. Our Constitution […] forbids it. Principles of our freedom forbid it. Morality forbids it. And the law I will sign tonight forbids it […] Its purpose is not to punish, […] not to divide, but to end divisions – divisions which have all lasted too long […] This Civil Rights Act is a challenge to all of us to go to work in our communities and our States, in our homes and our hearts, to eliminate last vestiges of injustice in our beloved country. (*7*)

Title VI applies to Federal grant programs, including transit financial assistance. Under President William Clinton, Executive Order (EO) 12898 imposed additional environmental justice requirements in 1994, and EO 13166 defined responsibilities to Limited English Proficiency (LEP) persons in 2000. FTA issued Circular C4702.1A in 2007 (supplanting UMTA's 1988 Circular C4702.1) providing Federal grant recipients with specific guidance on how these regulations should be met (*5*). Through quantitative analyses and Federal enforcement actions, EJ monitoring is now more effective and rigorous compared to Title VI's nascent years, when many major U.S. cities abandoned elevated train lines serving heavily minority and poor neighbourhoods.

New York City Transit's (NYCT) Title VI Program uses analytical methods for EJ evaluation in service changes (specific impact analyses) and service delivery (systemwide assessment).

Statistical data mining ensures racial equity and environmental justice in *operating* decisions, to meet FTA requirements in continuing systemwide monitoring. For the 2009 Budget Balance Service Rationalization Proposal, NYCT's quantitative data and methodology identified service cuts meeting budget criteria yet without adversely impacting minorities and low-income populations. Based on community inputs, modified service reductions are pending implementation in 2010.

LITERATURE REVIEW

Generally, transit agency EJ analysis concerns three main areas of operations: long-range capital investment decisionmaking, short-range service planning, and tactical day-to-day service delivery. Prior EJ research has described data sources, process, and challenges (*8*), particularly from highway (*9,10*), capital project (*11-12A*), or long range planning (*14,15*) standpoints in areas varied as Florida, Carolinas, Chicagoland, Southern California, and San Francisco Bay, but specific discussion from operating authority viewpoints are rare in the literature.

NYCT pioneered application of statistical significance testing to Title VI monitoring in 1995 (*17*). These methods are used in quality control, industrial engineering, medical testing, crime datamining, human resources (employee pool monitoring), but are not commonly applied to EJ issues. Statistical tests have since been adopted by MTA sister agencies Metro-North (*18*) and Long Island Rail Road, and more recently Long Island Bus and MTA Bus Company, but did not achieve widespread adoption outside New York.

Demographic Analyses

Title VI reports are submitted to FTA triennially. Although not widely distributed, some may be available via Freedom of Information Law (FOIL) requests. Title VI Compliance Reports or Program Updates for agencies in California, Florida, Virginia, and New York were reviewed to determine data sources and methodologies used.

Of the 10 reports reviewed (including large and small agencies, assortment of transport modes), nine used U.S. Census data, and many conducted passenger surveys to supplement their effort. Nine agencies published systemwide standards, guidelines, and performance measures. However, only six conducted aggregate system data comparisons (e.g. using average values) by demographics. Generally, agencies having demographic comparisons were thorough in Title VI coverage, providing demographic analyses on variables like number of routes, daily trips, peak/off-peak frequency, and average vehicle fleet age by route (*16*). Of eight non-MTA reports reviewed, none used statistical tests to determine whether average differences across demographics were significant.

Service Changes

Circular C4702.1A requires demographic analysis only for "major" service changes based on adopted guidelines. Of the 10 reports reviewed, four contained service change information, typically a list of changes occurred (*19*). Some explicitly stated that no major service changes occurred during the triennial period. Sometimes, qualitative narratives of affected neighbourhoods are provided, like "predominantly minority" (*16*).

Other EJ Analyses

Two typical EJ analyses completed during project Environment Impact Assessment (EIA) processes were reviewed (*20,21*). EO 12898 and the National Environmental Policy Act (NEPA) of 1969 requires EJ analysis in large capital projects. EIA processes use specialist quantitative tools to determine and compute expected environmental impacts (like noise, air quality, traffic levels), and quantitative average/ ranking comparisons are typically made across demographics. However, significance testing techniques don't appear widespread.

Applied Statistics

Two primary types of statistical tests can determine whether significant differences exist between two sets of observations. The quantitative *t*-test deals with measured differences. The chi-square (χ^2) test, in this context, is a binary test dealing with pass/fail observations. *Demonstrating* that service provided is independent of demographics (i.e. fulfills EJ criteria) essentially reduces to using appropriate statistical tests. Whereas directly comparing average values or quantities might seem straightforward, it could not distinguish between *significant* (results of policy or historical factors producing inequality) and *insignificant* (random chance artifact of sample data collection) differences (*22*).

t-Test

For quantitative *t*-tests, quantities being compared must be properly weighted and normalized. Weighting ensures services impacting more people or buses are proportionally accounted. Normalization expresses measurements as rates/ratios, instead of raw observations that can introduce undesirable biases for reasons other than demographic differences.

Two-sample unpaired *t*-tests determines whether services provided (measured by quantitative performance indicators) to two populations (e.g. minority versus non-minority) are disproportionate. A sample of observations is gathered from each population; *t*-statistic is calculated from both samples' means and standard deviations and compared to *t*-critical value (dependent on standard deviations and observation counts). If sample *t*-statistic falls within range delimited by *t*-critical value, two sample averages are close enough not to be statistically significant (*23*,*24*).

χ^2-Test

χ^2-tests (goodness of fit) determine whether existence of attributes or amenities is independent of demographics, essentially detecting correlations. χ^2-statistic is calculated from the attribute's observed and expected frequencies in each group, and compared to the χ^2-critical value dependent on degree of freedom (df); df equals one for 2×2 contigency tables – e.g. pass/fail versus minority/non-minority (*23*,*24*). If χ^2-statistic is below χ^2-critical value, observed and expected distributions are close enough to be statistically insignificant (*22*). This χ^2 application compares what actually happened to what hypothetically would have if "all other things were equal."

CASE STUDY: NYCT'S TITLE VI PROGRAM

Although ongoing actions are required to maintain compliance, detailed agency operations analyses are conducted every three years and whenever major service or fare changes are proposed. Analytical requirements to ensure race and income equity are in five specific areas:

- Customer Demographic Data
- Systemwide Service Standards
- Systemwide Service Policies
- Service and Fare Change Evaluation
- Transit Service Monitoring

Service standards (quantitative) and policies (qualitative) are intended to prevent discriminatory service design and forestall operational decisions with disparate impacts. Service and fare change evaluations ensure impacts are evenly distributed. Transit service monitoring verifies equitable service from customers' vantage points.

Data Sources

Generally, Circular C4702.1A requires using existing data sources to demonstrate compliance; while special data collection efforts can satisfy requirements, it's not necessary unless other data aren't readily available. Dedicated surveys should be considered a last resort. Common data sources include:

- U.S. Census demographics (100% enumeration every ten years)
- Operations data (train register sheets, pullout sheets, etc.)
- Ridership and data collected for planning studies
- Performance measures for internal audit and reporting (*25*)
- Agency management databases (e.g. asset registers)
- Routine surveys (e.g. customer satisfaction survey)
- Schedule data and on-line journey planning tools (scheduled travel times)

Typically, a plethora of data are readily available from mandatory reporting like National Transit Database (NTD), State Departments of Transportation (DOT) and Public Utilities Commissions (PUC), and management reporting, like Key Performance Indicators (KPIs) popular with international benchmarking groups. To minimize resource consumption, reporting can comprises of quantitative data mining efforts on available data, resulting in systemwide assessments much more representative and extensive than one-time special surveys. NYCT conducts most analyses using U.S. Census.

Customer Demographic Data

FTA's Circular requires demographic data collection and mapping because patterns are easily discerned visually. NYCT chose Locally Developed Alternative (LDA) with both Census and marketing survey data. Census establishes subway stations/bus routes "minority" or "low-income" category thresholds. Tracts having greater than average proportion of minority and

poverty residents are taggeds. The five-borough average indicates 65.02% of City residents are minority (per Census definition), and 21.25% live in households below the Federal poverty line. Figure 1 shows population distribution in New York City's five boroughs/counties. The map shows Bronx County example.

NYCT conducts MetroCard™ marketing surveys using a panel of 1,500 random City residents and collects demographic data, although not in a form readily usable for analyses. Panelists respond periodically to income range, mode choice, transit use, fare media choice, and automobile availability questions. Respondents describe trips taken within the last 48-hours (two days). Transit service quality questions, generating scores between "0" (worst) and "10" (best), include:

- Perception of speed
- Sense of personal security
- Reliability
- Safety from accidents
- Overall comfort
- Value for money
- Frequency of service
- Predictability and regularity
- Cleanliness
- Rush-hour crowding levels

While this survey can corroborate known trends, the stratified 1,500-resident sample limits its usefulness outside original survey design focusing on attitudes and perceptions.

Systemwide Service Standards

FTA's Circular requires objective systemwide standards, to compare services provided to different neighbourhoods quantitatively, requiring corrective actions for significant disparities. FTA-mandated standards are prescriptive, including (at a minimum) vehicle load, headway, on-time performance (reliability), amenity distribution, and service availability (maximum walking distance for transit access).

NYCT has long published service planning load and headway standards. Essential to attracting and keeping riders, reliability is particularly important (*26*) and has been in NYCT Committee Agendas since 1993. Availability standards are based on the industry-standard ¼-mile walking distance; a geographic transit network database is used for analysis.

NYCT developed subway amenity standards in 2003 in consultation with FTA and affiliated agency MTA using Passenger Environment Surveys' (*27*) amenity installation and functionality data. Criteria include seating (benches), trash receptacles, train arrival annunciators, MetroCard vending machines, passenger information centers, and system maps. Amenities χ^2-tests ensure their availabilities are independent of demographics (EJ criteria). NYCT doesn't set bus shelters standards, because New York City DOT maintains bus stops as citywide infrastructure, on multiple carriers' behalf.

Systemwide Service Policies

Service policies, unlike standards, are not necessarily based on quantitative thresholds. Circular C4702.1A is less prescriptive here, allowing agencies to set policies appropriate to their service.

NYCT's previous vehicles assignment decisions are operationally and convenience driven. No written policies existed on new bus depots and neighbourhoods allocations. With FTA, Department of Buses (DOB) developed feasible bus fleet assignment standards that achieve Title VI objectives in 2003. Bus fleet assignment constraints include:

1. Depot storage capacity cannot be exceeded.
2. Minimize deadhead mileage (out of service bus travel from depot to route's beginning when starting service).
3. Routes may be split between depots for efficiency and labor considerations.
4. Bus type appropriate to route characteristics:
    a. Articulated buses for high volume routes.
    b. Over-the-road coaches for express routes.
    c. Alternative fuel (compressed natural gas (CNG), hybrid electric) buses assigned to appropriate maintenance facilities.
5. Minimize reassignments between depots to improve individual vehicles' maintenance-tracking accuracy.
6. Minimize fleet types per depot to reduce spare inventories and specialized training requirements.

NYCT endeavours to maintain uniform fleet age across depots (EJ criteria) subject to these constraints, resulting in 6.0~7.5 year average fleet age (based on 12~15 year bus lifecycle). Fleet age *t*-tests at depot level ensures operationally-driven assignments don't inadvertently introduce fleet age biases.

Evaluation of Service and Fare Changes

FTA requires assessments of significant service and fare changes (and proposed improvements) during planning and programming, to detect potential discriminatory impacts. Agencies must define "major" service changes.

NYCT's routine "Platform Budget" service changes are usually small. Requirements for major changes include demographic maps, impact analyses, identification of transportation alternatives, and mitigation actions. For NYCT, this requirement was tested with the 2009 Budget Balance Service Rationalization Plan (BBSRP – see below), which included fare increases of up to 23% and major service changes on four subway lines and 27 bus routes. Although not implemented initially due to additional available funding, statistical analyses conducted in planning phases assisted NYCT to ensure compliance with EJ requirements.

Monitoring of Transit Service

Transit service monitoring verifies implementation of written policies and practices, and evaluates service provision from ultimate customers' viewpoints according to EJ criteria. NYCT monitors service delivery using *all* FTA criteria, incorporating:

- Level of Service (LoS) Methodology – LoS is measured separately for each mode. All NYCT subway routes are minority, making route-level comparison impossible. Route-level statistical tests are conducted for bus. The same analyses are repeated for income demographics. LoS elements include:

1. **Vehicle loads** at the route's busiest segment, measured against loading guidelines in service standards (see Worked Example), separately for peak and off-peak periods;
2. **Vehicle headway** (peak/off-peak), measured against systemwide standards;
3. **On-time performance**, where NYCT uses a 'Wait Assessment' measure (*25*);
4. **Transit amenities**, measured at the subway station level, as bus amenities are provided by NYCDOT;
5. **Service availability**, measured for combined subway and bus networks, for sample Census tracts by demographic; and
6. **Vehicle assignment**, measured against service policy using fleet age statistics. Though not FTA-required, NYCT monitors it.

- Quality of Service (QoS) Methodology – QoS methodology analyzes origin-destination (OD) travel time and costs by Census tracts. Origin tracts from Census Transportation Planning Package's (CTPP) Journey-to-Work OD matrix are randomly sampled (separately for minority/non-minority). Travel times/costs for three most travelled destinations from sample origins (i.e. OD pairs with heaviest traffic) are populated using computerized travel planner tools (see Service Change case study). *t*-tests determines if travel times/costs are significantly different across demographics.
- Analysis of Customer Surveys (ACS) – MetroCard marketing survey scores for service quality questions are analyzed by demographics. *t*-tests determined whether attitudes and perceived quality differ between minority/non-minority and high/low-income groups. LoS/QoS data is not used; ACS measures perceptions rather than service delivery.

NYCT uses all criteria because data collection is already undertaken routinely. For a little added effort, analysis becomes much stronger by using all available data and methods. Combined analyses are more likely to detect disparities, pinpointing relevant issues and permits corrective actions. Base demographic data, standards and policies, and actual conditions are all used.

CASE STUDY: 2009 BUDGET BALANCE SERVICE RATIONALIZATION PLAN

As part of MTA's normal budget process, NYCT designed a budget gap closing program to cover projected deficits from an economic downturn. The 2009 Budget Balance Service Rationalization Package (BBSRP) consists of service reductions, station changes, and fare increases that result in the least impact for the smallest number of patrons:

> In response to the extremely weak economic environment and the resulting severe budget gap, [NYCT] has developed several additional actions to achieve budget balance […] Total savings (net of revenue losses) of $167.2 million are proposed for 2008/09, $279.8 million of savings are proposed for [2010-2012…] Every effort was made to identify those actions that would achieve savings while minimizing impact to customers. (*28*)

Fare and subway route changes were proposed in the BBSRP, but not discussed here.

Designing Bus Route Changes

NYCT carefully selected bus routes planned for reduction and elimination based on performance criteria. All routes were ranked using established performance measures: ridership, farebox

recovery, passengers per payhour and per revenue mile, and % of hours operated above minimum productivity guideline at peak load point (MLP). Lowest ranking one-third of routes were flagged for further examination.

Early in this process, NYCT attached minority/income classifications to candidate routes for reductions, allowing bus planners to qualitatively understand their decisions' potential impacts without full demographic analyses. Routes with the worst performance were considered for total elimination unless no acceptable alternatives exist, or elimination results in substantial reductions of geographic coverage. NYCT uses Census data to classify routes as 'minority' or 'non-minority'. Routes having more than one-third route mileage in minority tracts are minority routes. All other routes are non-minority.

To seek further savings, low-performing routes were further classified (Figure 2) based on possible cost-saving actions, by limiting comparative analyses to isolate time periods when individual routes performed poorly. Route-level demographic information allowed planners to "look ahead" and fully understand consequences of proposed actions for minority and low-income patrons, as an integral part of decisionmaking.

Because NYCT employed purely performance criteria to select routes for rationalization, proposals had slightly higher impacts on non-minority and high-income routes. This is a natural consequence of New York's bus passenger demographic. Lower income population is more reliant on buses, and higher density neighborhoods accessible only by bus attract lower income population due to cheaper real estate. Buses serving predominantly higher income areas (like Eastern Queens) tend to have lower performance, and are more likely candidates for service reductions. From an equity standpoint, this offers an opportunity to equalize service on performance grounds, while offering substantial budget savings. Before budget proposals were complete, draft service plans were analyzed, complying with Title VI requirement for EJ analysis during "programming stages" of service changes.

Selection of Appropriate Analysis

FTA impact analyses requirements apply only to *major service changes* as ordinarily defined by each agency's standard procedures. NYCT's Service Change Guidelines (*29*) define major changes as exceeding at least one of three criteria:

1. Route restructuring actions with at least 25% route length change;
2. Span change of more than one hour;
3. Frequency adjustments with more than 25% change in revenue vehicle miles.

FTA's Circular describes only two types of analyses:

1. **Route Changes:** Requires service area demographic maps and travel time/cost analyses. Applies to major service changes that reduce or expand frequency, add, eliminate, or expand routes.
2. **Span of Service Changes:** Requires analysis of whether span change impacts are disproportionately affecting minority and low-income population. Applies to major changes reducing or expanding hours/days of service.

NYCT classified each proposal into FTA's mutually exclusive categories for Title VI analysis using these decision rules:

1. **Route Modification Actions** (elimination, rationalization, rerouting, extension, deletion, addition, etc.) with >25% change in route length of longest path requires **Route Change Analysis**, clearly identifying transportation alternatives. Changed portion of route was analyzed. (Entire route analyzed for complete elimination.)
2. **Span Modification Actions** (increase, decrease) causing 1+ hour change in service span (including days of service modifications, e.g. from daily to weekdays only) requires **Span Change Analysis**.
3. **Route Frequency Change Actions** (increase, decrease) exceeding 25% change in route annual revenue miles require **Route Change Analysis**. Analysis applies to route portion where frequency changed (typically, but not always the entire route).
4. For **Combination Actions** (e.g. shortening route and reducing span while eliminating weekend service) exceeding 25% annual revenue miles, NYCT determined whether **Span Change Analysis** or **Route Change Analysis** was appropriate, based quantitatively on the action having greatest contributions to total change in revenue miles.

Figure 2 shows each 2009 BBSRP option for local bus service, whether changes were major or minor, and rationale for analyses selected.

Route Change Analysis: Theory

Route change analysis must be conducted on the Census tract level to clearly identify travel time and cost impacts to distinct groups along that route. Statistical *t*-tests were conducted for each route, comparing before/after trip times and costs for top origins and destinations in the route's service area.

All tracts within ¼ mile of route were reviewed. Separately by demographics, top five origination tracts were selected from 2000 Census Journey-to-Work OD (Origin-Destination) table. Within these tracts, selecting top three destinations yields 15 OD pairs with heavy traffic for travel time analyses. Centriod-to-centroid trip durations were determined using freely available web journey planning tools (e.g. Google Transit) both *before* and *after* route rationalization:

1. Generally speaking, for departure times within analysis time period, 'before' travel time is the shortest path recommended by Google *using* route proposed for elimination. Shortest path *without* using the route is the 'after' travel time.
2. If shortest path is to *walk* between origin and destination tracts, walk time is entered for both 'before' and 'after' scenarios. Zero ($0.00) is entered for fare.
3. In some cases, forcing transfers at intermediate locations yields reasonable paths using subject route. Paths are rejected as unreasonable if they involve circuitous direction changes (e.g. bus travel south to return north on express bus).
4. If no *reasonable* path exists using subject route (e.g., origin tract is near route's northern terminus, but OD pair requires travellers to head north, thus every path results in 'going

south to go north'), then shortest path travel time is valid both before and after (i.e. route elimination has no impact on largest travel markets in its service area).

When all travel times/costs are populated, the *changes* are computed for each OD pair. *t*-tests determined if significant differences exist across demographics. Proposed rationalization has no discriminatory impacts if trip time/cost changes are substantially the same between top O-D pairs travelled by different demographics within the route's service area.

Span Change Analysis: Theory

Unlike route change analysis, span change analysis may be conducted on a route level to determine if span changes unfairly affect minority routes. NYCT conducts passenger load factor (PLF) analyses to show routes proposed for span reductions in protected demographics are equally underutilized compared to other span reduction routes. Statistical *t*-tests are conducted separately for each type of span reduction action, comparing PLFs across demographics. Three types of action were proposed:

(a) **Span Reduction by Hour:** Up to two hours of service near service day's beginning or end is eliminated.
(b) **Overnight Service Elimination:** Overnight service (1:30am~4:30am) is eliminated. Primary rationale for proposed by-hour and overnight service span changes is low ridership (about 4,000 riders in aggregate for all affected routes combined during specified time periods). This initiative primarily affects service between midnight and 6:00am, particularly overnight.
(c) **Weekend Service Elimination:** Routes not meeting minimum productivity thresholds on Saturday or Sunday have service span reduced from Daily to Weekdays. Reductions in weekend service resulted from systematic assessment finding lowest performing and most duplicative routes under budget balancing constraints. The package would have affected 41,230 Saturday and 29,781 Sunday passengers (*28*).

The subset of changes having more than one-hour reduction qualify as *major service changes*. To analyze proposed span changes, ridership during affected hours was gathered from a combination of sources and normalized for trips and onboard seats, giving average PLFs for affected time periods.

- **Span Reduction by Hour:** For 26 routes without overnight service, observed loads are derived from the Surface Ridecheck Program, where NYCT routinely monitors loads and running times with onboard traffic checkers for scheduling and frequency adjustments.
- **Overnight Service Elimination:** For 25 routes operating at all times and proposed for overnight elimination, Ridecheck data is not available, as only 18 hours are covered (6:00am~midnight). Farebox data from NYCT's MetroCard AFC system was used instead. Inferred PLFs conservatively assume all passengers travelled past MLP.
- **Weekend Service Elimination:** For 26 routes proposed for complete weekend elimination and the one route (BX8) subject to Sunday elimination, composite Ridecheck and AFC data was used to compute average PLFs during weekend operations, separately for Saturdays and Sundays as appropriate.

To determine if spans reductions are equitable, observed PLFs on impacted minority routes during proposed time periods are compared with the same on non-minority routes. Similar analysis is performed for low- and high-income routes. *t*-tests determine whether significant differences exists between observed route PLFs during proposed span reduction periods.

Subway Station Booth Closure Analysis: Theory

NYCT identified potential savings in booth closures. For historical reasons, certain subway stations have more than one "booths", ticket offices where patrons purchased tokens and gained system access. As automated fare control replaced tokens, "booths" were inconsistently converted to part-time "kiosks", control areas with roving "station customer assistants", and unstaffed "high entrance-exit turnstile" (HEET) locations. The proposal standardizes the system's 468 stations to each have exactly one full-service 24-hour booth, converting all remaining auxiliary entrances to unstaffed locations.

Booth closure analysis is conducted per-booth. Booths might be thought of as customer service facilities; to determine if closures disproportionately affected certain neighbourhoods, χ^2-tests are conducted on the systemwide booth dataset. Although not explicitly required by FTA, NYCT historically conducted booth closure analyses. An example analysis follows.

WORKED EXAMPLE: BOOTH CLOSURE ANALYSIS (INCOME χ^2-TEST)

This analysis determines whether proposed reductions are discriminatory to "at or below poverty level" (low-income) population. All 638 booths (at 468 stations) were classified as either low- or high-income. Low-income booths are located in or adjacent to low-income Census tracts (exceeding 21.25%); all other booths are high-income. The 185 booths proposed for staffing reductions are indicated.

χ^2-tests (Figure 3) are performed to see if statistically significant differences exist in booth staffing elimination proposals. With 5% error margin, 95% confidence level, and one degree of freedom, χ^2-critical value is 3.84. The χ^2-value computed from the booth dataset is 4.26. Because $4.26 > 3.84$, NYCT concluded that high-income areas are significantly more adversely affected by proposed staffing reductions than low-income neighbourhoods.

However, this disparity is compliant with Title VI/EJ requirements. FTA's Circular specifically permits service adjustments resulting in more adverse impacts to non-protected demographics compared to protected low-income or minority populations:

> "an agency should analyze, if any proposals under consideration would have a disproportionately high and adverse effect on below or at poverty and low-income riders." (*5*)

Even with these higher adverse impacts in affluent neighbourhoods, transit access is maintained. At all stations proposed for booth closure, at least one booth would remain open at all times, either at a different entrance or an adjacent station that provides a free transfer passageway.

WORKED EXAMPLE: BUS LOAD FACTOR MONITORING (MINORITY *t*-TEST)

Service scheduling standards set maximum bus crowding levels. Observed crowding may differ from tolerable standard levels due to planning concerns or service delivery deficiencies. *t*-tests determine if crowding is equitably distributed between minority and non-minority routes. Riders travelling at peak load point (MLP) in peak direction during peak hours are recorded in NYCT's Ridecheck Program. This measured quantity is normalized for bus frequency and vehicle size to produce average passenger load factors (PLFs), equally weighted for each route. The *t*-statistic compares PLF averages and variances by demographics to determine whether significant differences exist. Statistical comparisons are made at the route level. Comparing bus PLFs by Census tract is not meaningful, because bus crowding is experienced at MLP (bus's most crowded location along the route) – and not necessarily where passengers boarded.

Standards

NYCT's bus loading standards are complex and non-linear. Figure 4 shows loading guidelines for standard 40' buses, defined by minimum/maximum average MLP loads per trip. Guidelines are dependent on time-period (peak/off-peak), service characteristics (more crowding is tolerated on feeders because MLPs occur close to route terminals), and bus type. NYCT schedulers use Figure 4 for "frequency determination", looking-up required service frequencies using half-hourly rider counts.

Data Collection

NYCT's Ridecheck routinely collects half-hourly riders at MLPs, its main purpose being schedule and frequency recalibration. Weekday checks are normally completed for every route biannually. However, during scheduling, operational or community concerns may require planners to override loading guidelines. Service frequencies may exceed guidelines on very short routes where a single assigned bus provides better headways than half-hourly. On long routes with little demand, policy headways may require half-hourly service even though loads would not justify it. Actual service plans may thus deviate from loading guidelines. Bus PLF monitoring statistically shows that "planning" considerations don't inadvertently create more overcrowding in some neighbourhoods compared to others.

Normalization and Weighting

Standards are converted from Figure 4 to route-specific "guideline PLFs" (appropriate maximum permissible average loads divided by nominal bus seating capacity: 40 seats for standard bus, 62 for articulated, and 57 for express bus) for comparative analysis. Average riders per trip passing MLPs during the morning peak are computed from observed riders and bus trips, then converted to "actual PLFs" – average riders per trip divided by bus capacity.

Average peak PLFs measures the fraction of standees: PLF of 1.00 indicates every seat has one passenger and every passenger has a seat at MLP. PLF of 0.80 means 20% of available seats are empty. If PLFs are more than 1.00, buses are carrying more passengers than available seats – 1.50 indicates half as many passengers are standing than those seated.

Essentially, observations are normalized for variables that differ between routes, like headway and bus size, and converted to a crowding measure – route average peak PLF. Each bus route has equal weight, demonstrating route-by-route parity. Guidelines actually permit PLFs to exceed 1.00 considerably during peak periods (Figure 5) on busy routes like M16/34 (34th Street Crosstown, a short shuttle linking commuter bus and rail terminals with Manhattan's East Side).

Statistical Test

This analysis uses *t*-tests to compare measured quantities – on a borough basis. Figure 5 shows the Borough of Manhattan as an example. Differences between guideline (Figure 4) and actual PLFs are compared for each route to determine whether deviations from guideline are skewed in a statistically significant manner towards any specific groups (and not whether NYCT schedules exactly to guidelines). PLFs of other boroughs are tabulated and tested similarly.

Overall average allowed guideline PLFs are 1.28 for minority and 1.31 for non-minority for this dataset; actual PLFs are 0.95 and 1.02 respectively. Average difference was 0.33 (variance 0.02) for minority, and 0.29 (variance 0.01) for non-minority. Using two-tailed hypothesis test with 5% error margin at 95% confidence level, resulting *t*-statistic is 0.98 and *t*-critical values are ±2.03. Since $-2.03 < 0.98 < +2.03$, no statistically significant differences exist in average PLFs of local bus service provided to minority and non-minority groups in New York County during morning peak hours.

USE OF STATISTICAL ANALYSIS

As long as source data can be treated as distributions of discrete observations or quantitative measurements, statistical tests can be used to discern differences between populations. Title VI and EJ analyses form an integral part of NYCT service planning decisionmaking, to inform and assist NYCT in serving all groups equally (Figure 6).

When statistical tests are used, correct tests must be applied, standards defined, appropriate measurements selected (correctly normalized and weighted) to determine differences between demographic groups. Corrective action would be taken when and if disparities are found resulting in significantly more negative impacts to protected groups, as per FTA's Circular.

CONCLUSIONS

Through statistical analysis, NYCT demonstrated in Title VI triennial submissions that its service planning processes and service delivery meet all FTA Civil Rights and Environmental Justice requirements as dictated in FTA Circular C4702.1A.

By incorporating demographic information into service reduction planning, NYCT evaluated potentially discriminatory impacts towards protected demographics at the programming stage. Use of performance-based criteria for route selection resulted in very few impacts to heavily minority or low-income routes.

New York is a racially diverse city, as inferred by high percentages of minority population in all boroughs except Staten Island. Providing service without significant disparities poses unique challenges in such a metropolis. Community issues, whether or not racially related, constantly arise in all neighbourhoods throughout the City. NYCT's goal is to provide good service in all areas without regard to demographics. When service reductions are necessary, NYCT endeavours to minimize negative impacts in all neighbourhoods, taking particular care not to disproportionately affect minority areas.

Although the Civil Rights law was enacted in 1964, the struggle for equality and better quality of life is an ongoing process. Today's legal framework incorporates protection for rights of minorities, those suffering from poverty, and persons with limited English proficiency. As transit agencies work towards better service for all, these provisions will ensure that Federally funded improvements are distributed in a fair and equitable manner.

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LIST OF FIGURES

County (Borough)	Non-Minority	Minority	% Minority	Above Poverty	At or Below Poverty	% Low-Income
Bronx	193,651	1,138,999	85%	892,971	395,263	31%
Kings (Brooklyn)	854,532	1,610,794	65%	1,824,463	610,476	25%
New York (Manhattan)	703,873	833,322	54%	1,193,192	298,231	20%
Queens	732,895	1,496,484	67%	1,882,204	321,102	15%
Richmond (Staten Island)	316,316	127,412	29%	392,762	43,866	10%
Five-Borough Total	**2,801,267**	**5,207,011**	**65%**	**6,185,592**	**1,668,938**	**21%**

Note: Due to U.S. Census obfuscation at Census tract level, total New York City population by race and income do not sum to the same total. NYC's actual total Year 2000 Census population estimate was 8,008,278.

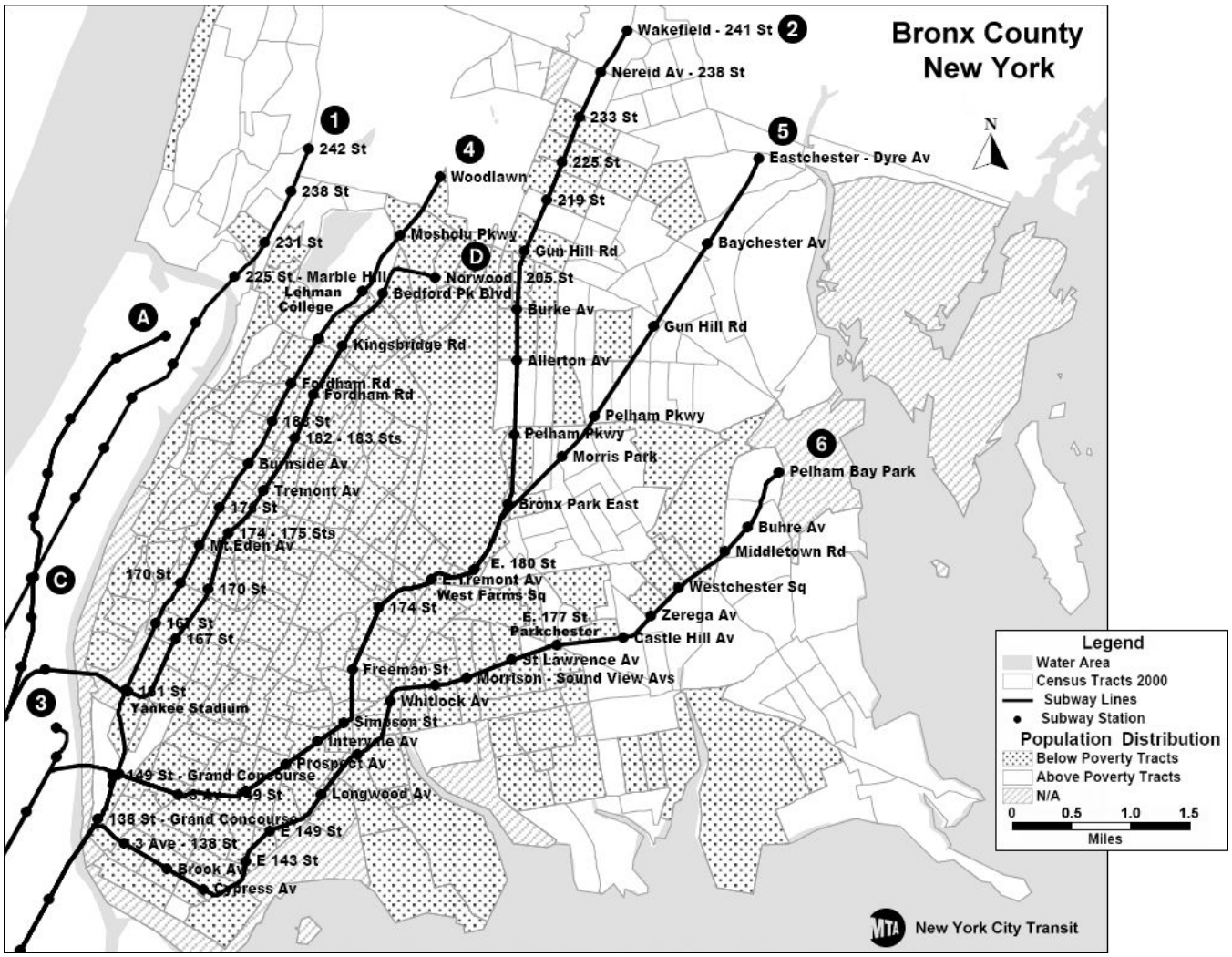

FIGURE 1 Population distribution summary in NYCT's service area and map example.

Category	Service Rationalization Initiative	Service Impact	Title VI Analysis Methodology
Local Bus (Major)	Eliminate daily service on low performing local bus routes	• 100% revenue mile reduction	**Route Change Analysis** on the eliminated routes: B23, B37, B39, B51, BX14, BX20, BX34, M6, M8, M18, M27, M30, Q26, Q74, Q75, Q84.
	Eliminate daily service on local bus routes that duplicate the subway	• 100% revenue mile reduction	**Route Change Analysis** on the eliminated routes: B25, B75, BX4, M10, Q56.
	Eliminate underutilized or duplicative route segments	• Greater than 25% route length changes.	**Route Change Analysis** for the affected routes in the affected areas only: M9 deletion, M21 addition, BX26 deletion, B13 deletion – triggered by >25% route length change.
	Eliminate weekend service on low performing local bus routes	• Span reduction from Daily to Weekdays	**Span Change Analysis** for impacted routes: B2, B4, B7, B16, B23, B24, B48, B57, B65, B69, B71, BX8 (Sun only), BX18, BX30, BX33, M21, M22, Q14, Q31, Q76, Q79, S42, S54, S57, S60, S76
	Eliminate overnight service on low performing local bus routes	• Span reduction of more than one hour – overnight	**Span Change Analysis** for impacted routes: B7, B14, B31, B45, B48, B57, B64, B65, B67, B77, BX10, M1, M2, M16, M22, M23, M42, M50, M66, M79, M96, M102, M103, M104, Q30.
	Reduce span of service on low performing local bus routes	• Various span reductions of between 30 minutes and 3 hours	**Span Change Analysis** for impacted routes with more than one hour span reduction: Weekday: B16, B69, B70, B71, Bx33, M11, M20, M21, S57, S66, B2, B4, B9, B11, B13, B16, B69, M21, Q42,Q79, S54, S60; Saturday: M20, M100, M116, B9, M20; Sunday: M20, B9, Q48.
Local Bus (Minor)	Shorten routes that duplicate the subway	• Less than 25% change in route length.	Not required. Route length and revenue miles reduction is less than 25% for Q24.
	Extend remaining routes to replace eliminated segments	• Less than 25% change in route length.	Not required. Route length and revenue miles change is less than 25% for B67 and B77.

FIGURE 2 2009 Budget Balance Service Rationalization Package (local bus) Title VI analysis plan.

	Low-income	**High-income**	**Total**
Booths proposed for staffing elimination	83	102	185
Booths not proposed for staffing elimination	244	209	453
Total booths	**327**	**311**	**638**
% of booths proposed staffing elimination	25%	33%	29%
		Calculated χ^2-value	4.26

FIGURE 3 Statistical χ^2-test example for 2009 proposed station booth staffing elimination.

Surface Transit Loading Guidelines — Standard 40' Bus

Grid Routes (Weekday Peak: 7am-9am, 4pm-7pm)						**Feeder Routes** (Weekday Peak: 6:30am-8:30am, 4:30pm-7:30pm)					
Per Half-Hour Passengers:			**Guideline Headway**	**Per Trip Average Loads:**		**Per Half-Hour Passengers:**			**Guideline Headway**	**Per Trip Average Loads:**	
Min	*Max*	**Trips**	**(Minutes)**	*Min*	*Max*	*Min*	*Max*	**Trips**	**(Minutes)**	*Min*	*Max*
20	35	1	30.0	20	35	20	35	1	30.0	20	35
36	53	1.5	20.0	24	35	36	63	1.5	20.0	24	42
54	89	2	15.0	27	45	64	93	2	15.0	32	47
90	119	2.5	12.0	36	48	94	130	2.5	12.0	38	52
120	155	3	10.0	40	52	131	170	3	10.0	44	57
156	190	3.5	8.6	45	54	171	210	3.5	8.6	49	60
191	220	4	7.5	48	55	211	250	4	7.5	53	63
221	250	4.5	6.7	49	56	251	285	4.5	6.7	56	63
251	290	5	6.0	50	58	286	325	5	6.0	57	65
291	320	5.5	5.5	53	58	326	355	5.5	5.5	59	65
321	360	6	5.0	54	60	356	390	6	5.0	59	65
361	420	7	4.3	52	60	391	455	7	4.3	56	65
421	480	8	3.8	53	60	456	520	8	3.8	57	65
481	540	9	3.3	53	60	521	585	9	3.3	58	65
541	600	10	3.0	54	60	586	650	10	3.0	59	65
601	660	11	2.7	55	60	651	715	11	2.7	59	65
661	720	12	2.5	55	60	716	780	12	2.5	60	65
721	780	13	2.3	55	60	781	845	13	2.3	60	65
781	840	14	2.1	56	60	846	910	14	2.1	60	65
841	915	15	2.0	56	61	911	990	15	2.0	61	66
916	975	16	1.9	57	61	976	1,055	16	1.9	61	66
976	1,035	17	1.8	57	61	1,041	1,120	17	1.8	61	66
1,036	1,100	18	1.7	58	61	1,106	1,185	18	1.7	61	66
1,101	1,160	19	1.6	58	61	1,171	1,255	19	1.6	62	66
1,161	1,220	20	1.5	58	61	1,236	1,320	20	1.5	62	66

FIGURE 4 An extract from "NYCT Surface Transit Loading Guidelines" used for frequency (headway) determination in the scheduling process.

Borough of Manhattan					Actuals				Guideline		
Route	Route Name	Grid	Artic Bus	Minor-ity	Riders	Trips	Avg. Riders /Trip	Load Factor	Riders /Trip	Load Factor	Load Factor Diff.
M1	5 Av - Madison Av	Yes	No	Yes	876	23	38	0.95	55	1.38	0.42
M2	5 Av - Madison Av - Upper 7 Av	Yes	No	Yes	495	14	35	0.88	52	1.30	0.42
M3	5 Av - St Nicholas Av	Yes	No	Yes	506	13	39	0.97	52	1.30	0.33
M4	5 Av - Madison Av - Upper Bway	Yes	No	Yes	834	29	29	0.72	55	1.38	0.66
M7	Lenox - Columbus - 6/7 Avs	Yes	No	Yes	545	15	36	0.91	52	1.30	0.39
M9	Avenue B & E Broadway	Yes	No	Yes	517	12	43	1.08	52	1.30	0.22
M10	7/8 Avs - Central Pk W	Yes	No	Yes	666	14	48	1.19	54	1.35	0.16
M14	14 St Crosstown	Yes	Yes	Yes	3,755	53	71	1.14	85	1.37	0.23
M18	Convent Av	Yes	No	Yes	116	6	19	0.48	35	0.88	0.39
M22	Madison St & Chambers St	Yes	No	Yes	737	16	46	1.15	54	1.35	0.20
M35	Harlem - Wards Island	Yes	No	Yes	482	12	40	1.00	52	1.30	0.30
M60	Harlem - 125 St - LaGuardia	Yes	No	Yes	669	16	42	1.05	54	1.35	0.30
M98	Washington Hts - 3 Av - Lex Av	Yes	No	Yes	854	19	45	1.12	55	1.38	0.25
M100	125 St - Amsterdam Av - Bway	Yes	No	Yes	516	14	37	0.92	52	1.30	0.38
M101	3 Av - Lex Av - Amsterdam Av	Yes	Yes	Yes	1,191	21	57	0.91	82	1.32	0.41
M102	3 Av - Lex Av - Lenox Av	Yes	Yes	Yes	539	12	45	0.72	70	1.13	0.40
M103	3 Av - Lexington Av	Yes	Yes	Yes	361	11	33	0.53	70	1.13	0.60
M106	106 St Crosstown	Yes	No	Yes	231	8	29	0.72	45	1.13	0.40
M116	116 St Crosstown	Yes	No	Yes	1,118	23	49	1.22	58	1.45	0.23
M5	5/6 Avs - Riverside Dr	Yes	No	No	830	19	44	1.09	55	1.38	0.28
M6	Broadway - 6 Av	Yes	No	No	141	7	20	0.50	35	0.88	0.37
M8	8/9 St Crosstown	Yes	No	No	411	11	37	0.93	48	1.20	0.27
M11	9/10 Avs - Amsterdam Av	Yes	No	No	544	13	42	1.05	52	1.30	0.25
M15	1/2 Avs	Yes	Yes	No	2,893	45	64	1.04	85	1.37	0.33
M16/34	34 St Crosstown	Yes	No	No	1,551	30	52	1.29	60	1.50	0.21
M20	7/8 Avs - Battery Park City	Yes	No	No	132	6	22	0.55	35	0.88	0.33
M21	Houston St - Avenue C	Yes	No	No	299	9	33	0.83	45	1.13	0.29
M23	23 St Crosstown	Yes	Yes	No	1,058	18	59	0.95	80	1.29	0.34
M27/50	49/50 Sts	Yes	No	No	1,233	31	40	0.99	58	1.45	0.46
M30	57/72 Sts Crosstown	Yes	No	No	462	13	36	0.89	48	1.20	0.31
M31	York Av - 57 St	Yes	No	No	1,078	23	47	1.17	58	1.45	0.28
M42	42 St Crosstown	Yes	No	No	2,120	41	52	1.29	60	1.50	0.21
M57	57 St Crosstown	Yes	No	No	513	12	43	1.07	52	1.30	0.23
M66	66/67 Sts Crosstown	Yes	No	No	1,483	27	55	1.37	60	1.50	0.13
M72	72 St Crosstown	Yes	No	No	446	11	41	1.01	48	1.20	0.19
M79	79 St Crosstown	Yes	Yes	No	1,744	28	62	1.00	84	1.35	0.35
M86	86 St Crosstown	Yes	Yes	No	2,391	32	75	1.21	85	1.37	0.17
M96	96 St Crosstown	Yes	No	No	1,687	32	53	1.32	60	1.50	0.18
M104	Broadway - 42 St	Yes	No	No	872	21	42	1.04	55	1.38	0.34

Note: Shaded area (lower half) indicates non-minority routes.

FIGURE 5 An extract of Manhattan's peak-hour passenger load factor (PLF) minority t-test data.

Category	Service Attribute	Standard	Data Source	Analysis Unit	Normalized Variable(s)	Stats Test
Level of Service (LOS)	Level of crowding	Loading standards (bus and rapid transit)	Bus Ridecheck Program (leave load at peak load point); subway load checks	Bus route or subway line	Load factor (volume to capacity ratio)	*t*-Test
	Headway of service	Headway guidelines (bus and subway)	Bus and subway schedules	Bus route or subway line	Average headway (peak and midday)	*t*-Test
	Service punctuality	Wait assessment	Performance Indicators Program (surface and rapid)	42 key bus routes; 23 subway lines	Percentage of passing intervals	*t*-Test
	Subway station amenities	Station design guidelines	Passenger Environment Survey	Subway station	Pass/fail for each standard (passenger information center, bench seating, farecard vending machine, train announciator, trash can, system map)	χ^2-Test
	Service availability (Transit access)	Industry standard (maximum ¼-mile walk)	Route map and Census data	Census tract	Walking distance to nearest subway station or bus stop	*t*-Test
	Vehicle assignment	Bus and subway assignment standard	Bus assignment data by depot; subway assignment data by line	Depot or line	Average age of buses in depot; average age of trains on line	*t*-Test
Quality of Service (QOS)	Travel time, transfers, cost per trip and cost per mile	Equal between origins by demographics for top three destinations	Google Transit; bus and subway route map; fare information	Census tract	Average peak hour travel time, transfers, cost per trip, and cost per mile	*t*-Test
Analysis of Customer Servey (ACS)	Transit opinion survey	Equal averages by demographic	Transit opinion survey	Each survey returned	Perception of speed, sense of security, reliability, safety, comfort, value for money, service frequency, predictability, cleanliness, and crowding – ranked on a 0 to 10 scale	*t*-Test
Fare and Route Change Analysis	Route change impacts for major service changes	Equal cost and trip time impacts for all demographics	Google Transit; fare information	Census tract	Average peak hour and midday travel time, and cost per trip	*t*-Test
	Span change impacts for major service changes	Equal load factors on routes subject to span elimination for all demographics	Ridecheck Program, Automated Fare Collection (AFC) data	Bus route	Average load factor during the period when route is subject to span reduction	*t*-Test
	Fare change impacts for fare increases	Equal average fare changes for all demographics	Aggregate AFC data; ridership and fare model	Bus route and subway station	Average fare by demographic group by station or route	*t*-Test
	Impacts of booth unstaffing	Equal impacts for all demographics	Booth unstaffing plan	Subway booth (fare control area)	Pass/fail – whether the booth is subject to destaffing actions	χ^2-Test

Note: Statistical test is either a t-test or a χ^2-test. *t*-test is used where measured values are numbers. χ^2-test is used where results are yes/no or pass/fail.

FIGURE 6 NYCT's use of statistical tests for Title VI "Locally Developed Alternative" equity analysis.