IMPROVING THE STATISTICAL METHODOLOGY OF NYC TRANSIT FARE EVASION ESTIMATES

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I. INTRODUCTION

New York City Transit (NYC Transit, or NYCT) has long wrestled with the problem of fare evasion on its subways and buses, which last summer the MTA announced resulted in lost revenue of nearly $250 million annually. As this concern has grown in recent years, the Office of the MTA Inspector General (OIG) evaluated the agency's methods for estimating the rates of evasion and in July 2019 suggested several improvements. At the same time, NYC Transit was making its own changes. Based in part on the OIG's work, in the fall of 2019, the Finance Committee Chair of the MTA Board questioned the validity of the estimates and urged further scrutiny. To that end, OIG and NYC Transit, with guidance by Dr. Kitty Kay Chan, a data analytics professor from Columbia University, began a collaborative effort to review the statistical methodologies underlying NYCT's estimates of the system-wide fare evasion rates on buses and subways.

The 4-month collaboration yielded a new approach to sampling and analyzing the data necessary to calculate fare evasion levels that should provide a more accurate estimate of fare evasion on subways and buses. The new methodologies are ready for use once pandemic-related restrictions are eased and ridership levels stabilize.

This document memorializes the approach taken to derive the new methodologies NYC Transit will use to estimate fare evasion.

II. BACKGROUND

NYC Transit has regularly conducted surveys[1] to estimate subway and bus fare evasion for the past 10 years. For each of the surveys, samples are drawn using different methods tailored to the distinct nature of bus and subway operations. Traffic Checkers collect data by

[1] A statistical survey is a study that obtains or records data from a subset of a population in order to estimate attributes of the entire population. While these surveys record whether individual riders evade the fare, the entities sampled are bus trips and parts of subway stations known as fare control areas.

recording the number of evaders they observe in defined areas of subway stations or on bus trips, at times and locations dictated by the sampling methods.

OIG reviewed NYCT's processes for estimating fare evasion, and in July 2019, OIG wrote a letter to NYC Transit describing weaknesses in the survey design and data collection processes, raising questions about the statistical methodology and suggesting possible improvements. OIG's review led NYC Transit to make several positive changes to its data collection practices, including simplifying the data collection instruments to make it easier for Traffic Checkers to accurately track fare evasion. NYC Transit initiated other improvements during the review period, such as creating a dedicated cadre for fare evasion work and assigning an increased number of Checkers to work on this task. In early 2019, the agency also revised its statistical methods for calculating the surveys' margins of error. Nevertheless, after OIG's July 2019 letter, the OIG and members of the MTA Board continued to raise questions regarding the validity of NYCT's estimates.

After assessing the changes NYC Transit had made in response to OIG's review, OIG agreed that a fresh look with expert input was still necessary to create appropriate statistical models. NYC Transit was willing to work with an outside data analytics expert and professor proposed by the OIG, and a team was formed to include the professor, NYC Transit officials[2], and OIG auditors (collectively, "the Team"). The Team then established a workshop process to begin developing these new methodologies. NYC Transit personnel made all final decisions about which methodologies to adopt, based on their understanding of the agency's operational constraints.

III. THE STATISTICAL METHODOLOGY PROJECT

A. The Scope

The Team focused on developing better methodologies to estimate system-wide fare evasion on subways and buses within specific constraints that NYC Transit identified (discussed below).

The new methodologies and the survey results are not designed to estimate fare evasion rates for individual bus routes or subway lines. NYC Transit also performs some individual line and route checks, but these are typically conducted in response to specific requests. These focused checks use "special samples," which are not randomly chosen and were not addressed in the Team's work. In addition, the bus methodology applies to Local/Limited buses only, and

[2] The NYCT participants were managers and analysts from the Division of Operations Planning and the Office of Management and Budget.

does not include Express or Select Bus Service (SBS) routes.[3]

B. The Process

Between November 2019 and March 2020 the Team collaborated extensively during 11 workshop meetings typically lasting 3 hours or more. The deliberative process fostered creativity and improved the transparency of the evasion estimates. Continuing in that spirit, we briefly describe the team's process here. Each member of the group played a distinct role in driving the project forward, both during and between the workshop sessions.

The data analytics professor provided knowledge on survey design and statistics. Before helping NYC Transit decide on its new methods, she developed a stronger understanding of the operations of the subway and bus systems, the way the agency had been conducting fare evasion surveys, and the data and labor resources available for use. The professor described the agency's current statistical methodology as a "hybrid method" (combining elements of different sampling techniques) that did not conform to traditional statistical practices given the specific structure of the data.

During the workshops, the professor presented different methodologies based on statistical rules in order to move away from this "hybrid," while NYC Transit ultimately chose which method would work best for the agency. She then guided the NYCT participants as they made resource-based adjustments to the methodology, while still following a justifiable set of rules. Between meetings, the professor used data provided by the agency to duplicate any simulations Team members had done, to confirm mutual understanding and technical accuracy. After several months of collaboration, the Team finalized the stratified[4] random sampling approaches described herein.

NYCT Operations Planning staff took on a leadership role in coordinating and scheduling the Team's meetings and work. During the early meetings, NYCT planning and budget staff members gave the group significant and up-to-date information on bus and subway operations, current and prior survey methodologies, resource constraints, fare evasion survey data, and ridership data. Between meetings, NYC Transit responded to any data requests from the professor and ran simulations related to her questions and proposals, to see how each potential

[3] NYC Transit has not surveyed fare evasion on Express buses since 2014, and the NYCT Eagle Team uses a distinct method to estimate fare evasion on SBS.

[4] To stratify means to divide the population into subgroups (strata) according to characteristics deemed significant and/or for which separate results are desired. Random samples are selected from each stratum and the results for each stratum are then weighted to calculate an overall result.

approach might affect the fare evasion estimate and margin of error, and to inform the Team's decisions. They raised any concerns they had about the proposed methodologies and suggested adjustments to improve their practicality.

OIG auditors monitored this process, participated in all sessions, and reviewed data and documents exchanged between the professor and NYC Transit staff. During the workshops, OIG raised questions based on knowledge from our initial audit, identified issues the Team might have overlooked, and help clarify potential misunderstandings or miscommunication among the parties. Between the workshop sessions, OIG facilitated communications between the professor and NYC Transit, reviewed all data and documents sent between these two parties, and fine-tuned the goals of the project with the professor as the workshops progressed. OIG also reviewed and commented on materials that NYC Transit staff members drafted as a result of this project, e.g. summaries of the new methodologies and presentations for the MTA Board.

C. Practical Challenges & Limitations

NYC Transit staff members described 3 significant limitations they faced in estimating fare evasion, which helped guide the Team as it developed the methodologies. The principal challenges cited were: (1) the limited number of Traffic Checkers who could be assigned to monitor fare evasion; (2) Operations Planning's analytical staffing and workload; and (3) the limited data available on bus ridership. Therefore, the Team sought a solution that balanced statistical validity and operational practicality.

- The number of Traffic Checkers working on fare evasion limits the number of surveys that can be completed for both buses and subways. To accomplish the optimal number of surveys needed to achieve a higher degree of statistical validity, the agency would need to hire more Traffic Checkers than management deems affordable. When developing the new methodologies, the Team kept in mind the resource demands for collecting data, choosing to use a manageable number of strata (i.e. subgroups), while trying to minimize the margin of error for the system-wide estimate.
- To a lesser extent, the NYCT members of the Team also expressed concern about the analytical burden that comes with stratification. While using more strata would likely provide a better estimate of the overall rate, the individual evasion rates and weights for each stratum would need to be calculated every quarter.
- The professor initially suggested that the Team consider models with more strata; however, the NYC Transit personnel raised concerns that this could exceed their resources. NYC Transit said that a 5-strata approach would be most manageable for subways. The Team then tailored the ridership ranges for each stratum to make sure each

would have a reasonable and sufficient number of sample surveys to be adequately represented in the overall estimate.

- Unlike the new subway method, the Team's chosen bus methodology does not use ridership-based strata because NYCT's current data collection system does not provide reliable ridership data at the level of the sampling unit (bus trips[5]). Such reliable trip level ridership data would be necessary for stratification based on ridership. Notably, NYC Transit is expecting new technologies to become available in the next few years that should help the agency capture additional ridership data; these include Automatic People Counters, video cameras, and the OMNY payment system. NYCT managers told us the agency is exploring how to incorporate these technologies into its fare evasion survey work.

D. Summary of New Methods for Estimating Fare Evasion

1. Subway Fare Evasion Methodology

Prior to this project, NYC Transit generated subway surveys by selecting random samples from all fare control areas (FCAs)[6] for 1-hour periods (FCA-hours). The agency recently began treating this sampling unit as a cluster for statistical purposes, and this does not change in the new method.[7] Now, however, NYC Transit plans to use a stratified random sampling method and will select random samples from 5 strata that are based on average paid ridership levels. The overall number of samples is based on the number of sample surveys NYC Transit was able to complete in recent quarters, while the number of samples allocated to each stratum is based in part on the total paid ridership in that stratum.

Importantly, the Team agreed that the use of stratified random sampling would provide a more reliable estimate than other methods. One statistical requirement for stratification is that the members of each stratum be relatively homogeneous. Prior surveys have found that fare evasion rates and FCA entries during the sample period are inversely related.[8] Therefore, the Team believes that strata based on ridership will group FCA-hour units with more similar fare-

[5] For example, the B44 6:30 a.m. departure on a given day is a bus trip.
[6] An FCA is a separate and roughly contiguous group of turnstiles and entry gates within a subway station. There are approximately 930 FCAs across the 472 stations.
[7] In cluster sampling, a researcher divides the population into mutually exclusive groups called clusters. Then a random sample of clusters is selected from the population for data collection and analysis.
[8] Prior surveys found that on average the fare evasion *percentage* was higher in FCA-hours with fewer riders.

evasion behavior together.

Once the survey samples are complete, the fare evasion rate will be calculated for each stratum and weighted based on estimated total ridership (paid and unpaid). After weighting, all 5 rates will be combined to determine the overall evasion rate.[9] The margin of error for the system-wide evasion estimate will be calculated using statistical methods based on stratified cluster sampling.[10] These surveys will yield an estimate of the overall evasion rate quarterly, which had been NYC Transit's standard reporting period for many years. The Team agrees that this method does not provide reliable figures for shorter periods.

2. Bus Fare Evasion Methodology

NYC Transit will generate surveys by drawing random samples of distinct bus trips from 5 strata, 1 for each borough of New York City. The number of samples drawn per strata will be based on the number of scheduled bus trips per borough. For the actual surveys, each sampled bus trip will be combined with a return trip on the same route.[11] While previously the number of samples was based on each borough's total paid bus ridership, the survey results were all added together without any weighting, regardless of whether the number of surveys completed was proportional to the ridership in a given borough. Any borough with a disproportionately high or low number of surveys was thus over- or under-represented, respectively, in the total system-wide result. In the new method, the results from each stratum will be weighted by an estimate of total ridership (paid and unpaid) in the stratum.

Similar to subways, each bus round-trip surveyed will be regarded as a cluster sample, and NYC Transit will calculate a system-wide margin of error based on stratified cluster sampling statistical techniques. The agency will be able to produce quarterly reports of the system-wide evasion rate based on the results of these surveys.

IV. IMPLEMENTING THE NEW METHODOLOGIES

Due to the Team's productive work on this project, NYC Transit was ready to implement the new methodologies in April 2020, the start of the second quarter. However, the global COVID-19 pandemic disrupted this plan. NYC Transit suspended fare evasion sampling checks

[9] NYC Transit's prior methodology did not adjust for the variation in ridership across FCA-hours, possibly causing the results to be unrepresentative of the population.

[10] "Stratified cluster sampling" refers to the fact that sampling units (FCA-hours) are clusters that have been grouped into strata for sampling purposes.

[11] Bus routes are assigned to strata based on the borough indicated in the bus route name; thus any inter-borough bus routes and sampled trips will be assigned to the strata of the bus name.

on both subways and buses in the middle of March 2020, and as of the end of May 2020 it was unclear when checks would resume.

When operating conditions permit and ridership has sufficiently stabilized, NYC Transit can initiate the new process. This would likely occur at the start of a new quarter. Allowing for roughly 3 months of analytical work and review following the end of the quarter, the first results based on the new method would be available about 6 months after implementation.

The Team believes that through the use of stratification and weighting, these new methodologies will produce more robust estimates of fare evasion that are less susceptible to the variability of simple random sampling. Going forward, this new methodology should continue to be assessed and revisited so as to remain suitable and reliable as agency operations change.

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The OIG would like to express our appreciation for the hard work of Professor Chan and the NYCT Division of Operations Planning and Office of Management and Budget on this successful team project.