Metropolitan Council

Program Evaluation and Audit

Northstar Commuter Rail

Fare Compliance and Ridership Estimates

04 October 2010

INTRODUCTION

Background

The Northstar Commuter Line commenced commuter rail service between Big Lake and Minneapolis in November, 2009. Northstar serves six stations: Big Lake, Elk River, Anoka, Coon Rapids, Fridley, and Target Field. This service offers six inbound and six outbound daily trips Monday through Friday, and three inbound and three outbound daily trips on Saturday and Sunday. Each trip carries four passenger cars, although seven or eight passenger cars are pulled for trips serving Twins baseball games. The service shares the Burlington Northern Santa Fe (BNSF) track and its rail service times are coordinated with BNSF's rail freight service. Northstar is the first commuter rail service in the metropolitan region.

The fare charged for this service range from $3.25 to $7 during weekdays depending on the station, and $2.50 to $5.25 on weekends. Discounted fares are available to Seniors, Youth, and Medicare card holders on weekends, and for persons with disabilities at all times. Children younger than six years of age ride free if accompanying a fare-paying adult. Tickets may be purchased at the stations. The fare amount will be deducted from Go-To Cards. Stored value magnetic strip cards and SuperSaver 31-Day Passes are not valid on Northstar. Family fares, offered after 9 a.m. each day, must be purchased at ticket vending machines (TVM's).

The Northstar Line is a barrier-free system, or a Proof of Payment fare compliance system, similar to the Hiawatha Light Rail Train (LRT). The train stations along Northstar Line do not have turnstiles or barriers to prevent nonpaying persons from the train platforms. Customers are subject to random proof-of-payment inspections.

Metro Transit Police Department assigns officers to the trains to enforce fare compliance. Officers are on board trains checking for proof of fare payment; Northstar conductors will also check for fare payment as their duties allow. However, only police officers may issue citations. As on light rail, passengers may receive a citation and fine of $180 for failure to purchase a ticket.

Officers and conductors use mobile phone validators (MPV) for verifying payment made by Go-To Cards. Fares are paid at TVMs or via smart cards which are tagged on a Rail Validator (RSV). Customers, whether transferring or originating, are required to tag on an RSV or get a ticket from a TVM to make the appropriate fare payment for a ride on Northstar. Consequently, an electronic record is created for every fare payment. These electronic records create a 100% boarding count for Northstar except for group ticket sales, children under 6 years of age, disabled veterans, and for family pass passengers where one person purchases the ticket. Each family pass can be used by up to 5 passengers (2 adults and up to 3 children from six to 17 years of age). Family passes are predominantly used when Northstar runs special service for events such as professional

baseball and football games. Family pass rides reportedly make up 30 percent of rides in summer.

All rides registered via TVM or RSV are collected, processed, stored, and reported through the Cubic NextFare system. Metro Transit conducts periodic samples to establish the ratio of riders for each family pass sold and applies these ratios to each family pass sold to calculate rides. Group ticket sales information is provided monthly by Metro Transit Sales Operations to Revenue and Ridership for inclusion in the monthly rider counts. These procedures create a 100% count of passengers for Northstar Commuter Line.

Purpose

This review was conducted to assess Metro Transit's methodology for collecting ridership information and projecting ridership counts on the Northstar Line. Activities conducted verified the accuracy of ridership counts and assessed the fare compliance of rail passengers.

Scope

Audit reviewed rider counts and fare compliance for Northstar Commuter Line.

The evaluation of Northstar ridership included an assessment of:

- The system for determining ridership counts,
- Reported ridership,
- Fare compliance procedures, and
- Reported passenger fare compliance rate.

The time period under review was July, 2010.

Methodology

To gain an understanding of Northstar Commuter Line ride counts methodology and reporting, as well as fare compliance, and to verify the accuracy of data in published reports, the following methods of inquiry were used:

- Personnel were interviewed from various areas of Metro Transit, including Northstar Commuter Rail, Finance, and the Police Department.
- Metro Transit Police Department's fare compliance procedures were reviewed.
- Metro Transit's rider count estimation methodology was reviewed.
- Observations and counts of riders boarding to and disembarking from Northstar Line trains were conducted by Program Evaluation and Audit.
- Onboard survey of Northstar passengers were conducted by Program Evaluation and Audit.

- Data from Program Evaluation and Audit, Sales Operations, and Revenue and Ridership were reviewed, compared and analyzed.
- Rider count practices and fare compliance practices of other rail agencies were researched.

Assurances

This audit was conducted in accordance with the Institute of Internal Auditors' *International Standards for the Professional Practice of Internal Auditing* and the U. S. Government Accountability Office's *Government Auditing Standards*.

OBSERVATIONS

Ridership Estimates

Metro Transit Revenue & Ridership estimates daily and monthly Northstar ridership primarily using Cubic fare data collected with TVM's and RSVs. Family pass rider counts are estimated based on periodic counts by Metro Transit Revenue & Ridership staff and group ticket sales are included in the monthly estimates. Audit staff used statistical sampling to test the accuracy of the ridership counts.

Audit staff drew a random sample of 59 rail cars in July using a stratified cluster sampling design method. Three populations, or strata, were selected to sample based on rail service types: 1) weekday regular service, 2) weekend regular service, and 3) special service. The sample sizes were to provide a 95% confidence level with five percent margin of error. In order to maximize staff resources, the samples were drawn from clusters of trips: 1a) morning weekday regular service, 1b) afternoon weekday regular service, 2a) Saturday weekend regular service, 2b) Sunday weekend regular service, 3a) weekday special service, and 3b) weekend special service. Please see Appendix A for a more detailed description of the methodology employed.

Statistical analysis was performed using a statistical survey package, SAS 9.2. The margins of error of the sample were compared against Revenue & Ridership's estimates to test for accuracy.

July rider estimates are within the sample's expected range.

Regular service trips for Friday, July 2, were excluded from being selected for the sample population because of the expected low ridership on the Friday at the beginning of a 3-day holiday weekend. Excluding rides from that day's regular service trips, but including that day's two special service trips, based on Metro Transit's ridership estimate methodology there would have been 71,481 rides on Northstar trains.

Sampling by Audit staff yielded the following results in Table 1.

Table 1. Northstar Ridership

Variable	Sample Size	**Mean**	Standard Error	Margin of Error (95%)	**Confidence Interval**	
Ridership	59	**61.64**	3.65	7.5	**54.08**	**69.19**

Source: Audit field observation; SAS/STAT 9.2

With 1,167 one-way rail passenger car trips in July – excluding regular service trains on July 2 – the sample mean of 61.64 rides would equate to 71,934 rides. At the 95% confidence level, the number of rides in July could vary from a low of 61,330 rides to a

high estimate of 82,537 rides. Metro Transit's estimate of 71,481 rides is within the range expected based on Audit's statistical sample.

Family pass rider estimates are higher than the expected range.

Metro Transit estimates family pass ridership with periodic counts at Target Field Station of disembarking passengers from special service trains. Thus the difference between the number of disembarking passengers and the number of fares recorded for that trip is attributed to family pass riders. For July the family pass factor – the average number of passengers per family pass – was estimated at 2.8 for weekdays and 3.4 for weekends.

Audit staff surveyed passengers in a single passenger rail car on 15 special service trains during July. Passengers were asked whether they purchased a family pass for that trip and how many adults and children were using that family pass. The results of the sampling yielded the results in Table 2.

Table 2. Northstar Family Pass Factor

Family Pass	Total # of Departure Times	Sample Size	**Mean**	Standard Error	Margin of Error (95%)	**Confidence Interval**	
Weekday	12	6	**2.67**	0.026	0.07	**2.60**	**2.74**
Weekend	18	9	**2.95**	0.115	0.27	**2.68**	**3.21**

Source: Audit field observation; SAS/STAT 9.2

At the 95% confidence level, the number of riders per family pass during weekdays could vary from a low of 2.60 to a high of 2.74. The number of riders per family pass during weekends could vary from a low of 2.68 to a high of 3.21. Metro Transit's weekday estimate of 2.8 riders and the weekend estimate of 3.4 riders are higher than the range indicated by the sample.

With 3,706 family passes sold in July, Metro Transit overestimated family pass ridership by 1,820 rides compared to the sample mean. Compared to the low and high range of the confidence intervals, Metro Transit overestimated family pass ridership anywhere from 567 rides to 3,073 rides in the month. It was reported by BNSF staff that there have been times, although not common, at Big Lake Station that due to long lines at TVMs that conductors will ask passengers to board the train if departure is imminent and ask the passengers to purchase their fares at their destination. If those passengers did not later purchase fares, that could contribute to an overestimation of family pass ridership.

Inter-station rides estimates are within the sample's expected range.

Metro Transit reports both ridership and passenger miles travelled (PMT) to the National Transit Database of the National Transit Administration. A key factor for determining PMT is inter-station travel.

Inter-station rides are any rides for which Target Field Station is neither the origination station nor the destination station. Automated passenger counters (APCs) are not installed on Northstar trains, so the number of alighting passengers is not regularly counted. Metro Transit estimates inter-station rides by calculating the difference between the number of fares paid for on inbound (towards Target Field Station) trips and the number of fares paid for at Target Field Station for outbound trips. Metro Transit estimates that five percent of rides are inter-station rides. Metro Transit had conducted an onboard count of passenger boardings and alightings, which confirmed the five percent estimate.

Audit staff recorded boardings and alightings for sampled weekday regular and weekend regular service trips. Sampling by Audit staff yielded the following results in Table 3.

Table 3. Northstar Inter-station Rides

Variable	Sample Size	Mean	Standard Error	Margin of Error (95%)	Confidence Interval	
Inter-station Rides	44	7.27%	1.28%	2.9%	4.37%	10.18%

Source: Audit field observation; SAS/STAT 9.2

At the 95% confidence level, the percentage of riders traveling inter-station could vary from a low of 4.37 percent to a high of 10.18 percent. Metro Transit's estimate of 5 percent is within the estimated range.

Fare Compliance

The fare inspection rate is comparable to peer barrier-free rail transit systems.

Fare inspection is an important element of a barrier-free transit system. Although one study has not found a statistically significant correlation between high inspection rates and high compliance rates, some level of fare inspection is necessary to deter free riders and ensure that fare compliance remains high.[1]

Fares are inspected on Northstar by Metro Transit police officers and conductors. Only police officers may issue fare evasion citations. Conductors may ask a passenger without proof of payment to pay the fare at the destination station, although the conductor is unable in most instances to confirm that a passenger had later paid the fare. While both

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[1] Transportation Research Board, Transit Cooperative Research Program Report 80: A Toolkit for Self-Service, Barrier-Free Fare Collection, 2002, p. 3-24.

police officers and conductors may ask a passenger without proof of payment to disembark from the train at the next station, Audit staff did not document any instance where that occurred. BNSF staff is reluctant to ask a passenger to disembark because staff considers that to be punitive due to the long wait for the passenger to board the next Northstar train, which can be nearly an hour, or the current one could even be the last one for that rush hour period.

The fare inspection rate is the percentage of transit riders that are inspected for proof of payment. The Transportation Research Board issued a report, TCRP Report 80: A Toolkit for Self-Service, Barrier-Free Fare Collection, in 2002 as a resource for rail transit agencies. In the report, 20 non-barrier transit agencies were compared for fare inspection and fare evasion rates.[2] The report looks at inspections performed by all employees assigned to fare inspections, both transit staff and police officers. On average there were 1.02 inspectors per 1,000 daily riders with an average inspection rate of 26 percent, with the majority of North American agencies reporting inspection rates between 15 and 30 percent. When looking at commuter rail lines only, the average is 2.73 inspectors per 1,000 daily riders and inspection rates varying between 4% to 100%. On Northstar in July there was an average of 2.4 inspectors per 1,000 daily riders or 0.9 police officers per 1,000 daily riders.

Fare inspection data for Northstar is not reported for magnetic strip tickets purchased from the TVMs. Mobile phone validators (MPV), which are Nokia cell phones reconfigured to scan Go-To Cards, are used by police officers and conductors to inspect fare payment on Go-To Cards. In July, Go-To Card media accounted for 31,000 out of 73,000 (43%) of rides on Northstar. While MPV data does not include paper tickets, the data may be used as a reasonable proxy for the fare inspection rate on Northstar.

Audit staff reviewed mobile phone validator data of Go-To Card fare inspections and Cubic fare data for July. Police and conductors inspected 9,124 Go-To Cards out of 30,912 Go-To Cards tagged in July, for an inspection rate of 30 percent. Of those fare checks, police officers accounted for 7,559 of the fare inspections, for a police-only fare inspection rate of 25 percent. The 25 percent and 30 percent inspection rates are comparable to peer non-barrier transit agencies.

Audit staff observed 19 out of 44 (43 percent) sampled regular service trips in July had fare inspections. 12 trips were inspected by police (27 percent) and seven trips were inspected by conductors (16 percent). All fares were inspected by police officers at Target Field Station as passengers entered the station following the end of Minnesota Twins baseball games for boarding onto a special service train.

The fare inspection rate is higher during the weekdays than during the weekends.

A review of MPV data shows that in July the fare inspection rate on weekdays was 30 percent (25 percent police only) and 14 percent (8 percent police only) on weekends. The

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[2] Transportation Research Board, Transit Cooperative Research Program Report 80: A Toolkit for Self-Service, Barrier-Free Fare Collection, 2002, p. 3-21, 3-23.

lower inspection rate reflects a smaller police presence onboard the trains on the weekends.

Audit staff observed 17 out of 27 (63 percent) sampled weekday regular service trips had fare inspections. Three out of 17 (18 percent) weekend regular service trips were observed by Audit staff to have fares inspections.

Fare compliance rates are comparable to peer barrier-free rail transit systems.

The fare compliance rate is the percentage of transit riders with proof of payment. The Transportation Research Board report shows an averaged compliance rate of 97.6 percent among the 20 non-barrier transit systems.[3] A review of MPV data and Cubic data indicates that Northstar had a fare compliance rate of 98 percent in July. The data shows the 8,944 out of 9,124 fares inspected were valid. Passengers that do not pay the fare for the entire duration of the trip but, rather, pay for a shorter distance of travel will not be recorded as an invalid fare by MPVs. The MPV will display to the inspector the fare amount and where the fare was purchased to help determine whether the fare was paid in full.

Fare compliance rates for passengers purchasing magnetic strip tickets from TVMs were not tested during the audit. The convenience of using Go-To cards and the usage of those tickets by commuters would tend to make the compliance rate of Go-To cards higher than for fares that should be purchased using a TVM. However, this audit did not discover how much if any variance exists between the compliance rates for Go-To card fare media and magnetic strip tickets. The fare compliance rates determined by use of Cubic data should be considered as the maximum rate.

The fare compliance rate is higher during the weekdays than during the weekends.

A review of MPV and Cubic data shows that the fare compliance rate on weekdays was 98 percent (8,885 out of 9,053 fares inspected) and 91 percent on weekends (59 out of 65 fares inspected).

Fare revenue losses due to fare evasion on Northstar are immaterial.

Fare compliance had not been identified as an issue of concern to Audit staff during interviews with staff from BNSF and Metro Transit. When asked about the risk of fare evasion, Metro Transit staff hypothesized that the risk of fare evasion may increase on weekends or on special service trains. Quantifying fare revenue losses is difficult because the fare compliance rate for tickets purchased through the TVMs is unknown. In order to estimate the impact of fare evasion on weekends, a sensitivity analysis was conducted using a low and high estimate of fare evasion.

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[3] Transportation Research Board, Transit Cooperative Research Program Report 80: A Toolkit for Self-Service, Barrier-Free Fare Collection, 2002, p. 3-21.

Weekday regular service averaged 1,732 rides daily in July. Weekend regular service averaged 585 rides daily. Using the respective fare compliance rates, the regular fare from Target Field to Anoka (as an average fare), and the average daily ridership estimates, fare revenue losses for the month from fare evasion would have been $2,700 for the weekdays and $430 for weekends. The total estimated revenue loss of $3,130 is 1.5 percent of $211,000 fare revenue collected.

If the fare evasion rate for tickets purchased at TVMs is twice the rate for Go-To cards – 4% weekday, 18% weekend – the monthly fare revenue loss on weekdays would be $4,200 and $2,000 on weekends. The total estimated revenue loss of $6,200 is 2.9 percent of revenue collected. An evasion rate of 18 percent is likely excessive, but it establishes a range of monthly fare revenue losses on weekends of between $430 and $2,000.

CONCLUSIONS

1.   The method for calculating and reporting Northstar ridership is largely accurate.

Generally, the ridership count methodology by Revenue & Ridership is sound. Monthly totals and inter-station ridership estimates were within the margins of error. Family pass ridership estimates were over reported, but not enough to make the variance of monthly ridership counts statistically significant.

2.   Current Metro Transit fare enforcement strategies are maintaining a relatively high level of fare compliance on Northstar.

The Northstar Line is barrier free so there will always be the opportunity for passengers to avoid paying the fare. The Council depends on MTPD fare enforcement, Northstar conductors' fare inspections, and the high cost of the fare evasion citation to encourage passengers to pay their fare. Audit found that MTPD officers check about 25 percent of passengers through random sweeps of trains; conductors inspect another 5 percent of fares. The compliance rate is 98 percent for Cubic based fares on Northstar Line trains. The weekend inspection rate and compliance rate are lower than the weekday commuter rate, but the lower ridership and fare amounts on weekends create a low potential fare revenue loss.

RECOMMENDATIONS

Program Evaluation and Audit recommendations are categorized according to the level of risk of the finding (conditions) they are designed to resolve. The categories are:

- **Essential** – Steps must be taken to avoid the emergence of critical risks to the Council or to add great value to the Council and its programs. Essential recommendations are tracked through the Audit Database and status is reported twice annually to the Council's Audit Committee.
- **Significant** – Adds value to programs or initiatives of the Council, but is not necessary to avoid major control risks or other critical risk exposures. Significant recommendations are also tracked with status reports to the Council's Audit Committee.
- **Considerations** – Recommendation would be beneficial, but may be subject to being set aside in favor of higher priority activities for the Council, or may require collaboration with another program area or division. Considerations are not tracked or reported. Their implementation is solely at the hands of management.
- **Verbal Recommendation** – An issue was found that bears mentioning, but is not sufficient to constitute a control risk or other repercussions to warrant inclusion in the written report. Verbal recommendations are documented in the file, but are not tracked or reported regularly.

1. (Consideration) Program the ticket vending machines (TVM) to require the purchaser of group fares, such as family passes, to input the number of riders using the group fare.

Estimating the number of riders on a family pass requires staff time to hand count riders and is susceptible to error. Requiring customers to input the number of riders using the group fare may improve the estimation of ridership and also remind users of the number of riders eligible to use the family pass. Self-reporting ridership by customers may need to be supplemented by less frequent hand counts. The additional time for customers to input the number of riders must be considered against the need for the trains to depart on schedule.

2. (Consideration) Signage onboard the trains should inform passengers of the fare structure and fines.

At the time of the audit, Northstar trains did not have signage in the passenger cars describing the fare structure, fine amounts, and rules for riding the train. While not a replacement for fare inspections, signage would supplement the education of new riders. BNSF staff mentioned the desirability of signage on the trains to inform riders of the rules of riding Northstar.

APPENDIX

Statistical Methods

A quick glance
Sampling Population: All train departure times between Big Lake and Target Field in July.
Unit of measurement: One-way passenger car trip.
Frequency of Sampling: Monthly.
Precision: 95% confidence interval, 5% sampling error, 2% expected error rate.
Sampling method: Stratified cluster sampling. Post-stratification weights will be applied.

This appendix will describe in detail the survey methods used by Audit in order to address the questions of Northstar Commuter Rail reported ridership and fare compliance procedures. Audit obtained estimates of the survey variables of greatest interest through statistical sampling. Statistical estimation produces robust results against which a 100-percent count for National Transit Database (NTD) reporting is compared. A significant deviation would indicate either significant undercounting in 100-percent counts or upward sampling and non-sampling errors in estimation (Chu 2005).

I.   Northstar Ridership and Inter-Station Rides Survey

Audit rode on commuter rail a statistically significant number of times to verify reported ridership and fare compliance procedures. Audit team first stratified the universe of departure times and then broke each stratum into clusters independently. Finally, one-way passenger car trips were selected at random for each departure time within each selected cluster. Audit counted passenger load as well as boardings and alightings at each Northstar station between Big Lake and Target Field.

The sample universe for the ridership survey included all departure times between Big Lake and Target Field for Monday through Sunday for the month of July. The route 888 schedule as of July 2010 and Northstar service schedule to select Twins games were used as a guide for determining population. Audit calculated the necessary sample size using the sample universe of three distinct strata, which totaled 302 departure times, a sampling error of 5% and a confidence level of 95%. Given these statistics, the necessary sample size was calculated to be 59 trips.

The ridership sample was stratified based on characteristics believed to be correlated with the survey variables of interest. The main strata are decided to be Northstar service types, namely a) weekday regular trips (am and pm trips), b) weekend regular trips (Saturday and Sunday trips) and c) special service trips to select Twins games.

July 2010 has twenty weekdays; there was no service on July the 5th. Audit excluded regular services on July the 2nd Friday from the universe due to the concerns about long holiday weekend and expected light ridership as a result. Regular 5:03pm southbound scheduled trips that operated right before Twins games were eliminated from population calculation due to the fact that these were not regular commuters. Stratum population was calculated to be 233 departure times which correspond to a sample size of 27 at 95% confidence level, and 5% sampling error. Audit randomly selected am and pm periods, which were treated as clusters in data calculations, and sampled one car as a sampling element for each departure time within each selected cluster.

July has 8 weekends; 5 Saturdays and 3 Sundays. July 4th had no regular service (only two special services to the Twins game). Weekend regular scheduled services on which Twins fans rode were excluded from the stratum population. Audit calculated the population size for weekend regular trips to be 38 with a statistical sample size of 17 departure times at 95% confidence level and 5% sampling error. Each weekend day was treated as a cluster. Audit selected one car for each departure time at random for each selected cluster.

Northstar Rail ran special service trips to select Twins games during the month of July. Audit defined 'special service trips' as these extra-scheduled trips *plus* regular scheduled services that serve passengers who do not regularly ride on Northstar. Audit expected ridership to be different for up to two regular scheduled trips prior to the game. For example, 10:23am and 1:23pm regular trips on a Saturday before 3:10pm Twins game were considered special service trips due to an expected greater number of family pass users and ridership. For weekdays, only the 5:03pm regular trip from Big Lake to Target Field was considered special event if there was an evening Twins game. In addition, Friday July the 2nd was considered a weekend for purposes of sampling special service trips due to the long holiday weekend. Friday July 2nd had two special services that were added to the sampling frame. Thus, the population of special event trips was calculated to be 30 with a statistical sample size of 15 departure times. Each special event was considered a cluster of cars. Audit then randomly selected one car for each sampled special service train. Table 1 summarizes sample size and population calculations.

Table 1. Sample Size and Sampling Error Calculation

STRATA	Weekday Regular Trips		Weekend Regular Trips		Special Service Trips	
Clusters	am period	pm period	Saturday	Sunday	Weekday	Weekend
Sampled Departure Times	14	13	10	7	6	9
Population Size	233		38		30	
Sampling Error	5%		5%		5%	

Audit used a complex sample design, namely stratified cluster sampling to estimate ridership and fare compliance. One commonly used technique to improve sampling efficiency is sample stratification (Smith 1993) and one common technique to reduce administrative costs is cluster sampling (Furth et al. 1988).

In considering statistical accuracy, stratified sampling is the most convenient option in that "*stratification of the population into groups can significantly improve the efficiency of sampling, resulting in either a smaller sample size to produce an estimate of equal precision, or an estimate of higher precision for the same sample size. To increase the efficiency, the variation between elements within the groups must be less than the variation between the elements when they are considered as one big group (i.e. the population)*" (Bucciarelli 1991). Thus, Audit selected independent samples from each service type and then estimated the population mean by post-weighting the sample based on the total number of one-way passenger cars that were operated in July. Please see Table 2 for post-stratification weight calculations.

"*While stratification of population improves the efficiency of estimation, clustering the sample can reduce the cost of collecting data*" (ibid). Instead of collecting the sample of interest randomly in a month, Audit selected one-way passenger car trips as unit of measurement sequentially in time. Each stratum has two clusters (primary sampling units), namely a) weekday regular am and weekday regular pm trips; b) Saturday and Sunday trips; c) Weekday and weekend special service trips. "*It is reasonable to assume that the ridership varies little between weekdays. Thus, a sample which contains all trips departing on one weekday will produce an estimate that is no less efficient than an estimate computed from a sample of the same size randomly selected from all departures over a month. In fact, if ridership varies significantly over time-of-day periods, the sample of all trips departing on a weekday is likely to be more efficient. It is much simpler and less expensive to measure ridership on all trips on the same day instead of some scattering of trips across all departures in a month*" (ibid). Audit found clustering trips to obtain a statistical sample of cars effective in reducing the cost of data collection.

Table 2. Northstar Ridership Strata and Post-Stratification Weight Calculation

Service (Stratum)	Total # of Departure Times	Total # of Cars	% Total Cars (A)	Sampled Cars	%Total Sampled (B)	Weight (A/B)
Weekday Regular	233	809	69%	27	46%	1.514837
Weekend Regular	38	148	13%	17	29%	0.440143
Special Services	30	210	18%	15	25%	0.707798
Total	301	1167	100%	59	100%	

Audit first drew a statistical sample of departure times for each service type within clusters (primary sampling units). For each sampled departure time, Audit staff selected one train car at random. The total number of cars with passengers for each departure time and service type was obtained from Northstar Operations upon the completion of field work in order to calculate post-stratification weights. As Audit drew samples independently from each stratum, post-stratification weight was employed to ensure that the sample reflects the population characteristics.

Audit staff rode on commuter rail between Big Lake and Target Field from July 1, 2010 to July 31, 2010. During fieldwork, Audit staff counted the number of passengers, i.e. the leaving load, on the selected cars once the doors were closed. Audit observed an average of 62 passengers on a train car (see Table 3).

Table 3. Northstar Ridership

Variable	Sample Size	Mean	Standard Error	Margin of Error (95%)	Confidence Interval	
Ridership	59	61.64	3.65	7.5	54.08	69.19

All calculations for ridership were done with SAS/STAT 9.2. Standard errors were calculated using the Taylor series expansion method, which obtains a linear approximation for the estimator and then uses the variance estimate for this approximation to estimate the variance of the estimate itself (Woodruff 1971, Fuller 1975).

In order to estimate the inter-station rides, Audit staff counted boardings and alightings for the selected car at each train station. As with the ridership survey, the sample universe for the inter-station rides survey included all weekday and weekend regular service departure times between Big Lake and Target Field stations, except for the special services. Due to logistics and limited informational value, inter-station rides during special event services were excluded from the universe. The inter-station rides survey sample size was calculated using 95% confidence interval and 5% sampling error which correspond to a sample size of 29. However, Audit observed 44 train cars to obtain vigorous results.

Table 4. Northstar Inter-Station Rides Post-Stratification Weight Calculation

Inter-station Rides	Total Number of Cars	% Total Cars (A)	Sample Size	% Total Sampled (B)	Weight (A/B)
Weekday	809	85%	27	61%	1.377607493
Weekend	148	15%	17	39%	0.400270453
Total	957	100%	44	100%	

Audit applied the population proportions to the results of the unweighted sample to produce an adjusted result (see Table 4). For example, 15% of one-way car trips occur during weekends. However, 39% of surveys were taken during weekends. In order to balance the over-sampling of weekend car trips, the calculated weight was employed. Table 4 shows that Audit observed a 7% of inter-station rides between Big Lake and Target Field. This means that 7% of passengers in the month of July did not use Target Field Station as either a departure or arrival station. Table 5 shows the statistical estimations.

Table 5. Northstar Inter-station Rides

Variable	Sample Size	Mean	Standard Error	Margin of Error (95%)	Confidence Interval	
Inter-station Rides	44	7.27%	1.28%	2.9%	4.37%	10.18%

All calculations for ridership were done with SAS/STAT 9.2. Standard errors were calculated using the Taylor series expansion method, which obtains a linear approximation for the estimator and then uses the variance estimate for this approximation to estimate the variance of the estimate itself (Woodruff 1971, Fuller 1975).

II.   Northstar Fare Inspection and Family Pass Ratio

This section addresses the questions of how often police are inspecting tickets on Northstar Commuter Rail and what is the family pass ratio for weekday and weekend special services.

As with the inter-station rides, the sample universe for the inspection survey included only weekday and weekend regular services. Audit employed the same post-weights in order for the sample to sufficiently reflect the population characteristics. While the necessary sample size was calculated to be 29 at 95% confidence level and 5% sampling error, Audit observed 44 one-way passenger cars for the purposes of accuracy. The sample was stratified according to routine fare inspection practices (see Table 6). As police presence is highly volatile depending on the day, the stratum identification was based on the days of the week.

Table 6. Fare Inspection Survey Post-Stratification Weight Calculation

Fare Inspection	Total Number of Cars	% Total Cars (A)	Sample Size	% Total Sampled (B)	Weight (A/B)
Weekday	809	85%	27	61%	1.377607493
Weekend	148	15%	17	39%	0.400270453
Total	957	100%	44	100%	

Audit staff noted the number of times they observed fare inspection by either police or conductor inside the car between each scheduled station stops. Table 7 shows that the combined fare inspection was 63% of the time during weekdays and 12% during weekends. Audit observed 41% fare inspection conducted by the police during weekdays and 6% during weekends. Table 8 shows the standard errors and the confidence intervals for each stratum.

Standard errors were calculated using the Taylor series expansion method by SAS/STAT 9.2.

Table 7. Northstar Fare Inspection

Fare Inspection	Sample Size	Mean	Standard Error	Margin of Error (95%)	Confidence Interval	
Weekday	27	63%	6.52%	16.8%	46.18%	79.74%
Weekend	17	11.76%	4.35%	12.1%	0%	23.86%

Table 8. Police Fare Inspection Survey

Police Inspection	Sample Size	Mean	Standard Error	Margin of Error (95%)	Confidence Interval	
Weekday	27	40.74%	7.44%	19.13%	21.61%	59.87%
Weekend	17	5.88%	3.72%	10.31%	-4.43%	16.20%

In order to estimate the family pass ratio, i.e. the number of passengers per family pass, Audit staff surveyed all passengers on the selected special service car trips between Fridley and Target Field stations. Audit staff asked all passengers if they were using a family pass at the time of the survey and if so, how many people on the pass were adults, how many were children between the ages of 6 and 17, and how many were under the age of 6. Audit staff conducted survey once the doors were closed and wanted to ensure that all passengers were surveyed before they disembarked at the next scheduled stop in order not to miss any family pass user. It took around 10 minutes to administer the survey, which is almost the travel time between Target Field and Fridley stations. Staff also counted the leaving load (all passengers inside the car) between Target Field and Fridley stations to obtain average family pass ratio for each selected car trip.

Audit calculated the necessary sample size using the population of 30 special event trips, a sampling error of 5% and a confidence level of 95%. Given these statistics, the necessary sample size was calculated to be 15 trips. Weekday and weekend special services were treated as strata due to different ridership characteristics. Audit then randomly selected one car per selected trip. The total number of one-way passenger cars operated during special events was obtained from Northstar Commuter Rail Operations in order to post weight the sample (see Table 9).

Table 9. Family Pass Survey Post-Stratification Weight Calculation

Family Pass	Total Number of Cars	% Total Cars (A)	Sample Size	% Total Sampled (B)	Weight (A/B)
Weekday	102	49%	6	40%	1.214286
Weekend	108	51%	9	60%	0.857143
Total	210	100%	15	100%	

Audit surveyed 2,011 passengers on 15 special event car trips. 1,312 passengers used a total of 478 family passes. Using Taylor expansion method, Audit found a family pass ratio of 2.67 for weekday special events and 2.95 for weekend special events (see Table 10).

Table 10. Northstar Family Pass Factor

Family Pass	Total # of Departure Times	Sample Size	Mean	Standard Error	Margin of Error (95%)	Confidence Interval	
Weekday	12	6	2.67	0.026	0.07	2.60	2.74
Weekend	18	9	2.95	0.115	0.27	2.68	3.21

III.   Design Effect

Although cluster sampling is quicker, cheaper and easier than simple random sampling, it can result in a loss in precision of estimates compared to a non-clustered sample of the same size (SAS OnlineDoc: Version 8). The loss in precision by the use of cluster sampling, instead of a simple random sampling, is called 'design effect'. Design effect takes the variance from the complex sample design and compares it to the variance that would have occurred under the assumption of simple random sampling. Design effect increases the confidence intervals around results and thus reduces the precision. It is used to calculate the effective sample size (i.e. the actual sample size divided by the design effect) and to estimate how much larger the standard errors and the confidence intervals as a result will be (Shackman 2001). Design effects may differ from survey to survey and from question to question.

Design effect is calculated as follows:

$$DEFF = 1 + \delta (n - 1),\ \text{where}$$
DEFF is the design effect,
δ is the intraclass correlation for the statistic in question, and,
n is the average size of the cluster.

A design effect of, say, 3.0 is interpreted that the sample variance is 3 times bigger than it would be if the survey were based on the same sample size but selected randomly (Turner 1996).

Audit calculated the design effects resulted from the use of cluster sampling with SAS/STAT 9.2. Table 11 shows the magnitude of the loss in precision under each stratum.

Table 11. Design Effect Calculations

Stratum	Total Departure Times	Total Number of Cars	Total Primary Sampling Units (Clusters)	Number of Sampled Clusters	Sampling Rate	Number of Observations	Design Effect
1	234	809	40	6	15.00%	27	0.6010
2	38	148	8	5	62.50%	17	0.2359
3	30	210	30	15	50.00%	15	0.1743

For example, the interpretation of the value of 0.60 is that the sample variance is 0.60 times bigger than it would be if Audit used simple random sampling. In other words, the confidence intervals for the first stratum, i.e. weekday regular service trips, will be 0.60 times as large as they would for a simple random sample (Shackman 2001). All confidence intervals listed above for each survey variable of interest are indeed larger than what Audit would have obtained had simple random sampling been employed.

To minimize the negative effect of cluster sampling on precision, units within clusters should be as heterogeneous as possible for the characteristics of interest (SAS OnlineDoc: Version 8). By randomly selecting one car for each selected train trip, Audit reduced δ, i.e. the intraclass correlation for ridership among train cars, which helped mitigate the loss of effectiveness resulting from multi-stage cluster sampling.

Exhibit A: Family Pass Compliance Survey Form

SURVEY SHEET			
2010-23 Northstar Rider Counts and Fare Compliance on **Special Event Services**			

Auditor:			
Date:			
Day of Week:			
Direction:	BIG LAKE		TARGET FIELD
Car #:			
Total # of Cars:			
Fare Inspection by: (Please Circle)	POLICE	CONDUCTOR	NONE
Notes:			

Purpose: Count the total number of passengers in the car and survey passengers in the same car as to how they paid their fares. The data will be compared to Cubic data to determine family pass ratio.

Methodology: Depending on the load and the destination, start asking passengers how they paid their fares one or two stations prior to or after Target Field station. Determine the number of people per pass, including the number of children under 6 and the number of adults.

Ridership	Originating Station	Departure Time	Total # of Passengers in the Car

No	Family Pass			Notes
	# of Children less than 6 years old	# of Children 6-17	# of Adults	
1				
2				
3				
4				
5				
6				
7				
8				

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