DEVELOPMENT PLANS FOR THE COLLECTION OF NATIONAL TRANSIT DATA AND TRANSIT MANAGEMENT INFORMATION

Contract 98-01

Prepared for:

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SECTION 1
OVERVIEW

1.1 Project Background

The Northern Virginia Transportation Commission (NVTC) received a grant to collect and provide critical bus ridership information for the Northern Virginia bus service providers. This grant addressed two different, but related needs. Given the size and complexity of the bus systems operated within the metropolitan area, accurate and timely ridership information is needed for effective management of the bus systems. Currently, WMATA collects some of the relevant data, but route level data are not available. Further, some important route planning data are not collected, such as passenger origins and destinations and transfer pattern information. It was also recognized that additional transit funds could be allocated to the region if transit properties currently not filing National Transit Database (NTD) reports could do so. Alexandria DASH, Arlington Transit (ART), Fairfax CUE and Loudoun Commuter Service had not previously filed NTD reports. NVTC contracted with George Hoyt & Associates, Inc. (GH&A) to design a cost efficient data collection program which would address both of these areas. Subsequently, the contract was modified to collect transit data for the Fairfax Connector bus service, which operates in and around Fairfax County. The Fairfax Connector already files NTD reports. However, County staff were interested in examining the possibility of using an alternative sampling plan. Data collected for the Connector will be used for fiscal year 1999 filing purposes.

This report provides two separate data collection plans. Section 2 contains the current and future year sampling plans for the collection of NTD related data. Background work completed by GH&A in conjunction with NTD data collection is also described. The sampling plans and estimation techniques identified in this report are for the collection of data to be used to complete parts of the Transit Agency Service Form (406). An analysis of the collection and reporting of financial data was undertaken as a modification to the contract. An overview of the assessment is provided, with in-depth summaries included as appendices. Section 3 provides a work plan for the collection of the necessary ridership information transit managers need to increase transit efficiency. This plan involves all of the major bus service providers in Northern Virginia, including Alexandria DASH, Arlington Transit, Fairfax CUE, Fairfax Connector, Loudoun Commuter Service and Metrobus.

1.2 Glossary of Terms

Following are the definitions of several terms which are used throughout this document.

- **Alternative Sampling Plan** - A statistically valid technique, other than a 100% count or an Federal Transit Agency (FTA) suggested technique, for collecting unlinked passenger trips and passenger miles. A qualified statistician must determine that the sampling technique meets FTA's confidence and precision levels for NTD reporting.
- **Bus Trip** - The one way movement of a bus in revenue service starting at one terminal point of a route and ending at another terminal point.
- **Busmeister** -A group of Loudoun Commuter Service passengers who volunteer to collect bus fares from fellow passengers. Busmeisters also record total boarding by route by trip.
- **National Transit Database (NTD)** - A federal government data collection and reporting system used to allocate Urbanized Area Formula funds from the FTA.
- **Passenger Miles** - The cumulative sum of the distance ridden by each passenger.
- **Ridecheck** - On-board collection of bus ridership data, including passenger boardings and alightings by stop, and mileage between stops.
- **Unlinked Passenger Trip** - The number of passengers who board a vehicle. A passenger is counted each time he boards a vehicle, including transfers from one vehicle to another on the same journey from origin to destination.

SECTION 2
NATIONAL TRANSIT DATABASE DATA COLLECTION

The Federal Transit Administration (FTA) has specific data requirements for filing NTD reports for fixed route operations. The bus ridership data elements are system-wide unlinked passenger trips (boardings) and passenger miles reported annually for an average weekday, average Saturday, average Sunday, and total. These data may be obtained by 100 percent enumeration, sampling using an approved FTA sampling plan or using a statistically valid alternative technique. For all plans other than complete enumeration, data must be estimated with ±10 percent precision at the 95 percent confidence level.

Our technical approach called for developing statistically valid alternative sampling techniques for the four non-filing properties - Alexandria DASH, Arlington Transit (ART), Fairfax CUE and Loudoun Commuter Service. A primary reason these transit properties have not filed NTD reports in the past is because of the costs involved in implementing a "standard" ride check program. In order to develop the alternative plans, some data collection was required to better understand the amount of variance in average trip length and passenger boardings. Our initial data collection program is described below. Summaries of the alternative sampling plans are then presented. These plans were prepared in conjunction with Dr. Peter Furth and include approaches for completing the remaining data collection for 1998, as well as for subsequent NTD mandatory data collection years. Finally, the data estimation procedures for non-mandatory data collection years are described. The detailed sampling plans and analyses completed by Dr. Furth, as well as his certification as to the statistical accuracy of the data using these alternative sampling techniques are included in Appendices A-D.

In a contract modification, GH&A was tasked with developing a statistically valid alternative sampling plan for the Fairfax Connector. The initial data collection effort is described in this section. The detailed sampling plan, analysis and certification for the Fairfax Connector are provided in Appendix E.

A second contract modification was issued to address the financial filing requirements for NTD reporting for the four non-filing properties. GH&A subcontracted this work to Littleton C. MacDorman, a recognized expert in this area. Mr. MacDorman visited the four properties to obtain a better understanding of their operations from a financial point of view. A summary of Mr. MacDorman's assessment is provided in section 2.5. and Appendices F and G contain the detailed analyses.

2.1 Initial Data Collection

GH&A staff met with representatives from all of the area bus service providers to better understand their on-going data collection programs. For the non-filing properties and the Fairfax Connector, supplemental data collection programs were designed. Samples of bus trips were selected from the universe of bus trips operated by each of the service providers. Surveyors rode these buses and collected traditional ride check information, including boardings and alightings by stop, mileage, stop arrival time and bus capacity.

In order to develop the ride check data collection forms, bus stop lists by route were requested. Complete bus stop lists were developed for the Fairfax CUE and the Fairfax Connector. Staff from both organizations reviewed the lists for completeness, and provided landmark information where available. During data collection, the stop lists were also validated by the ride checkers and corrected as necessary.

Once all of the data were collected, they were entered into a database for ease of processing. Passenger ons, offs, and cumulative boardings were entered by stop, as was the mileage related information. Data for each trip were entered and summarized at the route level for analysis and development of alternative sampling plans.

2.1.1 Alexandria DASH

DASH's fixed route operation consists of seven primary routes, with interlining among some of the routes. The AT-2, AT-6 and AT-8 do not overlap service. Routes AT-3 and AT-4 have some common service area, and on nights and weekends operate as a loop. There is interlining on the majority of the AT-5 and AT-7 routes. DASH operates seven days a week and all routes operate during and between the traditional peak periods. The major routes (AT-2, AT-5, AT-7 and AT-8) provide service late into the evening.

DASH also operates shuttle bus service to the Pentagon during peak periods only. Ridership data were not collected for the shuttle. It was determined that data collection would not be cost effective, so the shuttle has not been considered in future data collection for NTD reporting.

All buses in the DASH system are equipped with registering fareboxes, which provides the ability to compute passenger boardings, and decreases the need for sampling. Using data provided by DASH, GH&A prepared estimates of unlinked passenger trips and passenger miles. After analyzing the estimates, it was determined that a sample of 80 bus trips was needed for the supplemental data collection. Before drawing the sample, the AT-5 and AT-7 were grouped together because of interlining. This grouping reduced the overall sampling requirement. DASH service is provided seven days a week, so the sample includes weekday, Saturday and Sunday trips. Trips were chosen to include all time periods except late evening (after 8:00 p.m.). Trips were selected in pairs and for each route the same bus was ridden inbound as well as outbound. Scheduling efficiency was the primary determinant in choosing the sample trips. Table 1 shows the sample distribution (represented as single not round trips) by route and day type.

Table 1
Alexandria DASH Sample

Route Number	Wkday Trips	Sat. Trips	Sun. Trips
AT-2	8	4	4
AT-3	8	N/A	N/A
AT-4	8	N/A	N/A
AT-3/4	0	4	4
AT-5/7	8	4	4
AT-6	8	N/A	N/A
AT-8	8	4	4
Total	48	16	16

N/A means the service does not operate on that day.

GH&A staff met with DASH's General Manager to explain the proposed data collection effort and seek approval to conduct the ride checks. We also requested, and were given, fare media which allowed the checkers to ride free while conducting their work. After the ride check schedule was developed it was sent to the General Manager, who alerted the bus drivers that ride checkers would be on their buses. The drivers were instructed to provide assistance, if requested. Overall, the drivers were extremely helpful and cooperative.

Data collection on the DASH system was relatively easy and straightforward. It was very easy for the ride checkers to get to and from the sample buses using transit since most routes service a rail station. Transfer connections to other sample buses were also easy due to the frequency of service in Old Town.

The only problem encountered during data collection was that the odometers did not work on all of the buses. In order to validate the mileage data, it was necessary to geocode the bus stops for each route and compute the stop distance. This was accomplished using a GIS provided by the City of Alexandria. Without the base transit map for DASH it would have been necessary to trace each bus route in a private vehicle to calculate the mileage.

2.1.2 **Arlington Transit**

Arlington Transit operates weekday peak period service along a fixed two mile route in Crystal City. The route, a 20 minute loop, is operated during a three hour period in the morning and evening. It serves primarily as a distribution/collection service connecting workers in Crystal City with rail stations, hotels and eating establishments. Two separate buses are used during each peak period to provide this service and they operate on approximately ten minute headways.

ART also operates a "Free Shopper's Shuttle" between the hours of 11:00 a.m. and 2:00 p.m. The service, sponsored by the Charles E. Smith Realty Companies, operates every five minutes along the same route as the rush hour service. There are fewer stops during the midday and the service is provided free of charge. Because this is not revenue service, it was not considered as far as NTD data collection was concerned.

Arlington County contracts for the peak period service and the operator provides annual estimates of ridership, as well as other service related characteristics. Due to the nature of the service, initial estimates indicated significant variance in passenger boardings and trip length. In order to develop a statistically reliable plan, a larger than expected sample was necessary. Fifteen trips were sampled for each peak period, for a total of 30 samples. Count data and mileage information were collected on two separate days and both buses were ridden.

Approval to conduct a limited ride check program was granted at the initial meeting with Arlington County staff. Once the survey days were identified, the schedule was sent to the County's transit service planner who arranged for our ride checker to ride the buses free while he collected the necessary data.

Collecting the data was relatively easy, except for the mileage information. ART buses use hubdometers to record mileage. It was neither practical nor safe to have the ride checker get off the bus at each stop to read the meter. To obtain the stop-level mileage data, the route of the bus was driven using a private vehicle and the stop-to-stop mileage was collected. This process was done twice and the information was provided to Arlington County staff for review and approval.

2.1.3 <u>Fairfax CUE</u>

The City of Fairfax's fixed route system, called the CUE, consists of two distinct loops which operate in a clockwise and counter clockwise direction. The result is four separate routes - Green 1, Green 2 (counter clockwise), Gold 1 and Gold 2 (counter clockwise). Service is provided for most of the day, seven days a week. All routes share two common termini - the Vienna Metrorail station and the George Mason University (GMU) campus.

The bus system is partially subsidized by GMU, allowing faculty and students to ride free. As a result, the biannual passenger counts collect boardings by fare type at the route level. Stop level data are not collected. Because students comprise a large part of the passenger population, there is variability in boardings when school is in session compared to when it is not. To better understand the passenger loads and average trip length, data were collected on a total of 32 trips. The sample trips were selected in the same manner as for DASH. Scheduling efficiency was the primary determinant. Since service is provided seven days a week, the sample included weekday, Saturday and Sunday service. Passenger ons and offs, and odometer readings were collected at the stop level for each sample trip. Table 2 shows the sample distribution by route and day type.

Table 2
Fairfax CUE Sample

Route Number	Wkday Trips	Sat. Trips	Sun. Trips
Green 1	6	1	1
Green 2	6	1	1
Gold 1	6	1	1
Gold 2	6	1	1

GH&A staff met with the City's Director of Transportation and the manager of bus operations and discussed our proposed data collection plan. Approval was immediately granted. Once the ride check schedule was developed, it was sent to the bus operations manager who notified the drivers. The drivers were instructed to provide our ride checkers assistance, if necessary. The City also provided special passes which our ride checkers used to ride free. We encountered no problems with the data collection program for CUE.

2.1.4 Loudoun Commuter Service

Loudoun Commuter Service (LCS) provides weekday peak period bus service between Loudoun County and the District of Columbia. The furthest points served are Purcellville in Loudoun County and Union Station in Washington, DC In November 1997, a new bus was added for a total of nine morning and nine evening runs. There are five distinct morning patterns and four distinct evening patterns. The buses run non-stop between Sterling and Rosslyn.

There is an informal passenger count program on each of the buses. The County uses volunteers, called busmeisters, to collect boarding tickets from each passenger. The busmeisters record boardings by stop. This provides half of the necessary ridership statistics for NTD reporting. Data on passenger miles are not collected. For commuter bus service, between-day variance is an area of concern, as it could result in significant variance in passenger boardings and trip lengths. To better understand this variance, a sample which included four different buses was selected. Each bus was ridden four times. Passenger ons and offs were counted on the LCS 2 and LCS 4 in the morning and the LCS 3 and LCS 5 in the evening. Mileage data were also collected to compute average trip length. These four routes were chosen because they represented both the longest and shortest route patterns.

Implementing the data collection program for Loudoun Commuter Service was very challenging due to logistical issues. The bus service only operates one way; inbound in the morning and outbound in the evening. Getting the ride checker to the morning bus and home after the evening run was an issue. We determined the most efficient way to schedule the work was to ride both a morning and an evening bus in the same day. This cut down on the total number of survey days. Unfortunately, there is a significant gap between runs and finding "filler work" was difficult.

There is an advisory committee that oversees the operation of the bus service. Members of the advisory committee were kept informed as to the schedule and progress of the data collection effort.

2.1.5 Fairfax Connector

Unlike the other four properties, the Fairfax Connector already files NTD reports. In response to a request for an alternative sampling plan for fiscal year 1999, GH&A met with Fairfax County staff to discuss operations, explain the initial data collection program, and obtain the necessary approvals to go forth. Once the data collection schedule was developed, County staff was notified and they, in turn, notified the operators that ride checkers would be on selected buses. The drivers were instructed to provide assistance, if requested. For this data collection effort, we were able to use ride checkers who worked part-time for Fairfax Connector.

The Fairfax Connector operates bus service seven days a week, 19 - 20 hours a day. The bus system is operated by two different private contractors. The system consists of 52 routes, which includes local, community, feeder, express and shuttle service throughout Fairfax County. During the week, approximately 984 bus trips are run, compared to 247 on Saturday and 76 on Sunday. The majority of the weekday service is provided during the morning and evening peak periods.

Most buses in the Fairfax Connector system are equipped with registering fareboxes, which provides the ability to compute passenger boardings, and decreases the need for sampling. The buses operated under contract by TMSI in the western part of the County are not equipped with registering fareboxes, so this became a factor in developing the final sampling plan. Using data provided by Fairfax Connector, GH&A prepared estimates of unlinked passenger trips. After analyzing the estimates, it was determined that a sample of 230 bus trips was needed for the supplemental data collection. Trips were chosen to include all time periods, except late evening (after 11:00 p.m.). Trips were selected in pairs, and for each route the same bus was ridden inbound, as well as outbound. The sample trips were selected at random and included weekday service only.

Data collection on the Fairfax Connector system was relatively easy, especially since we had experienced ride checkers assisting us. The biggest challenge was collecting the mileage information. Most of the buses had hubdometers, which made collecting stop-to-stop mileage difficult. We determined the most efficient way to compute the mileage information was to geocode the bus stops for each route.

2.2 1998 NTD Data Collection Plan, Estimation Method & Statistical Analysis

The data collected for each property was analyzed and alternative sampling plans for the remainder of the Fiscal Year (FY) 1998 were developed. All of the recommended alternative sampling plans meet the FTA requirement which specifies that estimates of annual passenger miles have a precision of ±10 percent at the 95 percent confidence level. The various plans must be followed as specified for the precision and certification to remain valid.

The sampling plans provide the procedures for estimating annual passenger boardings and passenger miles. Passenger boardings, or unlinked passenger trips, is defined as the number of passengers who board the bus. A passenger is counted each time he boards a bus, even though he may be on the same journey from origin to destination. Passenger miles is defined as the cumulative sum of the distances ridden by each passenger. Passenger miles are estimated by computing an average trip length, which is derived by dividing the mileage by the number of boardings for that trip.

2.2.1 <u>Alexandria DASH</u>

2.2.1.1 <u>FY98 Sampling</u>

No further sampling was required for DASH to estimate FY98 boarding and passenger miles. Once the annual boardings for the year were tallied, the estimate was made by expanding the ratios that were calculated from the data already collected.

2.2.1.2 <u>Annual Passenger Miles Estimation Method</u>

Two separate methods for estimating annual passenger miles were used because the routes were stratified into two separate strata. Simple ratio estimation was used for the AT-6, which was the only route in the short average trip length strata, and the "combined ratio method" was used for the other routes, which were grouped together in the long average trip length strata. The "combined ratio method" is an application of stratified sampling, and is described in Appendix A.

To estimate passenger miles for the AT-6:

1. Find the average passenger miles and average boardings for each of the sample trips.

2. Divide the average passenger miles by the average boardings to calculate the average trip length.

3. Then multiply the average trip length by total annual boarding.

To estimate passenger miles for all other DASH routes:

1. For each stratum (i.e., route grouping), find the average passenger miles per trip contained in the sample. Multiply this by the number of trips operated per week to obtain an estimate of weekly passenger miles by stratum.

2. Aggregate the weekly passenger miles over the four long average trip length strata (routes) to obtain an estimate of weekly passenger miles for the strata which were combined (e.g., 3/4).

3. Repeat steps 1 and 2 for boardings, making sure to use the same samples. First, calculate an estimate of weekly boardings by stratum, and then one of weekly boardings for the four strata combined.

4. Next, calculate the average trip length for the four combined long average trip length strata using the weekly combined estimates (i.e., divide the passenger miles by weekly boardings).

5. Multiply the average trip length by the total annual boardings on all the routes in the four included strata.

Once this process is complete, sum the AT-6 annual estimate with the annual estimate from the other routes to obtain the system annual passenger miles estimate.

2.2.1.3 <u>Statistical Analysis of the Accuracy of the Estimates</u>

Dr. Furth completed a statistical analysis of the FY98 data and determined that the precision of the estimate of passenger miles was ±4.3 percent at the 95 percent confidence level. Since total boardings are captured using electronic registering fareboxes, no certification is necessary for the estimate of passenger boardings. The statistical analysis and certification completed by Dr. Furth are included in Appendix A.

2.2.2 **Arlington Transit**

2.2.2.1 FY98 Sampling

Based on the analysis of the supplemental data collected by GH&A, additional sampling would have been required to achieve a statistically valid sample for FY98 NTD reporting. The bus incentive payoff for estimating and reporting passenger miles was less than the cost of completing the additional data collection. As a result, a waiver for reporting passenger miles was requested and approved. Therefore, no further ride checks were done for FY98.

2.2.2.2 Annual Passenger Miles Estimation Method

The simple ratio estimation method should be used for estimating annual passenger miles. From the annual ride check sample, compute the average passenger miles per trip. Then, calculate the average boardings per trip from the same sample. Using these two numbers, divide the average passenger miles by the average boardings. This produces the average trip length, which is multiplied by annual boardings to compute the estimate of annual passenger miles.

2.2.2.3 Statistical Analysis of the Accuracy of the Estimates

Dr. Furth completed a statistical analysis of the FY98 data based on the proposed plan and determined that the precision of the estimate of passenger miles was ±5.8 percent at the 95 percent confidence level. Since total boardings are reported, no certification is necessary for the estimate of passenger boardings. The statistical analysis and certification completed by Dr. Furth are included in Appendix B.

2.2.3 **Fairfax CUE**

2.2.3.1 FY98 Sampling

To obtain a statistically valid sample from which to estimate annual passenger miles and boardings, additional weekly sampling would have been required for the balance of FY98. Since annual boarding counts are not collected, a more stringent sampling plan was necessary. The proposed plan called for a total of 156 trips a year to be ridden. GH&A collected data for 32 of these trips, leaving a balance of 124. The proposed methodology for collecting data on a weekly basis is very costly. CUE received a waiver from FTA and did not report passenger miles for FY98. The cost-benefit analysis showed that the financial return to the region was less than the cost of collecting the additional data.

After the data collection plans were developed for FY98 and future years, it was learned that CUE might be installing registering fareboxes on the buses. A second set of sampling plans and estimation procedures were developed in the event that fareboxes were installed. These alternative plans should only be implemented once the registering fareboxes are installed, tested and producing verifiably accurate data. This alternative plan is also included in Appendix C.

2.2.3.2 Annual Passenger Miles and Boardings Estimation Methods

Analysis of the data collected by GH&A showed the only substantial systematic difference in passenger miles per trip was between peak and off-peak periods. As a result, the method recommended for estimating passenger miles on CUE is simple expansion of the mean, with ex post facto stratification. This means that at the end of the year the data must be grouped into peak and off-peak strata, and the number of trips operated per year per strata must be determined. Average passenger miles per trip can then be estimated by time period. Finally, each stratum's sample mean should be multiplied by the number of annually operated trips in that stratum. The annual estimate of passenger miles is then determined by adding the peak and off-peak estimates.

The same process should be used to estimate annual boardings (i.e., expanding mean boardings per trip from the sample in the two strata and then summing the expanded products).

2.2.3.3 Statistical Analysis of the Accuracy of the Estimates

Dr. Furth completed a statistical analysis of the precision of the passenger miles and boarding data estimates based on data collected during November 1997. He determined that the precision of the estimate of passenger miles was ±7.0 percent at the 95 percent confidence level. The precision of the annual boardings estimate was ±8.2 percent at the

95 percent confidence level. The statistical analysis and certification prepared by Dr. Furth are included in Appendix C.

2.2.4 Loudoun Commuter Service

2.2.4.1 FY98 Sampling

Like DASH and ART, Loudoun Commuter Service (LCS) routinely counts all boarding passengers. As a result, passenger miles can be estimated by computing the ratio of passenger miles to boardings. LCS operates nine buses in each rush period. GH&A collected data on two different buses in each rush period. Additional sampling was required to accurately estimate the average trip length. GH&A was able to obtain from the contractor, Thomas Tours, stop-by-stop passenger counts for the remaining 14 buses not sampled. A detailed sampling plan and estimation methods are contained in Appendix D.

2.2.4.2 Annual Passenger Miles Estimation Method

Average trip length was estimated by first calculating the average passenger miles and average boardings per trip in the sample. Then average passenger miles was divided by average boardings to determine the average trip length. The average trip length was multiplied by the annual boardings to arrive at the estimate of annual passenger miles.

2.2.4.3 Statistical Analysis of the Accuracy of the Estimates

Dr. Furth analyzed all of the data for FY98. Using the "combined ratio method," the precision of the estimate of passenger miles was ±5.7 percent at the 95 percent confidence level. The statistical analysis and certification completed by Dr. Furth are included in Appendix D.

2.3 1999 NTD Data Collection Plan, Estimation Method & Statistical Analysis

For NTD service reporting purposes (i.e., compiling data for Form 406), every third year in the cycle is a mandatory data collection year. Fiscal Year 1999 is the next mandatory service data collection year. Data collection plans have been developed for each property and the highlights are summarized below. These procedures must be followed for each mandatory year. The detailed sampling plans are included in Appendices A-E. Each plan also includes an analysis which addresses the validity of the sampling plan with respect to schedule and route changes. The annual passenger miles estimation methodologies summarized in the previous sections are valid for FY99 and all other mandatory years.

2.3.1 Alexandria DASH

2.3.1.1 FY99 and Other Mandatory Year Sampling and Accuracy

In November, 1998, DASH restructured some of their routes. The AT-6 was eliminated. The service was replaced by expanding the coverage of the AT-7. This eliminated the interlining between the AT-5 and AT-7. There were also minor routing changes made to the AT-2 during the midday and evening time periods. These changes eliminated the need for stratifying the routes by average trip length, since the AT-6 was the only "short" route. It is still necessary to collapse the AT-3 and AT-4 into one route for weekend sampling purposes. For each sampling unit, which is a round trip, ons and offs must be collected by stop. Passenger miles can be estimated by calculating the ratio of passenger miles to boardings. The sample size/distribution by stratum for FY99 and each mandatory data collection year is shown in Table 3. As shown, a total of 38 round trips must be completed.

Table 3

Alexandria DASH Sample Requirements
FY99 and Future Mandatory Years

Route Number	Round Trips
AT-2	8
AT-3/4	8
AT-5	8
AT-7	6
AT-8	8

The trips must be spread out over the four time periods: a.m. peak, p.m. peak, midday and evening. Trips must also be selected for Saturday and Sunday. Appendix A describes the mechanics for implementing this strategy, including information on how to randomly pick and group the trips into efficient pieces of work (referred to as chains). It is important to follow the sample selection plan as described, since the certification of statistical accuracy is tied to the prescribed implementation. Following the sampling plan for FY99 and future mandatory years, the precision of the estimate of passenger miles is ±4.5 percent at the 95 percent confidence level.

2.3.2 **Arlington Transit**

2.3.2.1 FY99 and Other Mandatory Year Sampling and Accuracy

Because boarding counts are routinely collected for Arlington Transit, fewer trips must be sampled to accurately estimate annual passenger miles. For FY99 and each mandatory year, the sampling plan requires that one trip chain be completed per quarter. A trip chain is defined as riding both buses for the entire three hour period. The ride checker must ride one bus for 1½ hours and then switch to the other bus. On and off data must be collected on at least six trips per sample period. During the year, two a.m. and two p.m. trip chains must be completed. Each trip chain must be completed on a different day.

Following the sampling plan for FY99 and future mandatory years, the precision of the estimate of passenger miles is ±5.8 percent at the 95 percent confidence level. This is based on a total of 24 trips (six per trip chain). The precision would improve if more trips were sampled (e.g., seven - eight trips per chain).

2.3.3 **Fairfax CUE**

2.3.3.1 FY99 and Other Mandatory Year Sampling and Accuracy

The sampling plan described below assumes registering fareboxes are not installed. CUE requires a significant amount of data collection. First, the current practice of counting boardings twice a year does not provide sufficient data for estimating unlinked passenger trips. Second, the strong week to week variability in ridership is tied to the GMU calendar. Given this variability, ons and offs must be collected for one chain per week. A chain consists of three trips operated consecutively by the same vehicle. For 46 weeks, the counts are made on weekdays, and in the remaining six weeks, three

Saturday chains and two Sunday chains must be sampled. The remaining chain can be done on either Saturday or Sunday. The random process to draw the sample trips is described in detail in Appendix C. This process must be followed carefully since Dr. Furth's certification is based on this sampling strategy.

Based on the above recommended sampling plan, NVTC should perform a cost-benefit analysis to determine the feasibility of filing any data for Fairfax CUE. A waiver can only be granted the first filing year, so if NTD reports are to be filed for Fairfax CUE, data <u>must</u> be collected for 1999. Certainly, it would be more cost effective to file NTD reports for CUE if registering fareboxes were installed, as the number of required samples would drop from 156 to 20. This determination should be given top priority.

Following the non-registering farebox sampling plan for FY99 and future mandatory years, the precision of the estimate of passenger miles is ±7.0 percent at the 95 percent confidence level. The analysis of the boarding data results in a precision of ±8.2 percent at the 95 percent confidence interval.

2.3.4 **Loudoun Commuter Service**

2.3.4.1 FY99 and Other Mandatory Year Sampling and Accuracy

The sampling requirements for FY99 and future years involves riding each separate bus once. For FY99, there is a total of 18 sample trips which must be ridden. Ons and offs must be counted by stop. Data collection can be spread out over the course of the year, as long as the trips are not all sampled on the same day of the week.

Following the sampling plan for FY99 and future mandatory years, the precision of the estimate of passenger miles is ±5.7 percent at the 95 percent confidence level.

2.3.5 **Fairfax Connector**

2.3.5.1 FY99 Sampling

Based on the analysis of the data collected from the 230 bus trips, a sample of 156 bus trips is recommended for FY99 data collection. Annual passenger mile data will be collected from these trips and, using the reported annual boardings, these data will be expanded to estimate the average passenger trip length. Annual boarding information will be provided by Fairfax Connector staff based on the adjusted registering farebox and manual count method they have in place. These trips should be ridden during the period from January through June, 1999. We also recommend collecting passenger mile data from an additional 30 bus trips for the sole purpose of assessing the impact of the new Dulles Corridor service expected to begin in mid-July, 1999. These trips should be ridden in September, 1999 after service has stabilized.

To improve efficiency, a stratified sample of trips by route will be used. For those routes that operate service in both an inbound and outbound direction, ride checks will be collected on the pair of trips. For those routes which operate in only one direction, the sampling unit will be the one-way trip.

2.3.5.2 Annual Passenger Miles Estimation Method

Since the Fairfax Connector has a system for producing annual boarding counts, passenger miles can be estimated by computing the ratio of passenger miles to boardings. The sample is *post facto* stratified by one-way route mileage with average trip length calculated and expanded separately for five route mileage groups. The sampled boarding and passenger miles are totaled for each mileage stratum. Average trip length (ATL) is then computed by dividing the sum of passenger miles by the sum of boardings. To calculate the estimate of annual passenger miles in the stratum, expand the ATL by the count of mileage stratum annual boardings. A system-wide annual passenger mile estimate may be obtained by aggregating the passenger mile estimates over the strata. The detailed sampling and estimation plan for FY99 is contained in Appendix E.

2.3.5.3 Statistical Analysis of the Accuracy of the Estimates

To verify that the proposed sampling plan will achieve the accuracy level required by FTA, the sample of ride checks completed in 1998 were analyzed. The sample consisted of 228 trips, with observations of boarding and alightings, and passenger miles on each. The method employed stratified sampling, with equal allocation among strata, and with stratum-level estimates being made using a ratio estimate. The proposed method resulted in a recommended FY99 sample of 120 bus trips. Using the recommended sample of 156 bus trips will result in an annual passenger mile estimate of ±8.8 percent at the 95 percent confidence interval. This is well under the required ±10 percent precision at the 95 percent confidence interval required by FTA. Certification of this plan is provided in Appendix E.

2.3.5.4 Other Mandatory Year Sampling and Accuracy

If the sampling plan for FY99 is followed for future mandatory years, the precision of the estimate should remain at ±8.8 percent at the 95 percent confidence interval.

2.4 NTD Data Estimation Procedures

The transit providers currently not filing NTD reports all qualify for an automatic waiver from the requirement to collect average trip length on an annual basis for FY98. These properties are only required to collect these data in "mandatory" years, which occur every third year (e.g., 1999, 2002). In intermediate years, the regulations allow passenger miles to be estimated in one of the following ways:

- use data for boardings (unlinked passenger trips) and passenger miles from the last mandatory year,
- estimate passenger miles using average trip length from the last mandatory year and boardings from the current year,
- continue sampling.

There is no requirement to use the same estimation method for every intermediate year. However, when passenger-miles are estimated, the method used must be documented on Supplemental Information Form 005.

2.5 NTD Financial Reporting Assessment

The detailed report contained in Appendix F provides an assessment of the adequacy of information readily available from the financial accounts of the Cities of Alexandria and

Fairfax, and the Counties of Arlington and Loudoun to comply with the NTD reporting requirements for motor bus service. Based on the review conducted by Littleton MacDorman, the financial data and records maintained for public transportation services in all of the localities may be reliably used to prepare and report information for NTD purposes. Some allocation procedures will be necessary to report certain required functional financial information. These methods are described in Appendix F, showing the crosswalk between city/county account codes and NTD object/function codes.

Transit contractors need to report percentages of the total amount charged the government agency for accrued expenditures in four functional categories during the annual reporting period. Appendix G contains the information which transit contractors need to prepare their reports to government agencies.

SECTION 3
MANAGEMENT DATA COLLECTION PLAN

In addition to collecting data necessary to support NTD filings, NVTC wants to establish databases to support comprehensive bus transit planning and analysis. Having on hand current information on transit service and usage will allow staff to respond quickly and effectively to questions from elected officials, citizens, the media, transit operators and advocacy groups. While data describing some items of interest may not currently exist, transit operators and others routinely collect significant amounts of data on transit service and usage. In some cases, ongoing data collection programs provide, or can be easily modified to provide, required data. In other cases, new data collection activities will be required. There are several types of data necessary to support bus transit planning and analysis. Service operated data, such as time tables and the universe of revenue and non-revenue bus trips operated, is useful to understand what is currently provided. Ridecheck and pointcheck data provide information on patronage usage. These data, if maintained at the stop level are important to service planning evaluation efforts. Finally, passenger flow data, usually obtained through the conduct of an on-board passenger survey are important for understanding passengers' travel patterns.

During the course of this project, we sought to establish the availability and scope of existing data. Then, specific recommendations on how to supplement these data sources were developed. Finally, generalized data collection programs that might be undertaken were developed. These topics are described in the following sections.

3.1 Existing Data

During the project, meetings were held with technical personnel from each of the Northern Virginia bus operators. During each meeting, the availability of locally collected data was investigated. In each case where local data sources were identified, operator personnel were requested to provide the data, samples of data and/or descriptions of the data and data collection methods. Many of the electronic data items collected or developed for this project may be of some continuing value to NVTC. They are indexed in Appendix N and have been provided on separate diskettes. Following is a description of existing data organized by transit service provider.

3.1.1 <u>Metrobus</u>

WMATA, the operator of Metrobus, has extensive data from its ongoing and periodic data collection activities. Most of the data collected by WMATA are stored in electronic form. In many cases, source documents are retained for validation and further analysis.

3.1.1.1 <u>Service Operated Data</u>

All operated Metrobus schedules are available in printed and electronic form. Arrangements for getting electronic extracts of these data can be made with the Office of Planning. The Block Master File is one of the most convenient forms of stored electronic data. This file is bus trip based and provides details for both revenue and non-revenue trips, including the miles and hours allocated to each jurisdiction. The file is updated regularly and serves as the basis for many operations and service analysis reports generated by WMATA.

3.1.1.2 <u>Ridecheck Data</u>

The Office of Planning performs periodic ridechecks on all trips operated. For weekday service, routes are checked every 18 months. The most recent cycle of weekday ridechecks for Northern Virginia routes was completed during the fall and winter of 1997-1998. Plans are in place to perform weekend ridechecks on a three year cycle. The most recent cycle of weekend ridechecks was completed in 1995-1996.

Ridecheck data are maintained by line and are available electronically in both summary and detailed form. Data for each route within a line are maintained as separate entries within each line file. The summary form provides boarding, alighting, load and schedule adherence data by service segment (i.e., service between time points). Summaries are available in spreadsheet form within a few weeks after they are completed. The detailed form provides the same data at the stop-level, and may not be available until six months or more after completion. The stop-level data are more relevant for the kinds of analyses

NVTC is interested in performing. With some manipulation, the stop-level data can be aggregated by jurisdiction.

WMATA also performs 2-day point checks at the critical load point of each line three times per year. Point checks are reviewed to identify performance problems, such as capacity issues and schedule adherence. Point check data are seldom available in electronic form.

3.1.1.3 Passenger Flow Data

WMATA periodically performs a system-wide on-board passenger survey to gather data for revenue allocation purposes. A new survey is generally performed shortly after major service changes, such as the turn-backs that occur with the opening on new Metrorail phases. The last survey was completed in 1994. The next survey is scheduled for the fall of 1999, and is expected to include weekday and weekend service. A copy of the questionnaire used in the 1994 survey is shown in Figure 3-1. The on-board survey is designed to gather data for revenue allocation, and unrelated questions are rarely included. For example, data regarding trip origin, destination, or place of residence have never been collected. There is interest now at WMATA in having this information and there is a high probability that it will be collected in future surveys.

3.1.2 **Fairfax (County) Connector**

3.1.2.1 Service Operated Data

The Connector maintains some schedule and headway data in spreadsheets. Unfortunately, they are not maintained in a consistent or standard format. Data are not compatible with the WMATA service operated data. Printed timetables are available.

3.1.2.2 Patronage Data

The contractors that operate the Connector service report patronage by route by month. For two divisions, these data are assembled from registering farebox reports. The other division counts passengers manually. While the Connector employs three part-time ride-

Exhibit 3-1
WMATA 1994 On-Board Survey Questionnaire

1994 METROBUS PASSENGER SURVEY

M
metro

Please answer the questions and RETURN THIS CARD BEFORE GETTING OFF THE BUS. If you do not have time to finish this now, please complete it later and drop it in any mailbox - no stamp is necessary.

606701

Please fill out a survey card each time you receive one.

- Where did you get **on the bus** where you received this card?

______________ and ______________ (nearest intersecting streets or location) which is in [ ]DC [ ]MD [ ]VA

- Where will you get **off this bus**?

______________ and ______________ (nearest intersecting streets or location) which is in [ ]DC [ ]MD [ ]VA

- How did you get to **this bus**? (Check one)
  [ ]1 Metrorail [ ]4 DASH [ ]7 Fairfax Conn. (Route ____) [ ]10 VRE
  [ ]2 Another Metrobus [ ]5 RIBS [ ]8 THE BUS (PG Co) [ ]11 MARC/AMTRAK
  [ ]3 Ride-On [ ]6 CUE [ ]9 Auto, Walk, Other [ ]12 MTA/Laurel Conn.

- Where are you **coming from**? (Check one)
  [ ]1 Work [ ]3 Job-related business [ ]5 School [ ]7 Sightseeing or recreation
  [ ]2 Home [ ]4 Shopping or meal [ ]6 Personal Trip

- How did you pay to ride the bus where you received this card? (Check all that apply)
  [ ]1 Cash,Ticket,Token [ ]3 Rail Transfer [ ]5 VRE Ticket [ ]7 School Ticket or Token
  [ ]2 Bus Transfer [ ]4 MARC Pass [ ]6 Flash Pass [ ]8 Police, Postal, WMATA

- Did you pay an **Elderly or Disabled** Fare? [ ]1 Yes [ ]2 No

- If you used a **Flash Pass**, what kind? (Check one)
  [ ]1 DC Base Pass [ ]4 MD/DC Pass [ ]7 VA 2 Zone Pass
  [ ]2 DC Bus Only Pass [ ]5 Arlington Pass ($23) [ ]8 VA 3 Zone Pass
  [ ]3 MD Base Pass [ ]6 VA Base Pass [ ]9 Bus/Rail Super Pass

- If you transferred from **another metrobus**:

  How did you pay to ride your <u>FIRST</u> Metrobus? (Check all that apply)
  [ ]1 Cash,Ticket,Token [ ]3 Rail Transfer [ ]5 VRE Ticket [ ]7 School Ticket or Token
  [ ]2 Bus Transfer [ ]4 MARC Pass [ ]6 Flash Pass [ ]8 Police, Postal, WMATA

  How did you get to your <u>FIRST</u> Metrobus? (Check one)
  [ ]1 Metrorail [ ]4 RIBS [ ]7 Fairfax Conn. (Route ____) [ ]10 VRE
  [ ]2 Ride-On [ ]5 CUE [ ]8 Auto, Walk, Other [ ]11 MTA/Laurel Conn.
  [ ]3 DASH [ ]6 THE BUS (PG Co) [ ]9 MARC/AMTRAK

  Where did you get on your <u>FIRST</u> Metrobus?

  ______________ and ______________ (nearest intersecting streets or location) which is in [ ]DC [ ]MD [ ]VA

- On this **one-way trip**, what is the **total** amount of **cash, tickets or tokens** you put in Metrobus fare boxes? $________

- At the end of this bus ride, will you **transfer to Metrorail**? [ ]1 Yes [ ]2 No

- At the end of this bus ride, will you **transfer to another Metrobus**? [ ]1 Yes [ ]2 No

- If <u>YES</u>, where will you get off **your last Metrobus**?

______________ and ______________ (nearest intersecting streets or location) which is in [ ]DC [ ]MD [ ]VA

- Where are you **going now**? (Check one)
  [ ]1 Work [ ]3 Job-related business [ ]5 School [ ]7 Sightseeing or recreation
  [ ]2 Home [ ]4 Shopping or meal [ ]6 Personal Trip

- How many usable cars, vans or trucks are at your home? ____

Thank you for riding Metro and completing this survey!

checkers, they normally collect information for special studies, and perform stationary load checks. There is not a comprehensive, system-wide database of trip level patronage data.

3.1.3 Alexandria DASH

3.1.3.1 Service Operated Data

DASH maintains schedule and headway data in spreadsheets. Unfortunately, they are not maintained in a consistent or standard format. Data are not compatible with the WMATA service operated data. Printed timetables are available.

3.1.3.2 Patronage Data

Patronage data are provided by registering farebox reports.

3.1.4 Fairfax (City) CUE

3.1.4.1 Service Operated Data

Timetables for CUE are provided in printed form only.

3.1.4.2 Patronage Data

Boardings by fare type for each trip are counted during a two week period each spring and fall, and maintained in spreadsheets. During one of the data collection periods, regular fare paying passengers and George Mason University students are counted. During the other period, regular fare paying passengers and elderly patrons are counted.

3.1.5 Loudoun Commuter Service (LCS)

3.1.5.1 Service Operated Data

LCS provides timetables in printed form only.

3.1.5.2 Patronage Data

Passengers by trip are counted every day by volunteer busmeisters. These counts are maintained in spreadsheets.

3.1.6 **Arlington Transit (ART)**

3.1.6.1 Service Operated Data

ART operates on a continuous loop basis, so no timetables are available.

3.1.6.2 Patronage Data

Daily ridership counts are provided by the operators and are accumulated and available on an annual basis. Results of an attitudinal passenger survey conducted in 1996 are also available.

3.2 Supplemental Data Collection Requirements

3.2.1 **Service Operated Data**

NVTC can assemble a database of Northern Virginia bus service from existing sources. This database should be bus trip based and include the following key attributes:

- Operator,
- Type of equipment (capacity and lift availability),
- Route operated,
- Days operated,
- Begin terminal point and time,
- End terminal point and time.

Other operational attributes, such as division and block/run codes, should also be captured if this database is to be used for selecting samples for passenger surveys and/or ridechecks.

3.2.2 **Ridecheck Data**

Ridecheck data provides useful information on system performance and patronage. If maintained at the stop level, passenger trip length data and jurisdictional ridership can be derived.

Only WMATA has a comprehensive ridecheck program. It is recommended that similarly designed programs be implemented for the Fairfax Connector, DASH and CUE. The sharply focused nature of the LCS system and the very local nature of the Arlington

Transit system suggest that those two operations do not require such a program beyond that already recommended for NTD reporting.

The Connector, DASH and CUE combined currently operate approximately 2,100 weekday plus weekend one-way bus trips. A ridecheck program designed to collect data on each of these trips once over a three year cycle would provide a sufficient basis for system patronage planning. While the collection of data to develop average trip lengths for estimating NTD passenger miles (and in the case of CUE, passenger trips) could be handled separately, both objectives could be accomplished within the context of this ridecheck program. The implications of this on the overall program design are straightforward.

3.2.2.1 Combining Service Planning and NTD Ridecheck Programs

For the sake of consistency with NTD reporting, the system year should be thought of as running from July through June. Then within each year, one third of the trips (700 based on current service levels) expected to be operated by route are selected randomly and ridden. In the first year, the sample is drawn from the full universe of trips. In the second year, half the remaining trips are randomly selected and ridden. Then in the last year, the remaining third of the trips are ridden. An equivalent approach would be to initially assign each trip randomly (again by route) to a survey year. Conceptually, this is less desirable since it suggests that service patterns and levels will remain constant over the three year cycle. Whichever approach is used, the collection process must be designed to accommodate system change. This is readily accomplished by development of detailed plans and quarterly schedule reviews. Generally this provides sufficient lead time for staffing without running the risk of having to redo schedules or "change on the fly" to accommodate service changes. If service increases either on existing routes or by adding new routes, additional samples must be added to maintain the sampling rate at one third of the trips per year by route.

While the sample must be distributed roughly evenly over the course of the year, selecting small clusters of trips (two to four trips run back-to-back in a day) will allow for a more efficient data collection program without damaging the overall representativness of the sample. Naturally, this can only be implemented on routes with relatively high service levels. Lightly served routes many not have sufficient samples to permit clustering except for directional pairs. Sampling in directional pairs is always recommended when service patterns allow it.

Furthermore, data collection need not be scheduled every day or even every week. Planning to cluster the sample into every other or every third week packages is permissible as long as that pattern is consistently maintained. Obviously, trips that only operate on Saturday or Sunday must be ridden on that day. Weekday trips should be roughly evenly distributed over the days within each week when data is being collected.

3.2.2.2 Independent Service Planning Ridecheck Program

While combining the service planning and NTD ridecheck programs is appealing from a staff utilization/resource leveling point of view, there are also benefits to conducting separate surveys. The service planning ridechecks could be completed within a single season (quarter) or even within a single year. Many planners prefer data that is collected within the same season (generally spring or fall) so that seasonal variation in ridership doesn't frustrate comparison of results.

If this type of program is implemented, the work can be packaged in any efficient way. Many properties using this program design (including WMATA) develop schedules based on whole service blocks or runs.

3.2.2.3 Staffing Requirements

The level of staff productivity required to implement these programs varies. For example, for a weekly program geared to collect data on 15 bus trips per week (780 annual trips) two part time people each working about 20 hours per week will be required. This implies a rate of about 2.5 hours per bus trip to account for the significant amount of overhead necessary to get to, ride, and return from assignments which will generally consist of one trip each. As the number of trips per week increases, the overhead per trip decreases since there is more opportunity to schedule trips together. For a tri-weekly program (45 bus trips per week) a rate of 1.5 hours per trip is likely. This results in a requirement for about two full time people. The most aggressive program, riding all trips within a single season every three years will require 25 to 30 people to accomplish. The nature of the work requires people who are flexible in terms of hours and days worked. Some early morning, late evening and weekend work will be necessary.

Both WMATA and the Fairfax Connector have trained ridecheckers on staff. NVTC should consider the option of collaborating with these organizations to maximize the utilization of existing staff. Finding and retaining people who are flexible and dependable enough to succeed at this work is difficult.

3.2.2.4 Hardware/Software Environment

Relational database technology should be used to link the service operated database and the ridecheck database. This technology allows multiple data sources to be stored separately, but related by the use of key or common variables. While the ridecheck database should be maintained at the stop level in order to support facility related issues (e.g., the need for shelters and curb cuts) and to maintain jurisdictional identity, the capability to roll the data up by service segment and trip should also be provided. Data at these levels are much more desirable for service planning and performance evaluation.

Initially, these data should be stored in a relational database environment with query and filter capability. Ultimately, NVTC may find it desirable to analyze and display bus service and passenger data in a Geographic Information System (GIS). If this is contemplated, the dBase database software package is a good platform for the assembly work since most GIS packages recognize dBase format. Other commonly used databases (e.g., Microsoft Access) may require conversion to dBase format before being interfaced to a GIS.

Before committing to GIS, NVTC should carefully weigh the overall utility of GIS with its system maintenance requirements. While the visual impact of GIS is powerful for communicating many of the relationships and themes relating to transit service and patronage, maintenance of core databases necessary for creating these images will likely require a trained person half to full time. Furthermore, because of the growing number of GIS applications in the private sector, retention of trained staff may be difficult.

Alexandria City, Arlington County, Fairfax County and WMATA all use GIS to display transit service patterns. Alexandria uses ArcView and MapInfo to maintain an inventory of routes and bus stops. Arlington County uses MapInfo to create maps of transit routes and bus stops and has recently begun the development of a TransCAD system from GIS route coverage provided by WMATA. Fairfax County is using ArcInfo and ArcView to develop transit route system coverages.

3.2.3 Passenger Flow Data

Many of the passenger attributes desired by NVTC, such as origin, destination and jurisdiction of residence, can most readily be assembled through a passenger intercept survey. While other options exist for some data elements (e.g., transfer analysis), we recommend that these be gathered by an on-board survey.

As mentioned earlier, WMATA performs on-board surveys for Metrobus and has done so for many years. While the current scope of the bus survey does not satisfy many of NVTC's requirements, the approved changes in service delivery responsibility and financing make it more likely that WMATA will change the attributes used to stratify service and expand the scope of its questions. NVTC should take an active role in opening the line of communication with WMATA to discuss this possibility. While the current thinking at WMATA is to include more questions which are useful for planning, it is unlikely that they will expand the scope of their survey to include service provided by other operators. NVTC should contract for contemporaneous surveys on non-WMATA services using a compatible design and survey instrument.

WMATA's past surveys have been designed to provide data necessary to allocate revenue based on a complex formula adopted by the WMATA compact jurisdictions. In order to gather these data in the most statistically reliable and economical way, WMATA uses data collected from passengers riding a stratified random sample of bus trips. The sampling strata are defined by the following attributes:

- dispatch garage,
- predominate jurisdiction served,
- fare zones served,
- time period operated,
- dedication code, and
- travel direction.

Since the main objective of the surveys is to estimate and allocate revenue, some of these attributes relate directly to WMATA revenue collection and fare policies. Garage is the primary unit for controlling farebox cash revenue. By using garage as a stratifying attribute, it is possible to use actual revenue collection data to validate and/or adjust survey data. Dedication code is a hierarchical numeric code that describes the primary area of operation and sponsorship, types of fares charged, and how collected revenues are allocated among the sponsoring jurisdictions.

The revenue-based nature of the WMATA surveys is evident in other aspects as well. The attribute data collected from passengers are sharply focused on information necessary to determine what type of fare was paid, how much cash the passenger put in the farebox and how the revenue derived from the trip should be allocated to the sponsors. Such fundamental planning information as trip origin and destination have never been collected. Occasionally, some demographic and trip purpose data have been collected. For the 1994 Metrobus on-board survey, data on trip purpose and auto availability were collected. Another different aspect of the WMATA surveys is the method of assessing precision for determining required sample size. WMATA uses a method that is based on variance of passenger boardings.

From the viewpoint of collecting data for transit evaluation and planning purposes, the nature of the questionnaire should be different and designed to capture data on passenger attributes and movements. Furthermore, the precision basis for establishing sample size should be based on the estimation of passenger attributes, not boardings.

While the stratified random sampling approach is recommended, the attributes used to stratify the service should be much simpler and classify service based on:

- transit company,
- route operated,
- time period operated, and
- direction of travel.

Exhibit 3-2 provides a sampling plan that satisfies this requirement. It shows the total number of sample bus trips needed to estimate passenger attributes within ±10 percent accuracy at the 68 percent confidence level. The statistical basis for Exhibit 3-2 is provided in section 3.3.2.2.

3.3 Suggested Data Collection Work Program Procedures

The recommended procedures for each of the supplemental data collection programs are described below.

3.3.1 Ridechecks

The recommended ridecheck procedures follow those outlined by FHWA for collection of NTD information. At each stop, the ridechecker simply counts and enters the number of Ons (boarding passengers) and Offs (alighting passengers). Between stops, a count or estimate of load is provided as a check mechanism. Arrival time and mileage data by stop can also be collected.

The recommended form for compiling ridecheck data is shown in Exhibit 3-3. This form provides pre-printed information for known stops, as well as providing space for writing in information about new/missing stops. During the course of this project, ridecheck forms for a large number of Northern Virginia bus routes were developed. The route/path/direction/stop level databases used to generate these forms have been provided to NVTC.

EXHIBIT 3-2
ON-BOARD SURVEY SAMPLING PLAN AT ±10% STRATUM ACCURACY

Summary of On-Board Survey Sampling Plans

Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Sample Trips (Strps) / Total Trips (Utrps) (Rate)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level =	68%
Route/Period Accuracy =	10%
Route/Daily Confidence Level =	90%
System Confidence Level =	95%

		Weekday						Saturday				Sunday				
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily	
Operator	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		Overall
MetroBus	Utrps	840	342	852	203	122	2359	467	424	95	986	240	237	46	523	3868
	Ubrds	21759	9193	21606	5027	3101	60686	12547	11437	2642	26626	6384	6381	1390	14155	101467
	Rrsps	2392	678	2313	890	508	6781	708	682	376	1766	449	444	222	1115	9662
	Strps	308	83	300	109	64	864	149	143	57	349	89	89	32	210	1423
	Rate	36.7%	24.3%	35.2%	53.7%	52.5%	36.6%	31.9%	33.7%	60.0%	35.4%	37.1%	37.6%	69.6%	40.2%	36.8%
	Ersps	3017	855	2919	1066	652	8509	780	768	368	1916	497	512	222	1231	11656
	Accuracy	1.7%	3.2%	1.7%	2.7%	3.4%	1.0%	3.4%	3.4%	4.7%	2.2%	4.2%	4.2%	6.0%	2.7%	
Connector	Utrps	350	171	360	87	15	983	124	121	2	247	38	38	0	76	1306
	Ubrds	8244	3060	8106	1723	439	21572	2895	2841	67	5803	1101	1101	0	2202	29577
	Rrsps	928	352	922	314	130	2646	236	235	28	499	91	91	0	182	3327
	Strps	141	70	146	52	11	420	60	60	2	122	18	18	0	36	578
	Rate	40.3%	40.9%	40.6%	59.8%	73.3%	42.7%	48.4%	49.6%	100.0%	49.4%	47.4%	47.4%		47.4%	44.3%
	Ersps	1094	424	1109	355	131	3113	255	255	17	527	116	116	0	232	3872
	Accuracy	2.8%	4.4%	2.7%	4.6%	7.2%	1.6%	5.9%	5.9%	20.7%	4.1%	8.6%	8.6%		6.1%	
DASH	Utrps	106	77	107	27	11	328	67	62	6	135	46	37	4	87	550
	Ubrds	3165	2007	3114	446	106	8838	2243	2528	65	4836	1206	1050	50	2306	15980
	Rrsps	135	124	139	83	34	515	93	92	35	220	87	86	17	190	925
	Strps	24	30	18	15	8	95	16	14	6	36	18	14	4	36	167
	Rate	22.6%	39.0%	16.8%	55.6%	72.7%	29.0%	23.9%	22.6%	100.0%	26.7%	39.1%	37.8%	100.0%	41.4%	30.4%
	Ersps	192	164	169	86	35	646	115	108	17	240	99	86	13	198	1084
	Accuracy	6.9%	7.3%	7.3%	9.5%	13.6%	3.7%	8.9%	9.2%	20.6%	6.2%	9.4%	10.1%	23.6%	6.7%	
CUE	Utrps	39	51	32	11	6	139	28	28	0	56	20	18	0	38	233
	Ubrds	1185	1004	869	180	49	3287	655	323	0	978	347	149	0	496	4761
	Rrsps	92	91	89	64	33	369	87	77	0	164	76	60	0	136	669
	Strps	10	15	12	11	6	54	17	27	0	44	18	18	0	36	134
	Rate	25.6%	29.4%	37.5%	100.0%	100.0%	38.8%	60.7%	96.4%		78.6%	90.0%	100.0%		94.7%	57.5%
	Ersps	102	103	114	63	18	400	94	78	0	172	74	38	0	112	684
	Accuracy	9.3%	9.2%	8.6%	10.0%	18.6%	4.6%	9.4%	9.7%		6.8%	10.1%	13.8%		8.2%	

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Route/Daily Confidence Level =	90%
System Confidence Level =	95%

		Weekday						Saturday				Sunday				
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily	
Operator	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		Overall
Loudoun	Utrps	9	0	9	0	0	18	0	0	0	0	0	0	0	0	18
	Ubrds	303	0	295	0	0	598	0	0	0	0	0	0	0	0	598
	Rrsps	82	0	59	0	0	141	0	0	0	0	0	0	0	0	141
	Strps	5	0	5	0	0	10	0	0	0	0	0	0	0	0	10
	Rate	55.6%		55.6%			55.6%									55.6%
	Ersps	95	0	98	0	0	193	0	0	0	0	0	0	0	0	193
	Accuracy	8.3%		8.1%			5.8%									
ART	Utrps	18	0	18	0	0	36	0	0	0	0	0	0	0	0	36
	Ubrds	211	0	199	0	0	410	0	0	0	0	0	0	0	0	410
	Rrsps	22	0	22	0	0	44	0	0	0	0	0	0	0	0	44
	Strps	5	0	5	0	0	10	0	0	0	0	0	0	0	0	10
	Rate	27.8%		27.8%			27.8%									27.8%
	Ersps	26	0	25	0	0	51	0	0	0	0	0	0	0	0	51
	Accuracy	9.2%		9.4%			10.8%									
All	Utrps	1362	641	1378	328	154	3863	686	635	103	1424	344	330	50	724	6011
	Ubrds	34867	15264	34189	7376	3695	95391	18340	17129	2774	38243	9038	8681	1440	19159	152793
	Rrsps	3651	1245	3544	1351	705	10496	1124	1086	439	2649	703	681	239	1623	14768
	Strps	493	198	486	187	89	1453	242	244	65	551	143	139	36	318	2322
	Rate	36.2%	30.9%	35.3%	57.0%	57.8%	37.6%	35.3%	38.4%	63.1%	38.7%	41.6%	42.1%	72.0%	43.9%	38.6%
	Ersps	4526	1546	4434	1570	836	12912	1244	1209	402	2855	786	752	235	1773	17540
	Accuracy	1.4%	2.4%	1.4%	2.2%	3.0%	0.8%	2.7%	2.7%	4.5%	1.8%	3.3%	3.4%	5.8%	2.2%	
All without Metrobus	Utrps	522	299	526	125	32	1504	219	211	8	438	104	93	4	201	2143
	Ubrds	13108	6071	12583	2349	594	34705	5793	5692	132	11617	2654	2300	50	5004	51326
	Rrsps	1259	567	1231	461	197	3715	416	404	63	883	254	237	17	508	5106
	Strps	185	115	186	78	25	589	93	101	8	202	54	50	4	108	899
	Rate	35.4%	38.5%	35.4%	62.4%	78.1%	39.2%	42.5%	47.9%	100.0%	46.1%	51.9%	53.8%	100.0%	53.7%	42.0%
	Ersps	1509	691	1515	504	184	4403	464	441	34	939	289	240	13	542	5884
	Accuracy	2.4%	3.5%	2.4%	3.9%	6.0%	1.4%	4.4%	4.5%	14.5%	3.1%	5.4%	6.0%	23.6%	4.0%	

Exhibit 3-3
Ridecheck Data Collection Form

Asmt: Trip: Trip begins at : M and ends at : M

Route: 5G WEST page 1 Block ________ Run ________

Date: ___ / ___ / 98 Day: __________ Veh # ______ Checker: ______________________ Editor: ________

Num	On Street	At Street	Comment	Time	Odometer	Board	Alight	On After
1	W FALLS CHURCH METRO (N)			:	.			
2	HUNTER MILL RD	SUNRISE PLAZA		:	.			
3	SUNRISE VALLEY DR	PARKRIDGE BLVD E		:	.			
4	SUNRISE VALLEY DR	ALEXANDER BELLE DR		:	.			
5	SUNRISE VALLEY DR	ROBERT FULTON DR		:	.			
6	SUNRISE VALLEY DR	XFROM BARTON HILL		:	.			
7	SUNRISE VALLEY DR	PRESTON WHITE LA		:	.			
8	SUNRISE VALLEY DR	LAKEPORT WAY		:	.			

3.3.2 On-Board Passenger Surveys

The procedures described are based on standard practice, and where appropriate, have been modified to follow procedures used in the conduct of previous Metrobus passenger surveys. Since NVTC plans to coordinate their on-board data collection project with WMATA's, it makes sense to follow similar procedures. Another resource NVTC may find useful is The Travel Survey Manual (Publication No. FHWA-PL-6-029). This manual, published as part of the Travel Model Improvement Program (TMIP), describes several types of transportation data collection methods, including on-board passenger surveys.

3.3.2.1 Survey Design

The survey design provides the technical and statistical bases of the study. Universe stratification, sample selection and projected accuracy of the results are three essential issues that should be addressed in the survey design. The accuracy requirements of the survey directly impact sample selection. The sample must be large enough to meet the required accuracy. The accuracy analysis which we completed indicates that a minimum of 1,453 weekday and 869 weekend trips should be included in the sample. This level of sampling will provide a rich (and affordable) database of origin-destination information.

The objective of universe stratification is to identify trips with similar characteristics and group them together. If carefully performed, stratification will reduce attribute variance within the group and improve precision. As previously indicated, we recommend using transit company, route, time period and direction for stratification purposes.

3.3.2.2 Sampling Plan

The number of sample responses required to achieve a stated degree of precision (accuracy and confidence level) is determined by the following equation.

$$\pm e = 100\sqrt{\frac{z^2 pq}{n}}\sqrt{\frac{N-n}{N-1}} \qquad (1)$$

where: e = the percent absolute accuracy
z = the normal deviate (z score) for the desired confidence level
$z = 1.96$ for 95% confidence
$z = 1.65$ for 90% confidence
$z = 1.00$ for 68% confidence
p = the estimated proportion of passengers having an attribute
$q = 1 - p$ = the estimated proportion of passengers not having that attribute
n = the number of samples used to estimate the proportion
N = the total population of passengers

The first square root term on the right of the = sign is the basic accuracy computation. The second square root term adjusts the basic accuracy for a small universe size (N) or relatively large sample size (n) and is called the universe size correction factor.

The maximum (worst) absolute accuracy is produced for proportions of .5 (50%) and, generally, accuracy is computed for this worst case. Higher and lower proportions will always have somewhat better absolute accuracy.

Because only a portion of patrons who are surveyed will respond, and because not all responses will be usable, the number of questionnaires distributed must be substantially larger than the necessary responses. Usable response rates (e.g., usable responses divided by cards distributed) for this type of survey typically range from 25 to 60 percent depending on the nature of the patrons. Passengers making regular work-related trips respond at a much higher rate than students and non-work patrons.

Appendices H through M shows our complete analysis of the distribution and accuracy required to satisfy the recommended route/time period precision of ±10 percent at the 68 percent confidence interval. Sampling at this rate will produce very satisfactory route and system level precision.

3.3.2.3 Survey Procedures

It is important that several items be developed prior to actual field data collection. Questionnaire design, response bias analysis, on-board data collection procedures, editing and geocoding procedures, and weighting and validation procedures are the primary ones which should be described.

Origin-destination, boarding-alighting, and transfer activity are three pieces of data NVTC is interested in. Market segmentation is also something that NVTC has indicated an interest in analyzing. The survey questionnaire is the primary method for obtaining this information and it should be designed to gather data to support these areas of interest. Respondents should be asked questions about where they came from before they boarded the bus, where they are going, where they got on and off the survey bus, their modes of access and egress, routes used for transfer purposes and home address (or jurisdiction of residence). Other questions that provide useful information are trip purpose and frequency of ridership. General demographic information can be useful for marketing purposes. Questions about a person's age, gender, income and ethnicity are usually included in an on-board questionnaire.

Passengers cannot be forced to complete the survey questionnaire. However, methods can be employed to improve the likelihood of respondent cooperation. One method is the use of a bilingual form. Based on our recent experience conducting the origin-destination survey for Arlington County, a bilingual form would likely have improved response rates on several routes. Also, the use of a postage-paid mail-back option should be explored. Generally, mail back responses are not significant, but do provide another mechanism to encourage completion.

It is also important to determine if additional information needs to be collected using methods other than the questionnaire. For example, having the surveyor count passengers by ethnicity provides two pieces of important information. First, it serves as a control mechanism useful in the weighting and validation process. Counting by ethnicity also provides a means for adjusting for response bias. Other variables can be used for control purposes, such as fare type or gender. Simply tallying passengers by some type of geographical stratification can also provide useful information. For example, boarding passengers can be counted at each individual stop, or by neighborhood segment (suburb vs. inner city).

Control counts of some type are used to expand responding passengers to represent all passengers by sample trip within each assignment. The control counts taken by the surveyors should be recorded on some sort of log which is trip specific. The log should be designed so that tallies can be recorded separately based on the control variable (i.e.,. by stop). The control log should also be used to record other valuable information, such as what questionnaire was handed out at each segment break, bus arrival time by segment break, and any other pertinent information.

On-board survey equipment can also improve response rate. Providing passengers with pencils at the same time the card is given is one method. Having survey return boxes on the bus is another incentive. The role of the bus driver in this process should not be overlooked. Gaining the cooperation of the driver can mean the difference between success and failure.

Data editing, entry and geocoding procedures must be developed early in the process, and before field data collection. Data editing and entry should be conducted simultaneously with the field work. Otherwise, you have no easy means of identifying which trips have failed. Also, this is one way of identifying those surveyors in need of remedial training. Criteria should be established for determining if a trip passes or fails and setting a threshold for the minimum usable response rate. The definition of what constitutes a usable response should also be defined in the editing procedures. Given the goals for NVTC's data collection project, complete origin-destination, and boarding/alighting information should be required, at a minimum.

Since address information is being geocoded, procedures must be developed for how to edit address data. Standardizing address formats is important for ease in automated geocoding. Part of the geocoding process should involve travel pattern validation. It makes no sense to have travel patterns that are not valid in the dataset. When transfer activity is indicated, it should be verified that the transfer activity is possible. Manual geocoding procedures must also be documented. Manual geocoding procedures are more driven by the software being used than anything else. It is important to understand the capabilities of geocoding software prior to beginning. A lot of time and money can be saved if data are entered in the format compatible with the software.

Validation of survey data is essential to the delivery of accurate, reliable results. Frequent, unscheduled interaction between surveyors an field supervisors maximizes the chances that the data being collected are accurate. Also, requesting that the surveyor record a unique piece of information, such as driver name, helps to ensure the surveyor will be on the bus. Such information provides the ability for independent verification. When considering validation techniques, it is important to remember to control for refusals. Keeping track of refusals by not re-issuing the declined card is one easy way to accomplish this. As trips are edited, known trip characteristics (e.g., departure time, points served) should be compared to the information collected by the surveyor. Discrepancies should be resolved between the editor and surveyor before the trip is accepted. The editors should also spot check responses for similar handwriting styles in order to identify fabricated work.

Knowing how the data are to be weighted is critical and should be addressed before fielding the survey. If these decisions are not made prior to data collection, it is not likely you will have the necessary information to perform this important step.

3.3.2.4 Survey Administration

There are several tasks which must be accomplished prior to commencing with the field work. These include training (and hiring, if necessary) survey personnel. There are several jobs to fill. A sufficient number of supervisors, surveyors and editors must be trained.

There is a direct correlation between a good response rate and properly trained surveyors. Surveyors need to understand their role in the process. They need to understand the importance of getting the passenger to take the questionnaire, and then encouraging the passenger to complete it while on the bus.

Surveyor training is critical to the success of any data collection effort. Training for an on-board passenger survey must address several items. Surveyors needs to the understand basic rules about being on time, dressing appropriately, and exhibiting the proper demeanor. If temporary personnel are being used, the issue of getting paid is also important. Surveyors need to understand what constitutes a successful survey and how they will be compensated for performing their job correctly.

Surveyors must be trained on their duties and the importance of carrying them out in the manner in which they are trained. Surveyors need to understand the importance of their role in the successful performance of the data collection phase. A step by step guide should be developed, and accompany the surveyor on each assignment. Included in the manual are such things as when and where to report for the assignment, understanding transfer directions, how to tally passengers, how to approach passengers with the card, how to encourage passengers to complete the form while on the bus, what to do with refusals, and what pieces of equipment they will use in conducting the survey.

A critical component of training is performed on-board the bus. Classroom training is conducted, which describes their duties and responsibilities. Then, the trainers, supervisors and surveyors ride selected buses to demonstrate they understand the mechanics of the job. On-board training also helps to identify those people who might need additional training or closer supervision during the initial days of the survey. It is important that supervisors be trained as well, since they may be required to conduct a survey. Supervisors also need to understand what is expected of the surveyors since they will be spot-checking them. Another important aspect of training is re-training. Those surveyors whose work is deficient should be identified and re-trained immediately.

The project manager has overall responsibility for ensuring that the data collection is completed on time. The field operations manager has responsibility for assembling, dispatching and processing survey materials and assignments. Field supervisors are responsible for getting the work to their survey crew, spot checking their surveyors to make sure they are doing the work and doing it correctly, returning the completed work to the survey office, and picking work for their crew. The role of the editor is to check a surveyor's work for completeness. Editors are also responsible for analyzing the work for accuracy and correcting it where necessary. Depending on the size of the survey, editors can also be used for geocoding addresses. Since the editor reviews the cards before they go to data entry, it makes sense to have the editor involved with the geocoding.

Survey equipment and supplies (clipboards, pencils, maps for geocoding, etc.) must be ordered or purchased in advance of the field work. The survey instrument must be designed and printed. If the form is bilingual, it must be translated prior to printing. We recommend that the questionnaire be serially numbered. This is critical for validation and tracking purposes. If using special equipment on-board the bus, such as survey return boxes and pencil boxes, they must also be ordered in advance. Some of these items may be special order and require several weeks to produce.

Keeping track of all aspects of the field data collection effort is essential to a successful project. Mechanisms must be in place for scheduling the work, assigning it to surveyors, returning the completed work to the survey office in a timely manner, and tracking it throughout the process. We recommend, that to the maximum extent possible, automated field tracking mechanisms be used. These mechanisms should be designed to keep track of each sample trip from the time it is selected through every stage of the project.

3.3.2.5 Data Coding and Entry

Typical data editing tasks include reviewing control logs and responses for accuracy and completeness. Control logs should be examined to determine that the surveyor properly tallied passengers when compared to the number of cards handed out. Once control logs are edited, the information should be keyed. Response editing has several components. First, using the control log, the cards returned should be reviewed to make sure they were handed out in the order the surveyor indicated. If not, the editor must try to reconstruct the correct sequence based on the origin-destination and boarding-alighting information provided. Questionnaires should be reviewed for completeness, as well as correctness. For example, if a person says the mode of access is another bus, the route information should be provided. If is not, the editor should determine the most appropriate choice. Many times respondents report round trip information as opposed to one-way travel. Editors are responsible for reconciling these cases. Finally, usable responses should be separated from unusable responses for data entry purposes.

Responses deemed suitable for data entry should be keyed and 100 percent verified by skilled data entry personnel. A decision must be made whether to have the address information 100 percent verified, as this can significantly add to the cost of data entry. After both the logs and cards are keyed, a process should be developed that performs various logic checks on both components. Responses should also be edited with software that performs various inter-field edit checks.

As previously mentioned, geocoding is an important part of any travel survey. Travel patterns should be validated to ensure they make sense. This can be a costly endeavor, depending on the number of responses received. Therefore, it may be desirable to perform travel pattern validation on a sample of the data. Based on the accuracy of the results, it is possible to develop a system of random pattern validation.

3.3.2.6 Data Weighting and Validation

Since the sampling plan does not employ a constant sampling rate by stratum, the sample data should be weighted. This will permit meaningful aggregate analysis.

Typically, two separate weights are computed and combined. The first of these called the trip weight is computed at the stratum level as the total number of trips operated divided by the total number of trips surveyed. The second weight called the response weight is computed at the surveyed trip level as the total number of boarding passengers divided by the total number of responding passengers. In this regard, we recommend enumeration of passenger boarding by some characteristic that is a surrogate measure of economic class and trip type. Method of fare payment has been used frequently for this purpose. If boardings are enumerated by type, then the response weight should be computed separately for each type. The final weight is the trip weight times the response weight.

After weighting, the responses should be aggregated to produce estimates of some attributes that are known from other sources. For example, comparing estimated total boarding from the survey to counted boarding from registering farebox reports. In this regard, WMATA uses estimated versus actual revenue by garage.

Major differences in the survey estimates and control measures should be investigated and explained. If all attempts at explanation fail, an adjustment to the final survey weight should be implemented.

3.3.2.7 Data Storage, Management & Retrieval Systems

How the data are stored can have a significant effect on how useful the data are. Several databases can be maintained, which are related to one another based on a few common keys (such as assignment, trip number, and serial number). Demographic data can be maintained separately so quick analyses are possible. The address information can be maintained in a GIS, with layers representing various survey data. How the data are maintained is also a function of who is responsible for maintaining it. If the data are going to be turned over to the various transit properties, ease of storage and retrieval should be a consideration. It is important to maintain documentation regarding the contents and layout of the various data sets.

3.3.2.8 Documentation and Reports

Preparation of tabular results is an important task in the project. Frequency distributions should be prepared for all primary response variables. Cross tabulations of those variables that address the objectives of the project should be developed. All tabulations should be prepared using weighted data. It is possible to develop "canned" reports, as well as respond to individual requests for information. Users of the data should be polled to better understand their report requirements before developing standard reports.

Project reporting and documentation is another aspect that should not be ignored. While the survey is in the field, weekly status reports should be provided detailing how many samples have been surveyed, are yet to be scheduled, have been completed and passed the edit process.

A final report should be produced, which contains a discussion of the relevant components of the survey, including survey design, sample selection, procedures, questionnaire design, and weighting and validation procedures. A section should also be devoted to analysis of the results.

3.4 Data Collection Program Costs

Since several alternative data collection programs have been described in this report, it is not possible to compute a single overall cost for the final program. Several factors contribute to the various data collection costs and different types of data collection programs have different unit costs. On a per trip basis, ride checks are less expensive to complete than onboard surveys and there are economies of scale that come into play with both types of surveys. Also the unit prices vary depending on accounting methods (internal staff versus contractors) and individual firms' staffing and pricing structure.

Ride checks including sample selection, scheduling, data collection, entry and tabulation performed by consultants will generally cost between $50 and $75 per trip. The lower price applies to projects that are larger and compressed in time. For example, a program to perform ridechecks on all 2,100 Connector, DASH and CUE trips within a calendar quarter (season) should cost $100,000 to $110,000. Collecting data on the same number of trips using a uniform weekly program spread over three years should cost $150,000 to $175,000.

Estimating costs for an on-board survey is more difficult. Several issues affect the per trip cost. These include the expense of developing survey instruments (e.g., bilingual form), the size of the sample, the number of addresses to be geocoded, the level of geocoding (i.e., x/y coordinate versus Census block), and whether the survey distribution is performed by a dedicated surveyor or the operator. At first glance, operator administered surveys would appear to be less costly. However, a crew is still needed to deliver and pick up each survey from every bus. This must be done on the same day. If on-board equipment is to be used, the crew must also install and remove the equipment. Finally, no effective mechanism exists to collect control information in more detail than trip or block. If these controls are necessary for weighting, validation or quality control, staff may need to be on the bus to collect this information. Overall, the unit cost for surveyor administered on-board surveys is estimated at between \$125 - \$175 per trip. Based on 1998 service levels, an on-board survey of Northern Virginia bus systems might cost between approximately \$115,000 - \$160,000. Exhibit 3-4 summarizes the recommended data collection levels and associated costs.

Exhibit 3-4
Recommended Data Collection Levels and Associated Costs

		NTD Reporting (Trips)		Planning Data		
				Ride Checks		On-Board Survey
		w/Farebox	wo/Farebox	Trips		Trips
DASH		38	38	550		167
ART		24	24	36		10
CUE		20	156	233		134
LCS		20	20	18		10
Connector		156	156	1,306		578
Total Trips		258	394	2,143		899
Contract Cost Range	Low	NA	NA	$110,000	(note 1)	$115,000
	High	$20,000	$30,000	$160,000	(note 2)	$160,000

Note 1: Applicable to the entire program completed in one season (2-4 months)

Note 2: Applicable to a three year cycle with 1/3 of the trips ridden each year (about 60 trips/month). The annual cost of this program should be about $55,000. The program can be designed to accomplish most NTD trips as well.

APPENDIX A

ALEXANDRIA DASH

NTD SAMPLING PLAN AND STATISTICAL ACCURACY

Appendix A

Statistical Analysis of Passenger-Miles Estimate and Sampling Plan

Alexandria Transit Company DASH

Prepared for George Hoyt & Associates, Inc.
by
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January 2, 1998

Alexandria Transit Company operates several routes as part of its DASH fixed route service in and around Alexandria, Virginia. Counts are routinely made of all boarding passengers. Therefore, passenger-miles can be estimated by means of the ratio of passenger-miles to boardings, known as average (unlinked passenger) trip length. The basic sampling unit will be a round trip, on which ride checks (on/off counts by stop) are conducted, and from which boardings and passenger-miles on the sampled trips are measured.

Route Stratification
The DASH routes are doubly stratified as follows:

Routes with Long Average Trip Length

Route 2
Routes 3 and 4
Routes 5/7
Route 8

Routes with Short Average Trip Length

Route 6

Routes 3 and 4 are similar routes, for the most part parallel, and are combined into a single loop operation on weekends and evenings. Therefore they are treated together as one stratum. When the routes are combined (evenings and weekends), a round trip in this stratum is a loop. At other times, a round trip in this stratum is a round trip on either Route 3 or Route 4.

Route 7 is a short route that is basically an extension of Route 5, operated by the same bus in such a manner that through passengers do not have to transfer between vehicles. Therefore Route 5/7 is considered a single route. A round trip in this stratum is a trip leaving downtown Alexandria on Route 5, continuing as Route 7, and then returning. In the midday, there is a route variation to the 5/7 combination, but the basic definition of a round trip is still valid.

Appendix A

Sampling Plan

The sampling plan involves selecting round trips from each stratum, measuring boardings and passenger-miles on each by means of ride checks. The sample sizes for FY98 and for future years are as follow:

Sample Size (Round Trips)

Route	FY 98	Future years
2	8	8
3 / 4	16	8
5/7	8	8
8	8	8
6	4	6

Because of the small sample sizes within each stratum, a further informal level of stratification is used to select the sample within each stratum so the sample gives proportional coverage to the entire day and to the weekends. To make the checking schedule efficient, trips can be selected in the following way.

1. Select at random one trip from the a.m. peak schedule. Build around that trip, in any convenient manner, a chain of two round trips to check.
2. Do the same for the p.m. peak.
3. For the midday, either follow the same procedure as for the a.m. peak, or expand one of the peak hour chains into the midday by adding two midday round trips.
4. The final trips should be scheduled for Saturday, Sunday, or weekday evening (except for Route 6, which does not operate in the evening or on weekends). By lot, select two strata to be checked on weekday evening, one on Saturday, and one on Sunday. For example, Routes 2 and 3/4 might be selected for weekday evening, Route 8 for Saturday, and Route 5/7 for Sunday. For each stratum / period thus selected, choose a trip from the schedule for the corresponding period at random, and build a chain of two round trips about it.
5. For stratum 3/4, each chain should consist of one Route 3 round trip and one Route 4 round trip, except on evenings and weekends when the routes are combined. For stratum 5/7, each round trip should cover both routes.

The procedure described here will result in 15 to 19 chains of trips of 2 to 4 trips. The trip chains should be spread over the year in one of the following manners (either is valid):

a. Wide distribution, doing one chain every 3rd week. For weekday checks, the check on the first sampling week can be on a Monday, the next sampling week on Tuesday, etc.
b. Concentrated by quarter: each quarter, select a week at random, and do one quarter of the checks that week.

Whether a concentrated or distributed plan is used, the sequencing of the sample (e.g., which route to do first, or whether to do a.m. before p.m.) can be chosen arbitrarily.

Estimation Method
Estimating passenger-miles is done using one procedure for Route 6 (simple ratio estimation), and a slightly different procedure for the other routes known as "combined ratio method" (W.G. Cochran, *Sampling Techniques*, Wiley, 1977, section 6.11), which is an application of stratified sampling.

For Route 6:
1. For the sampled trips, find the mean passenger-miles and mean boardings per trip.
2. Divide mean passenger-miles by mean boardings to get average trip length.
3. Expand average trip length by total annual boardings.

For the Other Strata:
1. For each stratum, find the mean passenger-miles per trip from the sample. Expand it by the number of trips operated per week to get an estimate of weekly passenger-miles by stratum.
2. Aggregate weekly passenger-miles over the four "long average trip length" strata to get an estimate of weekly passenger-miles for those strata combined.
3. Repeat Steps 1 and 2 for boardings, obtaining first an estimate (from the same sample) of weekly boardings by stratum, and then one of weekly boardings for the four strata combined.
4. Take the ratio of the weekly combined estimates (passenger-miles divided by weekly boardings) to get average trip length for the four "long average trip length" strata combined.
5. Expand average trip length by total annual boardings on all the routes in the four included strata.

Summing the Route 6 Estimate with the Estimate for the Other Strata
Simply sum the Route 6 annual passenger-miles estimate with the annual estimate for the other set of strata to obtain the system annual passenger-miles estimate.

Average Trip Length Estimates for FY 1998
Calculations to estimate the needed average trip length ratios for FY98 are shown in the attached table, part a. The sample in FY98 was more concentrated than will be done in future years because of the need to get the data in time to plan for future years. The FY98 estimate is found by simply expanding the ATL ratio for Route 6 (1.095 mi.) by the annual boardings on Route 6, and the ATL ratio for the remaining routes (3.167 mi.) by the annual boardings on those routes, and then aggregating the two results.

Statistical Analysis Of The Accuracy Of The Passenger-Mile Estimates
A statistical analysis of the FY98 data was done to determine the level of accuracy expected from the sampling plan. Summary calculations are given in the attached table, parts a (for the FY98 sample) and b (for the sample in future years). For each stratum, the key statistical parameter is its unit (i.e., per round trip) variance of

passenger-miles based on the ratio estimator. This unit variance is calculated as follows. For each stratum, a deviation is calculated for each trip in the sample between observed and expected passenger-miles, where expected passenger-miles, based on the ratio estimator, is the product of observed boardings and the "appropriate" average trip length ratio. For each stratum, the unit variance is simply the within-stratum sample variance of those deviations (estimated using n-1 in the denominator, as usual). For Route 6, the appropriate average trip length ratio (used to calculate deviations) is Route 6's average trip length. For the other strata, the combined ratio (determined as described in the previous paragraph) is the appropriate average trip length ratio. The variance of the estimate is then found by combining the unit variance of the several strata following standard formulas for stratified sampling which account for the relative size of the stratum and the sample size within the stratum.

The standard error the estimate is the square root of its variance. The relative standard error or coefficient of variation (cv) of the estimate is the standard error divided by the mean of the estimate (i.e., mean passenger-miles per round trip). The precision of the estimate is the cv by multiplied by the t-ordinate for the desired confidence level; for the 95 percent confidence level, a t-value of 2 is used.

Based on this analysis, the precision of the FY98 estimate of passenger-miles, at the 95 percent confidence level, is ±4.3%. The precision of the estimate of passenger-miles following the sampling plan for future years, at the 95 percent confidence level, is ±4.5%. Therefore this sampling plan, both for FY98 and for future years, satisfies the FTA requirement for the National Transit Database that estimates of annual passenger-miles have a precision of ±10% or better at the 95 percent confidence level.

Validity Of The Sampling Plan With Respect To Schedule And Route Changes
While the analysis of the accuracy of the sampling plan was done based on data and schedules in FY98, it remains valid for route and schedule changes, as follows:

a. Schedule changes will not invalidate the plan. If a route's service is discontinued in a period (e.g., on weekends), the sample should simply be reallocated to other periods, keeping the sample size unchanged. However, if Routes 5 and 7 are uncoupled so that passengers must transfer from one route to the other, the stratum Route 5/7 should simply be divided into two strata, and 8 round trips sampled on each route.
b. Routing changes will not invalidate the plan.
c. Deletion of up to two routes will not invalidate the plan. The deleted routes are simply omitted from the sample. The precision will worsen, but will still be well within the ±10% level stipulated.
d. If new routes are added, they should simply be treated as new strata and added to the sampling plan with 8 round trips per route (6 if there is no weekend operation). Short new routes, like Route 6, should be added to the group that now consists of Route 6 alone, and this group should then be analyzed the same way as the other group (i.e., with a combined ratio estimate). Longer new routes should be added to the existing group of four strata. The addition of new routes, and with them new

samples, will improve the accuracy of the final estimate. This sampling plan will remain valid unless the new routes are responsible for 25% or more of the system boardings, in which case the sampling plan should be reevaluated.

Appendix A

Alexandria Transit "DASH" Service

Table A: Passenger-Miles Statistical Analysis, FY 98

Route	Scheduled Round Trips Wkd	Sat	Sun	Week	Relative Size	Sample n	Mean Brd	Mean Pmi	Ratio	Unit Variance	V(est)
2	28	16	10	166	19.4%	8	86.0	298.0		1238	5.85
3/4	57	14	10	309	36.2%	16	19.6	54.8		149	1.22
5/7	34	27	12	209	24.5%	8	67.1	208.3		636	4.76
8	27	18	17	170	19.9%	8	75.5	232.7		571	2.83
Week total				854	100.0%	40	47204	149477	**3.167**		14.65
All but 6				854	89.5%			175.0			11.74
6	20	0	0	100	10.5%	4	8.0	8.8	**1.095**	2.2	0.01
Overall				954	100.0%	44		157.6			11.75
cv											0.0217
Tolerance @ 95 percent confidence											**4.3%**

Table B: Sampling Plan Analysis

Route	Scheduled Round Trips Wkd	Sat	Sun	Week	Relative Size	Sample n	Pmi	Unit Variance	V(est)
2	28	16	10	166	19.4%	8		1238	5.85
3/4	57	14	10	309	36.2%	8		149	2.43
5/7	34	27	12	209	24.5%	8		636	4.76
8	27	18	17	170	19.9%	8		571	2.83
Week total				854	100.0%	32			15.87
All but 6				854	89.5%				12.72
6	20	0	0	100	10.5%	6		2.2	0.00
Overall				954	100.0%	38	157.6		12.72
cv									0.0226
Tolerance @ 95 percent confidence									**4.5%**

APPENDIX B

ARLINGTON TRANSIT

NTD SAMPLING PLAN AND STATISTICAL ACCURACY

Appendix B

Statistical Analysis of Sampling Plan for Estimating Passenger-Miles

Arlington Transit, Arlington County, VA

Prepared for George Hoyt & Associates, Inc.
by
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January 2, 1998

The Arlington Transit operates peak period service along one fixed route in Crystal City, a section of Arlington County, Virginia. The route, a 20 minute loop, is operated approximately every 10 minutes for a 3-hr period each morning and evening. It serves primarily as a distribution / collection service connecting workers in Crystal City with rail stations and hotels. Counts are routinely made of all boarding passengers. Therefore, passenger-miles can be estimated by means of the ratio of passenger-miles to boardings, known as average (unlinked passenger) trip length. The sampling unit is a trip, on which ride checks (on/off counts) are conducted, and from which boardings and passenger-miles on the sampled trips are measured.

Sampling and Estimation Plan

The sampling plan is to do one chain of ride checks each quarter. Each chain of ride checks lasts three hours, covering either the a.m. or the p.m. service period. The checker simply stays with a bus, doing a ride check on each trip operated. Part way through the 3-hour period, the checker can take a short break and switch buses. It is expected that such a chain of ride checks will provide data from at least 6 trips (more likely 7 or 8).

The checks should be done one day each quarter. Each should be on a different day of the week. A coin toss determines whether the check for a given quarter will be conducted in the a.m. or the p.m., subject to the requirement that two of the checks be in the a.m. and two in the p.m. Thus, for example, if the first two quarters were both checked in the a.m., the last two must be done in the p.m.

The estimation method used is simple ratio estimation. From the annual ride check sample, average trip length is estimated by first finding average passenger-miles per trip for the sample, and likewise average boardings per trip from the same sample, and then taking their ratio. Average trip length is then expanded by annual boardings to yield the estimate of annual passenger-miles.

Appendix B

Statistical Analysis Of The Sampling Plan
A statistical analysis was done to determine the level of accuracy expected from the sampling plan. The analysis is based on data from 30 trips collected in four ride check chains in Fall, 1997. The following parameters were estimated:

	pass-mi	boardings	
mean	9.75	11.40	
coef of variation (cv)	0.88	0.80	
correlation coefficient			0.99
ratio (avg trip length)			0.86
ratio unit cv			0.14
expected sample size			24
precision @ 95 percent confidence level			5.8%

The data show a very strong correlation (99%) between boardings and passenger-miles, with the result that only a small sample is needed to accurately estimate the ratio. With a sample size of 24 trips, the resulting precision of the annual passenger-miles estimate at the 95 percent confidence level is ±5.8%. Therefore this sampling plan satisfies the FTA requirement for the National Transit Database that estimates of annual passenger-miles have a precision of ±10% or better at the 95 percent confidence level. Naturally, if the sample has more than 24 trips (because trip chains may include more than 6 trips each), the precision will be still better.

Validity Of The Sampling Plan With Respect To Schedule And Route Changes
While the analysis of the accuracy of the sampling plan was done based on data and schedules in FY 98, it remains valid for route and schedule changes, as follows:

a. Changes to routing do not invalidate the plan, because there is only one route.
b. If service hours are extended, the plan remains valid as long as the sampling chains are extended correspondingly. If service hours are shortened, the plan remains valid as long as the annual sample size is at least 20 trips.

Application in FY 1998
For FY98, sampling did not begin until December, when intensive sampling was done in order to develop the sampling plan. Therefore, the summer sample is replaced with an additional fall sample. This is not expected to worsen the precision of the estimate significantly, as the correlation between boardings and passenger-miles is so high that there is little room for the summer quarter average trip length to vary much from the other quarters. The sample for FY98 will therefore consist of the following four ride check chains:

- December 4, 1997, a.m.
- December 5, 1997, a.m.
- Winter quarter, 1998, p.m. (date yet to be determined)
- Spring quarter, 1998, p.m. (date yet to be determined)

Appendix B

(On both December 4 and 5, data was collected in the p.m. as well as in the a.m. for the purpose of developing the sampling plan. Only one period is needed for the estimate, however, and it was selected by a coin toss. The p.m. data on those dates is therefore neglected in calculating the FY98 estimate.)

Because the FY98 estimate is essentially based on the sampling plan described in this report, it satisfies the FTA requirement for the National Transit Database that estimates of annual passenger-miles have a precision of ±10% or better at the 95 percent confidence level.

APPENDIX C

FAIRFAX CUE

NTD SAMPLING PLANS AND STATISTICAL ACCURACY

With and Without Registering Fareboxes

Appendix C

Statistical Analysis of Sampling Plan for Estimating Passenger-Miles

Fairfax CUE, Fairfax, VA

Prepared for George Hoyt & Associates, Inc.
by
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January 5, 1998

The City of Fairfax, Virginia operates fixed route service known as Fairfax CUE. The route structure consists of two loops, each of which is operated in both directions, yielding effectively four routes. Service is offered for most of the day, seven days a week. All routes share two common termini: the Vienna Metrorail Station, and the George Mason University campus. The routes' primary markets are feeder service to and from Metrorail, service to and from GMU, and general circulation within the City of Fairfax. The GMU market is expected to have strong variability in connection with the school calendar.

Existing passenger-counting activities consist of boarding counts, made on one fall and one spring week each year, plus counts of passengers in special fare categories on three other weeks. Other than that, no routine passenger counts are made. Because of the strong week to week variability in demand expected in connection with the GMU calendar, it is important that there be a primary source of counts conducted at least once a week.

Sampling Plan
The sampling plan is to do ride checks (on / off counts by stop, from which boardings and passenger-miles on the sampled trips are measured) on one chain of three trips each week. A chain of three trips means three trips operated consecutively by the same vehicle, or any similar convenient grouping of three trips. For 46 weeks, the counts are made on weekdays. In the remaining six weeks, there will be 3 Saturday checks, 2 Sunday checks, and one additional check on either Saturday or Sunday. The expected number of Saturday and Sunday checks are therefore 3.5 and 2.5 respectively. This distribution results in a sample that represents the three different day types in proportion to the number of trips in the weekly schedule.

Choosing the Survey Day for a Given Week
First, flip a coin to determine whether the undetermined weekend check should be done on a Saturday or a Sunday.

Appendix C

In a hat (literal or figurative) put 52 slips of paper. Label the slips as follows:

9 labeled "Monday"
9 labeled "Tuesday"
10 labeled "Wednesday"
9 labeled "Thursday"
9 labeled "Friday"
3 labeled "Saturday"
2 labeled "Sunday"
1 more labeled either "Saturday" or "Sunday" depending on the outcome of the coin toss.

For each week in the year, draw a slip at random. (Do not replace slips in the hat once they've been drawn.) That determines the day of that week on which to conduct a count. If the selected day is a major holiday (one with no service or a Saturday schedule), replace the slip and draw again. Do not redraw for minor holidays (those with a modified weekday schedule), unless another minor holiday has already been drawn, in which case replace the slip and draw again.

Selecting the Trips
Two different methods of selecting trip chains may be used. Either method is valid; however, the same method should be used for the entire year.

a. *Memoryless Selection.* The first method is to simply draw a trip at random from the daily schedule. The sample for that week will then consist of the selected trip, plus the trip preceding it and the trip following it. (If the trip is the very first or last trip of the day, take the two trips following or preceding it.) This method must be used for Saturday and Sunday samples, and it may be used for weekday samples as well. This method will result in 46 x 3 = 138 weekday trips, plus 18 weekend trips.

b. *Cover the Daily Schedule.* The second method, which may be used for weekday samples, is designed to cover every trip in the weekday schedule once a year, which will result in essentially the same weekday sample size because the weekday schedule has 139 trips. The weekday schedule should be divided into convenient chains of three trips (it is admissible for a few chains to consist of 2 or 4 trips if that is more convenient). Then each week for which the count day is a weekday, draw a chain at random from among the chains not yet selected; that will be the sample for that week. If the day selected for that week is a modified weekday schedule, and the trips in the selected chain are not operated on that day, draw a different chain.

Estimation Method
The estimation method used is simple expansion of the mean, with *ex post facto* stratification. Analysis of available data indicate that the only substantial systematic difference in passenger-miles per trip is between peak and off-peak periods. Therefore, when the data are analyzed at the end of the year, it should be sorted into two strata: peak and off-peak (weekends should be included in off-peak). Any reasonable

definition of peak period boundaries may be used. For example, an acceptable definition would include trips beginning between 6:30 and 9:29 a.m. and between 4:00 and 6:30 p.m. However, if another set of boundaries is customarily used or is preferred for any other reason, it will serve equally well.

After sorting the data, find the average passenger-miles per trip for peak and off-peak periods. In addition, determine the number of trips operated per year in the two strata. Expand each stratum's sample mean by the number of annually operated trips in that stratum. Then sum the products to yield the annual estimate of passenger-miles.

Notice that with *ex post facto* stratification there is no need to consider time of day stratification when selecting the sample. There is no problem, for example, with a trip chain that includes both peak and off-peak trips.

The identical procedure can be used to estimate annual boardings, expanding mean boardings per trip from the sample in the two strata and then summing the expanded products.

Statistical Analysis Of The Sampling Plan

Passenger-Miles

A statistical analysis was done to determine the level of accuracy in the annual passenger-miles estimate obtained following the sampling plan. The analysis is based on data from 32 trips collected in Fall, 1997, including a representative share of trips from all seven days of the week. Results and calculations are summarized in the following table:

Accuracy of Annual Passenger-Miles Estimate

	relative	passenger-mi		sample	effective	contribution to	
stratum	size	mean	std dev	size (n)	n	mean	variance
peak	0.29	105.01	23.35	45	30	30.61	1.53
off-peak	0.71	70.18	19.01	111	74	49.72	2.46
overall				156	104	80.33	3.99
modified estimate of variance							8.00
relative standard error (cv)							0.035
precision @ 95 percent confidence level							7.0%

In doing the analysis, the peak period boundaries used were 6:30 - 9:29 a.m. and 4:00 to 6:30 p.m., inclusive. (As stated earlier, when this sampling and estimation method is applied, any other reasonable boundaries may be equally well applied.) The mean and standard deviation of passenger-miles (per trip) was calculated from sample data. The effective sample size is determined based on the following assumptions:

Due to the cluster effect of trip chaining, the three trips sampled in each chain are as effective as two randomly sampled trips (design effect = 1.5).

With *ex post facto* stratification, the allocation of the sample between strata will be proportional to stratum size.

The variance of the estimate, found using standard formulas for stratified sampling, is estimated to be 3.99, However, there is reason to expect that there will be more variability in the data than exists in the analysis dataset, because the analysis dataset was concentrated over a period in which George Mason University was in session the entire time. A conservative estimate of the variance of the estimate accounting for variation expected due to seasonal and university-related fluctuations is double the value found in the data, or 8. This leads to a relative standard error (or coefficient of variation) of the estimate of 0.035. The precision of the annual passenger-miles estimate at the 95 percent confidence level is therefore ±7.0%. Therefore this sampling plan satisfies the FTA requirement for the National Transit Database that estimates of annual passenger-miles have a precision of ±10% or better at the 95 percent confidence level.

Boardings
A similar statistical analysis of the boardings data was done, and summarized in the following table:

Accuracy of Annual Boardings Estimate

	relative	boardings		sample	effective	contribution to	
stratum	size	mean	std dev	size (n)	n	mean	variance
peak	0.29	30.45	6.62	45	30	8.88	0.12
off-peak	0.71	20.86	7.13	111	74	14.78	0.35
overall				156	104	23.65	0.47
modified estimate of variance							0.94
relative standard error (cv)							0.041
precision @ 95 percent confidence level							8.2%

As the table indicates, the precision of the annual boardings estimate from this sampling plan, at the 95 percent confidence level, is ±8.2%, satisfying the FTA requirement for the National Transit Database that estimates of annual boardings have a precision of ±10% or better at the 95 percent confidence level.

Validity Of The Sampling Plan With Respect To Schedule And Route Changes
While the analysis of the accuracy of the sampling plan was done based on data and schedules in FY 98, it remains valid if there are routing and schedule changes, provided the sample size indicated is met. For example, if service expands to later hours, there is no need to increase the sample sizes; and if service decreases, the sample should not be decreased from the indicated sample size of 3 trips per week. However, if new routes are added to the system whose service hours represent 25% or more of the weekly schedule, a reevaluation should be done.

Appendix C

An Alternative Sampling Plan Based On Average Trip Length

If Fairfax CUE changes its operating procedures such that boardings are counted on every trip, it would then be possible to estimate annual passenger-miles by means of a ratio estimate (the ratio of passenger-miles to boardings, also known as average (passenger) trip length). The similar length of the four routes leads to a strong correlation between boardings and passenger-miles, such that a small sample of ride checks is needed to estimate the average trip length. An efficient but adequate sampling plan would be to do ride checks once a quarter on four three-trip chains, resulting in 16 chains and 48 trips a year being ride checked. One chain should be done on a Saturday, one on a Sunday, and the remainder on weekdays, distributed as evenly as possible over the five weekdays. The chains should be selected following plan (a) described earlier, "Memoryless Selection." The ride checks for a quarter could be concentrated over two days, or spread out.

The estimation method used is simple ratio estimation, without stratification. From the annual ride check sample, average trip length is estimated by first finding average passenger-miles per trip for the sample, and likewise average boardings per trip from the same sample, and then taking their ratio. Average trip length is then expanded by annual boardings to yield the estimate of annual passenger-miles.

An analysis of this sampling plan is summarized in the following table:

Accuracy of Annual Passenger-Miles Estimate Using Average Trip Length Expansion

	pass-mi	boardings	
mean	82.15	24.16	
coef of variation (cv)	0.32	0.34	
correlation coefficient			0.88
ratio (avg trip length)			3.401
ratio unit cv			0.17
sample size			48
effective sample size (design effect = 1.5)			32
precision @ 95 percent confidence level			5.8%

The effect of using three-trip chains (clusters), which are likely to be stay on a single route, is accounted for in the design effect, which makes the effective sample size smaller than the actual sample size. As the table indicates, the precision of the annual passenger-miles estimate from this sampling plan, at the 95 percent confidence level, is ±5.8%, satisfying the FTA requirement for the National Transit Database that estimates of annual passenger-miles have a precision of ±10% or better at the 95 percent confidence level.

Appendix C

Application in FY 1998

For FY98, the sampling plan described in this report (the primary plan, not the alternative plan) was applied, with a few necessary modifications, as follow. Sampling did not begin until November, when intensive sampling was done in order to develop the sampling plan. The November - December sampling followed a slightly different (but equally valid) trip selection scheme. The remainder of the sample should be collected between January and June, at a more intensive pace than spelled out in the sampling plan in order to arrive at a total sample size of 156 trips. There is no way to objectively quantify the effect of omitting July - October data on the accuracy of the estimate. Given that the sampling plan normally results in a precision of ±7.0%, it is my opinion that the absence of data from those three months will not worsen the accuracy of the annual passenger-miles estimate beyond the stipulated precision level of ±10% at the 95 percent confidence level. Therefore the FY98 estimate of annual passenger miles satisfies the FTA accuracy requirement for passenger mile estimates.

Appendix C

Statistical Analysis of Sampling Plan for Estimating Passenger-Miles Using Farebox Data

Fairfax CUE, Fairfax, VA

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The City of Fairfax, Virginia operates fixed route service known as Fairfax CUE. The route structure consists of two loops, each of which is operated in both directions, yielding effectively four routes. Service is offered for most of the day, seven days a week. All routes share two common termini: the Vienna Metrorail Station, and the George Mason University campus. The routes' primary markets are feeder service to and from Metrorail, service to and from GMU, and general circulation within the City of Fairfax.

CUE routes will soon have registering fareboxes, from which system boardings will be known. Before the fareboxes are introduced, large samples of boardings were collected during the GMU school year. A sample of ride checks is needed to estimate average (unlinked passenger) trip length (ATL), which is the ratio of passenger-miles to boardings.

Sampling Plan - Stratification

Because the GMU market is expected to have strong variability in connection with the school calendar, the sampling plan stratifies the system into three periods of the year: "school", consisting of the weeks in which the fall and spring semesters are in session; "summer", during the summer session; and "break", when school is not in session. For simplicity in sampling, a further level of stratification is done by day type: weekday vs. weekend. Any reasonable method may be used for segmenting the year (e.g., should the weekend after Thanksgiving be classified as "break weekend" or as "Fall weekend"), as long as the definition is clearly specified and is consistent throughout the sampling and estimation methodology. Because all four routes have very similar lengths, there is no reason to stratify by route.

Sampling Unit

In order to make sampling more efficient, trips will be sampled in chains of two trips, one on a Green route and one on a Gold route. The analysis of the sampling plan recognizes the cluster effect.

Appendix C

Sample Size
The sampling plan is to do ride checks (on/off counts by stop, from which boardings and passenger-miles on the sampled trips are measured) on a given number of two-trip chains each stratum, as specified in the following table:

Stratum	Sample size
School, weekday	8
School, weekend	2
Break, weekday	4
Break, weekend	1
Summer, weekday	4
Summer, weekend	1
Total	20

Creating Trip Chains for Sampling
Within each stratum, select one Green route trip at random from the daily schedule for each chain that is to be surveyed. (For weekend strata, select a trip from the merged Saturday / Sunday schedule). For strata with an even sample size, select half the trips from the Green clockwise loop and half from the Green counterclockwise loop.

Next, build the selected trips into chains by appending to each selected Green route trip a Gold route trip. The appended trip may be either a trip preceding or following the selected Green route trip, and may be either clockwise or counterclockwise, provided that there is a balance over the two directions.

Assigning Chains to Days
Each chain should be sampled on a different day (i.e., do not sample two chains on the same day). The school sample should be collected half in the fall semester, half in the spring semester. The sampling for "break" should be spread over at least three distinct break periods (e.g., the Christmas break, Spring break, the breaks before and after summer semester). As much as possible, spread the sample within each stratum over the days of the week. Other than these guidelines, the days may be selected in any convenient way. (For example, the Fall weekday sample could be concentrated in one week, or spread over the Fall semester.)

Estimation Method
Estimating passenger-miles is done using the "combined ratio method" (W.G. Cochran, *Sampling Techniques*, Wiley, 1977, section 6.11), which is an application of stratified sampling. The steps to be followed are:

1. Determine the number of trips per year operated in each stratum.
2. For each stratum, find the mean passenger-miles per trip from the sample. Expand it by the number of trips operated per year in that stratum to get an estimate of annual passenger-miles by stratum.
3. Aggregate those annual passenger-miles estimates over all the strata to get an estimate of system annual passenger-miles.

4. Repeat Steps 2 and 3 for boardings, obtaining first an estimate (from the same sample used in Steps 2 and 3, i.e., do not use farebox data or other passenger counts) of annual boardings by stratum, and then one of system annual boardings.
5. Take the ratio of the annual estimates (passenger-miles divided by weekly boardings) to get average trip length for the system.
6. Expand average trip length by total annual boardings in the system (as obtained from the farebox data).

Statistical Analysis Of The Sampling Plan - Passenger-Miles

A statistical analysis was done to determine the level of accuracy in the annual passenger-miles estimate obtained following the sampling plan. The analysis is based on data from 32 trips collected in Fall, 1997, including a representative share of trips from all seven days of the week. These data were collected in chains, and were summarized in chains of two trips. (Some trips were omitted from the analysis because a few chains had either 1 or 3 trips.) Because the sample was too small to make reliable estimates for individual strata, it was analyzed as a single stratum and the results are applied to every stratum. (This is a conservative approach, since stratum-specific estimates generally have lower variance.) Results and calculations are summarized in the following table:

Accuracy of Annual Passenger-Miles Estimate

Assumed population parameters (estimated from data)

Avg trip length (mi)	3.43
Pass-mi / trip chain	157.09

Stratum		relative size	Trip Chain Std Dev pass-mi	Trip Chain Std Dev brdgs	correlation	sample size	variance contrib's
school	wkday	41%	40.1	13.2	0.90	8	8.49218
school	wkend	16%	40.1	13.2	0.90	2	5.43500
break	wkday	10%	40.1	13.2	0.90	4	0.92470
break	wkend	4%	40.1	13.2	0.90	1	0.77298
summer	wkday	20%	40.1	13.2	0.90	4	4.24609
summer	wkend	8%	40.1	13.2	0.90	1	2.71750
Total						20	22.58846

estimate cv	0.030
precision @ 95% confidence	6.1%

As shown in the table, the precision of the annual passenger-miles estimate at the 95 percent confidence level is ±6.1%. Therefore this sampling plan satisfies the FTA requirement for the National Transit Database that estimates of annual passenger-miles have a precision of ±10% or better at the 95 percent confidence level.

Validity Of The Sampling Plan With Respect To Schedule And Route Changes

While the analysis of the accuracy of the sampling plan was done based on data and schedules in FY 98, it remains valid if there are minor routing changes. Schedule changes, even major ones, do not affect the sample plan accuracy. For example, if service expands to later hours, there is no need to increase the sample sizes; and if service decreases, the sample size should not be decreased.

Application in FY 1998
For FY98, the sampling plan described in this report was applied, with a few necessary modifications, as follow. Ride check sampling did not begin until November, when intensive sampling was done in order to develop this sampling plan. Because of the large quantity of data collected in the Fall semester, no "school" stratum data was collected in the Spring semester. Also, the "break" and "summer" data were all collected in the latter half of the year. Because there were no significant changes in the system or its environment in FY98, this concentration of data in different parts of the year is not expected to affect the accuracy of the average trip length estimate. Furthermore, the FY98 sample is a little larger than specified (because of the extra sampling done in the Fall semester), improving the accuracy over the value shown in the analysis.

Another modification in FY98 is that the annual boardings total by which the sample is expanded is an estimate, not a complete count. This was necessitated by the fact that registering fareboxes were not installed until late in the year, and even then were only installed on some of the buses. The estimate of annual boardings was made by expanding the sample mean for the same six strata described in the sampling plan. For the "school" strata, data from a full week of counts taken in fall, 1997 were also available and used in determining the annual boardings for those strata.

The final estimate of passenger-miles is therefore the product of two estimates, estimated average trip length and estimated annual boardings. The precision of the passenger-miles estimate is therefore somewhat worse than the precision of the estimate of average trip length. However, the annual boardings estimate is quite accurate -- better than ±3% precision at the 95% confidence level -- because of the large sample size from which it is derived. Its effect on the precision of the passenger-miles is therefore small. Using the upper limit of ±3% for the precision of the boardings estimate, the precision of the FY98 estimate of passenger-miles is ±6.8% at the 95 percent confidence level, satisfying the FTA accuracy requirement.

APPENDIX D

LOUDOUN COMMUTER SERVICE

NTD SAMPLING PLAN AND STATISTICAL ANALYSIS

Appendix D

Statistical Analysis of Sampling Plan for Estimating Passenger-Miles

Loudoun Commuter Services, Loudoun County, VA

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Northeastern University, Boston, MA
January 2, 1998

Loudoun Commuter Services offers express bus service between points in Loudoun County, Virginia and Washington, DC. In the current schedule, 8 trips are offered in the a.m. peak (all inbound), and 8 in the p.m. peak (all outbound). There are six distinct routing patterns in the a.m., and two in the p.m. Counts are routinely made of all boarding passengers. Therefore, passenger-miles can be estimated by means of the ratio of passenger-miles to boardings, known as average (unlinked passenger) trip length.

Sampling and Estimation Plan

The sampling plan is to do one ride check (on/off counts by stop, from which boardings and passenger-miles on the sampled trips are measured) on every scheduled trip once a year. From this sample, average trip length is estimated, and expanded by total annual boardings.

The ride checks may be concentrated in one part of the year (e.g., all in one day), or spread over the year in any convenient manner, because the essential seasonal variation in passenger-miles is captured by the daily boardings counts, and because the nature of the express service is such that average trip length per passenger cannot vary much over the year.

Average trip length is estimated by first finding average passenger-miles per trip for the sample, and likewise average boardings per trip from the same sample, and then taking their ratio. (If for some reason a given trip is sampled for more than one day, those days' results should first be condensed into an average passenger-miles and boardings for that trip, so that no trip is over-represented in the final averages from which the ratio is calculated.) Average trip length is then expanded by annual boardings to yield the estimate of annual passenger-miles.

Statistical Analysis Of The Sampling Plan

A statistical analysis was done to determine the level of accuracy expected from the sampling plan. Because the plan provides for sampling every scheduled trip, the only source of variability is between-day variability. To determine the effect of between-day variability, data was collected from four scheduled trips on four different days each in Fall, 1997.

The data was analyzed following the "combined ratio method" (W.G. Cochran, *Sampling Techniques*, Wiley, 1977, section 6.11), in which each scheduled trip is treated as a separate stratum. Summary calculations are given in the attached table. For each stratum, the key statistical parameter is its unit (i.e., per trip) variance of passenger-miles based on the ratio estimator. This unit variance is calculated for the four strata for which multi-day data were available as follows. A "deviation" is calculated for each trip in the sample as the difference between observed and expected passenger-miles, where expected passenger-miles is the product of observed boardings and the estimated average trip length ratio. The unit variance for a stratum is simply the within-stratum sample variance of those deviations (estimated using n-1 in the denominator, as usual). The average unit variance found in the four trips included in the analysis dataset was applied to the other strata for which no multi-day data were available.

The variance of the estimate is then found by combining the unit variance of the several strata following standard formulas for stratified sampling which account for the relative size of the stratum (equal in this case for every stratum) and the planned sample size (1) within the stratum.

The standard error the estimate is the square root of its variance. The relative standard error or coefficient of variation (cv) of the estimate is the standard error divided by the mean of the estimate (i.e., mean passenger-miles per round trip). The precision of the estimate is the cv by multiplied by the t-ordinate for the desired confidence level; for the 95 percent confidence level, a t-value of 2 is used.

Based on this analysis, the precision of an estimate of passenger-miles based on this sampling plan, at the 95 percent confidence level, is ±5.7%. Therefore this sampling plan satisfies the FTA requirement for the National Transit Database that estimates of annual passenger-miles have a precision of ±10% or better at the 95 percent confidence level.

Validity Of The Sampling Plan With Respect To Schedule And Route Changes
While the analysis of the accuracy of the sampling plan was done based on data and schedules in FY 98, it remains valid for route and schedule changes, as follows:

a. Changes to routing and scheduling of individual trips do not invalidate the plan, because every trip is included in the sample.
b. If trips are added to the schedule, they can simply be added to the sampling plan, and the overall accuracy will increase.
c. Deletion of up to four trips in the daily schedule will not invalidate the plan. The deleted trips are simply omitted from the sample.

Appendix D

Application in FY 1998

For FY98, the sampling plan described above is to be followed. Intensive sampling (4 days' observation) was done on four trips as part of the process of gathering data to support this statistical analysis. For each of those four trips, the average passenger-miles and boardings over those four days is therefore used. The remaining trips should each be observed once.

Appendix D

Loudoun Commuter Service
Passenger-Miles Statistical Analysis

Route	Relative Size	Analysis Sample Size	Future Sample Size	Mean Brd	Mean Pmi	Avg Trip Length (mi)	Unit Variance	V(est)
5:35 AM	6.3%	4	1	30.8	1208		918.3	3.59
7:00 AM	6.3%	4	1	34.3	1197		151.1	0.59
4:30 PM	6.3%	4	1	43.3	1543		476.3	1.86
5:15 PM	6.3%	4	1	29.3	1064		77.3	0.30
other AM	6.3%		1				*405.7*	1.58
other AM	6.3%		1				*405.7*	1.58
other AM	6.3%		1		*Estimate using*		*405.7*	1.58
other AM	6.3%		1		*average values*		*405.7*	1.58
other AM	6.3%		1		*from the four*		*405.7*	1.58
other AM	6.3%		1		*sampled trips*		*405.7*	1.58
other PM	6.3%		1				*405.7*	1.58
other PM	6.3%		1				*405.7*	1.58
other PM	6.3%		1				*405.7*	1.58
other PM	6.3%		1				*405.7*	1.58
other PM	6.3%		1				*405.7*	1.58
other PM	6.3%		1				*405.7*	1.58
Overall	100.0%	16	16	34.4	1253	**36.44**	405.7	25.36
cv								0.0283
Tolerance @ 95 percent confidence								**5.7%**

APPENDIX E

FAIRFAX CONNECTOR

NTD SAMPLING PLAN AND STATISTICAL ACCURACY

Appendix E

Statistical Analysis of Sampling Plan for Estimating Passenger Miles

Fairfax Connector, Fairfax, VA

Prepared Jointly
by
Peter G. Furth, Ph.D. and George R. Hoyt
July 3, 1998

The following sampling plan and estimation method for the Fairfax Connector provides annual passenger miles data consistent with the requirements of the FTA National Transit Database (also called Section 15). The sampling plan assumes that the Fairfax Connector has a reliable method of counting total annual passenger boardings by route. We understand that they use a combination of adjusted registering farebox and manual counts to produce these passenger totals. The approach recommended for estimating passenger-miles is to estimate the average passenger trip length (ATL), and then expand these by reported annual boardings to yield passenger-miles. Overall, we recommend sampling 186 bus trips. Of these, 156 samples are designated for current Connector routes. These should be ridden during the period from January through June, 1999. The remaining 30 samples are reserved to assess the impact of the new Dulles Corridor service expected to begin in mid-May, 1999. These should be ridden during June and July of 1999.

To improve the efficiency of the method, a stratified sample of trips by route will be picked. When sampling routes where service is provided in both directions within a time period, collecting data on pairs of trips (e.g., and inbound trip followed by an outbound trip) is recommended where possible. Where the Connector's routes operate in only one direction by time period, the sampling units are one-way trips.

Method to Estimate Average Trip Length and Expand based on Known Annual Boarding Counts

This method is recommended when reliable counts of annual boardings by route are available. The sample is used to estimate average trip length, which is the ratio of passenger-miles to boardings. Then for estimation, the sample is *post facto* stratified by one-way route mileage with average trip length calculated and expanded separately for five route mileage groups.

Sampling by Route

For sample selection, each route is a stratum and each trip scheduled to operate is a sampling unit. Where trips are scheduled for both inbound and outbound service within a time period, trips should be selected for sampling in pairs.

The Sampling Frame (Trip Lists)
The sampling frame is based on normal weekly service for each route. The sampling frame consists of a list of all trips operated during a normal week. Note that weekday trips should appear five times, once for each weekday. Each trip (or directional pair when paired service is operated) should be given a unique number reflecting the route, operating sequence and day operated. Generally a hierarchical code is recommended where the first two digits identify the route, the second two digits identify the trip (or trip pair) and the last (fifth) digit identifies the day operated.

Sample Size and Sequence
The recommended sample size for the current Connector system is 156 trips per year. Since all of the sampling will occur within the last six months of the fiscal year, this amounts to 6 trips per week. The sample should be allocated among the routes in proportion to the number of one-way trips operated per week, rounded to whole numbers, but never less than one. Sometimes with precise rounding the resulting total will be different than the intended total; if that is the case, small rounding adjustments should be made to get the totals to match (ensuring again, however, that every route gets at least one sample).

The sequence in which trips (or pairs of trips) will be sampled during the sampling period is determined randomly. The route-level sample size and sampling sequence should be determined at the beginning of the sampling period. If schedule changes are made during the course of the year such that the number of trips on a route changes, no changes will be made to the allocation. If a route is eliminated, the samples should be allocated to other routes (keeping the annual total samples unchanged). If a route is added, it should be sampled in proportion to the scheduled annual number of trips (thus increasing the annual sample size).

Scheduling the Samples
Sampling should be evenly spread over the sampling period by sampling roughly the same number of trips each week. Partial weeks at the start and end of the sampling period should get a (roughly) prorated sample size.

The weekly sample size and the sampling sequence will determine which routes to be sampled each week. For each route to be sampled, a random trip (or trip pair) should be drawn from that route's sampling frame (every unit in the sampling frame has an equal chance of selection) and sample that trip (or pair). If the week in question has a holiday schedule, the sampling frame will need to be adjusted accordingly. Note that it is possible that a given cluster for a given route may be selected more than once. Missed trips should be made up in the following week.

Measurement
Data for the selected trips are collected by recording passengers on and off by stop and then calculating trip-level boardings and passenger miles. Passengers on board at the start of the end of the trip should be recorded as well. To calculate passenger-miles, the inter-stop distances must be known. These mileages have been established for

each of the routes currently operated by the Connector, by route variation. When the sample selected is part of a trip pair, a separate ride check form should be used for each trip. On routes that operate as loops, a single ride check form should be used.

Compiling and Expanding the Data
At the end of the sampling period, the routes should be post-stratified by one-way route length. For the current Connector system, the recommended groups are:

less than 10 miles,
10 to 12.5 miles,
12.5 to 15 miles,
15 to 20 miles, and
over 20 miles.

The sampled boardings and passenger miles should be totaled for each mileage stratum. The ATL can then be computed by dividing the sum of passenger miles by the sum of boardings. To obtain an estimate of annual passenger miles in the stratum, expand the ATL by the count of mileage stratum annual boardings. A system-wide annual passenger mile estimate may be obtained by aggregating the passenger mile estimates over the strata.

Statistical Analysis of the Sampling Plan
To verify that this sampling plan will achieve the accuracy level required by FTA, a test sample of ride checks done in 1998 was analyzed. It consists of 228 trips, with observations of boardings and passenger-miles on each. In order to get good estimates of overall trip length variance, data were collected on most routes in the system.

The method employed stratified sampling, with equal allocation among strata, and with stratum-level estimates being made using a ratio estimate. At the stratum level (h is the stratum index), average trip length is estimated as

$$ATL_h = M_{ph} / M_{bh}$$

where M_{ph} is the sample mean of passenger-miles over all samples in stratum h, and M_{bh} is the corresponding sample mean of boardings. The formula for the annual estimate of passenger miles is

$$P = \sum B_h \, ATL_h$$

where B_h is the count of annual boardings in stratum h.

For each stratum, the relative unit variance of the average trip length is given by

$$u^2_h = s^2_{bh} + s^2_{ph} - 2\, r_h\, s_{bh}\, s_{ph}$$

where s_{bh} and s_{ph} are the standard deviations of boardings and passenger-miles in stratum h, respectively, and r_h is their correlation coefficient. If the overall sample size is n and each stratum's sample size is n/5, the relative variance of the overall estimate is

$$v^2 = (5/n) \sum z^2_h\, u^2_h$$

where z_h is the share of annual passenger-miles estimated to be in stratum h; that is,

$$z_h = (B_h\, ATL_h) / \sum (B_h\, ATL_h)$$

Using the test sample data and available counts, the necessary statistics (u^2_h and z_h) were calculated. To achieve the FTA-specified accuracy level of 10% precision at the 95 percent confidence level, v^2 must be no greater than $(0.05)^2$ or 0.0025. Thus, given the statistics, the necessary sample size n can be determined.

The numerical analysis shown in Table 1 indicates that the minimum necessary sample size is 120 trips. Given the number of routes, the complexity of the Connector system, and the compressed sampling period, we recommend a somewhat larger sample of 156 trips for the current system. This will result in an annual passenger mile estimate with expected precision of ± 8.8 percent at the 95 percent confidence level, well under the minimum level required by FTA for estimates of service consumed. In addition, we recommend collecting data on 30 trips of the new Dulles Corridor service to be able to assess the impact of this service on future year sampling requirements.

Validity With Respect to Network, Route, and Schedule Modifications
This sampling plan does not depend on any special structure of the network or schedule, and is valid if minor system changes occur. Since the Connector plans to add significant and, perhaps different, service in the Dulles Corridor at the end of the sampling period (mid-May, 1999), we recommend adding a small number of trips (30) to the sampling plan to assess the impact of this service.

Certification
Based on the preceding analysis, this recommended sampling plan will yield estimates of annual passenger-miles that satisfy the FTA requirement of ±10 percent precision at the 95% confidence level.

APPENDIX G

CONTRACTOR FINANCIAL REPORTING FOR NTD

Appendix G

Contractor Reporting for NTD

Transit contractors (seller of services) need to report percentages of the total amount charged the government agency (buyer of services) for accrued expenditures in four functional categories during the annual reporting period. This document has been prepared to assist transit contractors prepare their reports to government agencies.

The sum of the four category percentages will equal 100 percent of the total annual charges. Each of the four categories may contain expenditures that include:

- **salaries and wages** of owners and employees;
- **fringe benefits** of owners and employees including uniform and work clothing allowances;
- **services** such as management, professional, and/or technical services performed by outside organizations or persons;
- **materials and supplies** such as fuel, lubricants, tires and tubes, vehicle maintenance parts, cleaning materials, and office supplies;
- **casualty and liability costs** incurred for physical damage, public liability and property damage, and corporate insurance premiums; recoveries of physical damage losses, public liability and property damage settlements, and corporate losses; and payouts for uninsured public liability and property damage settlements;
- **taxes** such as federal and state income taxes; property taxes; vehicle licensing and registration fees; fuel and lubricant taxes;
- **miscellaneous expenses** including dues and subscriptions, travel and meetings, tolls, entertainment expense, charitable donations, fines and penalties, bad debts, and advertising/promotion media expenses;
- **interest expenses** such as interest on both short-term and long-term obligations;
- **leases and rentals** including passenger revenue vehicles, service vehicles, buildings, shops and garages, operating yards, other facilities and equipment;
- **depreciation** of passenger revenue vehicles, service vehicles, buildings, shops and garages, operating yards, other facilities and equipment;
- **purchase lease payments** for passenger revenue vehicles, service vehicles, buildings, shops and garages, operating yards, other facilities and equipment.

The four categories for which a percentage value is to be reported to the government agency include the following expenditures where applicable:

1. **Vehicle Operations** includes all labor wages and fringe benefits of employees who drive or operate revenue vehicles in service, supervise service such as street supervisors, dispatch and control service and support such as radio communications, schedule service, collect and process revenues, and provide or supervise security services. Vehicle operations also include any expenditures for operations management, professional, and/or technical services; revenue vehicle

propulsion fuel and lubricants including taxes; revenue vehicle tires and tubes; revenue vehicle licensing and registration fees; vehicle leases and rentals; vehicle depreciation; and vehicle purchase lease payments. The amount that vehicle operations expenditures are of total charges will vary depending on contract provisions but should range between 55 and 75 percent.

2. **Vehicle Maintenance** includes all labor wages and fringe benefits of employees who inspect, maintain, repair, service and clean, fuel, supervise, and administer maintenance of revenue and service vehicles. Vehicle maintenance also includes any expenditures for vehicle maintenance management, professional and/or technical services such as outside vehicle maintenance contractors; cleaning equipment and supplies; vehicle maintenance parts, supplies, and small tools; premiums for physical vehicle damage insurance; recoveries of physical damage losses to vehicles; service vehicle propulsion fuel and lubricants including taxes; service vehicle tires and tubes; service vehicle licensing and registration fees; shop and garage leases and rentals; shop and garage depreciation; and shop and garage purchase lease payments. The amount that vehicle maintenance expenditures are of total charges will vary depending on contract provisions but should range between 10 and 25 percent.

3. **Non-Vehicle Maintenance** includes all labor wages and fringe benefits of employees who inspect, maintain, repair, service and clean, supervise, and administer facilities, grounds, and equipment. Non-vehicle maintenance includes expenditures for radio communications equipment, fareboxes, buildings and grounds, custodial services, facility and equipment management, professional and/or technical services such as outside copy machine repairs or lift equipment maintenance; facility cleaning equipment and supplies; non-vehicle maintenance parts and supplies, non-vehicle maintenance equipment leases and rentals; non-vehicle maintenance equipment depreciation; and non-vehicle maintenance equipment purchase lease payments. The amount that non-vehicle maintenance expenditures are of total charges will vary depending on contract provisions but should range between 5 and 10 percent.

4. **General Administration** includes all labor wages and fringe benefits of employees as well as outside management, professional, and technical services and materials/supplies involved in general management and administration, finance and accounting, legal services, data processing, premiums for public liability and property damage insurance and settlements, general public liability insurance, safety-related expenses, personnel administration, purchasing and stores, office management and services, real estate management, office utilities, taxes, dues and subscriptions, travel and meetings, bad debts, customer services, promotion, market research, planning and engineering, office facilities and equipment leases and rentals; office facilities and equipment depreciation; and office facilities and equipment purchase lease payments. The amount that general administration expenditures are of total charges will vary depending on contract provisions but should range between 5 and 25 percent.

Appendix G

Profits for the contract service will account for the difference between expenditures and charges to the government agency. Profits can be assumed distributed among the four functional categories, for example, based on functional expenditures or simply added to the General Administrative function.

APPENDIX H

VIRGINIA METROBUS SERVICE SURVEY SAMPLING PLAN

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level =	68%
Route/Period Accuracy =	10%
Weekday Usable Survey Rate =	45%
Weekend Usable Survey Rate =	25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MD	EV	NT	Daily	MD	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
1B	Utrps	12	11	11	5	1	40	14	15	0	29				
	Ubrds	314	347	288	158	32	1139	363	389	0	752				
	Rrsps	23	23	23	22	14	105	23	24	0	47				
	Strps	2	2	2	2	1	9	4	4	0	8				
	Ersps	24	28	24	28	14	118	26	26	0	52				
	Accuracy	9.8%	9.1%	9.8%	8.6%	10.2%	7.2%	9.5%	9.5%		11.0%				
1C	Utrps	8	11	8	5	0	32	14	16	2	32				
	Ubrds	209	347	209	158	0	923	363	415	52	830				
	Rrsps	22	23	22	22	0	89	23	24	17	64				
	Strps	2	2	2	2	0	8	4	4	2	10				
	Ersps	24	28	24	28	0	104	26	26	13	65				
	Accuracy	9.6%	9.1%	9.6%	8.6%		7.6%	9.5%	9.5%	12.1%	9.8%				
1D	Utrps	2	0	4	1	0	7								
	Ubrds	52	0	105	32	0	189								
	Rrsps	17	0	20	14	0	51								
	Strps	2	0	2	1	0	5								
	Ersps	23	0	24	14	0	61								
	Accuracy	7.9%		9.0%	10.2%		8.7%								
1E	Utrps	5	0	5	0	0	10								
	Ubrds	131	0	131	0	0	262								
	Rrsps	21	0	21	0	0	42								
	Strps	2	0	2	0	0	4								
	Ersps	24	0	24	0	0	48								
	Accuracy	9.3%		9.3%			10.8%								
1F	Utrps	3	0	2	2	6	13	3	1	6	10	24	27	2	53
	Ubrds	79	0	52	63	189	383	78	26	155	259	268	301	22	591
	Rrsps	19	0	17	18	22	76	19	13	22	54	23	23	12	58
	Strps	2	0	2	2	2	8	3	1	4	8	9	9	2	20
	Ersps	24	0	23	28	28	103	20	7	26	53	25	25	6	56
	Accuracy	8.6%		7.9%	7.1%	8.7%	7.0%	9.7%	16.5%	9.0%	10.1%	9.5%	9.6%	17.8%	10.5%
1Z	Utrps	5	0	5	0	0	10								
	Ubrds	131	0	131	0	0	262								
	Rrsps	21	0	21	0	0	42								
	Strps	2	0	2	0	0	4								
	Ersps	24	0	24	0	0	48								
	Accuracy	9.3%		9.3%			10.8%								
2A	Utrps	1	0	0	0	6	7	2	0	6	8	8	5	2	15
	Ubrds	29	0	0	0	136	165	48	0	143	191	321	201	80	602
	Rrsps	14	0	0	0	21	35	17	0	21	38	23	22	19	64
	Strps	1	0	0	0	3	4	2	0	4	6	3	3	2	8
	Ersps	13	0	0	0	31	44	12	0	24	36	30	30	20	80
	Accuracy	10.5%				7.9%	10.7%	12.6%		9.3%	12.4%	8.7%	8.4%	9.7%	8.6%
2B	Utrps	11	11	8	7	2	39	15	16	1	32				
	Ubrds	324	250	236	159	45	1014	358	382	24	764				
	Rrsps	23	23	23	22	16	107	23	24	13	60				
	Strps	2	3	2	3	2	12	4	5	1	10				
	Ersps	27	31	27	31	20	136	24	30	6	60				
	Accuracy	9.2%	8.4%	9.1%	8.1%	8.4%	6.6%	9.9%	8.8%	18.1%	10.2%				

Virginia MetroBus Service On-Board Survey Sampling Plan
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Route/Period Confidence Level = 68%
Route/Period Accuracy = 10%
Weekday Usable Survey Rate = 45%
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		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
2C	Utrps	15	11	14	6	3	49	16	16	0	32	9	10	0	19
	Ubrds	442	250	413	136	68	1309	382	382	0	764	361	401	0	762
	Rrsps	24	23	24	21	18	110	24	24	0	48	23	24	0	47
	Strps	2	3	2	3	2	12	5	5	0	10	3	3	0	6
	Ersps	27	31	27	31	20	136	30	30	0	60	30	30	0	60
	Accuracy	9.3%	8.4%	9.3%	7.9%	9.5%	6.7%	8.8%	8.8%		10.2%	8.8%	8.8%		10.2%
2G	Utrps	4	0	6	0	0	10								
	Ubrds	118	0	177	0	0	295								
	Rrsps	21	0	22	0	0	43								
	Strps	2	0	2	0	0	4								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.5%		8.9%			10.2%								
2W	Utrps	7	0	5	2	0	14								
	Ubrds	96	0	69	27	0	192								
	Rrsps	20	0	19	0	0	39								
	Strps	4	0	4	0	0	8								
	Ersps	25	0	25	0	0	50								
	Accuracy	8.6%		8.0%			10.1%								
3A	Utrps	14	12	13	6	0	45	14	13	0	27	12	11	0	23
	Ubrds	345	181	320	90	0	936	250	232	0	482	264	242	0	506
	Rrsps	23	22	23	20	0	88	23	23	0	46	23	23	0	46
	Strps	3	4	3	3	0	13	6	6	0	12	5	5	0	10
	Ersps	33	27	33	20	0	113	27	27	0	54	28	28	0	56
	Accuracy	8.3%	8.9%	8.3%	9.9%		7.3%	9.1%	9.1%		10.6%	9.0%	8.9%		10.4%
3B	Utrps	14	10	15	2	0	41	15	12	0	27				
	Ubrds	345	150	370	30	0	895	268	214	0	482				
	Rrsps	23	22	23	14	0	82	23	22	0	45				
	Strps	3	4	3	2	0	12	6	5	0	11				
	Ersps	33	27	33	14	0	107	27	22	0	49				
	Accuracy	8.3%	8.7%	8.3%	9.9%		7.5%	9.1%	10.1%		11.2%				
3E	Utrps	3	0	1	2	10	16	3	4	8	15	5	4	2	11
	Ubrds	74	0	25	30	150	279	54	71	143	268	110	88	44	242
	Rrsps	19	0	13	14	22	68	17	19	21	57	21	20	16	57
	Strps	2	0	1	2	4	9	3	4	5	12	4	4	2	10
	Ersps	22	0	11	14	27	74	14	18	22	54	22	22	11	55
	Accuracy	9.0%		11.5%	9.9%	8.7%	8.2%	11.6%	10.3%	9.8%	10.1%	9.6%	9.3%	13.2%	9.8%
3F	Utrps	0	0	0	3	0	3	0	3	0	3				
	Ubrds	0	0	0	45	0	45	0	54	0	54				
	Rrsps	0	0	0	16	0	16	0	17	0	17				
	Strps	0	0	0	3	0	3	0	3	0	3				
	Ersps	0	0	0	20	0	20	0	14	0	14				
	Accuracy				8.4%		13.9%		11.6%		19.2%				
3W	Utrps	4	0	5	0	0	9								
	Ubrds	53	0	66	0	0	119								
	Rrsps	17	0	18	0	0	35								
	Strps	3	0	4	0	0	7								
	Ersps	18	0	24	0	0	42								
	Accuracy	9.7%		8.2%			10.3%								

Virginia MetroBus Service On-Board Survey Sampling Plan

Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level = 68%
Route/Period Accuracy = 10%
Weekday Usable Survey Rate = 45%
Weekend Usable Survey Rate = 25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
3Z	Utrps	5	0	6	0	0	11								
	Ubrds	66	0	79	0	0	145								
	Rrsps	18	0	19	0	0	37								
	Strps	4	0	4	0	0	8								
	Ersps	24	0	24	0	0	48								
	Accuracy	8.2%		8.6%			9.8%								
4A	Utrps	14	14	14	1	0	43								
	Ubrds	283	148	283	11	0	725								
	Rrsps	23	22	23	8	0	76								
	Strps	3	5	3	1	0	12								
	Ersps	27	24	27	5	0	83								
	Accuracy	9.2%	9.4%	9.2%	17.3%		8.5%								
4B	Utrps	9	15	14	8	5	51	16	15	3	34	15	16	0	31
	Ubrds	182	158	283	85	53	761	173	162	32	367	300	321	0	621
	Rrsps	22	22	23	19	17	103	22	22	14	58	23	23	0	46
	Strps	3	5	3	4	4	19	9	9	3	21	5	5	0	10
	Ersps	27	24	27	19	19	116	24	24	8	56	25	25	0	50
	Accuracy	8.9%	9.4%	9.2%	10.2%	9.3%	7.1%	9.5%	9.4%	15.6%	10.2%	9.6%	9.6%		11.2%
4E	Utrps	6	0	0	0	0	6								
	Ubrds	121	0	0	0	0	121								
	Rrsps	21	0	0	0	0	21								
	Strps	3	0	0	0	0	3								
	Ersps	27	0	0	0	0	27								
	Accuracy	8.5%					14.1%								
4H	Utrps	0	0	0	8	4	12	15	9	0	24				
	Ubrds	0	0	0	85	42	127	162	97	0	259				
	Rrsps	0	0	0	19	16	35	22	20	0	42				
	Strps	0	0	0	4	4	8	9	8	0	17				
	Ersps	0	0	0	19	19	38	24	22	0	46				
	Accuracy				10.2%	8.6%	11.2%	9.4%	9.4%		11.1%				
4S	Utrps	5	0	5	0	0	10								
	Ubrds	101	0	101	0	0	202								
	Rrsps	20	0	20	0	0	40								
	Strps	3	0	3	0	0	6								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.3%		8.3%			9.6%								
7A	Utrps	5	10	7	6	7	35	15	17	5	37	13	16	6	35
	Ubrds	107	278	150	167	195	897	434	492	145	1071	282	347	130	759
	Rrsps	20	23	22	22	22	109	24	24	21	69	23	23	21	67
	Strps	3	2	3	2	2	12	4	4	3	11	5	5	4	14
	Ersps	29	25	29	25	25	133	29	29	22	80	27	27	22	76
	Accuracy	8.0%	9.6%	8.4%	9.2%	9.4%	6.6%	9.0%	9.0%	9.9%	8.9%	9.2%	9.3%	9.8%	9.0%
7B	Utrps	5	0	5	0	0	10								
	Ubrds	107	0	107	0	0	214								
	Rrsps	20	0	20	0	0	40								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.0%		8.0%			9.3%								

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level =	68%
Route/Period Accuracy =	10%
Weekday Usable Survey Rate =	45%
Weekend Usable Survey Rate =	25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
7C	Utrps	8	0	7	0	0	15								
	Ubrds	172	0	150	0	0	322								
	Rrsps	22	0	22	0	0	44								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.5%		8.4%			9.8%								
7D	Utrps	4	0	4	0	0	8								
	Ubrds	86	0	86	0	0	172								
	Rrsps	20	0	20	0	0	40								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	7.6%		7.6%			8.8%								
7E	Utrps	18	0	17	0	0	35								
	Ubrds	386	0	364	0	0	750								
	Rrsps	24	0	23	0	0	47								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.9%		8.9%			10.4%								
7F	Utrps	7	11	5	7	2	32	15	14	1	30				
	Ubrds	150	306	107	195	56	814	434	405	29	868				
	Rrsps	22	23	20	22	18	105	24	24	14	62				
	Strps	3	2	3	2	2	12	4	4	1	9				
	Ersps	29	25	29	25	25	133	29	29	7	65				
	Accuracy	8.4%	9.6%	8.0%	9.4%	7.5%	6.5%	9.0%	9.0%	16.8%	9.8%				
7H	Utrps	2	0	2	0	0	4								
	Ubrds	43	0	43	0	0	86								
	Rrsps	16	0	16	0	0	32								
	Strps	2	0	2	0	0	4								
	Ersps	19	0	19	0	0	38								
	Accuracy	8.7%		8.7%			10.1%								
7P	Utrps	9	0	6	0	0	15								
	Ubrds	193	0	129	0	0	322								
	Rrsps	22	0	21	0	0	43								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.6%		8.2%			9.8%								
7W	Utrps	16	0	16	0	0	32								
	Ubrds	343	0	343	0	0	686								
	Rrsps	23	0	23	0	0	46								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.9%		8.9%			10.4%								
7X	Utrps	8	0	10	0	0	18								
	Ubrds	172	0	214	0	0	386								
	Rrsps	22	0	22	0	0	44								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.5%		8.7%			10.0%								

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level =	68%
Route/Period Accuracy =	10%
Weekday Usable Survey Rate =	45%
Weekend Usable Survey Rate =	25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
8S	Utrps	6	0	5	0	0	11								
	Ubrds	119	0	99	0	0	218								
	Rrsps	21	0	20	0	0	41								
	Strps	3	0	3	0	0	6								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.5%		8.2%			9.8%								
8W	Utrps	6	0	7	0	0	13								
	Ubrds	119	0	139	0	0	258								
	Rrsps	21	0	21	0	0	42								
	Strps	3	0	3	0	0	6								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.5%		8.7%			10.0%								
8X	Utrps	7	0	7	0	0	14								
	Ubrds	139	0	139	0	0	278								
	Rrsps	21	0	21	0	0	42								
	Strps	3	0	3	0	0	6								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.7%		8.7%			10.1%								
8Z	Utrps	14	0	14	1	0	29								
	Ubrds	278	0	278	20	0	576								
	Rrsps	23	0	23	11	0	57								
	Strps	3	0	3	1	0	7								
	Ersps	27	0	27	9	0	63								
	Accuracy	9.2%		9.2%	12.7%		9.8%								
9A	Utrps	17	21	16	11	15	80	32	32	12	76	16	16	9	41
	Ubrds	815	808	767	423	577	3390	1321	1321	495	3137	645	645	363	1653
	Rrsps	24	24	24	24	24	120	25	25	24	74	24	24	23	71
	Strps	2	2	2	2	2	10	3	3	3	9	3	3	3	9
	Ersps	43	35	43	35	35	191	31	31	31	93	30	30	30	90
	Accuracy	7.4%	8.3%	7.4%	8.1%	8.2%	5.8%	8.9%	8.9%	8.7%	8.4%	8.9%	8.9%	8.8%	8.5%
9E	Utrps	5	0	6	0	0	11								
	Ubrds	240	0	288	0	0	528								
	Rrsps	23	0	23	0	0	46								
	Strps	2	0	2	0	0	4								
	Ersps	43	0	43	0	0	86								
	Accuracy	6.9%		7.0%			8.1%								
10A	Utrps	17	21	17	9	8	72	30	27	9	66	15	16	3	34
	Ubrds	530	463	530	198	176	1897	671	604	201	1476	326	347	65	738
	Rrsps	24	24	24	22	22	116	24	24	22	70	23	23	18	64
	Strps	2	3	2	3	3	13	5	5	4	14	5	5	3	13
	Ersps	28	30	28	30	30	146	28	28	22	78	27	27	16	70
	Accuracy	9.2%	8.8%	9.2%	8.4%	8.3%	6.6%	9.3%	9.2%	10.1%	9.1%	9.2%	9.3%	10.9%	9.4%
10E	Utrps	8	0	8	0	0	16								
	Ubrds	249	0	249	0	0	498								
	Rrsps	23	0	23	0	0	46								
	Strps	2	0	2	0	0	4								
	Ersps	28	0	28	0	0	56								
	Accuracy	8.9%		8.9%			10.4%								

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level =	68%
Route/Period Accuracy =	10%
Weekday Usable Survey Rate =	45%
Weekend Usable Survey Rate =	25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
10B	Utrps	6	9	3	5	4	27	18	14	7	39	16	16	3	35
	Ubrds	384	371	192	206	165	1318	700	545	272	1517	677	677	127	1481
	Rrsps	24	23	22	22	22	113	24	24	23	71	24	24	21	69
	Strps	1	2	1	2	2	8	3	3	3	9	3	3	2	8
	Ersps	29	37	29	37	37	169	29	29	29	87	32	32	21	85
	Accuracy	8.9%	7.8%	6.6%	7.5%	7.3%	5.9%	9.1%	9.0%	8.8%	8.6%	8.6%	8.6%	10.0%	8.7%
10C	Utrps	13	12	13	6	2	46								
	Ubrds	832	495	832	247	82	2488								
	Rrsps	24	24	24	23	19	114								
	Strps	1	2	1	2	2	8								
	Ersps	29	37	29	37	37	169								
	Accuracy	9.1%	7.9%	9.1%	7.6%	6.1%	6.1%								
10D	Utrps							14	12	0	26				
	Ubrds							545	467	0	1012				
	Rrsps							24	24	0	48				
	Strps							3	3	0	6				
	Ersps							29	29	0	58				
	Accuracy							9.0%	9.0%		10.5%				
11P	Utrps	8	0	8	0	0	16								
	Ubrds	27	0	27	0	0	54								
	Rrsps	13	0	13	0	0	26								
	Strps	8	0	8	0	0	16								
	Ersps	12	0	12	0	0	24								
	Accuracy	11.0%		11.0%			12.7%								
11Y	Utrps	3	0	3	0	0	6								
	Ubrds	91	0	91	0	0	182								
	Rrsps	20	0	20	0	0	40								
	Strps	2	0	2	0	0	4								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.1%		8.1%			9.4%								
12C	Utrps	4	0	5	1	1	11								
	Ubrds	84	0	104	21	21	230								
	Rrsps	19	0	20	12	12	63								
	Strps	3	0	3	1	1	8								
	Ersps	28	0	28	9	9	74								
	Accuracy	7.8%		8.1%	12.9%	12.9%	7.9%								
12D	Utrps	3	0	4	0	0	7								
	Ubrds	63	0	84	0	0	147								
	Rrsps	18	0	19	0	0	37								
	Strps	2	0	3	0	0	5								
	Ersps	19	0	28	0	0	47								
	Accuracy	9.7%		7.8%			10.0%								
12E	Utrps	5	0	5	0	0	10								
	Ubrds	106	0	106	0	0	212								
	Rrsps	20	0	20	0	0	40								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.0%		8.0%			9.3%								

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level =	68%
Route/Period Accuracy =	10%
Weekday Usable Survey Rate =	45%
Weekend Usable Survey Rate =	25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
12F	Utrps	3	0	3	1	0	7								
	Ubrds	64	0	64	21	0	149								
	Rrsps	18	0	18	12	0	48								
	Strps	2	0	2	1	0	5								
	Ersps	19	0	19	9	0	47								
	Accuracy	9.7%		9.7%	12.9%		10.0%								
12L	Utrps	5	0	7	0	0	12								
	Ubrds	122	0	171	0	0	293								
	Rrsps	21	0	22	0	0	43								
	Strps	2	0	3	0	0	5								
	Ersps	22	0	33	0	0	55								
	Accuracy	9.7%		7.8%			10.0%								
12M	Utrps	3	0	4	0	0	7								
	Ubrds	73	0	98	0	0	171								
	Rrsps	19	0	20	0	0	39								
	Strps	2	0	2	0	0	4								
	Ersps	22	0	22	0	0	44								
	Accuracy	9.0%		9.4%			10.7%								
12R	Utrps	3	0	3	0	0	6								
	Ubrds	38	0	38	0	0	76								
	Rrsps	15	0	15	0	0	30								
	Strps	3	0	3	0	0	6								
	Ersps	17	0	17	0	0	34								
	Accuracy	9.1%		9.1%			10.6%								
12S	Utrps	7	0	7	0	0	14								
	Ubrds	89	0	89	0	0	178								
	Rrsps	20	0	20	0	0	40								
	Strps	4	0	4	0	0	8								
	Ersps	23	0	23	0	0	46								
	Accuracy	9.0%		9.0%			10.5%								
13A	Utrps	16	0	10	3	5	34	6	8	3	17	6	8	3	17
	Ubrds	284	0	178	24	41	527	43	57	21	121	49	66	25	140
	Rrsps	23	0	22	13	16	74	16	18	12	46	17	18	13	48
	Strps	3	0	3	3	5	14	6	8	3	17	6	8	3	17
	Ersps	24	0	24	11	18	77	11	14	5	30	12	17	6	35
	Accuracy	9.8%		9.5%	11.3%	8.9%	8.7%	13.2%	11.7%	20.0%	13.1%	12.7%	10.5%	18.2%	12.1%
13B	Utrps	12	1	14	0	0	27	4	4	0	8				
	Ubrds	213	8	249	0	0	470	29	29	0	58				
	Rrsps	22	6	23	0	0	51	14	14	0	28				
	Strps	3	1	3	0	0	7	4	4	0	8				
	Ersps	24	4	24	0	0	52	7	7	0	14				
	Accuracy	9.6%	18.9%	9.7%			10.8%	16.8%	16.8%		19.4%				
13F	Utrps							3	0	1	4	3	0	0	3
	Ubrds							21	0	7	28	25	0	0	25
	Rrsps							12	0	6	18	13	0	0	13
	Strps							3	0	1	4	3	0	0	3
	Ersps							5	0	2	7	6	0	0	6
	Accuracy							20.0%		32.3%	27.5%	18.2%			30.0%

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level = 68%
Route/Period Accuracy = 10%
Weekday Usable Survey Rate = 45%
Weekend Usable Survey Rate = 25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
13G	Utrps							4	0	1	5	3	0	1	4
	Ubrds							29	0	7	36	25	0	8	33
	Rrsps							14	0	6	20	13	0	6	19
	Strps							4	0	1	5	3	0	1	4
	Ersps							7	0	2	9	6	0	2	8
	Accuracy							16.8%		32.3%	24.2%	18.2%		32.7%	25.8%
13M	Utrps	0	10	0	0	0	10								
	Ubrds	0	81	0	0	0	81								
	Rrsps	0	19	0	0	0	19								
	Strps	0	6	0	0	0	6								
	Ersps	0	22	0	0	0	22								
	Accuracy		9.2%				15.1%								
15K	Utrps	7	0	12	1	0	20								
	Ubrds	109	0	187	16	0	312								
	Rrsps	20	0	22	10	0	52								
	Strps	3	0	4	1	0	8								
	Ersps	21	0	28	7	0	56								
	Accuracy	9.8%		8.7%	14.6%		10.0%								
15L	Utrps	5	0	0	0	0	5								
	Ubrds	78	0	0	0	0	78								
	Rrsps	19	0	0	0	0	19								
	Strps	3	0	0	0	0	3								
	Ersps	21	0	0	0	0	21								
	Accuracy	9.4%					15.5%								
16A	Utrps	8	12	7	2	0	29								
	Ubrds	291	422	254	70	0	1037								
	Rrsps	23	24	23	19	0	89								
	Strps	2	2	2	2	0	8								
	Ersps	33	32	33	32	0	130								
	Accuracy	8.2%	8.5%	8.1%	6.6%		6.8%								
16B	Utrps	9	0	0	1	9	19	2	3	5	10	0	2	5	7
	Ubrds	327	0	0	35	317	679	75	112	186	373	0	71	177	248
	Rrsps	23	0	0	15	23	61	19	21	22	62	0	19	22	41
	Strps	2	0	0	1	2	5	2	3	3	8	0	2	3	5
	Ersps	33	0	0	16	32	81	19	28	28	75	0	18	27	45
	Accuracy	8.3%			9.3%	8.4%	8.6%	10.0%	8.2%	8.7%	8.5%		10.3%	8.9%	11.1%
16C	Utrps	7	11	9	6	5	38	23	22	6	51	15	16	6	37
	Ubrds	254	387	327	211	176	1355	858	820	224	1902	530	565	212	1307
	Rrsps	23	24	23	22	22	114	24	24	23	71	24	24	22	70
	Strps	2	2	2	2	2	10	3	3	3	9	3	3	3	9
	Ersps	33	32	33	32	32	162	28	28	28	84	27	26	27	80
	Accuracy	8.1%	8.5%	8.3%	8.2%	8.0%	6.1%	9.3%	9.3%	8.9%	8.8%	9.4%	9.6%	9.0%	8.9%
16D	Utrps	8	10	9	1	0	28								
	Ubrds	291	352	327	35	0	1005								
	Rrsps	23	23	23	15	0	84								
	Strps	2	2	2	1	0	7								
	Ersps	33	32	33	16	0	114								
	Accuracy	8.2%	8.4%	8.3%	9.3%		7.3%								

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level = 68%
Route/Period Accuracy = 10%
Weekday Usable Survey Rate = 45%
Weekend Usable Survey Rate = 25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
16E	Utrps	0	0	0	3	0	3	22	20	1	43	15	14	0	29
	Ubrds	0	0	0	106	0	106	820	746	37	1603	530	494	0	1024
	Rrsps	0	0	0	20	0	20	24	24	15	63	24	24	0	48
	Strps	0	0	0	2	0	2	3	3	1	7	3	3	0	6
	Ersps	0	0	0	32	0	32	28	28	9	65	27	26	0	53
	Accuracy				7.4%		12.2%	9.3%	9.3%	14.7%	10.0%	9.4%	9.6%		11.0%
16F	Utrps	12	0	11	0	0	23								
	Ubrds	436	0	399	0	0	835								
	Rrsps	24	0	24	0	0	48								
	Strps	2	0	2	0	0	4								
	Ersps	33	0	33	0	0	66								
	Accuracy	8.4%		8.3%			9.8%								
16G	Utrps	6	0	5	0	0	11								
	Ubrds	218	0	182	0	0	400								
	Rrsps	23	0	22	0	0	45								
	Strps	2	0	2	0	0	4								
	Ersps	33	0	33	0	0	66								
	Accuracy	8.0%		7.9%			9.3%								
16J	Utrps	11	11	13	2	0	37								
	Ubrds	399	387	472	70	0	1328								
	Rrsps	24	24	24	19	0	91								
	Strps	2	2	2	2	0	8								
	Ersps	33	32	33	32	0	130								
	Accuracy	8.3%	8.5%	8.4%	6.6%		6.9%								
16S	Utrps	5	0	5	0	0	10								
	Ubrds	107	0	107	0	0	214								
	Rrsps	20	0	20	0	0	40								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.0%		8.0%			9.3%								
16U	Utrps	7	0	7	0	0	14								
	Ubrds	149	0	149	0	0	298								
	Rrsps	22	0	22	0	0	44								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.4%		8.4%			9.7%								
16W	Utrps	11	0	12	3	0	26								
	Ubrds	235	0	256	64	0	555								
	Rrsps	23	0	23	18	0	64								
	Strps	3	0	3	2	0	8								
	Ersps	29	0	29	19	0	77								
	Accuracy	8.7%		8.8%	9.7%		8.7%								
16X	Utrps	7	0	8	0	0	15								
	Ubrds	149	0	171	0	0	320								
	Rrsps	22	0	22	0	0	44								
	Strps	3	0	3	0	0	6								
	Ersps	29	0	29	0	0	58								
	Accuracy	8.4%		8.5%			9.8%								

Virginia MetroBus Service On-Board Survey Sampling Plan
Bus Trips Scheduled by Route and Start Time Period (Utrps)
Estimated Boardings by Route and Start Time Period (Ubrds)
Required Responses by Route and Start Time Period (Rrsps)
Bus Trips to Survey by Route and Start Time Period (Strps)
Estimated Responses by Route and Start Time Period (Ersps)
Accuracy Projected (Accuracy)

Route/Period Confidence Level =	68%
Route/Period Accuracy =	10%
Weekday Usable Survey Rate =	45%
Weekend Usable Survey Rate =	25%

		Weekday						Saturday				Sunday			
		AM	MD	PM	EV	NT	Daily	MO	EV	NT	Daily	MO	EV	NT	Daily
Route	Statistic	5:30A-9:30A	9:31A-2:59P	3:00P-7:00P	7:01P-10:00P	10:01P-5:29A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A		6:00A-1:59P	2:00P-9:59P	10:00P-5:59A	
17A	Utrps	5	1	4	4	1	15								
	Ubrds	49	10	40	40	10	149								
	Rrsps	17	7	16	16	7	63								
	Strps	4	1	4	4	1	14								
	Ersps	18	5	18	18	5	64								
	Accuracy	9.5%	16.7%	8.9%	8.9%	16.7%	7.8%								
17B	Utrps	2	1	1	2	0	6								
	Ubrds	20	10	10	20	0	60								
	Rrsps	11	7	7	11	0	36								
	Strps	2	1	1	2	0	6								
	Ersps	9	5	5	9	0	28								
	Accuracy	12.7%	16.7%	16.7%	12.7%		11.5%								
17F	Utrps	6	0	5	0	0	11								
	Ubrds	59	0	49	0	0	108								
	Rrsps	18	0	17	0	0	35								
	Strps	5	0	4	0	0	9								
	Ersps	22	0	18	0	0	40								
	Accuracy	8.5%		9.5%			10.4%								
17M	Utrps	6	0	8	0	0	14								
	Ubrds	59	0	79	0	0	138								
	Rrsps	18	0	19	0	0	37								
	Strps	5	0	5	0	0	10								
	Ersps	22	0	22	0	0	44								
	Accuracy	8.5%		9.1%			10.3%								
17G	Utrps	6	0	10	0	0	16								
	Ubrds	119	0	198	0	0	317								
	Rrsps	21	0	22	0	0	43								
	Strps	3	0	3	0	0	6								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.5%		9.0%			10.2%								
17H	Utrps	8	0	8	0	1	17								
	Ubrds	158	0	158	0	20	336								
	Rrsps	22	0	22	0	11	55								
	Strps	3	0	3	0	1	7								
	Ersps	27	0	27	0	9	63								
	Accuracy	8.8%		8.8%		12.7%	9.4%								
17K	Utrps	5	0	8	0	0	13								
	Ubrds	99	0	158	0	0	257								
	Rrsps	20	0	22	0	0	42								
	Strps	3	0	3	0	0	6								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.2%		8.8%			10.0%								
17L	Utrps	5	0	6	0	0	11								
	Ubrds	99	0	119	0	0	218								
	Rrsps	20	0	21	0	0	41								
	Strps	3	0	3	0	0	6								
	Ersps	27	0	27	0	0	54								
	Accuracy	8.2%		8.5%			9.8%								