# Memorandum

Date: April 28, 2014

From: AECOM

To: Charlotte Area Transit System

Re: CATS 2013 Transit Survey Expansion Methodology

## Introduction

This document details the process used to expand the 2013 CATS rail and bus survey data using the on-to-off survey sample and Automatic Passenger Count (APC) data. The transit survey consisted of three separate datasets, including an On-to-Off survey, Full survey, and park-and-ride (PNR) counts. The On-to-Off survey was conducted in March of 2013, and had a goal of at least 20% of riders on each route. The Full survey was conducted in the spring and fall of 2013, with a goal response rate of approximately 10% of system ridership. Both surveys were system-wide, including rail, bus, and trolley. Detailed information about the survey sampling plan and survey instrument is provided in the RSG/ETC’s report.

The full survey is a questionnaire intended to capture the characteristics of travel, including route, direction, time, origin, and destination, as well as access/egress modes, trip purpose, and other respondent demographics. The On-to-Off survey collects fewer data at a higher sampling rate, including route, boarding and alighting locations and time, for use in determining the boarding to alighting flows. The PNR data was collected at each PNR lot and included the entries and exits by time of both vehicles and vehicle occupancy.

The final piece of data used in the survey expansion were APC data collected in October of 2013, to develop control totals for station/stop segment boardings and alightings.

The survey expansion process was done separately for the rail records and the bus records. The process for rail and bus survey expansion was slightly different due to -- (1) fewer and farther apart stops on the rail line versus the bus line which allowed for computing flows for rail at stop level; (2) to allow for adjusting the expansion factors for rail to take into account the PNR counts at the rail stations.

## Developing Expansion Factors for Rail Survey Records

### Creating Control Totals

The first step of the survey expansion process was to develop control totals based on APC data (boardings and alightings by station and direction, summed up to the two time periods, peak and off-peak). Peak is defined as opening to 9:30 am and 3:31 pm to 6:30 pm. Off-peak is the remainder of the day. The available APC data included boardings and alightings by direction for each station for each day in October 2013. The weekday boardings and alightings were summed up for each time period (peak and off-peak), and divided by 23 (number of weekdays) to get the average weekday boardings and alightings by direction and time period. Because these are averages, the boardings and alightings do not match, which can cause issues later on in the iterative proportional fitting (IPF) procedure, so they must be balanced. This was done by holding the boardings constant at the average calculated values and scaling the alightings by time period (i.e., average peak alightings at station \* total peak boardings / total peak alightings). The APC data were also adjusted to remove illogical counts at the two end stations (for example, having counts for riders boarding at the 7th Street station in the inbound direction or alighting at I-485 station in the inbound direction). A summary of the final control totals by time of day is shown in Table 1 below.

Table : Rail Survey Expansion Control Totals Developed from APC Data

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Station** | **Boardings** | | | | **Alightings** | | | |
| Peak | | Off-Peak | | Peak | | Peak | |
| Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound |
| 7th St Station | - | 493 | - | 413 | 415 | - | 251 | - |
| CTC Station | 198 | 1,787 | 214 | 1,602 | 2,273 | 41 | 1,665 | 41 |
| 3rd/Convention Center Station | 46 | 712 | 21 | 327 | 1,228 | 15 | 459 | 17 |
| Stonewall Station | 40 | 198 | 15 | 101 | 294 | 23 | 62 | 21 |
| Carson Station | 113 | 39 | 100 | 41 | 49 | 88 | 35 | 91 |
| Bland Station | 159 | 44 | 132 | 62 | 57 | 118 | 52 | 125 |
| East/ West Station | 220 | 144 | 184 | 185 | 155 | 159 | 163 | 180 |
| New Bern Station | 197 | 97 | 161 | 112 | 113 | 155 | 108 | 183 |
| Scaleybark Station | 370 | 168 | 260 | 140 | 133 | 241 | 169 | 240 |
| Woodlawn Station | 283 | 81 | 239 | 113 | 91 | 266 | 101 | 261 |
| Tyvola Station | 424 | 111 | 282 | 111 | 100 | 369 | 103 | 312 |
| Archdale Station | 314 | 97 | 262 | 115 | 96 | 261 | 124 | 286 |
| Arrowood Station | 578 | 114 | 554 | 97 | 97 | 566 | 107 | 598 |
| Sharon Rd West Station | 720 | 43 | 389 | 34 | 41 | 577 | 38 | 432 |
| I-485 Station | 1,482 | - | 626 | - | - | 1,249 | - | 666 |
| **Total** | **5,145** | **4,129** | **3,439** | **3,453** | **5,145** | **4,129** | **3,439** | **3,453** |

### Developing Station to Station Flows

Using the control totals previously developed and the on-to-off survey sample, the next step was to create the station to station flows by direction and time of day. This was done with IPF, using the on-to-off survey sample as the seed matrix and factoring it up to match the boardings and alightings from the APC data. For a few station to station pairs, there existed full survey data but no on-to-off survey records, so the number of full survey records was used in the seed matrix, to maintain a more accurate geographic distribution of the seed matrix. The closure criteria used for this method was within +/- 1%, which was accomplished in five iterations. Table 2 and Table 3 show the station to station flows by time period and direction created from the IPF process.

Table : Peak Station to Station Flows

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 7th St | CTC | 3rd/ Convention Center | Stonewall | Carson | Bland | East/ West | New Bern | Scaleybark | Woodlawn | Tyvola | Archdale | Arrowood | Sharon Rd West | I-485 | **Total** |
| 7th St |  | 41 | 4 | 7 | 9 | 19 | 25 | 25 | 11 | 32 | 60 | 25 | 35 | 72 | 127 | **493** |
| CTC | 196 |  | 11 | 16 | 45 | 66 | 112 | 68 | 143 | 140 | 149 | 123 | 306 | 210 | 397 | **1,983** |
| 3rd/ Convention Center | 8 | 38 |  | - | 31 | 27 | 17 | 32 | 38 | 42 | 55 | 30 | 41 | 91 | 308 | **758** |
| Stonewall | - | 40 | - |  | 4 | 6 | 6 | 9 | 23 | 6 | 16 | 9 | 15 | 33 | 69 | **237** |
| Carson | 10 | 84 | 20 | - |  | - | - | 8 | 5 | - | 7 | 3 | 7 | 4 | 6 | **153** |
| Bland | 5 | 96 | 49 | 4 | 5 |  | - | 3 | 4 | 6 | 3 | 3 | 3 | 10 | 12 | **203** |
| East/ West | 15 | 98 | 89 | 15 | - | 3 |  | 9 | 7 | 13 | 19 | 5 | 47 | 20 | 24 | **364** |
| New Bern | 6 | 122 | 48 | 3 | 7 | 4 | 6 |  | 9 | 10 | 16 | 10 | 6 | 22 | 25 | **295** |
| Scaleybark | 12 | 182 | 88 | 21 | 3 | 4 | 27 | 34 |  | 17 | 39 | 29 | 32 | 27 | 24 | **539** |
| Woodlawn | 13 | 184 | 46 | 9 | - | 3 | 9 | 13 | 6 |  | 4 | 13 | 20 | 20 | 25 | **364** |
| Tyvola | 24 | 203 | 84 | 31 | 7 | 2 | 27 | 4 | 21 | 22 |  | 11 | 31 | 18 | 52 | **535** |
| Archdale | 15 | 157 | 42 | 18 | 10 | 2 | 12 | 4 | 8 | 13 | 34 |  | 23 | 26 | 47 | **412** |
| Arrowood | 12 | 271 | 84 | 14 | 3 | 16 | 31 | 20 | 35 | 32 | 21 | 39 |  | 24 | 90 | **693** |
| Sharon Rd West | 20 | 356 | 134 | 51 | 3 | 11 | 25 | 22 | 13 | 9 | 30 | 19 | 27 |  | 43 | **763** |
| I-485 | 79 | 442 | 545 | 127 | 12 | 12 | 19 | 16 | 50 | 16 | 16 | 38 | 70 | 41 |  | **1,483** |
| **Total** | **415** | **2,314** | **1,244** | **317** | **138** | **175** | **315** | **269** | **374** | **357** | **469** | **357** | **663** | **618** | **1,249** | **9,273** |

Table : Off-Peak Station to Station Flows

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 7th St | CTC | 3rd/ Convention Center | Stonewall | Carson | Bland | East/ West | New Bern | Scaleybark | Woodlawn | Tyvola | Archdale | Arrowood | Sharon Rd West | I-485 | **Total** |
| 7th St |  | 41 | - | - | 15 | 24 | 16 | 42 | 31 | 18 | 39 | 22 | 52 | 26 | 88 | **413** |
| CTC | 193 |  | 17 | 21 | 44 | 66 | 130 | 110 | 113 | 149 | 153 | 118 | 303 | 196 | 183 | **1,795** |
| 3rd/ Convention Center | 1 | 20 |  | - | 32 | 27 | 21 | 10 | 48 | 25 | 25 | 8 | 29 | 39 | 63 | **348** |
| Stonewall | 2 | 6 | 8 |  | - | - | 4 | 7 | 14 | 4 | 15 | 3 | 7 | 15 | 32 | **116** |
| Carson | 3 | 76 | 19 | 3 |  | 8 | 3 | 8 | - | 2 | - | 4 | 7 | 3 | 6 | **142** |
| Bland | 6 | 72 | 48 | 5 | - |  | 7 | - | 6 | 3 | 9 | 14 | 12 | 8 | 4 | **194** |
| East/ West | 5 | 128 | 36 | 2 | 11 | 4 |  | 7 | 18 | 34 | 23 | 11 | 29 | 15 | 48 | **371** |
| New Bern | 3 | 98 | 18 | 17 | 3 | 4 | 19 |  | 9 | 5 | 15 | 31 | 14 | 16 | 23 | **274** |
| Scaleybark | 6 | 133 | 71 | 2 | 3 | 7 | 26 | 14 |  | 22 | 14 | 20 | 37 | 16 | 30 | **401** |
| Woodlawn | 5 | 129 | 39 | 4 | 7 | 12 | 9 | 12 | 23 |  | 18 | 27 | 25 | 10 | 33 | **353** |
| Tyvola | 3 | 169 | 27 | 3 | - | 4 | 9 | 25 | 23 | 21 |  | 28 | 34 | 15 | 34 | **395** |
| Archdale | 3 | 146 | 11 | 2 | 2 | 6 | 23 | 17 | 9 | 12 | 32 |  | 48 | 33 | 33 | **378** |
| Arrowood | 4 | 261 | 53 | 8 | 2 | 3 | 35 | 28 | 60 | 30 | 22 | 51 |  | 40 | 56 | **655** |
| Sharon Rd West | 3 | 203 | 37 | 2 | 4 | 6 | 9 | 9 | 13 | 12 | 15 | 24 | 55 |  | 34 | **426** |
| I-485 | 15 | 224 | 93 | 13 | 4 | 7 | 32 | 2 | 41 | 27 | 33 | 49 | 52 | 38 |  | **630** |
| **Total** | **251** | **1,707** | **476** | **83** | **126** | **177** | **343** | **292** | **410** | **363** | **415** | **410** | **705** | **469** | **666** | **6,893** |

### Creating Initial Expansion Factors

Once the flows were calculated using the IPF procedure, the initial expansion factors for the full survey were calculated. Since the sampling rate for the full survey were not as high as the on-to-off survey, not every station-to-station pair by time of day and direction was represented in the full survey dataset, and therefore the stations had to be combined into segments. The segments contain one to three stations each, with the definitions of each shown in Table 4.

Table : Station Segment Definitions

|  |  |
| --- | --- |
| **Station** | **Segment** |
| 7th St Station | Inner East Stations |
| CTC Station | Inner East Stations |
| 3rd/ Convention Center Station | Inner West Stations |
| Stonewall Station | Inner West Stations |
| Carson Station | Inner West Stations |
| Bland Station | Middle Stations |
| East/ West Station | Middle Stations |
| New Bern Station | Middle Stations |
| Scaleybark Station | East PNR Stations |
| Woodlawn Station | East PNR Stations |
| Tyvola Station | Mid PNR Stations |
| Archdale Station | Mid PNR Stations |
| Arrowood Station | West PNR Stations |
| Sharon Rd West Station | West PNR Stations |
| I-485 Station | I-485 Station |

After cleaning the full survey dataset to remove incomplete records, the dataset contained 2,037 records, which is approximately 14% of the average daily ridership. The number of survey records boarding and alighting at each station is shown in Table 5.

Table : Summary of Full Survey records by Boarding and Alighting Station

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Station** | **Boardings** | | | | **Alightings** | | | |
| Peak | | Off-Peak | | Peak | | Peak | |
| Inbound | Outbound | Inbound | Outbound | Inbound | Outbound | Inbound | Outbound |
| 7th St Station | - | 56 | - | 49 | 44 | - | 42 | - |
| CTC Station | 9 | 214 | 8 | 309 | 339 | 7 | 366 | 5 |
| 3rd/ Convention Center Station | 2 | 83 | 3 | 56 | 110 | 5 | 21 | - |
| Stonewall Station | 2 | 24 | 3 | 17 | 26 | 2 | 9 | 1 |
| Carson Station | 10 | 4 | 8 | 5 | 3 | 4 | 1 | 8 |
| Bland Station | 16 | 4 | 20 | 2 | 6 | 8 | 3 | 10 |
| East/ West Station | 20 | 17 | 23 | 14 | 4 | 15 | 13 | 32 |
| New Bern Station | 13 | 7 | 13 | 10 | 3 | 9 | 5 | 11 |
| Scaleybark Station | 42 | 16 | 36 | 14 | 10 | 32 | 14 | 21 |
| Woodlawn Station | 34 | 6 | 28 | 8 | 3 | 26 | 4 | 48 |
| Tyvola Station | 48 | 9 | 36 | 9 | 2 | 42 | 5 | 54 |
| Archdale Station | 39 | 8 | 46 | 9 | 11 | 29 | 8 | 50 |
| Arrowood Station | 62 | 5 | 87 | 3 | 3 | 76 | 8 | 66 |
| Sharon Rd West Station | 82 | 6 | 73 | 5 | 1 | 66 | 4 | 65 |
| I-485 Station | 186 | - | 119 | - | - | 137 | - | 139 |
| **Total** | **565** | **459** | **503** | **510** | **565** | **459** | **503** | **510** |

The full survey records and the estimated flows from the IPF procedure were both summed up at the station segment to station segment level by time of day. The initial expansion factors were calculated as the number of estimated flows divided by the number of full survey records.

### Adjusting Station to Station Flows for PNR Counts

The initial station to station flows do not take into account the PNR counts available for each of the stations with a PNR lot (I-485, Sharon Rd West, Arrowood, Archdale, Tyvola, Woodlawn, and Scaleybark). The PNR counts include auto occupancy, so the number of riders by PNR access/egress can be calculated for each of the stations. Table 6 shows the PNR entry and exit control totals by station (both vehicles and riders).

Table : Rail PNR control totals

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **Entries** | | **Exits** | |
| **Station** | **Time of Day** | Riders | Vehicles | Riders | Vehicles |
| Archdale Station | PK | 30 | 27 | 20 | 18 |
| Arrowood Station | PK | 163 | 132 | 138 | 119 |
| I-485 Station | PK | 1,170 | 1,155 | 775 | 763 |
| Scaleybark Station | PK | 165 | 155 | 141 | 133 |
| Sharon Rd West Station | PK | 310 | 181 | 295 | 144 |
| Tyvola Station | PK | 197 | 186 | 140 | 134 |
| Woodlawn Station | PK | 135 | 125 | 94 | 83 |
| Archdale Station | OP | 0 | 0 | 10 | 10 |
| Arrowood Station | OP | 94 | 68 | 105 | 81 |
| I-485 Station | OP | 72 | 61 | 460 | 453 |
| Scaleybark Station | OP | 59 | 57 | 87 | 79 |
| Sharon Rd West Station | OP | 90 | 67 | 106 | 104 |
| Tyvola Station | OP | 84 | 60 | 131 | 112 |
| Woodlawn Station | OP | 70 | 52 | 106 | 94 |
| **TOTAL** | **DAILY** | **2,639** | **2,326** | **2,608** | **2,327** |

The PNR Entry Factor is an additional factor which is multiplied within the initial expansion factor, for all PNR access survey records. It is calculated using the following formula:

To make sure the total entries still matches the counts, the non-PNR surveys also need to be adjusted. This is calculated similarly to the PNR factor, using the formula below:

The PNR egress survey records are similarly factored using the PNR person exit counts. Because the PNR counts are compared to average weekday counts, there are some discrepancies on the total number of entries at each station with the PNR entry and exit factors. Therefore, a final adjustment of projected boardings divided by the actual boardings is applied, in order to get the overall expansion weight. Table 7 shows the results of applying all expansion factors to the survey records (initial, PNR and Non-PNR, and final boarding adjustment). There are a small number of large weights, but 77% of records have a weight of 10 or less.

Table : Distribution of Final Rail Expansion Weights

|  |  |  |
| --- | --- | --- |
| **Expansion Factor** | **Survey Records** | **% of Survey Records** |
| 1 to 2.5 | 60 | 2.9% |
| 2.6 to 5 | 592 | 29.1% |
| 5.1 to 10 | 916 | 45.0% |
| 10.1 to 15 | 303 | 14.9% |
| 15.1 to 20 | 77 | 3.8% |
| 20.1 to 25 | 39 | 1.9% |
| 25.1 to 30 | 22 | 1.1% |
| 30.1 to 35 | 17 | 0.8% |
| 35.1 to 50 | 6 | 0.3% |
| 50.1 to 90 | 5 | 0.2% |

Table 8 and Table 9 detail the expansion factors by station segment pair, direction, and time of day. These will vary slightly for records at the PNR stations, but represent the average expansion factor.

Table : Rail Peak Expansion Factors by Boarding to Alighting Segment

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Inner East Stations | Inner West Stations | Middle Stations | East PNR Stations | Mid PNR Stations | West PNR Stations | I-485 Station |
| Inner East Stations | 15.8 | 8.4 | 12.6 | 8.6 | 8.1 | 7.3 | 8.6 |
| Inner West Stations | 12.8 |  | 15.0 | 7.1 | 10.1 | 7.9 | 7.4 |
| Middle Stations | 9.0 | 20.1 | 26.0 | 16.2 | 7.9 | 10.7 | 8.7 |
| East PNR Stations | 7.1 | 9.3 | 44.6 | 23.0 | 12.2 | 8.2 | 16.3 |
| Mid PNR Stations | 6.1 | 11.9 | 10.3 | 63.1 | 44.7 | 8.2 | 24.8 |
| West PNR Stations | 6.3 | 12.0 | 41.6 | 14.8 | 15.5 |  | 13.3 |
| I-485 Station | 5.3 | 9.8 | 23.5 | 11.0 | 9.0 | 36.9 |  |

Table : Rail Off-Peak Expansion Factors by Boarding to Alighting Segment

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Inner East Stations | Inner West Stations | Middle Stations | East PNR Stations | Mid PNR Stations | West PNR Stations | I-485 Station |
| Inner East Stations | 19.5 | 10.8 | 9.0 | 6.3 | 4.5 | 5.6 | 3.6 |
| Inner West Stations | 8.3 |  | 9.7 | 5.8 | 4.7 | 11.1 | 3.1 |
| Middle Stations | 6.2 | 23.5 | 19.7 | 37.6 | 20.5 | 11.8 | 8.3 |
| East PNR Stations | 4.8 | 20.9 | 80.7 | 15.0 | 7.9 | 29.5 | 10.5 |
| Mid PNR Stations | 4.5 | 14.8 | 85.2 | 12.9 | 15.1 | 16.3 | 9.6 |
| West PNR Stations | 3.8 | 15.2 | 7.5 | 19.1 | 16.1 | 31.9 | 11.3 |
| I-485 Station | 2.8 | 12.2 | 6.9 | 11.4 | 16.4 | 10.0 |  |

## Developing Expansion Factors for Bus Survey Records

The bus survey records were expanded using a similar method to the rail records, with a few differences, primarily dealing with the amount of segmentation required, due to the scarceness of stop to stop records, and also not incorporating PNR counts.

### Creating Control Totals

The first step of the survey expansion process was to develop control totals based on APC data (boardings and alightings by stop segment and direction, summed up to the two time periods, peak and off-peak). The available APC data included boardings and alightings by direction for each stop for each day in October 2013. The weekday boardings and alightings were summed up for each time period (peak and off-peak), and divided by 23 (number of weekdays in October 2013) to get the average weekday boardings and alightings by direction and time period. Whereas the rail data contained enough information to perform the IPF procedure at the station to station level, bus routes contain too many stops to adequately determine flows at the stop level. The bus stops were aggregated into stop segments in order to allow for some disaggregation, while maintaining adequate coverage with the survey records. The number of segments range from one to six, depending on the route ridership. Table 11 details the weekday ridership, on to off survey records, full survey records, and number of segments for each route by direction and time period.

Table : Characterization of Bus Routes

|  |  | **Ridership** | | **On to Off Survey** | | **Full Survey** | | **Number of Segments** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Route** | **Direction** | Peak | Off-Peak | Peak | Off-Peak | Peak | Off-Peak |
| 1 | IB | 367 | 251 | 118 | 140 | 33 | 33 | 4 |
| 1 | OB | 357 | 384 | 152 | 174 | 34 | 36 | 4 |
| 2 | IB | 139 | 146 | 120 | 137 | 16 | 29 | 1 |
| 2 | OB | 168 | 207 | 93 | 133 | 25 | 38 | 1 |
| 3 | IB | 472 | 366 | 136 | 108 | 35 | 36 | 4 |
| 3 | OB | 383 | 492 | 119 | 164 | 43 | 48 | 4 |
| 4 | IB | 130 | 114 | 60 | 83 | 13 | 17 | 1 |
| 4 | OB | 148 | 222 | 32 | 90 | 15 | 21 | 1 |
| 5 | IB | 330 | 424 | 106 | 95 | 30 | 31 | 4 |
| 5 | OB | 431 | 482 | 121 | 111 | 32 | 38 | 4 |
| 6 | IB | 83 | 123 | 34 | 71 | 11 | 13 | 1 |
| 6 | OB | 299 | 409 | 61 | 73 | 18 | 29 | 3 |
| 7 | IB | 828 | 827 | 276 | 296 | 80 | 82 | 4 |
| 7 | OB | 856 | 1,157 | 274 | 370 | 101 | 102 | 3 |
| 8 | IB | 423 | 334 | 129 | 199 | 29 | 35 | 4 |
| 8 | OB | 335 | 455 | 131 | 191 | 42 | 50 | 4 |
| 9 | IB | 1,137 | 1,047 | 272 | 379 | 92 | 89 | 4 |
| 9 | OB | 1,056 | 1,450 | 389 | 409 | 102 | 121 | 6 |
| 10 | IB | 388 | 359 | 136 | 132 | 26 | 34 | 3 |
| 10 | OB | 443 | 585 | 98 | 192 | 33 | 45 | 3 |
| 11 | IB | 1,170 | 1,139 | 344 | 387 | 98 | 116 | 4 |
| 11 | OB | 1,109 | 1,453 | 461 | 394 | 114 | 115 | 5 |
| 12 | IB | 171 | 203 | 55 | 62 | 15 | 14 | 1 |
| 12 | OB | 116 | 124 | 61 | 69 | 14 | 16 | 1 |
| 13 | IB | 250 | 230 | 94 | 89 | 23 | 25 | 4 |
| 13 | OB | 249 | 344 | 90 | 98 | 30 | 38 | 3 |
| 14 | IB | 293 | 312 | 74 | 138 | 28 | 28 | 4 |
| 14 | OB | 322 | 289 | 89 | 118 | 31 | 25 | 4 |
| 15 | IB | 381 | 642 | 88 | 179 | 40 | 52 | 4 |
| 15 | OB | 533 | 580 | 124 | 191 | 40 | 55 | 4 |
| 16 | IB | 512 | 485 | 235 | 254 | 40 | 44 | 4 |
| 16 | OB | 525 | 574 | 234 | 248 | 44 | 53 | 4 |
| 17 | IB | 338 | 365 | 66 | 120 | 33 | 31 | 4 |
| 17 | OB | 306 | 453 | 110 | 174 | 31 | 37 | 4 |
| 18 | IB | - | - | - | - | 3 | 4 | 0 |
| 18 | OB | - | - | - | - | 5 | 5 | 0 |
| 19 | IB | 197 | 263 | 81 | 140 | 27 | 24 | 5 |
| 19 | OB | 329 | 352 | 105 | 170 | 26 | 42 | 5 |
| 20 | IB | 161 | 145 | 46 | 98 | 21 | 14 | 3 |
| 20 | OB | 201 | 198 | 65 | 100 | 29 | 19 | 2 |
| 21 | IB | 41 | 44 | - | - | 6 | 11 | 1 |
| 21 | OB | 116 | 134 | - | - | 15 | 16 | 1 |
| 22 | IB | 328 | 308 | 113 | 185 | 41 | 40 | 5 |
| 22 | OB | 454 | 487 | 196 | 178 | 40 | 45 | 5 |
| 23 | IB | 500 | 436 | 173 | 145 | 43 | 52 | 4 |
| 23 | OB | 481 | 569 | 162 | 162 | 52 | 58 | 3 |
| 24 | IB | 169 | 178 | 41 | 47 | 18 | 23 | 1 |
| 24 | OB | 146 | 186 | 60 | 29 | 13 | 21 | 1 |
| 25 | IB | 68 | 64 | - | - | 9 | 4 | 1 |
| 25 | OB | 36 | 60 | - | - | 7 | 12 | 1 |
| 26 | IB | 180 | 152 | 72 | 63 | 14 | 20 | 4 |
| 26 | OB | 115 | 136 | 44 | 62 | 17 | 29 | 4 |
| 27 | IB | 630 | 589 | 182 | 195 | 50 | 41 | 4 |
| 27 | OB | 614 | 754 | 222 | 259 | 57 | 59 | 3 |
| 29 | IB | 133 | 81 | 66 | 31 | 22 | 10 | 1 |
| 29 | OB | 140 | 138 | 46 | 76 | 14 | 17 | 1 |
| 30 | IB | 148 | 160 | 73 | 69 | 19 | 27 | 3 |
| 30 | OB | 201 | 210 | 63 | 50 | 13 | 22 | 4 |
| 33 | IB | - | 2 | - | - | - | - | 1 |
| 34 | IB | 274 | 408 | 82 | 219 | 30 | 41 | 4 |
| 34 | OB | 452 | 529 | 128 | 200 | 31 | 47 | 4 |
| 39 | IB | 269 | 283 | 95 | 163 | 26 | 29 | 5 |
| 39 | OB | 253 | 352 | 112 | 131 | 39 | 38 | 5 |
| 42 | IB | 21 | - | - | - | 4 | - | 1 |
| 42 | OB | 14 | - | - | - | 4 | - | 1 |
| 43 | IB | 109 | 88 | - | - | 10 | 14 | 1 |
| 43 | OB | 151 | 91 | - | - | 13 | 8 | 1 |
| 47 | IB | - | - | - | - | - | - | 1 |
| 47 | OB | 80 | 129 | 68 | 25 | 30 | 40 | 1 |
| 49 | IB | 42 | 59 | 55 | 90 | 12 | 17 | 1 |
| 49 | OB | 28 | 51 | 21 | 52 | 12 | 16 | 1 |
| 50 | IB | 363 | 639 | 73 | 87 | 20 | 27 | 2 |
| 50 | OB | 118 | 221 | 100 | 58 | 14 | 24 | 3 |
| 51 | IB | 33 | 18 | - | - | - | - | 1 |
| 51 | OB | 31 | 23 | - | - | - | - | 1 |
| 55 | IB | 114 | 145 | 68 | 41 | 15 | 10 | 2 |
| 55 | OB | 200 | 176 | 48 | 66 | 11 | 10 | 2 |
| 56 | IB | 318 | 400 | 103 | 161 | 20 | 30 | 4 |
| 56 | OB | 422 | 490 | 115 | 115 | 34 | 33 | 4 |
| 57 | IB | 121 | 93 | 61 | 34 | 10 | 10 | 2 |
| 57 | OB | 125 | 84 | 46 | 26 | 11 | 15 | 2 |
| 58 | IB | 86 | 100 | 29 | 31 | 9 | 15 | 2 |
| 58 | OB | 174 | 188 | 61 | 72 | 12 | 19 | 2 |
| 60 | IB | 81 | 65 | 13 | 12 | 6 | 9 | 1 |
| 60 | OB | 158 | 87 | 19 | 16 | 16 | 7 | 1 |
| 84 | IB | - | - | 70 | 66 | 23 | 16 | 1 |
| 84 | OB | - | - | 130 | 44 | 13 | 18 | 1 |
| 86 | IB | 363 | 543 | 122 | 135 | 67 | 55 | 3 |
| 86 | OB | 204 | 292 | 122 | 235 | 45 | 52 | 2 |
| 94 | IB | - | - | - | - | - | 2 | 1 |
| 94 | OB | - | - | - | - | - | 1 | 1 |
| 97 | IB | 37 | 45 | - | - | 7 | 9 | 1 |
| 97 | OB | 55 | 62 | - | - | 5 | 7 | 1 |
| 98 | IB | 20 | 30 | - | - | 9 | 4 | 1 |
| 98 | OB | 16 | 22 | - | - | 4 | 3 | 1 |
| 99 | IB | 22 | 27 | - | - | 3 | 6 | 1 |
| 99 | OB | 29 | 36 | - | - | 4 | 5 | 1 |
| 201 | IB | 37 | 47 | - | - | 7 | 8 | 1 |
| 201 | OB | 43 | 70 | - | - | 6 | 8 | 1 |
| 204 | IB | 137 | 158 | 51 | 46 | 12 | 9 | 1 |
| 204 | OB | 102 | 125 | 80 | 51 | 12 | 22 | 1 |
| 211 | IB | 143 | 136 | 70 | 92 | 32 | 23 | 1 |
| 211 | OB | 308 | 384 | 177 | 152 | 21 | 27 | 1 |
| 221 | IB | 75 | 144 | 10 | 18 | 11 | 10 | 1 |
| 221 | OB | 112 | 189 | 32 | 67 | 9 | 12 | 1 |
| 222 | IB | 54 | 70 | - | - | 9 | 15 | 1 |
| 222 | OB | 90 | 133 | - | - | 12 | 22 | 1 |
| 232 | IB | 105 | 168 | 83 | 117 | 19 | 23 | 4 |
| 232 | OB | 144 | 189 | 83 | 93 | 22 | 23 | 4 |
| 235 | IB | 66 | 86 | - | - | 12 | 13 | 1 |
| 235 | OB | 73 | 84 | - | - | 11 | 9 | 1 |
| 40x | IB | 75 | - | - | - | 19 | - | 1 |
| 40x | OB | 79 | - | - | - | 23 | - | 1 |
| 41x | IB | 103 | - | - | - | 6 | - | 1 |
| 41x | OB | 137 | - | - | - | 16 | - | 1 |
| 45x | IB | 44 | - | - | - | 5 | - | 1 |
| 45x | OB | 45 | - | - | - | 5 | - | 1 |
| 46x | IB | 88 | - | - | - | - | - | 2 |
| 46x | OB | 83 | - | - | - | - | - | 2 |
| 48x | IB | 174 | - | - | - | 30 | - | 1 |
| 48x | OB | 184 | 11 | - | - | 20 | 2 | 1 |
| 52x | IB | 88 | - | - | - | 8 | - | 1 |
| 52x | OB | 65 | - | - | - | 8 | - | 1 |
| 53x | IB | 66 | - | - | - | 7 | - | 1 |
| 53x | OB | 83 | - | - | - | 7 | - | 1 |
| 54x | IB | 379 | 13 | 124 | 2 | 66 | - | 4 |
| 54x | OB | 408 | 31 | 69 | 3 | 56 | 2 | 4 |
| 61x | IB | 131 | - | - | - | 13 | - | 1 |
| 61x | OB | 127 | - | - | - | 15 | - | 1 |
| 62x | IB | 98 | - | - | - | 9 | - | 1 |
| 62x | OB | 105 | - | - | - | 22 | - | 1 |
| 64x | IB | 140 | - | - | - | 15 | - | 1 |
| 64x | OB | 130 | 8 | - | - | 13 | 3 | 1 |
| 65x | IB | 132 | - | - | - | 10 | - | 1 |
| 65x | OB | 113 | - | - | - | 14 | - | 1 |
| 74x | IB | 86 | - | - | - | 4 | - | 1 |
| 74x | OB | 76 | - | - | - | 20 | - | 1 |
| 77x | IB | 326 | 32 | 72 | 5 | 30 | 3 | 4 |
| 77x | OB | 318 | 107 | 68 | 34 | 31 | 17 | 4 |
| 80x | IB | 128 | - | - | - | 21 | - | 1 |
| 80x | OB | 130 | - | - | - | 21 | - | 1 |
| 82x | IB | 82 | - | - | - | 14 | 1 | 2 |
| 82x | OB | 76 | - | - | - | 16 | - | 2 |
| 85x | IB | 88 | - | - | - | 19 | - | 1 |
| 85x | OB | 85 | - | - | - | 14 | - | 1 |
| 88x | IB | 39 | - | - | - | 7 | - | 1 |
| 88x | OB | 33 | - | - | - | 6 | - | 1 |
| **Total** |  | **31,251** | **30,636** | **9,452** | **10,886** | **3,306** | **3,080** |  |

Ridership Source: October 2013 APC Data

Because the control total counts are averages, the boardings and alightings do not match, which can cause issues later on in the iterative proportional fitting (IPF) procedure, so they must be balanced. This was done by holding the boardings constant at the average calculated values and scaling the alightings by time period (i.e., average peak alightings for stop segment \* total peak boardings / total peak alightings).

### Developing Stop Segment to Stop Segment Flows

Using the control totals previously developed and the on-to-off survey sample, the next step was to create the stop segment to stop segment flows by direction and time of day. This was done with IPF, using the on-to-off survey sample (aggregated to segments) as the seed matrix and factoring it up to match the segment level boardings and alightings from the APC data. The IPF procedure was done separately for each route with more than one segment, and the routes with one segment (because of low ridership) had the control totals assigned as the flows. The closure criteria used for this method was within +/- 15%, which was accomplished in six iterations.

### Creating Expansion Factors

Once the segment to segment flows were calculated using the IPF procedure, the initial expansion factors were calculated. Because the IPF was already done at the stop segment level, the initial expansion factor is equal to the number of flows divided by the number of full survey records. Similarly to the rail records, a final boarding adjustment is necessary to ensure the control totals are met. This adjustment is equal to the number of actual boardings divided by the number of projected boardings. Table 10 shows the distribution of the final bus expansion weights, with 86.1% of records having an expansion weight of 15 or less.

Table : Distribution of Final Bus Expansion Weights

|  |  |  |
| --- | --- | --- |
| **Expansion Factor** | **Survey Records** | **% of Survey Records** |
| 1 to 2.5 | 259 | 4.1% |
| 2.6 to 5 | 982 | 15.7% |
| 5.1 to 10 | 2,748 | 43.9% |
| 10.1 to 15 | 1,405 | 22.4% |
| 15.1 to 20 | 473 | 7.6% |
| 20.1 to 25 | 175 | 2.8% |
| 25.1 to 30 | 82 | 1.3% |
| 30.1 to 35 | 46 | 0.7% |
| 35.1 to 50 | 70 | 1.1% |
| 50.1 to 90 | 20 | 0.3% |