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FMCOG Model Construction and Calibration Technical Documentation

June, 2003

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1.0 Introduction

This document describes in detail the process and methodology used in developing Fargo/Moorhead Council of Government's (FMCOG) TP+ transportation planning model. This technical reference documents the methodology and assumptions underling each major step within the model.

The data used in the model have been either provided by FMCOG or produced by ATAC as a result of literature reviews or primary data collection. The data are compatible with the existing GIS data system used by the FM-COG.

The model has been developed to run in the TP+ modeling system produced by Citilabs and has been completely developed within Citilabs' CUBE software product. CUBE provides an effective method for organizing the script and is used to view and edit the input and output files.

The modeling is performed in the following six steps, which correspond to dedicated chapters:

Data Preparation inputs two way links from GIS and properly assigns parameters to one-way links. Description of data preparation can be found beginning on page 2 in Chapter 2.

Trip Generation uses static equations based upon persons per household, jobs, and occupancy rates to generate appropriate number of trips produced or attracted to each Traffic Analysis Zone (TAZ). Further description of Trip Generation process can be viewed starting on page 4, Chapter 3.

Trip Distribution assigns the productions and attractions generated during the previous step to their proper origin-destination location. Trip distribution process can be viewed in Chapter 4 starting on page 9.

Mode Split essentially distributes the trips based on the percentage trips using different modes, vehicles, transit bus, or trains. Further discussion of mode split is discussed on page 11, Chapter 5.

Assignment essentially distributes the trips to the network links while trying to minimize cost or distance of the trips. This process description can be found in Chapter 6 beginning on page 12.

Calibration forces the model to resemble volumes occurring in the field. The description of calibration can be seen in Chapter 7 beginning on page 13.

2.0 Data Preparation

This step is needed to convert the input and data to a form that is compatible with TP+. This allows the model's basic structure to remain unchanged while evaluating various scenarios.

The network attributes are input from the two-way links in the GIS network and properly assigned to the one-way links in the TP+ network. All the network variables receive their generic names that are used throughout the rest of the modeling process.

2.1 Capacity Calculation

Ideally, state of the art modeling would use the Highway Capacity Manual (HCM) to predict the signal timings at an intersection and to perform a signalized intersection analysis. The model would then determine the intersection capacity and delay. Although this method, would be theoretically the most accurate, it has many drawbacks. First, the analysis of the intersection is dependant on the volume of vehicles and the turning percentage of those vehicles. These parameters are extremely dynamic and it is possible the model would never converge on a solution. Second, this method is relatively untested and does not have widespread application by planning organizations.

Alternatively, the most common practice is to develop a table of capacities per lane that are dependent on the facility type and the area in which the facility resides. This is similar to what other MPOs in North Dakota are doing. This approach has the drawback that the capacities are static and not affected by lane configuration changes in the network. Many models use average values that do not represent the traffic in the area or use the philosophy of the area's traffic engineers in how they manage their signals.

The approach that ATAC has taken has been a mix of the two methods. ATAC believes that it is important to hold the HCM up as an ideal and realizes that capacities vary widely depending on the traffic volumes and signal management in that area. ATAC also realizes the value in simplicity and importance of having a robust model that relies upon proven techniques.

For this reason, ATAC began work on the model by cataloging all of the intersection approaches analyzed in the Fargo-Moorhead area. Data from previous ATAC work on 222 approaches were compiled and many techniques to predict the capacity of an approach were tested. Finally, by combining the functional class of the roadway, the number of through lanes, and the number of left and right turning lanes, ATAC developed Equation 2.1 to predict the capacity of the roadway with a correlation factor of 0.70.

$$\text{Capacity} = -582 - 108C + 1556T + 73L + 447R \qquad \textbf{Equation 2.1}$$

where:

C = Link Functional Class
T = Number of Through Lanes
L = Number of Left Turns
R = Number of Right Turns

2.2 Node Delay Calculation

The routes through the model need to be based on what influences route selection in real life. ATAC found that there was a need to address delays at controlled intersections because the model was outputting travel times significantly lower than actual field travel times. ATAC developed an effective technique to estimate node delays at controlled intersections.

ATAC surveyed signalized approaches analyzed in the past. It was also found that the delay at an intersection varies significantly based on turning movements through the intersection. For example, a right turn movement will incur much less delay, due to allowed right turn on red. However, unprotected left turns incur more delay because they must not only wait for a green light, but must also wait for a gap in the oncoming traffic.

Because of these characteristics, it was necessary to assign penalties based on the movement of traffic through the intersection. TP+ allows a penalty assignment for each specific movement by using a turning movement penalty file. ATAC assigned an average through control delay based on the functional class of the roadway. These values were established based on surveys conducted at signalized intersections. The studies showed that it took an average of 5 seconds longer than the existing through control delay for left turn movements to complete the maneuver. Right turns onto a major or one-way required 3 seconds less time and right turns onto a local or a collector used 6 seconds less than the existing control delay. Therefore looking at Table 7.5, major arterials have a 10.0 second through control delay. If a vehicle wanted to make a left turn, 5.0 seconds are added to the existing 10.0 seconds to generate a total delay of 15.0 seconds.

3.0 Trip Generation

Trip Generation is the second step within the transportation model. This step takes the zonal and external trip data as input and produces an array of production and attraction values. The values within the array are the number of person trips produced within and attracted to each Traffic Analysis Zone (TAZ) or to zones located outside the planning model.

3.1 Production for Internal Zones

The number of trips produced in an area is estimated by applying a trip rate to the number of households in the area. The household data consists of 2000 census data compiled by the Fargo-Moorhead Council of Governments (FMCOG). The household counts were disaggregated into seven categories and these were compiled to create the following five categories:

1. Households consisting of 1 person
2. Households consisting of 2 persons
3. Households consisting of 3 persons
4. Households consisting of 4 persons
5. Households consisting of 5 or more persons

These five groups were used in determining the home based work (HBW), home based other (HBO), and non-home based (NHB) production trips. The number of productions for each of the five categories was found by multiplying the total number of households in each (shown in Table 3.1), of person trips per household per day. Then, the appropriate fraction was applied to determine the proportion of the trips that would be made for each purpose. The productions were then divided by the occupancy rate in order to have the output in vehicle trips. The average daily person trips per households were adjusted during calibration in order to replicate the trip making behavior in the area.

Table 3.1: Trip estimation variable by urban size population of 50,000-199,999

Household Size	Average Daily Person Trips per Household	% Average Daily Person Trips by Purpose		
		HBW	HBO	NHB
1	3.7	20	54	26
2	7.6	22	54	24
3	10.6	19	56	25
4	13.6	19	58	23
5+	16.6	17	62	21

Source: National Research Board, Report 365, Table 9.

3.2 Attraction for Internal Zones

To estimate attractions, each TAZ within the planning area is classified as being within a Central Business District Area (CBD) or a Non-Central-Business-District (NCBD) Area. The equations used to determine HBW, HBO, and NHB attractions for the NCBD and CBD zones, are listed below in Table 3.2. Again, the equations were applied to all of the 375 TAZ zones using TP+.

Table 3.2: Person-trip attraction rates

Purpose	CBD	NCBD
HBW	1.45 x TE	1.45 x TE
HBO	2.0 RE + 1.7 SE + 0.5 OE + 0.9 HH	9.0 RE + 1.7 SE + 0.5 OE + 0.9 HH
NHB	1.4 RE + 1.2 SE + 0.5 OE + 0.5 HH	4.1 RE + 1.2 SE + 0.5 OE + 0.5 HH

Source: National Research Board, Report 365, Table 8.

where,
TE = Total Employment
RE = Retail Employment
SE = Service Employment
OE = Other Employment
HH =Households

3.3 University Trip Productions and Attractions

Concordia College, Minnesota State University Moorhead (MSUM), and North Dakota State University (NDSU) were treated as special generators within the model and a new trip type for home based university trips was implemented. The trip generation model used equations that were produced by ATAC to determine the number of productions and attractions generated by college students. Using NDSU as a model, primary data were gathered and combined with current data to determine the number of trips made to and from campus and areas directly affected by the trips generated at NDSU.

It was then determined how the number of trips could be predicted based on variables that the FMCOG was able to forecast. Using the method developed, each institution was evaluated individually to determine the number of trips produced for each of the zones affected by the schools. Table 3.3 shows the trip estimation variables used to determine the trips generated for each campus.

Table 3.3: University trip estimation variables

Purpose	Rate		Predictive 2000 Enrollment Concordia College	MSUM	NDSU
HBW Productions	0.32	On-Campus Students	1,670	1,680	2,666
HBO Productions	0.74	On-Campus Students	1,670	1,680	2,666
NHB Productions	0.34	Total Students	2,800	7,400	9,894
HBS Productions	0.24	On-Campus Students	1,670	1,680	2,666
HBW Attractions	0.60	Total Students	2,800	7,400	9,894
HBO Attractions	0.88	Total Students	2,800	7,400	9,894
NHB Attractions	0.34	Total Students	2,800	7,400	9,894
HBS Attractions	1.44	Off-Campus Students	1,130	5,720	7,228

The productions and attractions were calculated by multiplying the appropriate rate with the predictive 2000 enrollment of the school and the ratio of activity that was associated with each affected zone. The ratio of activity in each affected zone was determined through interviews and parking data provided by the administration at each institution. Table 3.4 shows the trips produced by the universities.

Table 3.4: University trips generated by purpose

Purpose	Concordia College	MSUM	NDSU
HBW Productions	534	538	853
HBO Productions	1,202	1,213	1,973
NHB Productions	952	2,516	3,364
HBS-University Productions	401	403	640
HBW Attractions	1,680	4,440	5,936
HBO Attractions	2,464	6,512	8,707
NHB Attractions	952	2,516	3,364
HBS-University Attractions	2,405	8,237	10,408

3.4 High School and Grade School Productions and Attractions

The HBS attractions of area high schools and grade schools were calculated independently. The rates used were developed by ATAC using information provided by the school districts and a survey of parents throughout the area.

To determine the relative attractiveness of area schools, the initial value of attractions per zone was set to the number of students enrolled in the school zone. The population was divided into two different age groups to distinguish between high school and grade school aged students. This was done because of the different trip characteristics of the students who have a driver license.

The trip productions were initially calculated as one production for each person in the population age bracket. During subsequent runs the productions were adjusted using equations that ATAC developed. Table 3.5 shows the total values of home based school attractions and production trips for grade schools and high schools in the model.

Table 3.5: Total attractions and productions for grade and high schools

Purpose	High School	Grade School
HBS Productions	8,298	16,105
HBS Attractions	6,825	17,482

3.5 Airport Trip Generation

Special consideration was taken for TAZ number 42 that houses Fargo's Hector International Airport. ATAC wanted to make sure the productions and attractions for the airport were accurately accounted for in the transportation model. The basic trip generation equations were used to determine the preliminary HBO and NHB attractions for that zone. It was found that Fargo's Hector International Airport had approximately 230,969 enplanements for the year 2000. The HBO and NHB attraction trips attributed to the airport found by dividing the enplanements by 365, to obtain the trip generation in trips per day, and then multiplying it with the average person trip ends found from ITE's Trip Generation reference book. The attractions produced by the airport were added together with the trips produced from the household data in this TAZ. This method produced results that accounted for both households living in TAZ number 42 and airport trip generation.

3.6 External Trips

Trips that begin and end outside the planning area and do not stop within the planning area are considered external-external trips. They were assumed to account for 10% percent of the interstate traffic. The model subtracts from the external productions and attractions the trips made from an external zone to an external zone without stopping within the model.

Trips with only one trip end outside the planning model were calculated using a special methodology. These trips are described as external-internal or internal-external trips. Attractions for external nodes were found by multiplying the average daily traffic with the percentage of trips by purpose at each external node. To calculate the number of productions for the interstate highways, ATAC subtracted the total number of through trips from the ADT and then multiplied it by percentage of trips by purpose.

3.7 Adjustment

Applying the equations described in prior sections to the TAZ data, yields unadjusted production and attraction totals. It is important to note that since each production must be matched to an attraction to form a trip, the total productions must equal the total attractions for each trip type. Generally, the production totals are more accurate than attractions and as a result it is necessary to adjust the attraction values to match the total number of productions. Table 3.6 shows the unadjusted number of productions and attractions generated by trip purpose.

Table 3.6: Total number of productions and attractions generated by purpose

Purpose	Number of Productions	Number of Attractions
HBW	132,849	166,755
HBO	261,834	366,399
NHB	134,693	137,544
HBS-University	8,629	21,050
HBS-High School	8,298	6,825
HBS-Grade School	16,105	17,482

To adjust the attractions, the total number of attractions was divided by the total number of productions for each trip purpose. This produced a factor for each trip purpose, which was applied to each TAZ's attraction total to find the new adjusted attraction values, as shown in Table 3.7. It is important to note that HBS-University production trips were adjusted to match the number of attractions because it is easier to quantify the number of trips arriving at the universities than it is to predict the location from which the students are generating their trips.

Table 3.7: Adjusted production and attraction values by purpose

Purpose	Number of Production	Number of Attractions
HBW	132,849	132,849
HBO	261,834	261,834
NHB	134,693	134,693
HBS-University	21,050	21,050
HBS-High Schools	8,298	8,298
HBS-Grade Schools	16,105	16,105

4.0 Trip Distribution

The Trip Distribution Step is performed using the Gravity Model. The purpose of trip distribution is to match the productions and attractions for each zonal pair in order to define a trip. The gravity model assigns trips based on the number of productions, attractions, a friction factor, and a k factor. The friction factor is a value that is inversely proportional to, distance, time, or cost, measure the impedance between the zonal pairs.The k factor is a scaling factor that is used during calibration and it limits or increases the volume of traffic that crosses sections of the network. Chapter 7.0 discusses k factors in more detail. Equation 4.1 shows the Gravity Model equation.

$$T_{IJ} = P_I \frac{K_{IJ} A_J F_{IJ}}{\sum (K_J A_J F_J)}$$

Equation 4.1

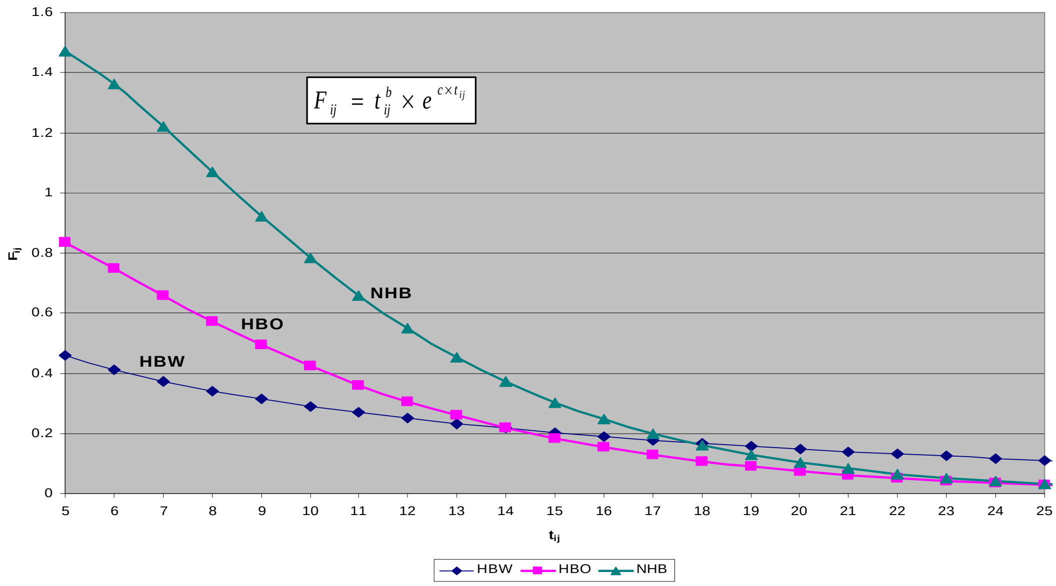
where:
T_{IJ} = The number of trips assigned between Zones i and j
P_I = Number of Productions in Zone I
A_J = Number of Attractions in Zone J
F_{IJ} = The Friction Factor
K_{IJ} = A scaling factor used in calibration to influence specific IJ pairs

4.1 Friction Factor Computation

The friction factors is a measure of the impedance or resistance to flow in the model. The impedance used was travel time for all trip purposes except home based school, in which case, distance was used. This would allow the school trips to be assigned to the nearest zone with a school, which is similar to how sub-districts are divided in the area.

For the initial iteration, free flow travel times are used for calculating impedance. The model is run a second iteration, using output congested speeds from the first iteration. The friction factors can be shown to follow a gamma function, shown in Figure 4.1. This allows a continuous function for the friction factor without any irregularities. Friction factors make short trips more desirable and the benefit decreases as the trips get longer.

Figure 4.1: Friction factors



The transportation model's gamma function has two calibration constants b and c. These are used to calibrate the length of the trips assigned by the gravity model. The Census's Public Use Micro-Sample Data (PUMS) was used to determine a trip length distribution based on the travel time for work trips. The friction factor curve was then calibrated until the model was replicating this curve. The NHB trips and HBO trips are estimated at 80% of the length of home based work trips. Friction factor curves were calibrated to replicate these shorter trips. Finally, the HBS trips were calibrated to be as short as possible, therefore assigning the trips to the nearest school. The final model coefficients used are shown below in Table 4.1.

Table 4.1: Model coefficients by purpose

Purpose	Model Coefficients	
	b	c
HBW	-0.351	-0.043
HBO	0.548	-0.212
NHB	1.11	-0.28
HBS-University	-0.351	-0.043
HBS-High School	-6.00	-0.05
HBS-Grade School	-6.00	-0.05

5.0 Mode Split

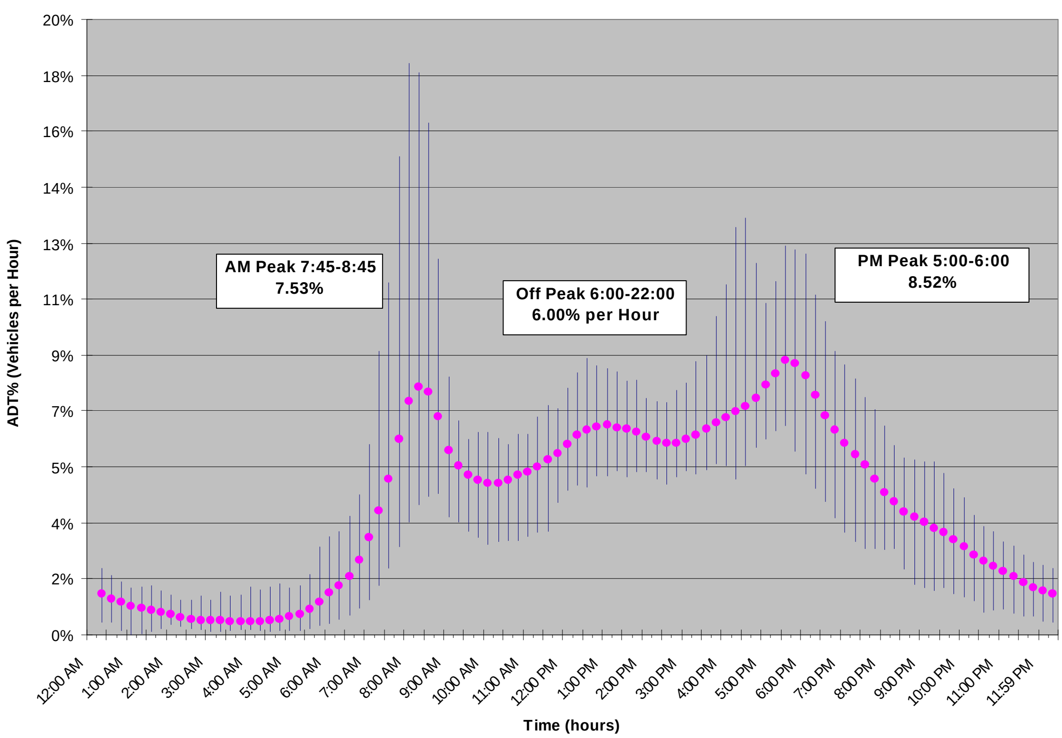
Mode choice and mode split models are traditionally used to determine the number of trips using each different mode. Since the area has a low percentage of public transit use, automobiles are the only mode choice in this transportation model.

5.1 Hourly Origin-Destination Calculation

Up to this point, the number of trips generated in the model was vehicle trips per day. However, the model needs to assign trips in hourly increments so the assigned trips have the same capacity of the roadway, vehicles per hour. The daily matrix of trips has to be changed to an hourly matrix that can be assigned to the roadways. Based on analysis of several hourly counts throughout the city, daily traffic was divided into as follows: AM Peak (7:45-8:45, 7.53%), PM Peak (5:00-6:00, 6.0%), and all other as Off Peak (6.0%/hr*14hrs. = 84% ADT).

The production attraction matrix is added to the transposed production attraction matrix and then the trips are divided by two. Using this method, it is assumed that half of the trips go from production to attraction and half of the trips are returning from the attraction back to the production. The matrix then was multiplied by the appropriate time of day percentage to obtain three origin destination matrices. Figure 5.1 shows the time of day percentages for the Off peak and each peak hour. These peak hour matrices were added together to determine the total volume for each link.

Figure 5.1: Fargo-Moorhead traffic survey



6.0 Assignment

Traffic assignment is the final step performed by the model. The output from traffic assignment often is the basis for determining if the model has produced applicable results. The results used in calibration (described in Chapter 7.0) to adjust the volumes to match the actual ADTs. ATAC has decided to use the user equilibrium traffic assignment method, an iterative convergent process that when complete, no traveler can improve their path by changing links. User equilibrium was implemented using a cost function to evaluate the most desirable path. This method was chosen for the convenience of conducting toll facility studies.

Assignment begins with three separate origin-destination (OD) matrixes, AM peak, PM peak, and Off peak, which contain the volumes that are to be assigned to each OD pair. User equilibrium in TP+ uses built in functions in order to assign trips to paths from each origin zone. ATAC used a vehicle cost variable which required trips to be assigned by minimizing the cost of the trips in dollars. The value for the vehicle cost variable in 2000 was $11.50 per hour, produced by the North Dakota Department of Transportation (NDDOT). Travel time was set to the free flow travel time for the first iteration and then changed with iterations depending on congestion. This iterative process continued until there was no available path at which the cost could be lessened. If the system has severe congestion, it may be impossible to reach a state of equilibrium. However, the 2000 model reached a state of equilibrium after 13 iterations. Table 6.1 shows vehicle cost adjustment with iterations.

Table 6.1: Vehicle cost adjustment with iterations

	Am Peak		PM Peak		Off Peak	
Iteration	**Vehicle Cost ($)**	**Vehicle Distance (miles)**	**Vehicle Cost ($)**	**Vehicle Distance (miles)**	**Vehicle Cost ($)**	**Vehicle Distance (miles)**
1	168,912	264,017	182,797	263,276	85,340	191,972
2	103,150	266,169	101,135	264,985	73,099	192,318
3	101,647	265,877	99,797	264,230	72,262	192,112
4	101,606	265,400	99,578	264,131	72,395	191,720
5	101,309	265,013	99,532	263,362	72,157	191,697
6	101,209	264,783	99,286	263,296	72,123	191,693
7	101,073	264,662	99,155	263,226		
8	101,054	264,497	99,146	263,220		
9	100,963	264,394	99,159	263,196		
10	101,011	264,345	99,134	263,089		
11	100,939	264,322	99,128	263,116		
12	100,920	264,318	99,119	263,094		
13			99,124	263,101		

7.0 Calibration

Calibration is the final stage in the development of a transportation model. The goal of calibration is to make as many links as possible meet the designated criteria range as shown in Table 7.7. Calibration is a tedious process that needs to be conducted in a thorough and exacting manner. A flow chart is shown in Figure 7.2 describing ATAC's methodology for calibration.

7.1 Trip Length Distribution

The first stage of calibration is to check if the model vehicles trips are similar in length to the trips made in the area. Information regarding trip lengths for trip times ranging from 0-45 minutes were found from PUMS. Shorter trips tend to occur more frequently than do longer trips. The transportation model needed to represent this trend. ATAC compared the modeled HBW, HBO, and NHB trip lengths to the PUMS research data. If the modeled trend did not follow the PUMS data trend, ATAC adjusted friction factor coefficients until the model resembled, as closely as possible, the PUMS data. The targets for the trips were as follows: HBW-100%, HBO-80.0% of the HBW, and NHB-80.0% of the HBW data. As can be seen from Figure 4.1 HBO and NHB trips were modeled as 76.87% and 76.32% of the HBW data, respectively. Figure 7.1 shows the adjusted friction factors for each trip purpose and the trip length distribution respectively.

Figure 7.1: Final trip length distribution graph

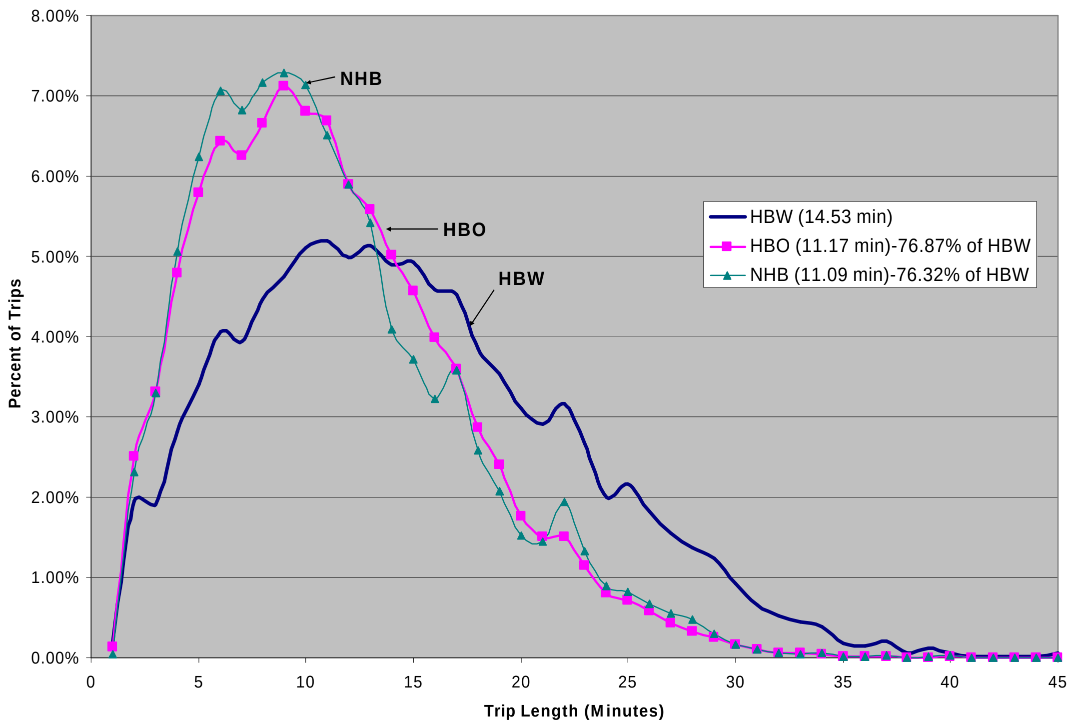
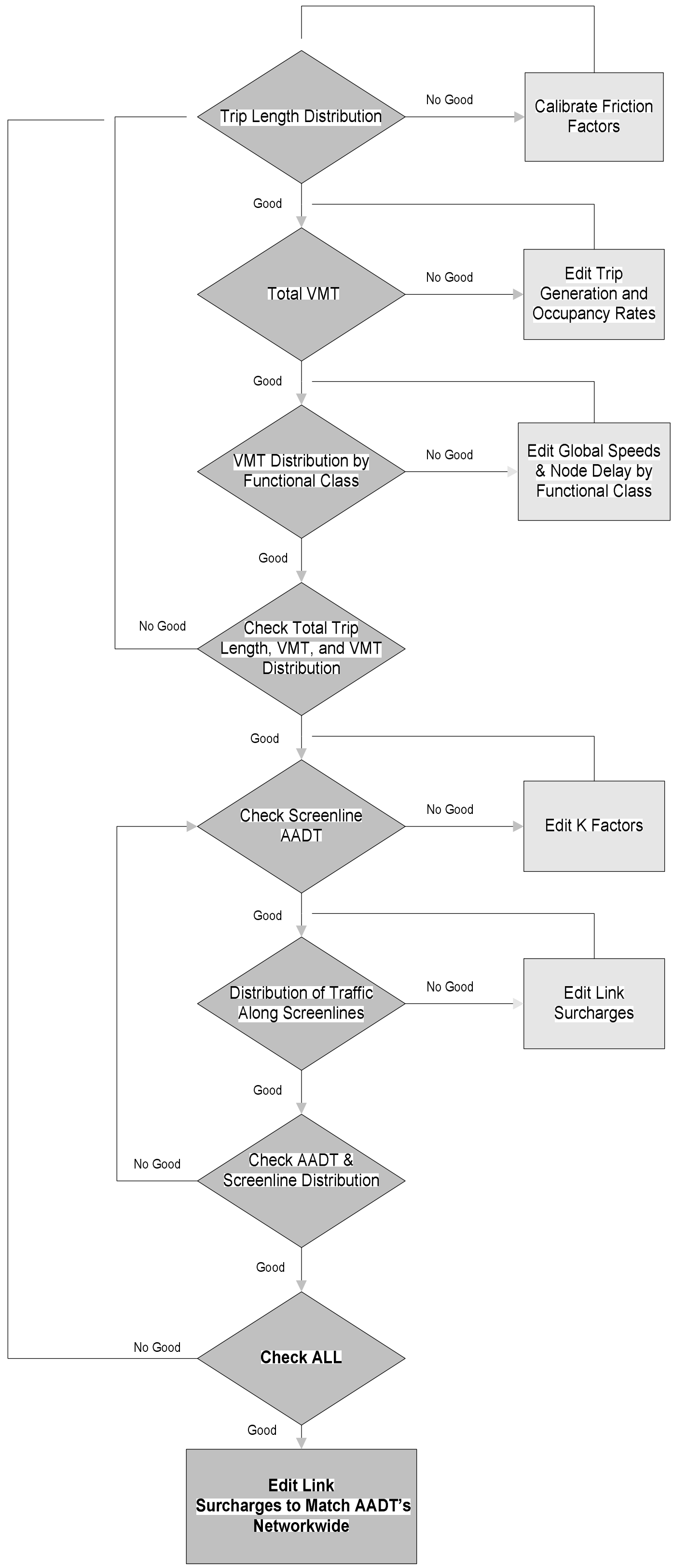


Figure 7.2: Calibration flow chart



7.2 Total Vehicle Miles Traveled (VMT)

VMT is dependent on the number of trips generated and the length of those trips. ATAC first calibrated the total VMT for the entire network. If the model values were different than the values produced in the field, ATAC adjusted the trip generation and occupancy rates until the model VMT was similar. Adjusting the trip generation and occupancy rates adjusts the total number of trips that are generated within the transportation model. This in turn increases or decreases the total number of vehicle miles traveled. The overall adjusted VMT was within 2% of the actual reported VMT. This is well within the standard 5% given in the Travel Model Improvement Program's Model Validation and Reasonable Checking Manual. Table 7.2 shows the adjusted trip estimation variables, while Table 7.3 shows the vehicle miles traveled by jurisdiction.

Table 7.2: Adjusted trip estimation variables

Household Size	Average Daily Person Trips per Household	% Average Daily Person Trips by Purpose		
		HBW	HBO	NHB
1	5.75	20	54	26
2	10.25	22	54	24
3	14.0	19	56	25
4	17.5	19	58	23
5+	20.0	17	62	21

Table 7.3: Vehicle miles by jurisdiction

Jurisdiction	Vehicle Miles Reported	Vehicle Miles Modeled	Difference in Vehicle Miles	Percent Difference
Fargo	1,311,740	1,333,530	21,790	2%
Moorhead	336,242	329,719	-6,523	-2%
West Fargo	127,378	148,520	21,142	17%
Dilworth	35,504	39,927	4,423	12%
ND	1,439,118	1,482,050	42,932	3%
MN	371,747	369,646	-2,101	-1%
Metropolitan Area	**1,810,864**	**1,851,696**	**40,832**	**2%**

7.3 VMT Distribution by Functional Class

Once the total VMT was on target, ATAC checked the VMT distribution by functional class. If the functional class distribution was off, global speeds and node delays were adjusted according to facility class. It is important to note that NDDOT reported VMT by facility class, while MNDOT reported VMT by funding class. Therefore, ATAC calibrated VMT to Fargo's values because Fargo's area is much larger and has a more representative sample of the different classes of roadways. Table 7.4 and Table 7.5 show the total VMT by functional class and control delay, respectively.

Table 7.4: Vehicle miles by functional class

Facility	Reported Distribution	Modeled Distribution	Difference
Interstate	28.3%	27.7%	**-0.60%**
Principle Arterial	32.2%	32.7%	**0.50%**
Minor Arterial	29.3%	30.1%	**0.90%**
Collector	10.3%	9.5%	**-0.80%**

Table 7.5: Control Delay penalties

Functional Class	Control Thru Delay (seconds)
One-Way	10.0
Major Arterial	10.0
Minor Arterial	20.0
Collector	31.0
Local	31.0
Stop Sign	28.0

7.4 Screenlines

Screenlines are an important component during calibration. First, ATAC checked the total AADT of the links crossing a screenline. If the total volume of vehicles crossing a screenline was above the specified criteria, a lower k factor was assigned. This would inhibit traffic from crossing the screenline. Similarly, if the screenline had a volume below the designated criteria, a higher k factor would be applied to affected zones. This would make zonal pairs that cross the screenline more attractive.

Next, ATAC examined the distribution of traffic on the links crossing each screenline. If the link had a significant higher or lower volume than the AADT, the link surcharges were edited. After achieving an accurate screenline distribution, the calibration process was repeated starting with checking the trip length distribution, until all the successive calibration components were completed. Table 7.6 shows the k factors used in the transportation model.

Table 7.6: Screenline k factors

Screenline	k factor	AADT	Modeled ADT	Volume Difference	Percent Difference
Interstate 29	1.43	177,696	178,343	647	0.36%
Interstate 94	1.69	178,046	175,977	-2,069	-1.16%
Red River	0.75	111,500	114,434	2,934	2.63%
Railroad	1.36	203,103	202,915	-215	-0.11%

7.5 Network Wide Adjustment

The final phase of calibration looks into the whole network link AADT distribution. ATAC examined how the modeled link's volume compared to the AADT for that link. If the link was found to have a volume above the specified AADT criteria a positive surcharge was added to the link. Likewise, if the link had a volume below the AADT criteria count, a negative surcharge was applied to the modeled link. This would allow more vehicles to use the link because the route would cost less. Using an appropriate surcharge would help each link to fit into the specified criteria range. Table 7.7 and Table 7.8 show the percentage of links that meet each criterion based on volume range and functional class, respectively. Figure 7.3 shows the link distribution by traffic volume range.

Table 7.7: Model assignment by traffic volume range

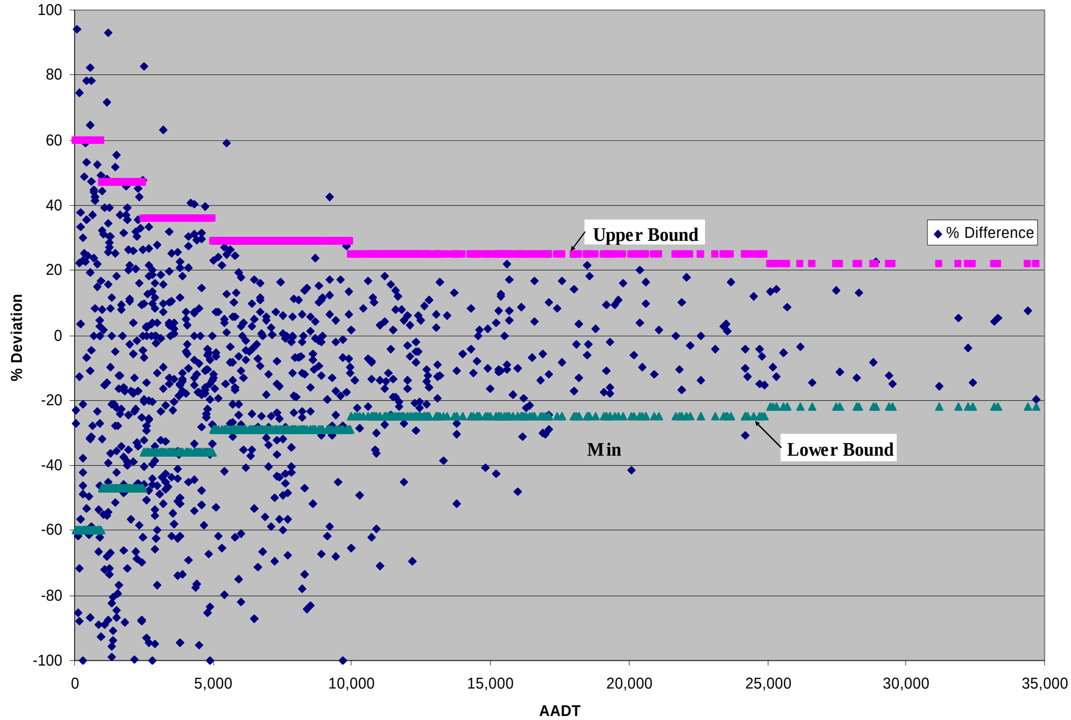
Volume Range	Above Criteria	Meets Criteria	Below Criteria	Percent Within Criteria	RMSE	ND Criteria Percent Deviation
AADT > 25,000	0	24	3	88.89%	0.1329	± 22%
25,000 to 10,000	0	165	20	89.19%	0.1892	± 25%
10,000 to 5,000	7	171	30	82.21%	0.2721	± 29%
5,000 to 2,500	10	142	41	73.58%	0.3885	± 36%
2,500 to 1,000	16	95	23	80.51%	0.6324	± 47%
AADT < 1,000	23	51	7	62.96%	6.0773	± 60 %
Total	56	648	124	78.26%		

Root mean square error (RMSE) is a method for determining the overall error for each link. It is found by squaring all of the errors for each link. Then these values are averaged and by taking the square root of the averages determines the RMSE.

Table 7.8: Model assignment by functional class

Functional Class	Above Criteria	Meets Criteria	Below Criteria	Percent Within Criteria
Interstate	0	38	2	95.00%
One-Way	0	52	4	92.86%
Major Arterials	17	168	20	81.95%
Minor Arterials	16	216	39	79.70%
Collector	19	151	51	68.33%
Local Roads	4	23	8	65.71%
Total	56	648	124	78. 26%

Figure 7.3: Link distribution by volume range



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