Appendix A - Connections 2040

Duluth-Superior Metropolitan Area Travel Demand Model Update

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Introduction

The purpose of this report is to document the development of the Duluth-Superior area travel demand model, developed in support of the Metropolitan Interstate Council (MIC) and the Duluth-Superior Metropolitan Area Long Range Transportation Plan. The travel demand model was updated and validated for existing year conditions and travel demand is forecasted for the year 2040. This is an update that follows the model update done in January 2009.

The model was developed based on 2010 socio-economic data and roadway inventory and which is considered as the most recent existing year conditions available. The demographic data was forecasted for the forecast year 2040. This report discusses about the three major steps that were involved in the 2010 model update:

- ***Model Development Summary***
- ***Base Year Model Validation (2010)***
- ***2040 Travel Demand Model Forecast Results***

MODEL DEVELOPMENT SUMMARY

What is a travel demand model?

The practice of travel demand forecasting is roughly 35 years old and was mainly used to provide and objective tool for evaluating major infrastructure investments and preparing long-range, regional transportation plans. These travel forecasts were produced with mainframe software programs. Eventually improved micro-computerized model procedures emerged out that could predict travel changes in response to changes in development patterns, transportation systems, and demographics given certain assumptions about travel behavior based on existing conditions. The region's demographic characteristics such as population, size of households, vehicles available and employment are the inputs used to estimate the number of trips made. These trips are then distributed and "loaded" onto a computerized network representing the street system to determine traffic volumes on individual roadway segments.

Most travel demand models use what is often referred to as the "four-step process." The four-steps include:

- Trip Generation,
- Trip Distribution,
- Mode Choice, and
- Trip Assignment.

The Duluth-Superior Area has a relatively low percentage of daily trips made using public transit. Because of this, and due to the time and cost restraints, the Duluth-Superior model does not include a mode split element in the sense of separating transit and auto trips. However, the model does generate "person trips", which are converted to auto trips using an auto occupancy factor for various trip purposes.

Forecasting traffic volumes on alternative proposed freeway and street alignments is a common model application. However, it must be remembered that transportation models are only a part of a larger set of engineering analysis tools, and in-and-of-itself provides limited insight into the "right" decision. The main advantage of a validated model is that it provides a systematic analysis process so that alternatives can be evaluated in an even-handed manner.

The remainder of this report documents the development of the Duluth-Superior travel demand-forecasting model to incorporate current transportation, socioeconomic, and land use characteristics. It also documents the results of the model validation process, the projection of future social and economic conditions, and the development of future traffic forecasts for the 2040 Long-Range Transportation Plan.

The following documentation describes the methodology used in developing the Duluth-Superior Travel Demand Model. The model was developed using the travel demand modeling software CUBE Voyager by Citilabs.

Transportation Analysis Zones (TAZs)

Transportation Analysis Zones (TAZs) are sub areas of the region that are used to geographically summarize land use, demographical, and travel data. TAZs are developed based on Census blocks and block groups as defined by the US Census Bureau. In urban areas, blocks are typically much smaller than TAZs, while blocks in rural areas are usually too large to be used directly for modeling purposes.

Table 1: New TAZ numbering by MCD

	TAZ Numbering		
Duluth C	1	to	353
Superior C	354	to	497
Hermantown C	498	to	546
Proctor C	547	to	565
Oliver V	566	to	567
Superior V	568	to	569
Duluth T	570	to	573
Lakewood T	574	to	578
Rice Lake T	579	to	591
Canosia T	592	to	602
Grand Lake T	603	to	612
Solway T	613	to	621
Midway T	622	to	628
Superior T	629	to	632
Parkland T	633	to	638
Lakeside T	639	to	639
External TAZs	640	to	659

A comprehensive review of TAZ system in 2005 model update as an effort to improve model accuracy and detail resulted in increasing the number of area TAZs from 336 to 639. The increase in TAZs was not due to an increase in the coverage area, but rather the splitting of larger TAZs into smaller ones. The near doubling of the TAZ system provided the increased detail needed to improve "traffic loading points" within the model network to better replicate existing travel patterns. The TAZ numbering system that was updated in 2005 as shown in **Table 1** was used for the 2010 model update.

External TAZs – In order to account for the vehicular trips that do not originate within or travel through the study area, "External TAZs" are identified on the study area perimeter at major road crossings. The 2005 model included 20 external TAZs. The same external stations were assumed to hold good for the 2009 model update. **Table 2** shown below lists the external station locations in the Duluth-Superior region.

Table 2: External TAZs

640	CSAH 61 / Scenic Highway
641	STH 61
642	CSAH 37 / Jean Duluth Road
643	CSAH 34 / Howard Gnesen Road
644	CSAH 4 / Rice Lake Road
645	CSAH 48 / Lavaque Road
646	US 53 / Miller Trunk Highway
647	CSAH 46
648	US 2
649	CSAH 45
650	I-35
651	STH 23
652	CTH B
653	STH 35
654	CTH A
655	CTH K
656	Anderson Hill Road
657	CTH E
658	US 53 / US 2 (WI)
659	STH 13

Network Development

The model network refers to the computerized representation of the study area's transportation system. The model network includes all roads functionally classified as a collector or higher. The model network also includes some key local roads where they added unique access between the Traffic Analysis Zones (TAZ) and the regional roadway system.

Links – The models network is made up of road segments called links. Each link is a line between two points or nodes. Nodes generally represent intersections where two or more roads connect.

Centroids and Connectors – Centroids refer to Nodes that represent TAZs. TAZ trip data is assigned to a corresponding centroid and loaded to the road network by centroid connector links, which represent the local road networks or drive access to the larger road system. Centroid placement within the TAZ boundary is important to accurately reflect the center of trip activity and distance to the road system to ensure trips load onto the network similar to actual traffic patterns.

Network Data

The following roadway network data was gathered, reviewed and updated where necessary:

- Distance
- Facility type (functional classification)
- 2010 Annual Average Daily Traffic
- Number of through-lanes
- Area type
- Lane capacity
- Travel time
- Posted speed limit
- Model speed
- One-way or two-way
- Cross section type
- Turn lanes
- Capacity (estimated from generalized standards extrapolated from the Highway Capacity Manual and approved by the MIC and assigned according to facility type, area type, and number of lanes)

A description of each link attribute is explained in **Appendix A** attached to this report.

Tables 3 – 6 list the capacity assumptions for freeways, arterials, and collector/local streets provided by MnDOT. Total Daily Capacity was set at Level of Service (LOS) D, which is highlighted in bold text. The column number corresponding to the identified LOS (A-F) indicates the upper limit for that LOS classification. **Figure 1** provides LOS descriptions. These capacities are based on conditions and assumptions, which are identified below the tables.

Table 3: Urban/Rural Freeway Total Daily Traffic Capacity

Lanes	A	B	C	D	E	F
Volume/Capacity	0.28	0.45	0.65	**0.85**	1.0	> 1.0
4-lane AADT (vpd)	< 25,000	40,000	60,000	**77,500**	90,000	> 90,000
6-lane AADT (vpd)	< 37,500	62,500	90,000	**115,000**	135,000	> 135,000
8-lane AADT (vpd)	< 50,000	80,000	118,000	**155,000**	180,000	> 180,000

Typical Conditions and Assumptions:

- Free-flow speed: 55 mph to 60 mph
- Portion of AADT in Peak Hour: 0.092

Source: MnDOT

Table 4: Suburban/Urbanizing Arterial Total Daily Traffic Capacity

Lanes	A	B	C	D	E	F
Volume/Capacity		0.50	0.70	**0.90**	1.0	> 1.0
2-lane AADT (vpd)		< 8,500	12,000	**15,000**	17,000	> 17,000
4-lane AADT (vpd)		< 17,000	24,000	**30,000**	34,000	> 34,000

Typical Conditions and Assumptions:

- Signal Spacing: ¼ mile to ½ mile
- Free-flow speed: 35 mph to 40 mph
- Signal Cycle Length: 80s to 90s
- Portion of AADT in Peak Hour: 0.09
- Effective Green Ration (g/C): 0.50
- Left-turn lanes: Yes

Source: MnDOT

Table 5: Urban/Urban Core Arterial Total Daily Traffic Capacity

Lanes	A	B	C	D	E	F
Volume/Capacity		0.50	0.70	**0.90**	1.0	> 1.0
2-lane AADT (vpd)		< 8,000	11,000	**14,500**	16,000	> 16,000
4-lane AADT (vpd)		< 16,000	22,000	**29,000**	32,000	> 32,000

Typical Conditions and Assumptions:

- Signal Spacing: 500 ft to 1/8 mile.
- Free-flow speed: 30 mph
- Signal Cycle Length: 70 seconds
- Portion of AADT in Peak Hour: 0.09
- Effective Green Ration (g/C): 0.50
- Left-turn lanes: Usually

Source: MnDOT

Table 6: Collector/Local Street by Area Type Daily Total Daily Traffic Capacity

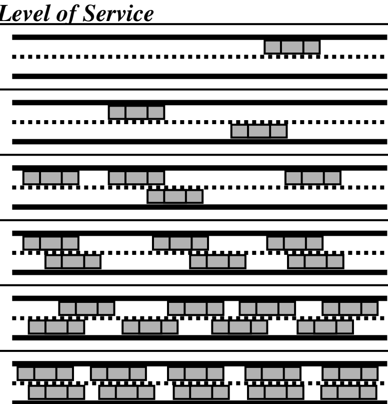
	Lanes	B	C	D	E
Rural	2	9,444	10,222	**11,222**	12,556
	4	19,000	20,556	**22,444**	25,333
Suburban	2	N/A	7,444	**9,333**	9,778
	4	N/A	16,333	**18,778**	19,667
Urban	2	N/A	5,333	**8,667**	9,333
	4	N/A	11,333	**17,444**	18,000
Dense Urban	2	N/A	N/A	**8,667**	8,889
	4	N/A	N/A	**17,444**	18,000

N/A = Not achievable given assumptions below

Typical Conditions and Assumptions:	Rural	Suburban	Urban	Dense Urban
▪ Signal Density per mile	0.08	3	5	10
▪ Free-flow speed	50	40	35	30
▪ Signal Cycle Length	110	90	80	70
▪ Effective green ratio	0.45	0.45	0.45	0.45
▪ Adj. sat. flow rate	1,850	1,800	1,750	1,700
▪ Portion of AADT in Peak Hour	0.09	0.09	0.09	0.09
▪ % lefts, % rights	10	10	10	10
▪ Left-turn bay	Yes	Yes	Yes	Yes

Source: Highway Capacity Manual, URS Corp.

Figure 1: Levels of Service Descriptions



Level of Service	Description
A	**FREE FLOW.** Low volumes and no delays.
B	**STABLE FLOW.** Speeds restricted by travel conditions, minor delays.
C	**STABLE FLOW.** Speeds and maneuverability closely controlled due to traffic volumes.
D	**STABLE FLOW.** Speeds considerably affected by change in operating conditions. High-density traffic restricts
E	**UNSTABLE FLOW.** Low speeds, considerable delay, volume slightly over capacity.
F	**FORCED FLOW.** Very low speeds, volumes exceed capacity, long delays with stop-and-go traffic.

Figure 1 attempts to describe what a driver would experience at each LOS. LOS A represents the least amount of traffic on a roadway, which provides drivers with free flow vehicle maneuverability and no traffic related delays. In contrast, LOS F represents very restricted vehicle maneuverability, slower speeds and longer delays due to the amount of traffic on the roadway.

Trip Generation

The trip generation model estimates the number of trips produced by and/or attracted to a transportation analysis zone (TAZ). The number of trips generated within a zone is a function of the demographic, socioeconomic, and land use characteristics of the zone. Trip generation models have three parts: trip production, trip attraction, and trip balancing which involves normalizing or scaling process that "matches" the total number of production and attraction trip ends.

Trip generation models are designed to produce estimates of either person trips or vehicle trips, depending on the derivation of the trip rates or equations. A model that produces estimates of vehicle trips in the trip generation step of the process precludes the application of a separate mode choice model because the mode has been predetermined to be auto (or vehicle) for all of the trips generated. The MIC area trip generation model rates and equations calculate person trips. Vehicle occupancy rates are applied to derive vehicle trips.

Two different levels of trip generation were developed within the MIC travel model:

- *Internal Trip Generation*: Internal trip generation was based on the procedures outlined in *Travel Estimation Techniques for Urban Planning*, NCHRP Report 365, Transportation Research Board, 1998. The MIC model utilized trip generation rates and production equations that were derived from the 2000 National Household Transportation Survey (NHTS) data and add-on data for Wisconsin. While these trip rates are specific to Wisconsin, they include survey data from Superior and are based on communities similar in size and characteristics as that of the MIC metropolitan planning area.

- *External Trip Generation (Including Internal-to-External Trips)*: Trip generation for internal-to-external and external-to-internal (I-E) traffic was based on traffic counts available from MnDOT and WisDOT.

Trip Purposes

By utilizing the National Household Transportation Survey (NHTS) data and add-on data for Wisconsin and WisDOT's assistance, two additional trip purposes were added by subdividing Home-based-other trips into home-based-shopping, home-based-school, and home-based-other.

The more trip purposes that the model accounts for, the more sensitive the model will be to changes in the projected demographics of the area. A balance between the number of trip purposes, the statistical relevance of the purposes, and the effort involved in modeling the trip purposes must be found. Using the NHTS data, five trip purposes have been defined for use in the model.

There are five trip purposes that were used for the MIC model trip purposes. They are listed below:

- Home-based work (HBW),
- Home-based Shopping (HBSh),
- Home-based school (HBSc),
- Home-based other (HBO), and
- Non-home based (NHB) trips.

As a general rule, the greater the number of trip purposes that can be successfully modeled, the more sensitive the model will be to changes in future socioeconomic conditions. The trip characteristics of each trip purpose are unique to that trip purpose and the question becomes how fine a distinction can be made among home-based non-work trip purposes.

The HB-Shopping, HB-Other, and HB-School trip purposes are subdivisions of the HB-Non-Work trip purpose. Each of these trip purposes has different characteristics in terms of average trip length and trip frequency. HB-Other trips include all trips from home that are not for any of the other HB trip purposes. Examples of such trips include a trip from home to the doctor's office for a medical appointment or a trip on personal business.

It is possible not to differentiate among these types of trips and assume that all HB-Non Work trips are governed by the same determinants and people behave in a similar manner when taking different types of non-work trips. This would imply that differences in average travel times and average trip frequencies between, say, HB-School and HB-Shopping trips would not be distinguished, and a single set of variables would be used to model both trip purposes. Intuitively we know that there are differences between these types of travel, and aggregation of the two purposes would represent a weakness in a model.

The discussion of internal trip generation parameters is divided into trip production and trip attraction sections.

Trip Productions

The trip generation model estimates the number of motorized person trips to and from each TAZ by purpose in the study area. In this step socioeconomic data are used to estimate the number of daily-motorized person trips within the study area (i.e. internal-internal) and with origins or destinations outside the study area (i.e. external-internal or internal-external).

***Production Trip Generation Rates* –** URS will work with the Wisconsin Department of Transportation (WisDOT) to develop and apply new trip rates based on the National Household Transportation Survey results.

WisDOT purchased "add-on" surveys for Wisconsin communities from which trip rates by purpose were developed. Trip rates solely from Superior, WI survey data was not created. However, Superior survey data was combined with other MPO survey data to create trip rates. These trip rates were averaged with trip generation rates of similar sized Wisconsin communities for use in the Duluth-Superior Trip Generation Model. It is reasonable to assume that travel behavior data from similar sized Wisconsin communities would not differ dramatically from travel behavior in Duluth and thus it is reasonable to apply such rates to the Duluth-Superior trip generation model. Trip Production rates in the travel demand model are listed below in **Table 7**.

Table 7: Trip Generations Rates - Productions

Home Base Work					
		WORKERS/HH			
AUTOS		**0**	**1**	**2**	**3+**
	0	0.0236	0.834	2.533	2.816
	1	0.026	1.148	2.835	4.004
	2+	0.069	1.617	3.022	5.309

Home Base Shopping					
		HH SIZE			
AUTOS		**1**	**2**	**3**	**4+**
	0	0.480	1.449	1.397	1.747
	1	0.733	1.887	1.751	1.892
	2+	0.770	1.934	2.302	2.941

Home Base School					
		HH SIZE			
AUTOS		**1**	**2**	**3**	**4+**
	0	0.064	0.368	0.556	2.256
	1	0.062	0.334	1.388	2.741
	2+	0.089	0.246	1.205	3.256

Home Base Other					
		HH SIZE			
AUTOS		**1**	**2**	**3**	**4+**
	0	0.605	2.626	2.038	5.628
	1	1.171	3.555	5.526	5.992
	2+	1.184	3.192	5.178	7.640

Non Home Based					
		HH SIZE			
AUTOS		**1**	**2**	**3**	**4+**
	0	0.670	2.150	2.139	2.831
	1	1.164	2.455	3.081	4.188
	2+	1.391	3.060	4.525	5.550

TAZ socioeconomic data – As the above trip rates indicate, the demographic data required for calculating productions included the number of households by the number of workers per household and the number of vehicles available and the number of households by household size and the number of vehicles available. This information was pulled from the Census Transportation Planning Package (CTPP) for year 2010.

Trip Productions Summary – Applying the trip generation rates for productions to the demographic data from the 2010 US Census and CTPP, the following trip productions were estimated for the MIC Planning Area for the base year 2010 and for the forecast year 2040. **Table 8** below lists the Trip Productions Summary for 2010 and 2040.

Table 8: Trip Productions Summary

Type	2010		2040 Conservative Scenario		2040 Aggressive Scenario	
	Trip ends	% Trips	Trip ends	% Trips	Trip ends	% Trips
HBW	89,599	16%	97,389	16%	106,212	16%
HBshop	90,130	16%	98,133	16%	107,072	16%
HBSch	89,412	16%	86,496	14%	93,014	14%
HBO	157,681	28%	171,693	28%	187,277	28%
NHB	142,217	25%	154,958	25%	169,082	26%
Total	**569,039**	**100%**	**608,669**	**100%**	**662,657**	**100%**

Trip Attractions

Trip attraction relates the trips attracted to a TAZ by the type and intensity of employment in that zone. Trip attraction models are linear regression models that quantify the relationship between different types of employment and the attractiveness of a TAZ for corresponding trip purposes.

Attraction Trip Generation Rates – Attraction trip generation rates shown below in **Table 9** were developed from the WI NHTS add-on sample and used the following variables to estimate trip attractions for each trip purpose. These rates are applied to the household and vehicle availability data provided by MIC to obtain trips.

- Households
- Total Employment
- Retail Employment
- Service Employment
- Other Employment
- School Enrollment

Table 9: Trip Generations Rates - Attractions

Trip Purpose	Variable	Attraction Rate Estimate
Home-Based Work Attractions	Total Employment	1.18
Home-Based Shopping Attractions	Retail Employment	8.42
Home-Based Other Attractions	Households	1.13
	Retail Employment	0.86
	Service Employment	0.51
Non Home-Based Attractions	Households	0.68
	Retail Employment	6.99
	Service Employment	0.97
	Other Employment	0.01
Home-Based School Attractions*	High School Enrollment	1.71
	Middle School Enrollment	1.62
	Elementary School Enrollment	1.29
	Junior College Enrollment	1.20
	University/College Enrollment	2.38

* School trip attraction rates are based on Trip Generation: 7th Edition; Institute of Transportation Engineers; 2003 in order to better reflect trip differences between school grade levels and student travel behaviors. University and college enrollment figures were adjusted to reflect students living on-campus.

TAZ socioeconomic data – Employment data by sector is available through the 2010 CTPP except only at the old TAZ boundaries. The CTPP data was then assigned to the new TAZ system based proportionately on the locations and employment from the businesses database.

Trip Attractions Summary – Applying the trip generation rates for attractions to the socioeconomic data, the following trip attractions were estimated for the MIC Planning Area for the base and forecast years in the 2009 model update. **Table 10** provides trip attraction summary for base and forecast years for the 2009 MIC model update. **Table 11** lists the Employment Summary for 2010 as well as projections for 2040 forecast year.

Table 10: Trip Attractions Summary

Type	2010		2040 Conservative Scenario		2040 Aggressive Scenario	
	Trip ends	% Trips	Trip ends	% Trips	Trip ends	% Trips
HBW	85,264	17%	94,611	18%	101,380	18%
HBshop	70,054	14%	75,064	14%	79,914	14%
HBSch	89,412	18%	86,496	16%	93,014	16%
HBO	104,618	21%	113,315	21%	122,658	22%
NHB	149,938	30%	161,905	30%	173,324	30%
Total	**499,287**	**100%**	**531,391**	**100%**	**570,290**	**100%**

Table 11: Employment Summary and Projection

	Households	Service Employment	Retail Employment	Other Employment	Total Employment
2010	63,792	49,761	8,320	13,471	71,552
2040 Conservative	69,095	54,061	8,915	16,490	79,466
2040 Aggressive	75,530	57,150	9,491	18,573	85,214

Special Generators – During the validation process, large trip attractors were identified and reviewed as candidates for special generators. Because model volume estimates were consistent with observed traffic volumes, and trips to these TAZs appeared reasonable, special generators were not used. As noted earlier however, the daily trip generation rates for primary and secondary schools, junior college, and university school trips are based on the ITE's *Trip Generation*, 7th Edition.

Though no special generator zones are there in this model, it is to be noted that the home base work (HBW) trips from and to the TAZ 509 that has the airport were adjusted in the model to reflect the airport trips.

Trip Balancing

Balancing Productions and Attractions – Because each trip consists of a productions/origin and an attraction/destination, the number of trip productions and trip attractions for each trip purpose need to be the same. Attraction trips are generally balanced to production trips since there tends to be more confidence in census household data and trips per household tend be more consistent than trips based on employment data. The MIC model balanced attraction trips to production trips except for home-based school trips. These trips were balanced to attraction trips, which were based on actual school enrollment data at individual school locations.

External Trips

External trips relate to trips that have either the origin or destination outside the Model Study area (external to internal, internal to external; i.e. E-I trips) or are through-trips that have both their origin and destination outside the study area (external to external; i.e. E-E trips). External trips are counted as vehicle trips corresponding to the Annual Average Daily Traffic (AADT) volume at the external station along the study area perimeter.

Ideally, external trip pattern data would come from an origin-destination survey conducted at each external station site. An Origin-Destination (O-D) survey was completed in 2003 by WisDOT on the Wisconsin side of the MPO study area. However, an O-D survey was not conducted for the Minnesota side. The Wisconsin data was used to allocate E-E and E-I trips for Wisconsin external stations. The Transportation Research Board's NCHRP Report 365: *Travel Estimation Techniques for Urban Planning* provided guidance for estimating E-E trip percentages and distribution for external stations in Minnesota.

The percent of E-E trips for the base year 2010 for this model update, were determined as mentioned above using the NCHRP 365 procedures. The initial 2010 E-E trip matrix was then balanced using a series of iteration processes. The final balanced 2010 E-E trip table was then used as an input into a FRATAR model with appropriate ADT growth rates to get the 2040 E-E balanced trip table. MIC provided URS with the projected ADT counts for the base and forecast year's external stations.

Trip Distribution

The trip distribution model links trip productions in the region with trip attractions to create matrices of interzonal and intrazonal travel, called trip tables. The critical output of trip distribution is trip length and travel orientation (suburb to CBD, CBD to suburb, etc.), and the resulting magnitude of traffic volumes. The most common form of model used for trip distribution is the gravity model. The gravity model theory states that the number of trip interchanges between two transportation analysis zones will be directly proportional to the number of productions and attractions in the zones, and inversely proportional to the spatial separation between the zones. The gravity model requires three data inputs:

1. *Travel Impedance* – URS updated the travel times and checked for reasonableness for the 2005 model update. The same data has been assumed to hold good as the zone structure has not changed between 2005 and 2008.

2. *Terminal Times* – URS updated the terminal times for the 2005 model update. The same data has been assumed to hold good as the zone structure has not changed between 2005 and 2008.

3. *Gravity Model & Friction Factors* – Friction factors developed for 2005 model update were assumed to be valid for the current model update as 2000 Census data is still the latest data available.

An iterative process of the gravity model brings attraction estimates by zone in-line with trip generation estimates. The first model iteration overestimates trips to highly accessible areas and underestimates trips to inaccessible areas. The program computes a balancing factor by dividing estimated attractions into input attractions. The resulting factor is applied to estimate attractions in the next cycle. **Table 12** shows the number of trips distributed in the MIC area model for 2010 and 2040 by trip purpose. The same trip lengths are used for the 2009 MIC model update.

Table 12: 2010 & 2040 Average Trip Lengths

Trip Purpose	2010	2040 Conservative Scenario	2040 Aggressive Scenario
HBW	15.8	16.0	16.1
HBshop	14.1	14.1	14.1
HBsch	14.2	14.4	14.5
HBO	12.9	12.9	12.9
NHB	14.0	14.0	13.6
E-I	22.3	22.3	22.2

Note: Average Trip Lengths are in minutes.

Mode Choice

A mode choice model was not developed as part of this or past travel demand models, which is common for small MPO's, where transit trips tend to make up a relatively small proportion of trips and the costs of developing mode choice models are prohibitive.

Auto Occupancy **–** Auto occupancy rates are used for converting person trips to vehicle trips. Auto occupancy rates by trip purpose for similar communities generated from the 2000 National Household add-on data for Wisconsin were provided by WisDOT and applied to the MIC model.

Traffic Assignment

The traffic assignment is the last step of the traditional 4-step process, which is the process of loading vehicle trips between zones onto specific segments of the roadway network. The resulting traffic forecasts and related data are some of the most commonly used outputs from the entire modeling process. Therefore, a great deal of effort is spent to make these forecasts as accurate as possible. Inevitably, even after model validation, estimated link volumes will differ from ground counts.

Vehicle trips loading onto the highway network use a range of path-building algorithms, and typically iterate each assignment to account for congestion on the system. The equilibrium method used in the MIC model is an iterative process that searches for the best combination of the current and previous iterations. Equilibrium is achieved when no trip can reduce travel impedance by changing paths.

The equilibrium model adjusts the travel time for each path based on congestion as defined by the volume-to-capacity ratio. This is known as a capacity restrained assignment. These adjustments are made through volume-delay equations that estimate the delay associated with traffic volumes for each segment in the system. Speed/delay curves serve to adjust the operating speed of a facility downward as volume-to-capacity ratios increase and the facility reaches capacity. Therefore, in an equilibrium assignment model, traffic will be diverted to alternative routes as traffic and congestion increase on parallel facilities.

Based on the premise that different facilities respond differently to congestion, three different speed/delay curves were used for the traffic assignment element of the MIC area model. Separate speed/delay curves were used for the freeways as well as the higher speed multi-lane arterials. A single curve was used for the remainder of the system.

Model Calibration & Validation

Model calibration and validation are terms often used interchangeably. While linked with calibration, validation refers to checking model results against observed data. Once the model results fall within an acceptable range of error, the model is considered valid. The assumption is that if the model can replicate existing conditions, it can reliably forecast future conditions. Calibration, in contrast, is the process of adjusting model parameter values until the model volumes reach the validation criteria. Validation typically occurs through an iterative process with calibration.

Highway assignment models are calibrated and validated based primarily on the comparison of estimated model volumes to traffic counts and achieving an acceptable level of error. At the very minimum, the model should include traffic counts on ten percent of the area-wide highway segments being analyzed plus on all screenline links. This ten percent goal also applies to the distribution of counts in each functional classification. **Table 13** shows the percentage of links having counts in the MIC model. Thirty-four percent of all the links in the network have counts.

Table 13: Links with Counts by Functional Class

Functional Class	Number of Links	Links with Counts	% Links with Counts
Freeway & Expressway	94	71	76%
Principal Arterial	403	280	69%
Urban Minor Arterial	1,062	695	65%
Urban Collectors	1,256	527	42%
Rural Minor Arterial	118	72	61%

A validated model is one that can accurately replicate existing traffic patterns and trip-making characteristics for a given area. Validation ensures that the model provides a firm foundation for forecasting future traffic conditions. Comparing traffic volumes from the highway assignment model with observed traffic counts provides one of the best opportunities to check the accuracy of model outputs.

It is important to recognize that traffic counts are themselves only estimates of traffic volume. Base ground counts should be thought of as approximations of existing traffic, just as the base model estimate is an approximation to existing traffic. Counts could have errors caused by variation in the mix of vehicles or may not be appropriately adjusted for season or day-of-the-week variations. Errors could also be due to mechanical counter failure, field personnel mistakes, or improper count location.

Validation

Model validation is usually performed at different levels. First, system-wide performance is reviewed to determine if regional inputs or parameters should be changed. Second, assigned volumes on different facility types are reviewed to check if speed and capacity assumption need to be changed. Third, specific corridors and links are checked for network coding errors or trip loading errors.

Absolute criteria for assessing the validity of all model systems are not precisely defined. However, a number of target values have been developed. These commonly used values provide guidance for evaluating the relative performance of particular models. The Federal Highway Administration (FHWA) and the Michigan Department of Transportation defines targets for daily volumes by facility type as shown below in **Table 14**.

Table 14: Percent Difference Targets for Daily Traffic Volumes by Facility Type

Facility Type	FHWA Targets	MDOT (MI)
Freeway	+/- 7%	+/- 6%
Major Arterial	10%	7%
Minor Arterial	15%	10%
Collector	25%	20%

Source: *Model Validation and Reasonableness Checking Manual*, Travel Model Improvement Program, US Department of Transportation June 2001.

The MIC model validation results system-wide and by facility type are indicated in **Table 15**. The table shows that the model is under-estimating traffic volumes by less than four percent on the entire transportation network, which is within an acceptable percentage of error. All model volumes by functional class are also well within the percent of acceptable error. The model is slightly over-assigning traffic volume on Freeway and Expressway links. The model under-estimates traffic volumes on the urban minor arterials, and over-assigns traffic slightly on rural minor arterials. The model under-assigns urban collector traffic, although the results from the model overall are still well within the acceptable percentage of error.

Table 15: MIC Model Volumes vs. Traffic Counts by Functional Class

Functional Class	Model ADT	Count ADT	Model/Count %
Freeway & Expressway	1,082,957	1,035,280	4.6%
Principal Arterial	1,811,298	1,882,911	-3.8%
Urban Minor Arterial	2,304,211	2,559,207	-10.0%
Urban Collectors	705,994	875,798	-19.4%
Rural Minor Arterial	126,136	136,655	-7.7%
Total	6,030,597	6,489,851	-7.1%

Another system validation check is to look at model volumes compared to traffic counts according to the total volume of traffic the roadway carries as shown in **Table 16**. The model tends to over-estimate the lowest volume roads and the highest volume roads. Links with the middle ranges tend to be slightly under-estimated. However, all ranges of traffic volumes fall within acceptable percentage of error.

Table 16: Model volumes vs. traffic counts by Range of Traffic Volumes

Traffic Volume Range	Links	Model ADT	Count ADT	Model/Count %
0 - 1,000	419	255,722	238,011	7%
1001 - 2,500	647	1,068,949	1,125,519	-5%
2,501 - 5,000	409	1,274,466	1,510,771	-16%
5,001 - 10,000	335	2,196,421	2,348,769	-6%
10,001 - 20,000	74	928,728	950,008	-2%
20,001 - 30,000	18	435,999	450,000	-3%
Total	1902	6,160,285	6,623,078	-7%

A more stringent measure of model accuracy is provided by the root mean square error (RMSE) between estimated and observed link volumes. This measure summarizes the error in individual link volumes and eliminates the tendency of VMT summaries to obscure results due to compensating errors.

The RMSE output for the MIC area model along with an acceptable percent RMSE by ADT count range is shown in **Table 17**. As shown in this table, the MIC model is well within the limits of RMSE acceptability for links with volume ranges greater than 2,500. The amount of error for low volume links is not within the percent acceptable range. Because the MIC model includes numerous low volume links, the typical range of acceptability category of 0-5,000 was subdivided between 0-2,500 and 2,500-5,000. By doing this, it becomes apparent that the high number of low volume links (<2,500) explains why the total RMSE is outside the acceptable desired RMSE percentage.

Table 17: RMSE by ADT Count Ranges

Volume Range	Links with Counts	Model RMSE %	Acceptable %
0 - 2,500	1,066	71%	45% - 55%
2,501 - 5,000	409	51%	45% - 55%
5,001 - 10,000	335	29%	35% - 45%
10,001 - 20,000	76	21%	27% - 35%
20,001 - 30,000	18	16%	24% - 27%
0 - 30,000	**1,904**	44%	**32% - 39%**

2040 Traffic forecasts

Following the calibration and validation of the base year model, the next step in the process was to use the calibrated base year model to test future year socioeconomic and roadway system improvement assumptions, and to ultimately determine future year traffic forecasts. For the MIC area, the future forecast year for the 2010 Model Update is 2040. It is assumed that all of the socioeconomic growth and roadway system improvements in the model will occur by 2040. The 2040 estimated volume presented in this section of the report is directly related to the socioeconomic and roadway system changes expected to occur in the area over the next 30 years.

The level of future roadway system improvements and capacity expansions represent the final piece of information necessary for projecting future traffic volumes.

The 2040 Model forecasts are based on 2040 population and employment forecasts, from which trips are calculated. Production and Attraction Trips summaries are indicated in the trip generation section of this report.

Because travel demand models have some range of error, particularly at the individual link level, 2040 model volumes are adjusted to account for those individual link errors. For links with traffic counts, the absolute difference and the percentage difference between the base year model volumes and the base year traffic counts are averaged and applied to the 2040 model volumes. Since a traffic count is needed, only some links are adjusted.

Table 18 lists system-wide vehicle miles traveled (VMT) and vehicle hours traveled (VHT) for the 2010 base year model and the 2040 conservative scenario and 2040 aggressive scenario models. Given the 2040 growth assumptions, the model estimates an increase in the vehicle miles of travel to increase by 36 percent. The amount of time spent in traveling on the system is estimated to increase by 46 percent. The percentage increase in traffic and travel times is estimated to outpace the 6 percent population growth that is forecast. This is reasonable considering that most of the areas planned to accommodate growth will likely occur on the urban fringe resulting in greater distances between home, jobs, and commercial areas.

Table 18: 2040 Forecast Summary Data

	VHT	**VMT**
2010	67,894	3,010,946
2040 Conservative	89,766	3,755,722
2040 Aggressive	98,962	4,103,340
% Change	46%	36%

As with all models, the MIC area model was developed with the most current information available. As new information become available, it should be incorporated to the extent possible to further improve and refine the model.

APPENDIX A – Field Definitions

Segment Distance – Segment distance is the length of each link (in miles). This attribute is automatically read by TP+ from the geographic network file, so accuracy in network development is critical in attaining realistic segment distances and reliable travel time calculations. Distance was recalculated in GIS (i.e. ArcMap) to ensure accuracy.

Facility Type (Functional Classification) – This is the type of highway facility that each link represents. The following facility types were used:

- Facility Type 01 = Urban/Rural Interstate
- Facility Type 02 = Urban/Rural Freeway
- Facility Type 03 = Urban/Rural Freeway Ramps
- Facility Type 04 = Urban/Rural Expressway
- Facility Type 11 = Urban Principal Arterial (Other)
- Facility Type 12 = Urban Minor Arterial
- Facility Type 13 = Urban Collector
- Facility Type 14 = Urban Local
- Facility Type 21 = Rural Principal Arterial
- Facility Type 22 = Rural Minor Arterial
- Facility Type 23 = Rural Major Collector
- Facility Type 24 = Rural Minor Collector
- Facility Type 25 = Rural Local
- Facility Type 99 = Zone Centroid Connector

Annual Average Daily Traffic (AADT) – The observed average daily traffic volumes were collected from MnDOT, WisDOT coverage count programs. These traffic counts define the actual traffic conditions to which the traffic modeling results will be compared.

Number of Lanes – The number of through lanes for each link in each direction. Note that this does not include turning lanes at intersections for the purposes of travel demand modeling.

Surrounding Area Type – Area Type indicates the generalized land use surrounding a given link within the network. Table 5.4, from the WisDOT's *Model Inputs Standards Guide*, provides guidance for determining TAZ area types. The Four area type codes used in this model are:

- Area Type 10 = Rural
- Area Type 20 = Suburban
- Area Type 30 = Urban
- Area Type 40 = Dense Urban

Table 5.4: Area Type Definitions

Population (density) by Area Type		Employment (density) by Area Type	
0-500	Rural	0-500	Rural
500-1,000	Suburban	0-5,000	Suburban
1,000-5,000	Urban	5,000-10,000	Urban
5,000+	Dense Urban	10,000+	Dense Urban

- If Employment Type = Dense Urban then Area Type is Dense Urban
- If Employment Type = Urban then Area Type is Urban
- If Employment Type = Suburban AND Population Type = Dense Urban OR Urban then Area Type is Urban
- If Employment Type = Suburban AND Population Type = Suburban OR Rural then Area Type is Suburban
- If Employment Type = Rural AND Population Type = Rural then Area Type is Rural

Lane Capacity – The hourly capacity per lane assigned based on WisDOT's *Model Inputs Standards Guide*. Lane capacity was not used in calculating total daily link capacities, which were provided by MIC staff and MnDOT.

Travel Time – Travel time is calculated along each network roadway link as a function of the segment's distance and model speeds. This refers to non-congested travel time.

Posted Speed Limit – This is the actual speed limit posted on a road by the respective state transportation departments.

Model Speed – This is the speed used in the network to determine travel time on the roadway link. This value is based on a lookup table and may vary from the posted speed limit.

The model speed lookup table used in the MIC model is from WisDOT's *Model Inputs Standards Guide* and is listed below (see Table 5.5). In some situations, these values may have been adjusted within a reasonable range based on specific known roadway characteristics and/or as part of the model calibration process.

Table 5.5: Model Speed Look-up Table

Functional Classification Group	Speed (MPH) Dense Urban	Urban	Suburban	Rural
Interstate	55	65	65	70
Freeway	55	60	60	65
Expressway	40	45	55	65
Principal Arterial	35	40	50	55
Minor Arterial	30	35	45	50
Major Collector	NA	NA	40	45
Minor Collector	NA	NA	40	45
Collector	25	30	35	NA
Local	25	25	25	25
Ramps	35	35	35	35
Centroid	15	15	25	35

Source: WisDOT, STN and Wisconsin Statewide Model

Cross Section Type – The type of roadway cross-section for each link in the network.

- Cross Section 1 = Undivided
- Cross Section 2 = Divided
- Cross Section 3 = Center Turn Lane

Screenline – Screenlines are used to validate models by verifying that major regional traffic flows estimated by the model are consistent with observed regional traffic flows.

Turn Lane Geometry – Turn lane geometry were assigned as follows

- Geo_ID 0 = No Turn Lane
- Geo_ID 1 = Single Left Turn Lane
- Geo_ID 2 = Double Left Turn Lanes
- Geo_ID 3 = Single Right Turn Lane
- Geo_ID 4 = Double Right Turn Lanes
- Geo_ID 5 = Single Left and Right Turn Lanes
- Geo_ID 6 = Double Left and Single Right Turn Lanes
- Geo_ID 7 = Single Left and Double Right Turn Lanes
- Geo_ID 8 = Double Left and Right Turn Lanes

G/C Ratio – Estimated green time to Cycle length.

- Low Signal Priority – GC = .45
- Medium Signal Priority – GC = .50
- High Signal Priority – GC = .55

Intersection Control – The type of Intersection control corresponding to the link approach.

- Control 0 = Freeway Link
- Control 1 = Signalized Intersection
- Control 2 = All Way Stop
- Control 3 = Two Way Stop
- Control 4 = Yield
- Control 5 = No Intersection Control Listed
- Control 6 = Centroid Connector

One-way Indicator – An indicator for a one-way or two-way link included in the network. A “0” indicates that a link is two-way, while a “1” indicates the link is a one-way facility.