# Travel Demand Model for McLean County RPC

*Technical Report*


Prepared by

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# 1 Introduction

The McLean County Regional Planning Commission (MCRPC) Travel Demand Model (TDM) is a transportation planning tool developed to facilitate the analysis of the existing transportation system and to estimate long-range travel forecasts which are a vital input to the Long-Range Transportation Plan (LRTP) development process in MCRPC. The model utilizes the study area roadway network, socio-economic data, land use data, and existing travel patterns to estimate the future travel demand. The model also predicts the future travel pattern in the region based on changes to the roadway network and/or land-use data. The model results provide sufficient information for decision makers to evaluate future investment scenarios that help achieving regional long-range transportation goals and objectives.

Based on the 2019 ACS 5-year estimates, McLean County has a total population of approximately 172,578, with a majority residing in the Bloomington-Normal Area. The MCRPC TDM was developed to address the transportation needs of this area. **Figure 1** shows the model study area for the MCRPC TDM.

The TDM employs the traditional four-step travel forecasting process to evaluate auto trips for both daily and peak hour scenarios. In general, TDM incorporates transit trips, but MCRPC TDM does not cover public transit. This is because the MCRPC public transit system operates on a limited service, so it may not be able to be modeled. The base year for the model is 2019. The MCRPC TDM uses Bentley Cube Voyager to develop the model.

This document provides detailed information on the steps involved in the development of the MCRPC TDM and the model validation process. The document also provides details about the processes and parameters used in each module of the four-step model. The validation checks for each of the four model steps are discussed in the corresponding chapters.

## 1.1 Study Objective

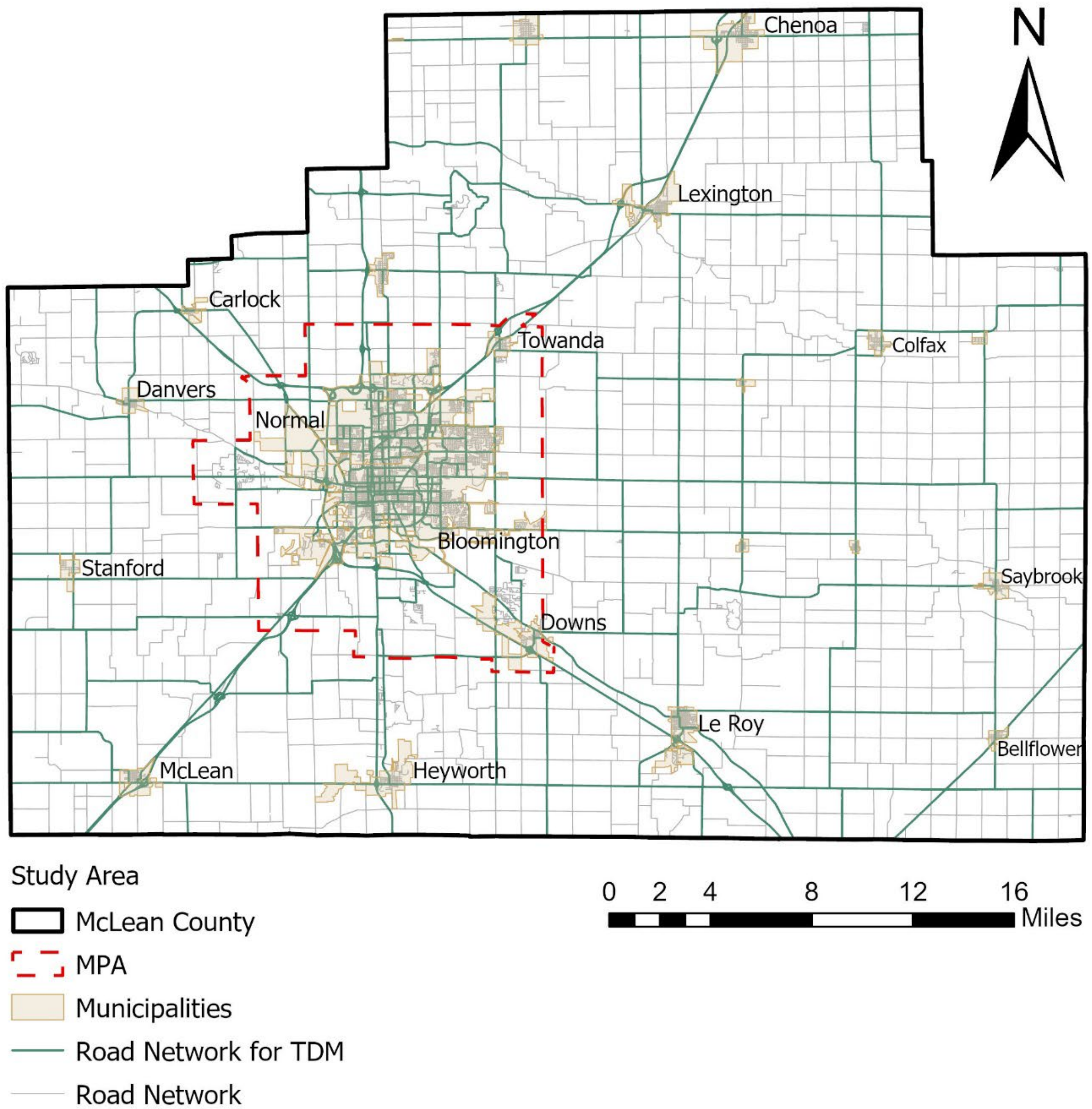
The objective of developing the MCRPC TDM was to:

- Build the MCRPC area travel demand model to serve as a tool to be used for transportation planning.

The objectives of this report were to:

- Identify the needs and benefits of the MCRPC travel demand model.
- Document the detailed step-by-step process involved in the development of the MCRPC travel demand model.
- Document the validation checks performed for each model component and the final overall model.

**Figure 1: MCRPC Model Study Area**



## 1.2 Report Organization

The model documentation report provides a step by step process used to develop the MCRPC TDM. The report is organized into the following chapters:

Chapter 1: Introduction - This chapter provides an introduction to the report and identifies the objectives of the MCRPC TDM and the model documentation report.

Chapter 2: Overview of the MCRPC Travel Demand Model - This section of the report identifies the benefits of a travel demand model and provides an overview of the four-step modeling process.

Chapter 3: Delineating Traffic Analysis Zones - This chapter describes the method used to divide the model study area into small geographical areas called Traffic Analysis Zones (TAZs).

Chapter 4: Roadway Network - This chapter details the development of the roadway network for the MCRPCTDM. The model network validation process is also described.

Chapter 5: Socio-Economic Data - This chapter describes the socio-economic data used as input in the MCRPC TDM. Aggregate checks were performed to validate the model input data.

Chapter 6: Trip Generation - This first module of the four-step forecasting process estimates the number of trips being produced and attracted to each zone in the model, based on the zonal socio-economic data. The inputs to the trip generation module include zonal household and employment data, any available household or/and external surveys, and the ADT counts at the external stations. The output of this step is the zonal trip attractions and productions by trip purpose. Trip generation validation checks are described.

Chapter 7: Trip Distribution - The chapter describes the process used to distribute the trips generated from each TAZ to every other TAZ in the model study area by trip purpose. The input to the trip distribution step is the balanced trip production and attractions and the travel impedance matrix. Since the MCRPC TDM does not include public transit system, the mode choice step is not conducted. Vehicle occupancy rate is applied to convert vehicle trips to person trips. The output of this step is zone-zone person trip matrix for each trip purpose. The trip distribution validation checks are described.

Chapter 8: Trip Assignment - This last step of the modeling process describes the method used to assign the auto and transit trips on the corresponding networks. The time-of-day (TOD) factors are described and applied to the model to reflect temporal variation in daily travel pattern. The trip assignment and full model validation checks are discussed.

# 2 Overview of the MCRPC Travel Demand Model

The MCRPC travel demand model uses a traditional four-step forecasting process. A brief overview of the four-step forecasting process is discussed and the model validation and calibration process is explained.

## 2.1 Primer to the Four-Step Travel Demand Modeling Process

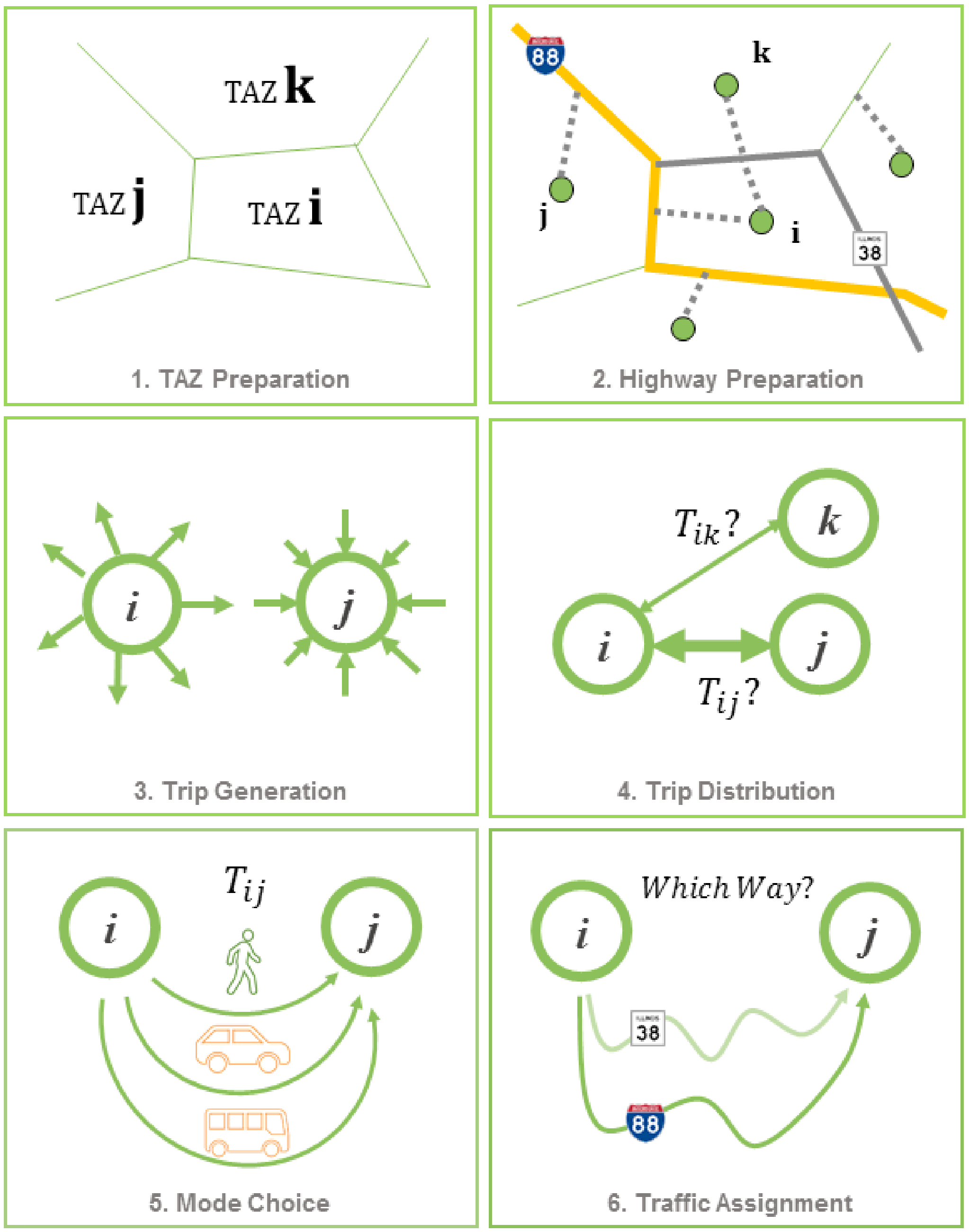
The MCRPC travel demand model is a person trip model built on the Cube transportation modeling software platform and follows the typical four-step forecasting process. This section presents a brief summary of the modeling process, although the forecasting process will be discussed in more detail later in the report. The following elements are the major modules of a four-step model:

- Trip Generation
- Trip Distribution
- Model Choice
- Trip Assignment

A “trip” is defined as person/vehicle traveling from an origination to a destination without any intermediate stops. In the modeling process, trips (person/vehicle) are generated, distributed between model zones and assigned on the roadway network. A trip within the model can be made for various purposes such as going to work, for shopping, recreation, etc. The model categorizes trips into various trip purposes to capture the characteristics of each trip type. The major trip purposes are Home Based Work (HBW), Home Based Other (HBO), and Non-Home based (NHB). These basic trips classifications can be subdivided further to increase the sensitivity of the model.

The model study area is divided into smaller geographical areas, known as traffic analysis zones (TAZs) for analysis. Trip generation utilizes land-use, socio-economic data and trip rates/equations to estimate the number of trips beginning and ending at each TAZ by trip purpose. The trip distribution step allots the trips from one zone to every other zone in the model. The gravity model is the most common trip distribution model which uses spatial separation between zones and magnitude of zonal activity to distribute the trips. The mode choice module splits the model trips by the competing modes of travel in the region. Once the transit and non-motorized trips are separated from the total model trips, the remaining person trips are converted into automobile trips using auto occupancy factors. However, MCRPC travel demand model does not incorporate this step due to its limited public transit services. The trip assignment step assigns the auto and transit trips on the highway network and the transit network, respectively. Various models using different trip allocation and route selection methodology are available for executing the trip assignment step. **Figure 2** illustrates the general 4-step model process used to develop a travel demand model.

**Figure 2: TDM Traditional Four-Step Forecasting Process**



## 2.2 Model Validation and Calibration

In order to achieve reliable travel forecasts, the travel demand model needs to be calibrated and validated for the base year conditions. Model validation involves comparing the model results to the observed base year data. A travel demand model is not considered reliable for future year forecasts until it is validated to replicate the existing base year traffic patterns in the region. Model calibration is the process of adjusting the model input parameters to ensure the model results are comparable to the observed data. The "Model Validation and Reasonability Checking Manual" published by the Federal Highway Administration (FHWA) defines validation and calibration as the following:

"*Calibration* is the adjustment of constants and other model parameters in estimated or asserted models in an effort to make the models replicate observed data for a base (calibration) year or otherwise produce more reasonable results."

"*Validation* is the application of the calibrated models and the comparison of the results against observed data. Ideally, the observed data are data *not* used for the model estimation and calibration. Validation data may include additional data collected for the same year as the estimation or calibration of the model or data collected for an alternate year."

Errors in a travel demand model can be propagated through a lack of reliable input data, errors in processing the input data and/or inadequate knowledge of model tools and scripting. Ideally, the model results are validated after each forecasting step to ensure model credibility. The "Travel Model Validation and Reasonability Checking Manual" published by FHWA recommends a set of comprehensive calibration and validation checks for each of the travel demand modeling steps and for the complete model. The sources for the MCRPC Travel Demand Model validation data include NCHRP Report 365 data, ILMUG TDM Guidelines data, National Household Travel Survey data, and the base year traffic counts.

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# 3 Delineating Traffic Analysis Zones

The model study area covers all of the areas within the MCRPC region. For modeling purposes, the study area was divided into series of small geographical areas called traffic analysis zones (TAZs). The TAZs are the locations where trips begin (trip producers) and end (trip attractors). TAZs are characterized by their socio-economic conditions (population and employment data) and are used to evaluate the traffic flow patterns in the region. A TAZ in a model is represented by a centroid and is connected to the roadway network via centroid connectors.

The spatial extent of a TAZ is based on the U.S. Census block data, land use characteristics, density of population and employment, physical/jurisdictional boundaries, natural barriers, and the model roadway network. Ideally, the TAZs contain similar land uses to minimize intra-zonal trips. The size of the TAZ also depends on the density of the area and the nature of the model. Urban areas are expected to have smaller TAZs compared to rural areas.

## 3.1 Development of MCRPC Traffic Analysis Zones

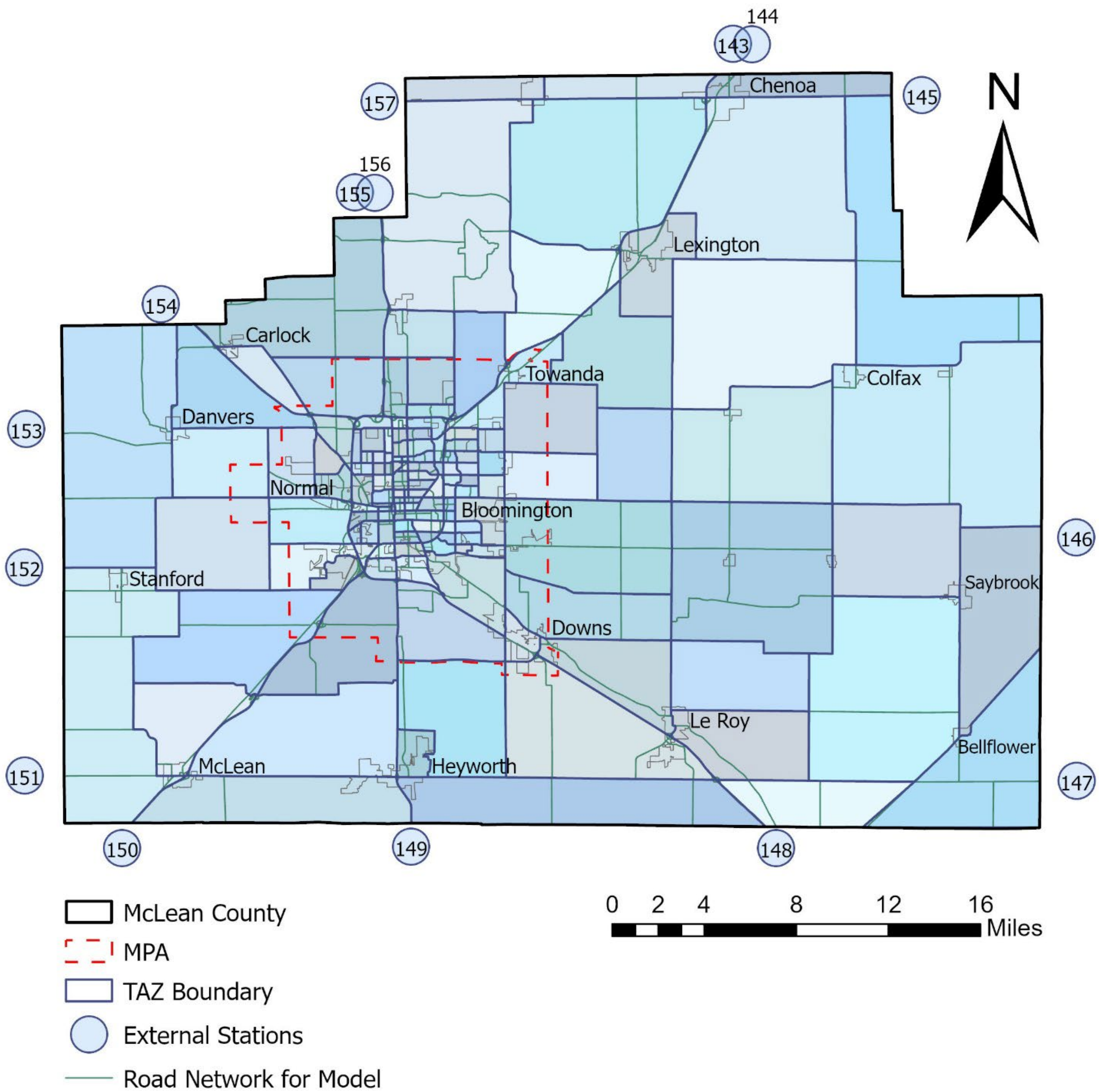
The following files were used to develop the MCRPC model TAZs:

- 2010 Census TAZ boundary GIS file
- Illinois statewide TDM TAZs

The MCRPC model TAZs were created in ArcGIS by initially using the 2010 Census TAZ boundary data for McLean County and were adjusted to establish smaller, more contiguous TAZs. The Illinois statewide TDM TAZ boundaries were also given consideration for the final MCRPC TAZ boundaries. Other key considerations for TAZ boundaries were major highways, railroads, and streams. Minor adjustments were made to the TAZ boundaries based on local knowledge of the area.

External stations were identified along the intersection of major roadways (Interstates, State/County routes) and the model study area boundary to determine the amount of internal-external/external-internal and external-external travel in the model. The MCRPC TDM study area contains 142 TAZs (internal zones) and 15 external stations. **Figure 3** shows the model TAZs and the external stations.

**Figure 3: MCRPC Model TAZs with External Zones**



# 4 Roadway Network

The model roadway network is an essential input to the TDM and represents the supply side of the modeling process. The roadway network is used to distribute and assign model trips. The model network contains all the basic roadway information to be used in the modeling process. The network is also used to store model outputs such as traffic volume and Vehicle Miles Traveled (VMT). The model network for the base year was developed using GIS Software (ArcGIS and QGIS) to represent the 2019 base year roadway network. Cube Voyager accommodates multiple networks to represent base year and alternate/future scenarios. This chapter discusses the general roadway structure used in Cube Voyager and the development of the base year MCRPC travel demand model network.

## 4.1 Roadway Network Structure

The model network is composed of nodes and links. Nodes represent the intersection of roadway links. Node attributes include node number, x-coordinate, and y-coordinate. Links represent the roadway segments in the model. The network links store basic roadway information such as link attributes which are used to distribute/ assign trips in the model. Basic link attributes include lane configuration (one-way/two-way, number of lanes), link length, area type, facility type, speed, and roadway capacity. The accuracy of these attributes is essential to develop a reliable travel demand model. The roadway network in a travel demand model is limited to interstates/ freeways, arterials, and collector roadways. The local roadway system is too detailed for modeling purposes and is represented using centroid connectors. Some local roadways are included in the model when they provide crucial network connection to major roadways.

The Cube model network also stores the intermediate model calculation and final model outputs in the "assigned" model network after a model run. Cube stores multiple network files (*.NET) representing alternate and future year scenarios. Additional roadway links can be added to the future year roadway network to represent the planned or/and the committed roadways. The Long-Range Transportation Plan and Transportation Improvement Plan (TIP), along with other planning documents can be used to identify proposed roadway improvements. The modified network representing the future year scenario(s) is saved as a new *.NET file. Multiple future year scenarios can be evaluated with the same TDM structure and minimal changes to the input files (e.g. turn penalty file and link attributes).

## 4.2 Model Network Link Attributes

The basic link attributes required for the modeling process are link distance, speed and capacity. All other input link attributes are used to either identify a link in the network (A and B nodes) or to calculate link distance, speed, and capacity. **Table 1** shows the link attributes incorporated in the MCRPC TDM. The model input attributes are discussed more in detail in the following sections.

Attributes 1 to 4 are used to identify a link in the network. Attributes 5 through 19 are used to calculate link speed, capacity and SPD_CRV. SPD_CRV is based on the facility type and free flow speed of the link and is used as an input in the trip assignment module. The accuracy of the travel demand model depends heavily on the quality of the input variables.

**Table 1: MCRPC Model Link Attributes**

| Number | Attribute | Description |
|---|---|---|
| 1 | A Node | Identifies the "from" node of the link |
| 2 | B Node | Identifies the "to" node of the link |
| 3 | LANES | Number of lanes |
| 4 | ROADWAY | Roadway Name |
| 5 | TWLTL | Two way left turn lane (0 - not present or 1 - present) |
| 6 | FACILITY | Functional classification of the roadway (1-7) |
| 7 | ZONE | Adjacent zone number (used to calculate area type) |
| 8 | AREA | Area Type 1=CBD, 2=Fringe, 3=Residential, 4=OBD, 5=Rural |
| 9 | SPD_CRV | Code used to calculate volume delay functions |
| 10 | SPD_CLS | Code used to calculate link speed |
| 11 | CAP_CLS | Code used to calculate link capacity |
| 12 | SPD_FF | Free flow link speed |
| 13 | Capacity | 24-hour roadway capacity |
| 14 | AADT | Observed annual average daily traffic |
| 15 | SPEED | Operating Link speed |
| 16 | Distance | Actual link distance between nodes |
| 17 | SPEED_ADJ | Adjusted Speed |
| 18 | LINK_ID | Link ID |
| 19 | ROW | Roadway right-of-way (1 - one-way or 2- two-way) |

## Facility Type/Functional Classification

The facility type or functional classification determines the function of each link in the model network. The link facility type is used to determine the free flow speed, capacity and volume-delay characteristics for the network link. The MCRPC roadway network links were classified into the following seven functional classifications:

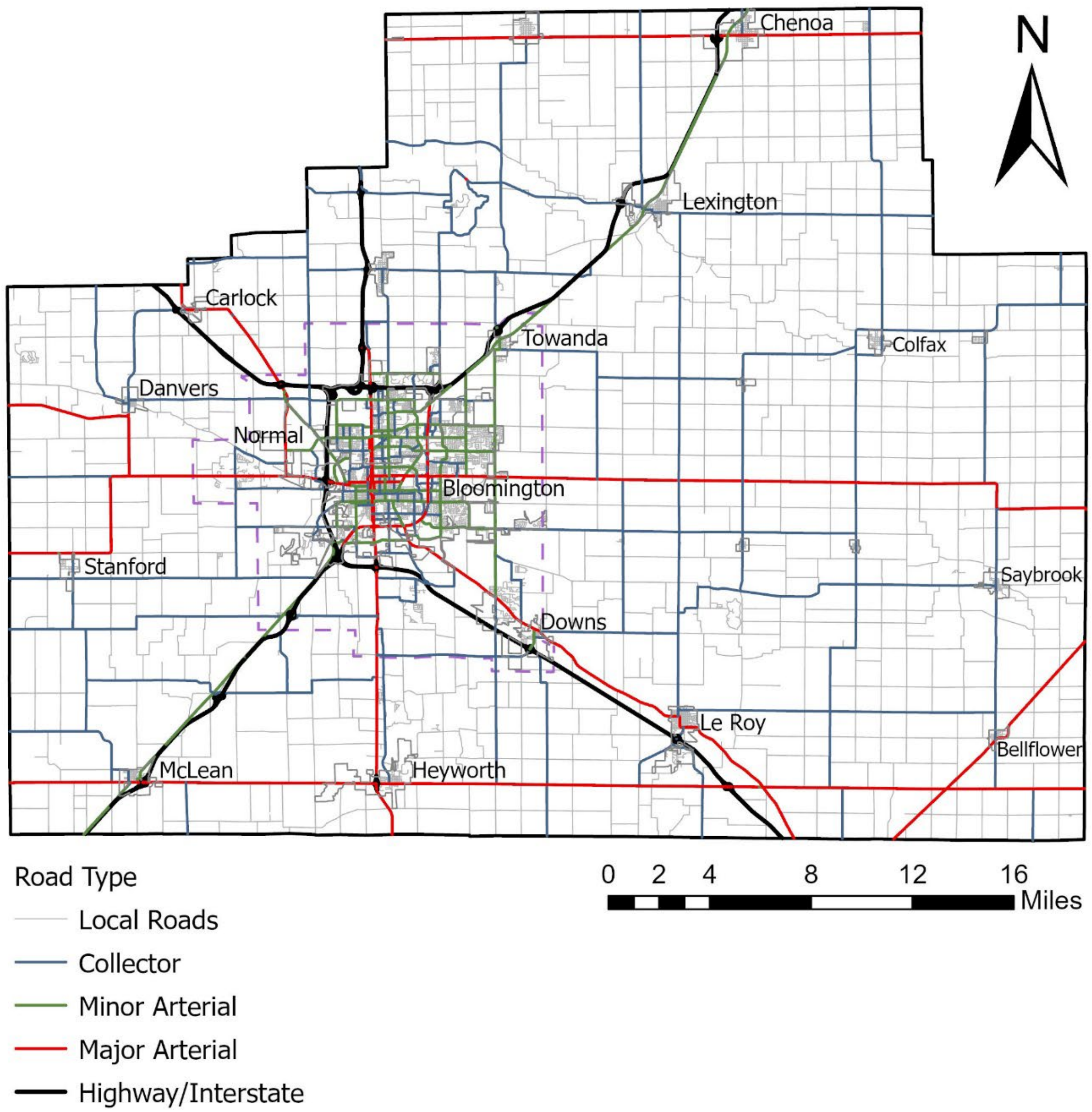
- Centroid Connector represents the majority of the local roadways in the model and connects the model TAZ centroids to the adjacent roadway network. These links have high capacity and very low speed.
- Local roadways provide limited mobility and offer primary access to the local land uses. These links have low capacity and low volume. Local roadways are rarely represented in the model network.
- Collectors connect local roadways/centroid connectors with arterials. These roadways balance mobility with local access. Collectors make up for the majority of the links in the roadway network.
- Minor Arterials are high volume links connecting collectors/local roadways to major collectors and interstates. These links have moderate speed and capacity. Access to land use activities are limited.
- Major Arterials serve major traffic movement in the community with high mobility and limited land access. These links have high speed and capacity.
- Freeways provide the highest mobility and high speed with limited access via ramps.
- Ramps connect freeways/interstates with the rest of the roadway network.

IDOT functional classification, which is based on the FHWA guidelines and local knowledge, was used to create the MCRPC travel demand model network. The facility type codes used in the MCRPC travel demand model are presented in **Table 2**. **Figure 4** shows the roadway facility types in the MCRPC TDM.

**Table 2: Facility Type Classification**

| Code | Facility Type |
|---|---|
| 0 | Centroid Connector |
| 2 | Collector |
| 3 | Minor Arterial |
| 4 | Major Arterial |
| 5 | Freeway Ramps |
| 7 | Freeways |

**Figure 4: MCRPC Facility Type Classification**



## Area Type Classification

Area type is used to categorize the model TAZs and the adjacent roadway links based on the socio-economic characteristics and land use density of the zone. The zonal population and employment density have a direct impact on the speed and the capacity of the adjacent roadway links. High intensity TAZs are expected to have more traffic congestion, intersection & access density, and pedestrian volumes, which can be related to slower speed and lower roadway capacity. A roadway link in or bordering a high density urban TAZ is expected to have low speed and capacity compared to the link associated to a low density rural TAZ. The area type for the TAZs should be changed in future scenarios based on changes to the socio-economic information. The MCRPC area types were categorized as follows:

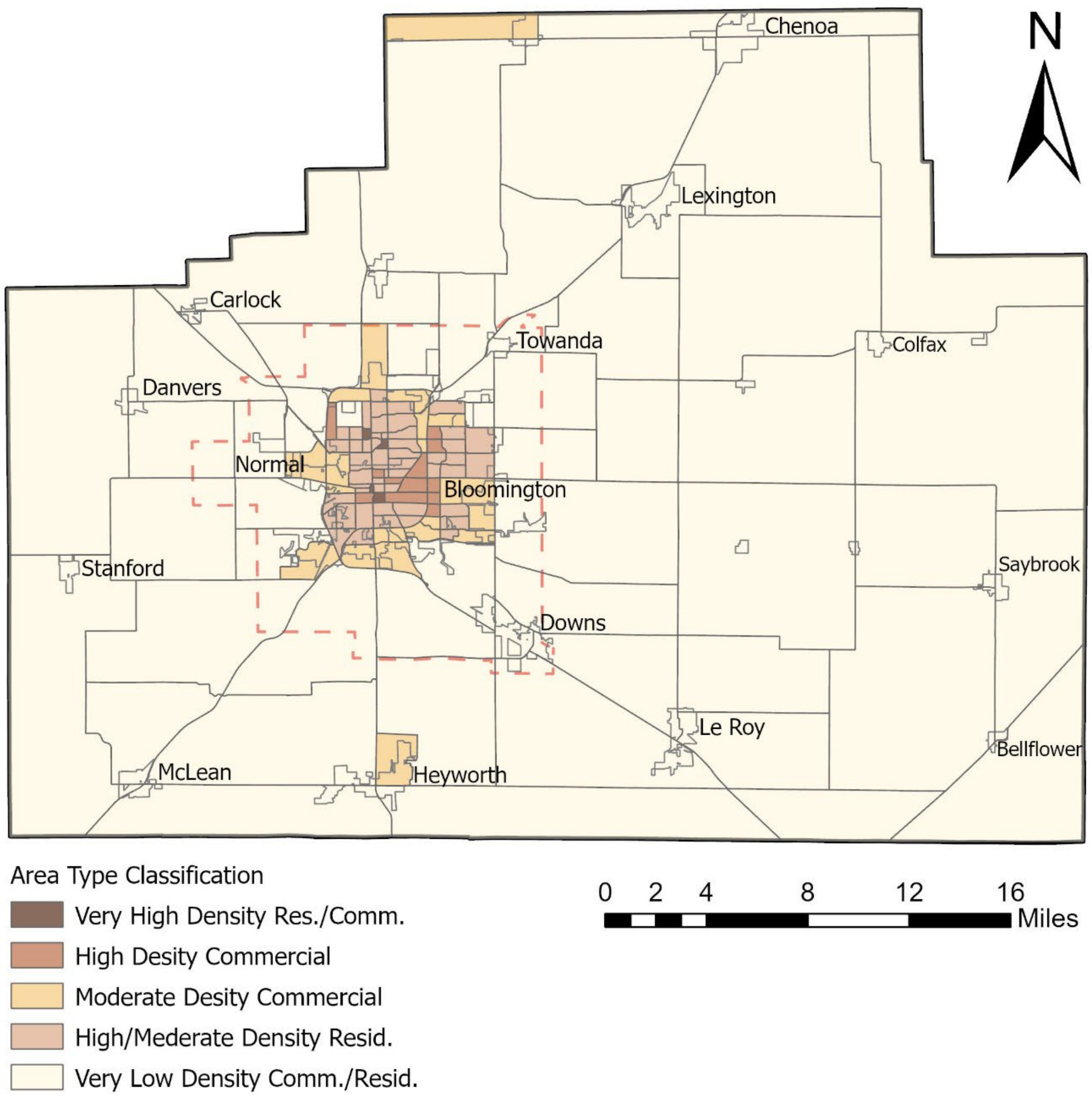
- 1 – Very High Density Commercial/Residential
- 2 – High Density Commercial
- 3 – Moderate Density Commercial
- 4 – High/Moderate Density Residential
- 5 – Very Low Density Commercial/Residential

The area types for the zones in the MCRPC TDM were determined based on the employment and population density lookup table. The reference table was derived from the MCRPC TDM. **Table 3** shows the area type criterionassociated with the population and employment density per square mile. The lookup table was included in the model script to uniformly assign the area types to the network links. **Figure 5** shows the area type classification for the TAZs in the MCRPC TDM. Due to the lack of traffic signal data, an 'Area Type 6' was used in the model to address the issues presented by Veterans Parkway, a unique business loop, in the Bloomington-Normal Area. The network processing script of the model has the details of the assumptions used.

**Table 3: MCRPC Area Type Classification**

| One Mile Radius Population Density (Pop./Sq. mi) | One Mile Radius Employment Density (Emp./Sq. mi) | | | | |
|---|---|---|---|---|---|
| | 0 - 50 | 51 - 900 | 901 - 2,850 | 2,851 - 6,650 | > 6,650 |
| 0-150 | 5 | 5 | 3 | 2 | 2 |
| 151-1,950 | 5 | 3 | 3 | 2 | 2 |
| 1,951-4,550 | 4 | 4 | 4 | 2 | 2 |
| 4,551-10,000 | 4 | 4 | 4 | 2 | 1 |
| >10,000 | 4 | 4 | 4 | 4 | 1 |

**Figure 5: MCRPC Area Type Classification**



## Link Distance

The network link distance information was derived from the MCRPC Roads shapefile. The shapefile contains the link length based on the true shape of the roadway. The link distance in miles is automatically saved as an attribute when the roadway network shapefile is imported into Cube.

## Link Speed

The link speed, referred to as the free flow speed, is an important input in the modeling process. The ideal method to estimate the free flow speed is by conducting travel time studies along the roadway included in the model network. Due to time and financial constraints, this approach was not always feasible for the MCRPC TDM. The free flow links speeds for the MCRPC TDM were estimated based on the link facility type and the area type. The free flow speed is usually lower than the posted speed limits in urban areas.

The speed table (**Table 4**) was used for the MCRPC TDM model. The speed table was derived based on available literature and other regions' models. The free flow speed for each link was estimated based on the facility type and area type of the link. The lookup table was included in the model script to uniformly assign the link speed to the network links. **Figure 6** shows the link speed for the model roadway network. As mentioned before, for the special 'Area Type 6', a flat 40 MPH free flow speed was used for all segments of the Veterans Parkway.

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**Table 4: Link Free Flow Speed (mph) for the MCRPC TDM**

| | Area Type | | | | |
|---|---|---|---|---|---|
| Facility | 1 | 2 | 3 | 4 | 5 |
| 0 - Centroid Connector | 15 | 15 | 20 | 20 | 25 |
| 1 - Local | 15 | 30 | 35 | 30 | 55 |
| 2 - Collector | 25 | 30 | 35 | 30 | 55 |
| 3 - Minor Arterial | 30 | 30 | 35 | 30 | 55 |
| 4 - Major Arterial | 30 | 30 | 35 | 35 | 55 |
| 5 - Freeway Ramp | 25 | 45 | 50 | 50 | 55 |
| 6 - Freeway to Freeway Ramp | 30 | 45 | 50 | 50 | 55 |
| 7 - Freeway | 70 | 70 | 70 | 70 | 70 |

Area Types:

1 - Very High Density Commercial/Residential

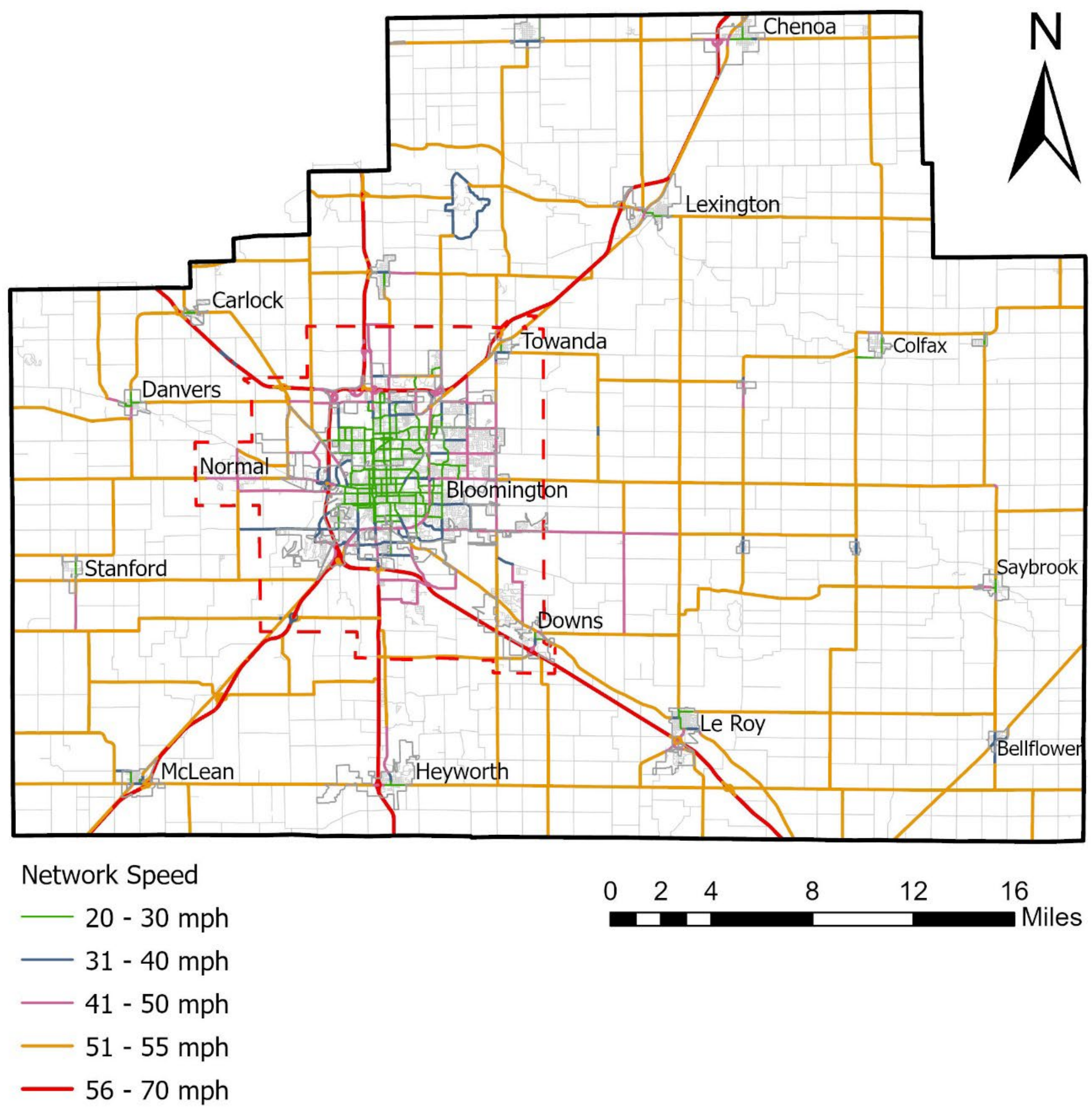
2 - High Density Commercial

3 - Moderate Density Commercial

4 - High Moderate Density Residential

5 - Very Low Density Commercial/Residential

**Figure 6: MCRPC Roadway Network Speed**



## Link Capacity

The link capacity is an important criterion when assigning traffic on the model network. The daily capacity for each link in the MCRPC model network was calculated based on its facility type and area type, as shown in **Table 5**. The link capacity was used to determine the volume delay functions in the trip assignment process. The lookup table was included in the model script to uniformly assign the capacity on the model network. **Figure 7** shows the link capacity for the model roadway network. For all segments of Veterans Parkway, the Area Type 6, the capacity was determined to be 950.

**Table 5: Link Capacity (number of vehicles per hour per lane) for the MCRPC TDM**

| | Area Type | | | | |
|---|---|---|---|---|---|
| Facility | 1 | 2 | 3 | 4 | 5 |
| 0 - Centroid Connector | 9999 | 9999 | 9999 | 9999 | 9999 |
| 1 - Local | 400 | 550 | 550 | 600 | 700 |
| 2 - Collector | 500 | 600 | 650 | 700 | 850 |
| 3 - Minor Arterial | 600 | 700 | 750 | 850 | 1050 |
| 4 - Major Arterial | 800 | 850 | 900 | 950 | 1150 |
| 5 - Freeway Ramp | 1300 | 1300 | 1300 | 1400 | 1500 |
| 6 - Freeway to Freeway Ramp | 1400 | 1400 | 1400 | 1500 | 1500 |
| 7 - Freeway | 1900 | 1950 | 2000 | 2000 | 2050 |

Area Types:

1 - Very High Density Commercial/Residential

2 - High Density Commercial

3 - Moderate Density Commercial

4 - High Moderate Density Residential

5 - Very Low Density Commercial/Residential

## Right-of-Way (One-way and Two-way Roadways)

The right-of-way of roadway is an important factor that affects traffic on the model network. Roadway shapefiles and local knowledge are used to determine the right-of-way of each link. **Figure 8** shows the right-of-way of the model roadway network.

**Figure 7: MCRPC Roadway Network Capacity**

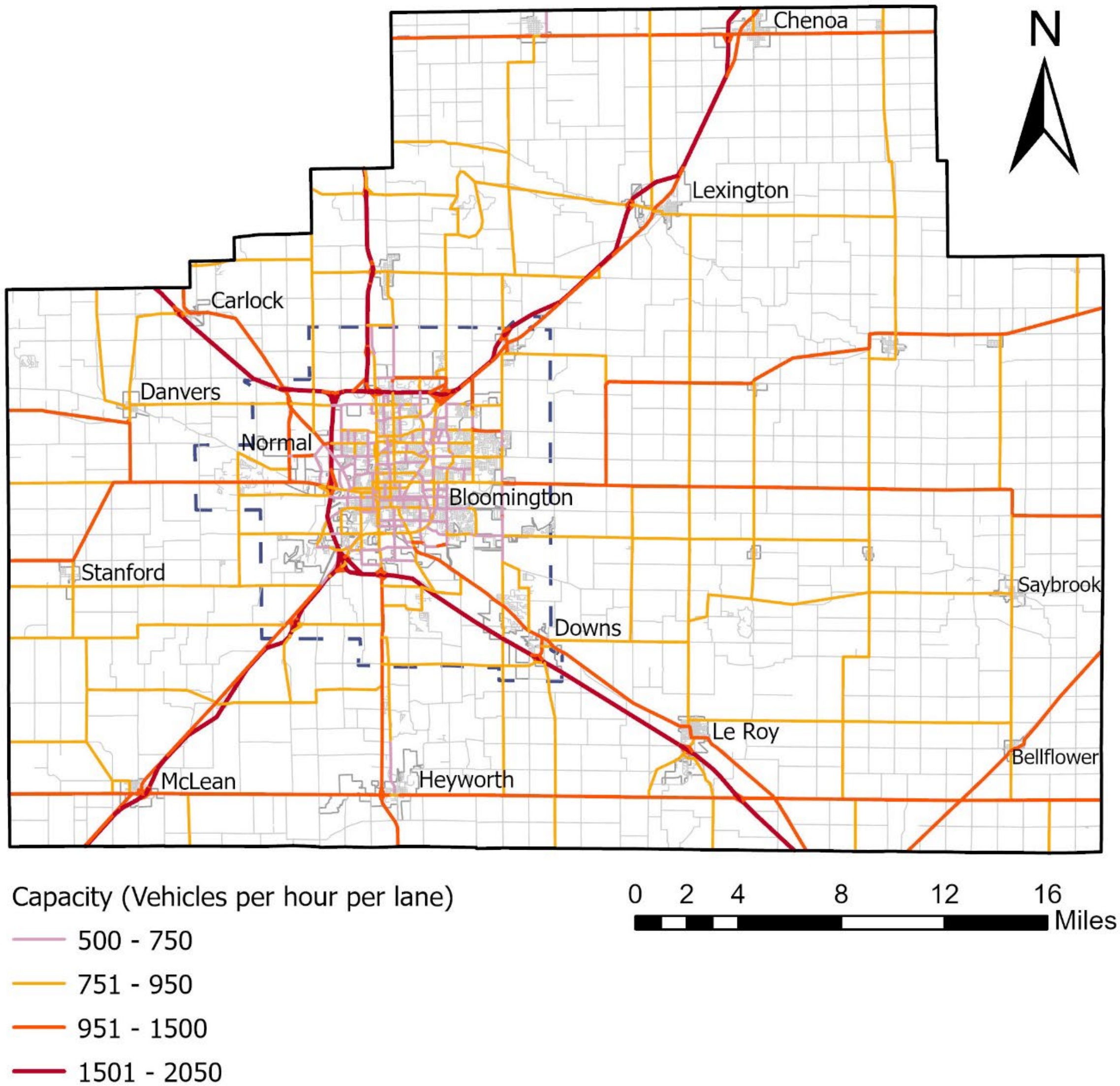
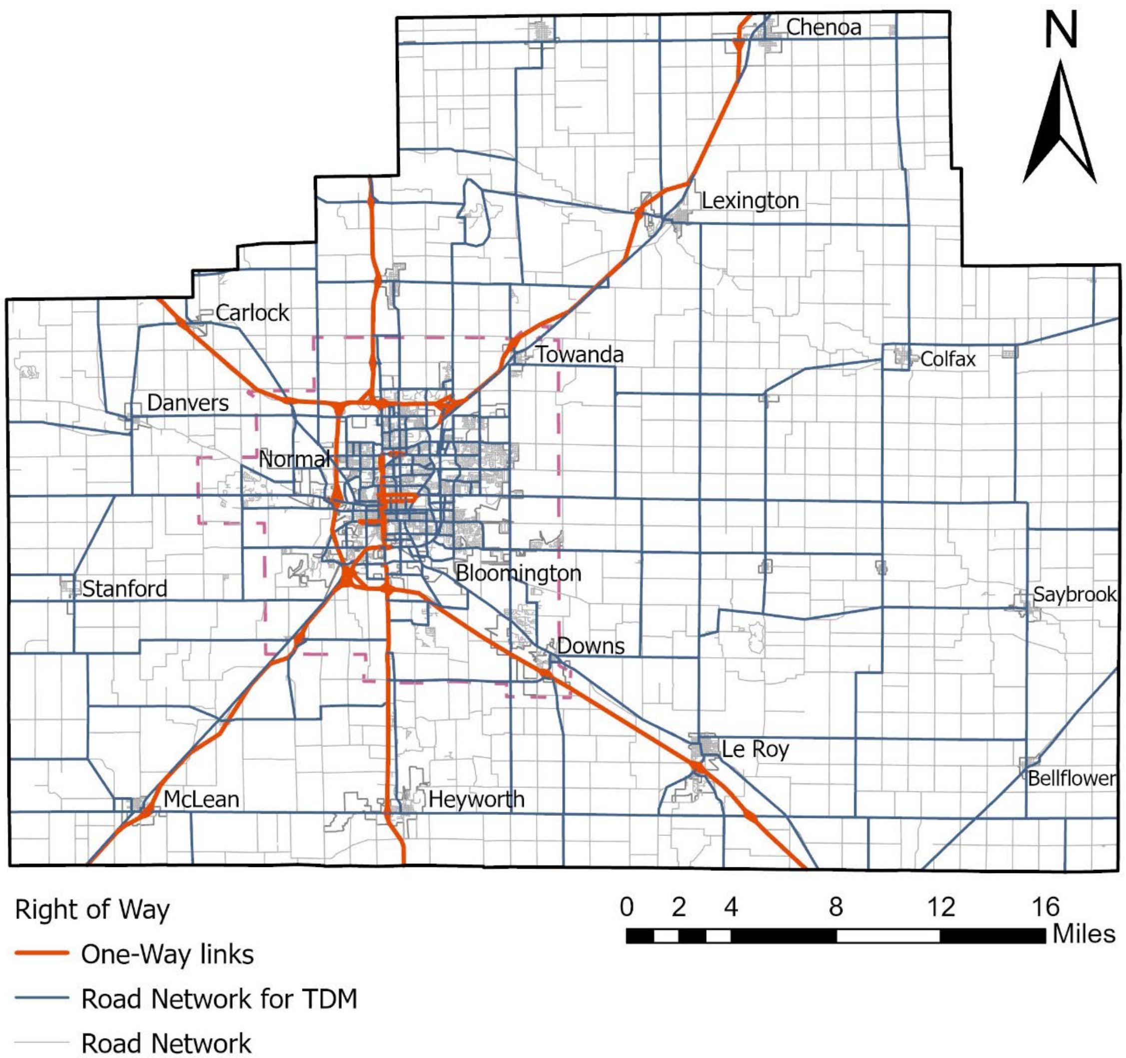


**Figure 8: MCRPC Road Network ROW**



## 4.3 Centroids and Centroid Connectors

The TAZ centroid represents the activity center of the zone and contains the socio-economic information pertaining to the TAZ. The centroid represents the point of trip origin and destination within the zone. The centroid connectors represent the local roadways in the model and provide a link between the centroids and the adjacent roadway network. The centroid location, the number of centroid connectors in a zone and the length of the centroid connectors impact the way the model trips are loaded onto the roadway network. Suitable adjustments were made continuously to the centroid locations and the centroid connectors during the modeling process to improve the model representation of the base year local conditions. **Figure 9** shows Centroids and Centroid Connectors in the MCRPC TDM.

## 4.4 Turn Penalties

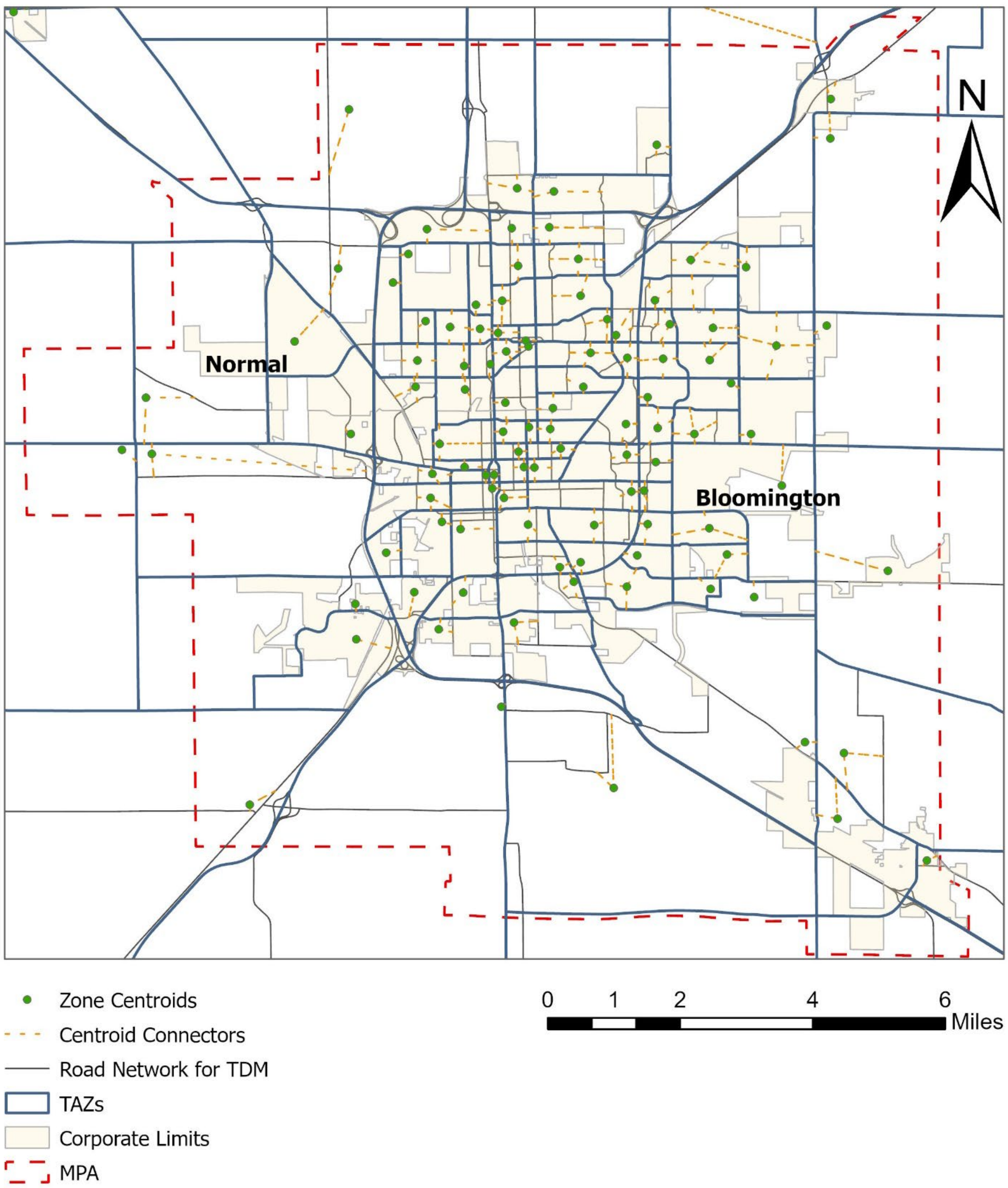
The turn penalties are a crucial input in the trip assignment process. They are included to add delay to the turn movements in the model network. In certain cases, turn penalties can also be used to prohibit a turn in the network. Each turn penalty entry is a combination of three successive nodes making up the turn which needs to be restricted or prohibited. Specific turn penalties can be adjusted to represent the existing and future conditions. The MCRPC travel demand model includes a 0.5-minutes delay for all right turns and a 1-minute delay for all left turns in the model network.

## 4.5 Model Network Validation

The MCRPC travel demand model network was compared against the existing roadway network as part of the validation process. Visual checks were performed using the aerial photographs as the major validation source. Local knowledge of the area was used to make necessary adjustments to the model network. The following checks were performed to validate the model roadway network.

- Color figures were plotted for various network attributes to highlight any possible discrepancies.
- The freeway to freeway ramp coding was checked for proper connections.
- The location of the zone centroids and the access points at which the centroid connectors were linked to the highway network was compared with aerial photographs. The location of some of the centroids/external stations and the access points were corrected to match with the existing ground condition. The network connectivity was checked using the tools provided in Cube Voyager.
- Origin-destination paths were plotted between zones in Cube and checked for reasonability.

**Figure 9: MCRPC Model Centroid and Centroid Connector Locations**



# 5 Socio-Economic Inputs

The zonal socio-economic data is another major input into the modeling process. Basic socio-economic data for each TAZ includes data on population, household, and employment. Trip productions from each TAZ are related to the household characteristics of the zone, while the attractions to each TAZ are based on the zonal employment information. The socio-economic data collected for MCRPC's 2019 model base year was obtained from the following sources:

- 2019 American Community Survey (ACS) Data (Population and Household)
- 2019 Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES) Workplace Area Characteristics (WAC) Data.
- 2019 Bloomington-Normal Economic Development Council

Depending on the data structure of the available sources, adjustments were made to the input data (aggregation/disaggregation) to match the model's TAZ structure.

## 5.1 Population & Household Data

Population and household data for the base year condition was derived from the 2019 ACS 5-year estimates. Population data was taken from the smallest available geography, Census Blocks. Because McLean County's original TAZs are larger than ACS blocks, the total population within each TAZ was calculated by adding the population of the blocks within each TAZ.

Household 2019 data was collected by gathering the total number of households, and the number of households by size (1, 2, 3, and 4+ person households). However, household data for 2019 was only available at the Block Group level and because block groups vary in shape and size, they did not always align with TAZs. Therefore, the final household data for each TAZ was calculated with the following steps:

a. When TAZs were the same size or larger than block groups:
    - Block group data was directly allocated to the corresponding TAZ.

b. When TAZs were smaller than block groups, and/or a block group did not coincide with TAZs:
    - The percentage of each block group within each TAZ was calculated and the number of households was allocated to each TAZ based on this percentage.
    - The percentage of residential land use within TAZs was also calculated.
        - The number of households previously allocated was reviewed and if necessary, re-distributed based on the residential land within each TAZ compared to the surrounding TAZs.

The person per household data used in MCRPC's model was compared against the 2019 National Household Travel Survey (NHTS) data and the American Community Survey (ACS) data, See Table 6. The NHTS data provides comprehensive information on travel and transportation patterns in the United States. Utilizing the NHTS data, the nationwide average person per household and the percentage of households by number of persons were derived. The American Community Survey is a continuous effort conducted by the Census Bureau where one in every 40 addresses in the United States is surveyed every year. The 5-year estimate data was obtained and used to validate MCRPC's TAZ household data. The comparison shows that MCRPC's model household input data is very similar to the ACS and the NHTS datasets. Finally, the household data was mapped for visual validation. Figure 11. shows the household information for the model TAZs.

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## 5.2 Employment Data

The employment data was derived from the 2010 Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES), Workplace Area Characteristics (WAC) Data, and the Bloomington-Normal Economic Development Council (B-N EDC). Employment data was categorized into retail, service, and other based on the classification of the LODES WAC data.

a. LODES data was available at the block level, however, the number of people in the workforce from LODES did not match B-N EDC's number. Therefore, employment data was calculated with the following steps:
b. When LODES employment data was available per block level, the number of employees per block was assigned to the corresponding TAZ.
c. The initial distribution was then reviewed and recalculated based on B-N's EDC data (number of employees from major employers).

The employment data for each TAZ went through a final review using local knowledge, existing land uses, and aerial maps.

Table 7 shows the aggregate comparison of the employment data used in the model against the Bureau of Economic Analysis (BEA) data, noting that the model inputs are similar to BEA Data. Figure 12 shows the employment distribution for McLean County's TDM. Major travel attractions such as State Farm campuses and shopping areas are shown in dark orange.

**Table 6: Percentage of Household by Household Size**

| Household Size | Model Inputs | 2019 ACS | 2017 NHTS Survey |
|---|---|---|---|
| 1 Person | 28.8% | 27.9% | 27.9% |
| 2 Person | 34.7% | 33.9% | 33.9% |
| 3 Person | 15.3% | 15.7% | 15.7% |
| 4+ Person | 21.2% | 22.4% | 22.4% |
| Avg. Person per HH | 2.6 | 2.62 | 2.13 |

**Table 7: Comparison of the Employment Data**

| Industry | Model Inputs | BEA Data |
|---|---|---|
| Service | 40.1% | 38.4% |
| Retail | 8.9% | 9.2% |
| Others | 51.1% | 52.4% |

**Figure 10: Population Profile of the MCRPC Model TAZs**

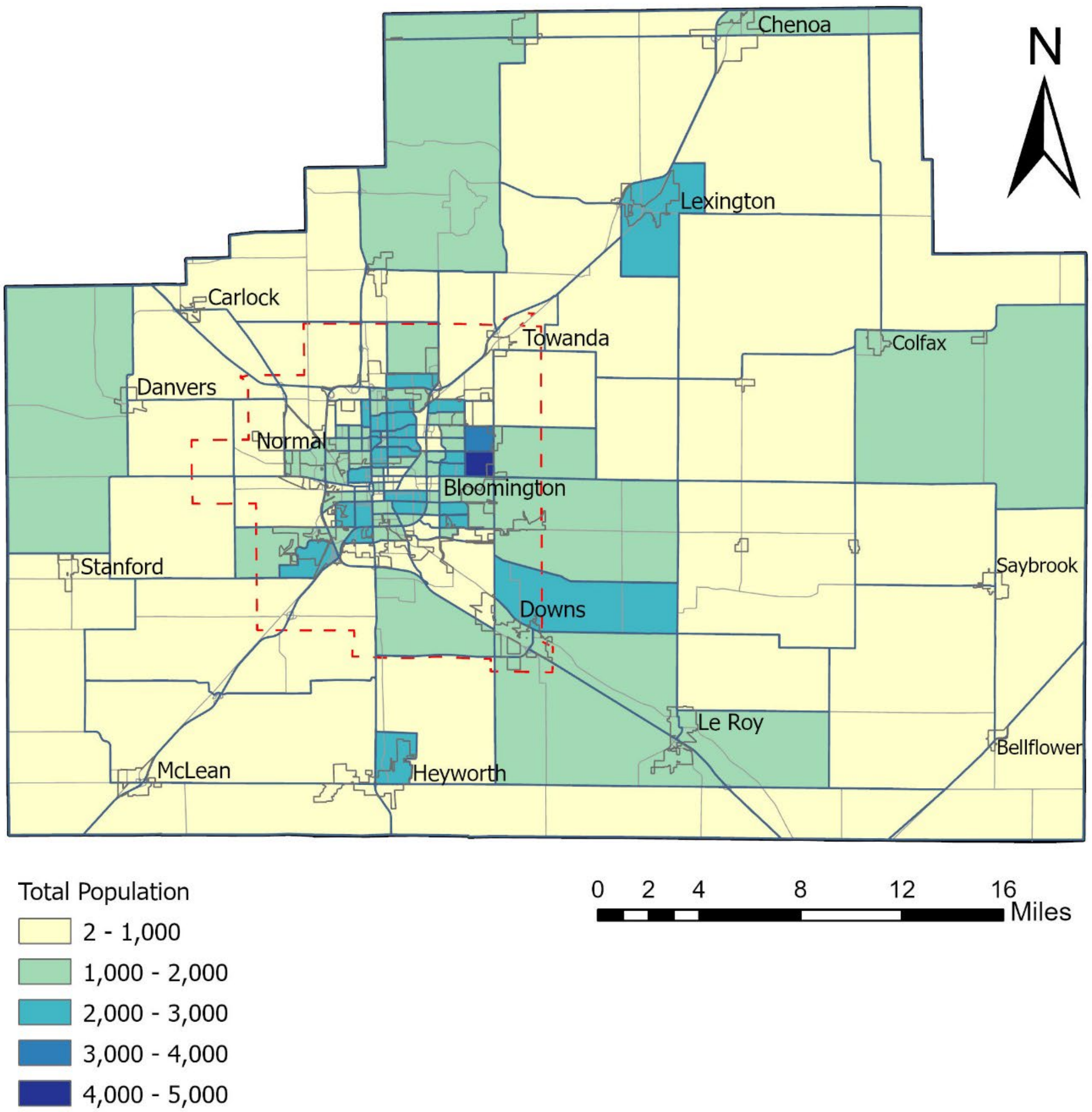


**Figure 11: Household Profile of the MCRPC Model TAZs**

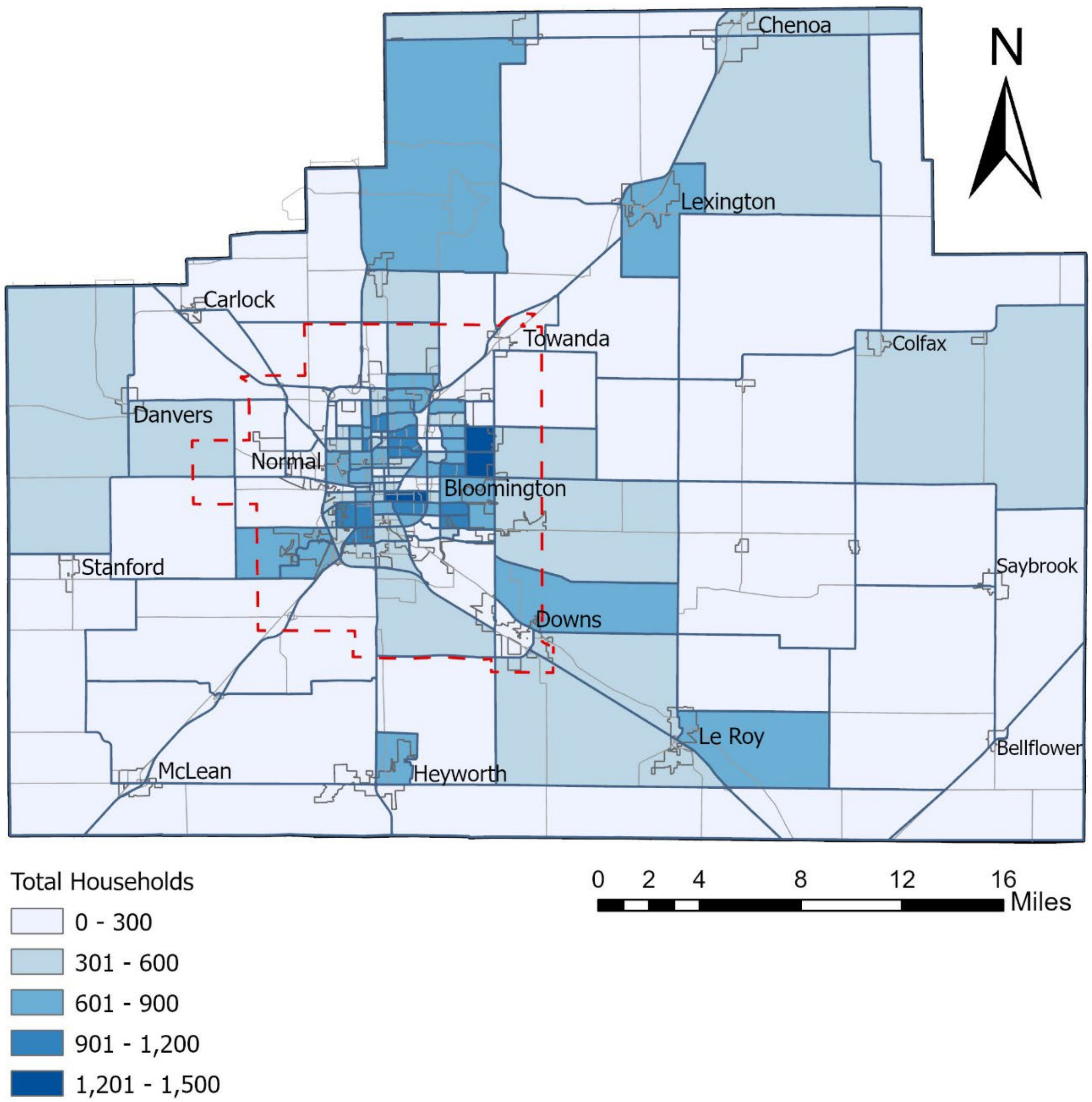
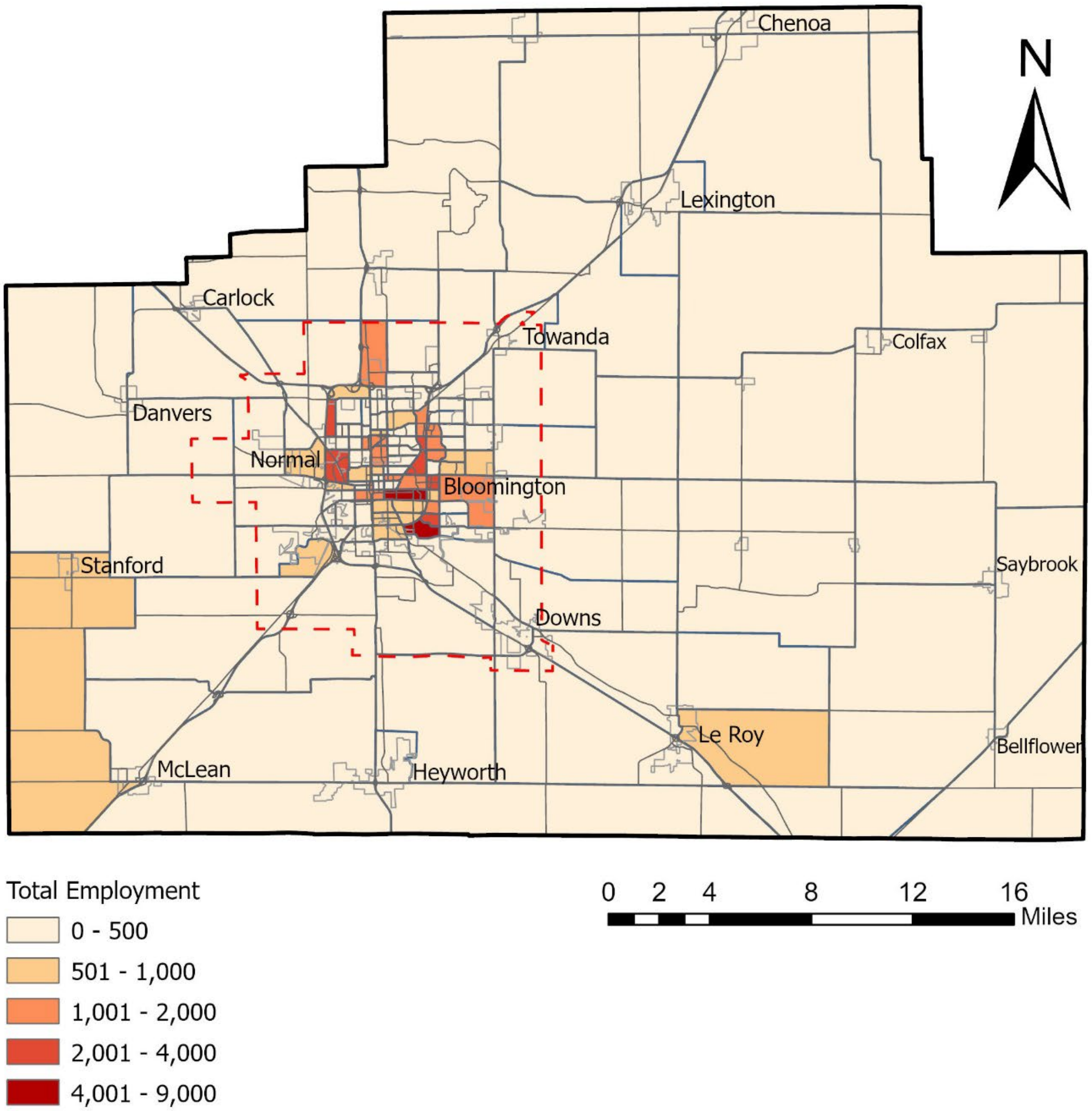


**Figure 12: Employment Profile of the MCRPC TDM TAZs**



# 6 Trip Generation

The trip generation module estimates the trips being produced and attracted to each zone in the model, based on the zonal socio-economic data. The trip productions are associated with zonal household data whereas the trip attractions are associated with the employment in the zone. The trips are generally produced at home and are attracted to the activity centers, although some trips which do not start or end at home are also modeled. Model trips include Internal-Internal (I-I) trips where both trips end within the model study area, Internal-External (I-E) trips where one trip ends outside the model study area and External-External (E-E) trips where both trips end outside the model study area. This section discusses steps involved in the trip generation process:

- Determining the model trip purposes.
- Estimating the trip production and attraction rates by trip purpose.
- Estimating the amount of external travel (I-E/E-I and E-E trips).
- Balancing I-I, I-E/E-I, and E-E trip productions and attractions.
- Validation of the model trip generation rates.

The inputs to the trip generation step include zonal household and employment data, any available household, or/and external surveys, and the AADT counts at the external stations. The outputs of this step were the zonal trip attractions and productions by trip purpose, which were used in the trip distribution module for zone-zone trip distribution.

## 6.1 Trip Purposes

Production and attraction trips are categorized into different trip purposes based on the nature of the trip. While most of the model trips either start or end at home, the trips are categorized based on the activity at the trip destination. Trip purposes differ in characteristics such as trip length and auto occupancy and are sensitive to specific socio-economic data. The three basic trip purposes are Home Based Work (HBW), Home Based Other (HBO), and Non Home Based (NHB). The trip purposes are further classified to increase the sensitivity of the model to the regional planning needs. For the MCRPC TDM, the Home Based Other (HBO) trips were further disaggregated into Home Based School (HBSc) and Home Based Other (HBO). In some cases, two or more linked trips (pass by trips) were combined to establish the trip purpose. Below is a more comprehensive explanation of the model trip classifications:

- Home Based Work (HBW) – Model trip between home and work or work-related activities.
- Home Based School (HBSc) – Model trips between home and school.
- Home Based Other (HBO) – Model trips between home and shopping activities as well as other social and recreational activities such as movie theaters, visiting relatives and friends, banking, recreation centers, etc. HBO includes all home-based trips which do not fit into the above two trip categories (HBW & HBSc).
- Non-Home Based (NHB) – Model trips which neither start nor end at home. (e.g. – trip from work to restaurant for lunch).

## 6.2 Trip Production & Attraction Rates

Trip production and attraction rates are developed to estimate the amount of travel generated in the region based on disaggregated socio-economic data. These trip rates are used to estimate the Internal-Internal (I-I) and Internal-External (I-E) trips for the model TAZs. The trip rates for each purpose vary based on the specific household and employment variables, such as household size and employment type. Trip production rates estimates the production trips from each model TAZ based on the household data. The trip attraction rates estimate the trips attracted to each TAZ and are based on employment (by type) and total households. The trip rates for the MCRPC model were developed based on the NCHRP Report 365 nationwide average trips rates and the ILMUG TDM Guideline Report. **Table 8** and **Table 9** present the trip production and attraction rates for the four trip purposes.

**Table 8: Trip Production Rates for MCRPC TDM**

| | Trip Purpose | | | |
|---|---|---|---|---|
| Household Size | HBW | HBSc | HBO | NHB |
| 1 Person | 0.74 | 0.37 | 1.74 | 0.85 |
| 2 Person | 1.52 | 0.76 | 3.57 | 1.75 |
| 3 Person | 2.12 | 1.06 | 4.98 | 2.44 |
| 4+ Person | 2.72 | 1.36 | 6.39 | 3.13 |
| 5+ Person | 3.32 | 1.66 | 7.80 | 3.82 |

**Table 9: Trip Attraction Rates for MCRPC TDM**

| | Trip Purpose | | | |
|---|---|---|---|---|
| Type | HBW | HBSc | HBO | NHB |
| Retail | 1.45 | 1.53 | 7.47 | 4.1 |
| Service | 1.45 | 0.289 | 1.411 | 1.2 |
| Other | 1.45 | 0.085 | 0.415 | 0.5 |
| Households | - | 0.153 | 0.747 | 0.5 |

## 6.3 Special Adjustment Factor

Special generators are introduced in a model when the model trip generation rates do not accurately estimate the trip activity or travel patterns for certain facilities/establishments in the model. Common examples of special generators include universities, airports, hospitals, adventure parks, and military bases.

The ideal way to determine the special adjustment factor is to derive it from household travel survey data. However, due to the limited data available for the MCRPC area, no special adjustment factor was applied to the model (i.e., adjustment factor = 1).

## 6.4 External Travel

Model trips with one or both trips ending outside the study area are defined as external trips. Trips with one end outside the model study area are called External-Internal (E-I) trips or Internal-External (I-E) depending on the origin of the trip. Some of the I-E trips are calculated along with I-I trips as part of TAZ productions. Trips with both ends outside the model study are called External-External (E-E) trips. Even though the E-E trips do not originate or end within the study area, the trips utilize the model network and should be included in the trip assignment process.

The external stations are identified at locations where major roadways including interstates, state routes and major county roadways cross the model boundary. The volumes on these major routes account for the majority of the traffic entering/exiting the model study area. The MCRPC TDM contains 15 external stations. Annual Average Daily Traffic (AADT) counts were collected from the "Getting Around Illinois" AADT map at the external stations. **Table 10** shows the external stations identified for the MCRPC TDM and the AADT counts at each station.

Ideally, an external cordon survey or Origination-Destination (OD) survey is required to estimate the external travel in the model. Due to the lack of time and resources to conduct an external station OD survey, the I-E/E-E and the E-E trips for the MCRPC travel demand model were determined based on the procedure outlined in the NCHRP Report 365 and the ILMUG TDM Guideline Report. The following steps were performed to determine the I-E/E-I and the E-E trips:

- Estimating the split between thru (E-E) trips and I-E/E-I trips
- Estimating the thru percentage at each external station
- Estimating I-E (production) trips and E-I (attraction) trips by trip purpose.

**Table 10: MCRPC External Station Data**

| Station | Roadway | Location | Facility | AADT | THRU |
|---|---|---|---|---|---|
| 143 | I-55 | N of CR 24 | 7 | 20500 | 52% |
| 144 | Old Route 66 | N of CR 24 | 2 | 2700 | 24% |
| 145 | US Hwy 24 (E 800 N Rd) | E of N360 East Rd | 4 | 4900 | 30% |
| 146 | SR 9 | E of CR 3850 E | 3 | 1600 | 10% |
| 147 | US Hwy 136 | W of Fisher | 3 | 1700 | 60% |
| 148 | I-74 | W of 2450 East Rd | 7 | 23500 | 57% |
| 149 | US Hwy 51 | S of Heyworth | 7 | 9650 | 15% |
| 150 | I-55 | S of Village of McLean | 7 | 24000 | 57% |
| 151 | US Hwy 136 | W of CR 1800 E | 4 | 2200 | 51% |
| 152 | SR 122 (E 1100 North Rd) | W of CR 24 | 3 | 1500 | 7% |
| 153 | Route 9 | S of Old Peoria Rd | 3 | 2450 | 4% |
| 154 | I-74 | NW of Carlock | 7 | 27000 | 57% |
| 155 | I-39 | N of CR 8 | 7 | 18500 | 50% |
| 156 | SR 251 (Dixon Ave) | S of Kappa | 2 | 2850 | 19% |
| 157 | US Hwy 24 | W of El Paso | 4 | 3800 | 22% |

## 6.5 Trip Generation Validation

The following checks were performed to validate the trip rates established for the MCRPC TDM. The MCRPC trip rates were compared against the 2017 NHTS data. The following checks were performed to validate the MCRPC travel demand model trip rates:

- Average daily person trips by household size: **Table 11** shows a positive relation between the household size and the trip rate; as the household size increases, the trip rate increases. The trip rates derived for the MCRPC TDM were close to the nationwide averages.

**Table 11: Comparison of Average Daily Person Trips per Household**

| Household Size | MCRPC | 2017 NHTS |
|---|---|---|
| 1 Person | 3.7 | 3.8 |
| 2 Person | 7.6 | 7.03 |
| 3 Person | 10.6 | 9.9 |
| 4+ Person | 14.7 | 15.1 |

- Percent distribution of trips by purpose: The trip percent distribution closely matches the trip distribution in other cases from the NCHRP Report 365, the ILMUG TDM Guideline Report, 2009 NHTS, and 2017 NHTS.

**Table 12: Comparison of Percentage of Trip Generation by Purpose**

| Trip Purpose | MCRPC | NCHRP 365 | ILMUG | 2009 NHTS | 2017 NHTS |
|---|---|---|---|---|---|
| HBW | 21.4% | 20% | 15.7% | 18.7% | 19.0% |
| HBSc | 9.8% | - | 5.6% | 9.6% | 10.9% |
| HBO | 45.3% | 57% | 46.% | 42.5% | 38.5% |
| NHB | 23.4% | 23% | 32.2% | 29.2% | 31.7% |

- Person Trip Rates per Person & per Household: The person trip rates for the MCRPC model were found to be consistent with the validation sources.

**Table 13: Comparison of Person Trip Rates per Person and per Household**

| Person Trip Rates | MCRPC | 2009 NHTS | 2017 NHTS |
|---|---|---|---|
| Per Household | 9.1 | 9.5 | 8.6 |
| Per Person | 3.5 | 3.8 | 3.4 |

The trip attraction rates used in the MCRPC travel demand model are solely based on the NCHRP 365 report and the ILMUG TDM Guideline report. There are no available data or procedures to validate the trips attraction rates for the MCRPC TDM.

# 7 Trip Distribution

Trip distribution allots the trips generated from each TAZ to every other TAZ in the model study area by trip purpose. The MCRPC TDM uses the standard gravity model for trip distribution. In the gravity model, the allocation of trips between zones depends on the magnitude of activities at the destination zone and the spatial separation between the two zones. The following equation describes the gravity model:

$$T_{ij} = P_i * \frac{A_j F_{ij} K_{ij}}{\sum_{j=0}^{n} A_j F_{ijK_{ij}}}$$

where,

$T_{ij}$ = Number of trips from zone i to zone j

$P_i$ = Number of trip productions in zone i

$A_j$ = Number of trip attractions in zone j

$F_{ij}$ = Friction factor relating to spatial separation between zone i to zone j

$K_{ij}$ = Trip distribution adjustment factor between zone i to zone j

The gravity model utilizes network travel/highway impedance and friction factors to distribute trips between the zones. The zone to zone travel impedance matrix represents the path of least resistance between the zone pair. Friction factor is a measure of impedance or unwillingness of persons to make a trip based on spatial separation between zones. K-factors are occasionally used in the travel demand model to adjust the attractiveness of trips between two zones due to a physical barrier or distinct zonal socio-economic characteristic. The K-factors were not used in the MCRPC travel demand model. This section discusses the following steps involved in the trip distribution process:

- Estimating the network impedances
- Estimating the model friction factors
- Distributing the External-External Trips

The input to the trip distribution step is the balanced trip production and attractions and the travel impedance matrix. The output of this step was zone-to-zone trip production/attraction matrix for each trip purpose.

## 7.1 Network Impedance

The MCRPC travel impedance represents the shortest travel time path between the zone pair. Zonal highway/ travel impendence matrices are created based on travel times, distance, and additional factors influencing travel (e.g. travel, tolls) between zones. When more than one variable is used, then a generalized cost function is used to derive the signal impedance variable. The shortest path in the MCRPC model network was calculated using the following generalized cost function.

Cost Variable = Travel time * *Cost of time* + Travel distance * *Cost of distance*

*Where,*

*Cost of time*= 50% of median wage: $0.24/min (McLean County Median wage from BLS- $29.09/hr=$0.48/min)

*Alternate Cost of time* = $16.2 per hour = $0.27/minute (according to the U.S. DOT BCA guideline 2020)
*Cost of distance* = Average fuel price ($ per gallon) / Average fuel economy (miles per gallon)
= $0.15/mile (according to MCRPC staff and the American Automobile Association)

## 7.2 Friction Factors

Friction factors measure the impact of spatial separation and travel time between the two zones on the model trips. The friction factors are used to enhance the gravity model by regulating the trip lengths and trip length frequency distribution for each trip purpose. Adjustments to the friction factors reflect the change in the travel patterns across the region. As the travel time increases, the friction factor decreases. The friction factors for the MCRPC TDM were calculated using the gamma function, described in the following equation.

$$\boldsymbol{F_{ij} = a * t_{ij}^{b} * e^{c * t_{ij}}}$$

*Where,*

$F_{ij}$ = the friction factors between zones i and j

a, b, and c = model coefficients

$t_{ij}$ = the travel time between zone i and j, and

e = the base of natural logarithms (Euler's number)

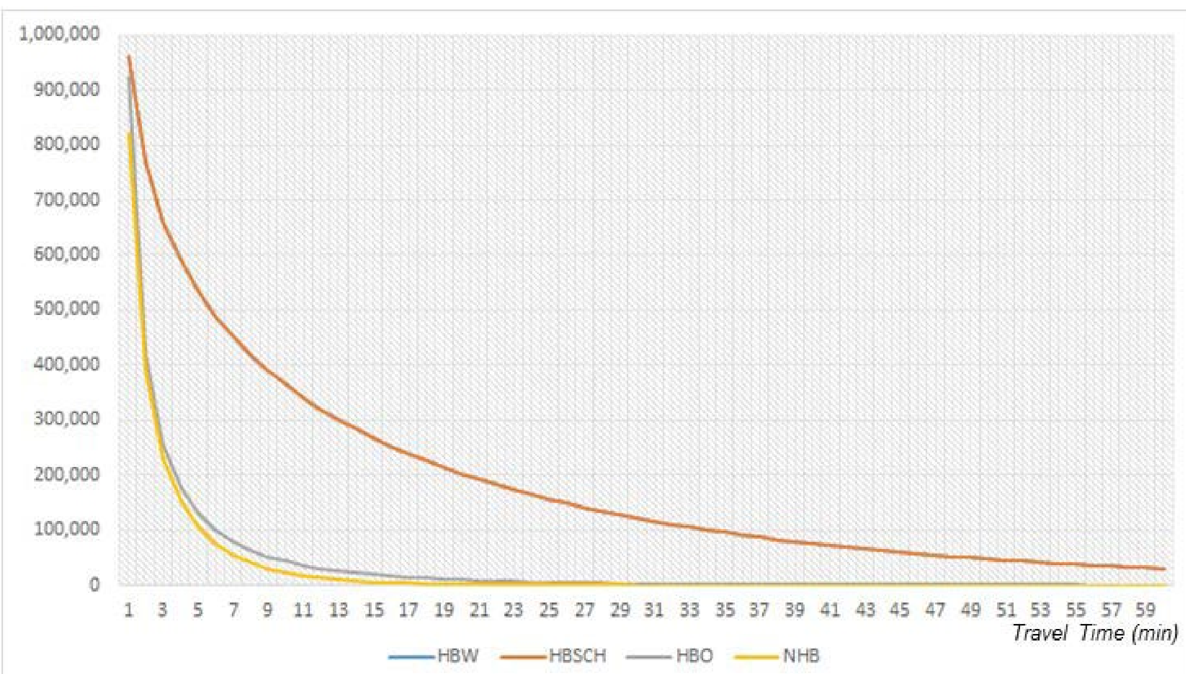
The friction factors for the MCRPC TDM were developed using the NCHRP Report 716 Synthetic Friction Factors, and can be adjusted based on the local knowledge. The initial gamma function coefficients from the NCHRP Report716 are shown in **Table 14**.

**Table 14: Initial Gamma Function Coefficients from NCHRP Report 716**

| Trip Purpose | b | c |
|---|---|---|
| HBW (HBSc) | -0.265 | -0.04 |
| HBO | -1.017 | -0.079 |
| NHB | -0.791 | -0.195 |

The NCHRP Report 716 provides gamma function coefficients for three basic trips purposes: HBW, HBO, and NHB. The initial gamma function coefficients for HBW were used for HBSc. The trend of the friction factors curves by trip purpose in the MCRPC model are shown in **Figure 13**.

**Figure 13: Friction Factor Curves by Trip Purpose used in the MCRPC TDM**



## 7.3 External-External Trip Distribution

The distribution of E-E trips between external stations depends on the percentage of through trips at the origin and the destination stations, the average daily traffic volume, and the route connectivity between the external stations. The distribution of thru trips between the external stations was estimated using the formula presented in the NCHRP Report 365. The functional classification of the destination stations dictates the use of one of the following equations.

Interstates: $Y_{ij} = -2.70 + 0.21 * PTTDESj + 67.86 * RTECONij$

Principal Arterials: $Y_{ij} = -7.40 + 0.55 * PTTDES_j + 24.68 * RTECON_{ij} + 45.62 * \left(\frac{AADT_j}{\sum_{j=1}^{n} AADT_j}\right)$

Other Roadways: $Y_{ij} = -0.63 + 30.04 * RTECON_{ij} + 86.68 * \left(\frac{AADT_j}{\sum_{j=1}^{n} AADT_j}\right)$

Where,

$Y_{ij}$ = percentage distribution of through-trip ends from origin station i to destination station j,

$PTTDESj$ = percentage through trip ends at destination station j,

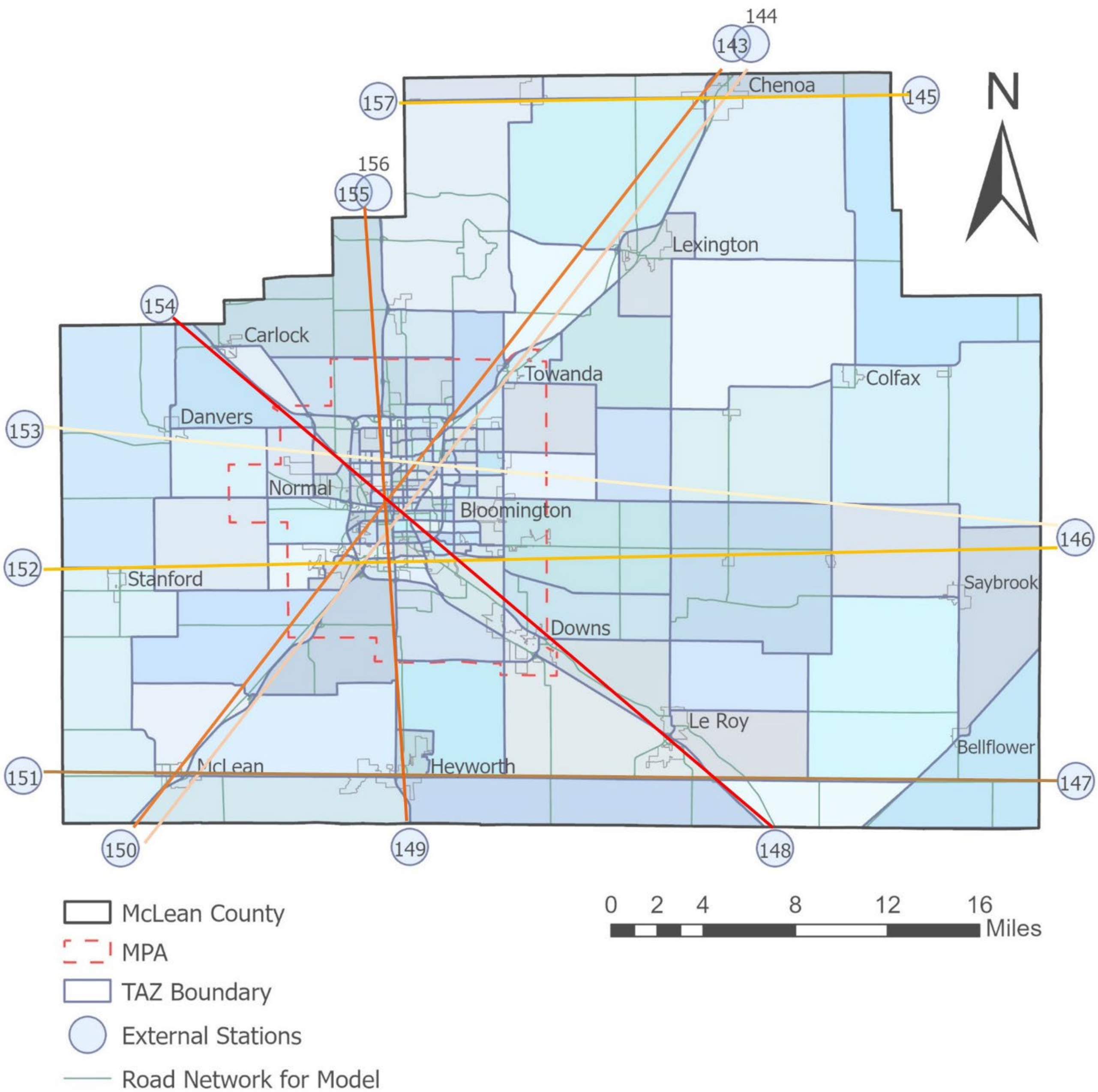
$RTECON_{ij}$ = route connectivity between stations i and j: 1 = yes, 0 = no, and

$AADT_j$ = annual average daily traffic at the destination station j

The higher percentages of trips are assigned between external stations with direct connectivity. **Figure 14** shows the external stations with direct connectivity through the model area.

The traffic movement patterns were verified against the local knowledge of the region and adjusted to reflect the base year traffic patterns. The resulting E-E trip percentages were normalized to equal 100%. Ideally, the trips entering and exiting the model area at an external station should be the same. The E-E trips between the zone pair were balanced using an iterative proportional factoring (Fratar) process. The balanced E-E trip matrices were utilized in the trip assignment process. The E-E trip distribution was checked against local knowledge for reasonability.

**Figure 14: External Station Connectivity in the MCRPC TDM**



## 7.4 Trip Distribution Validation

The following checks were performed to validate the trip distribution step of the modeling process:

- Travel Time Impedance: **Figure 15** shows the histogram for the shortest travel time paths in the model. As can be seen in the figure, the majority of the MCRPC travel demand model paths are between 10 and 20 minutes. **Figure 16** shows the travel time map for trips originating from TAZ 59 in downtown Bloomington.

- Intrazonal Trips by Purpose: The "Model Validation and Reasonableness Checking Manual" suggests that the intrazonal trips in most cases are less than 5% of the total trips. The region wide intrazonal trips were 3.89%. **Table 15** shows intrazonal trip percentages by trip purpose.

**Figure 15: Distribution of Travel Time Impedance in the Model**

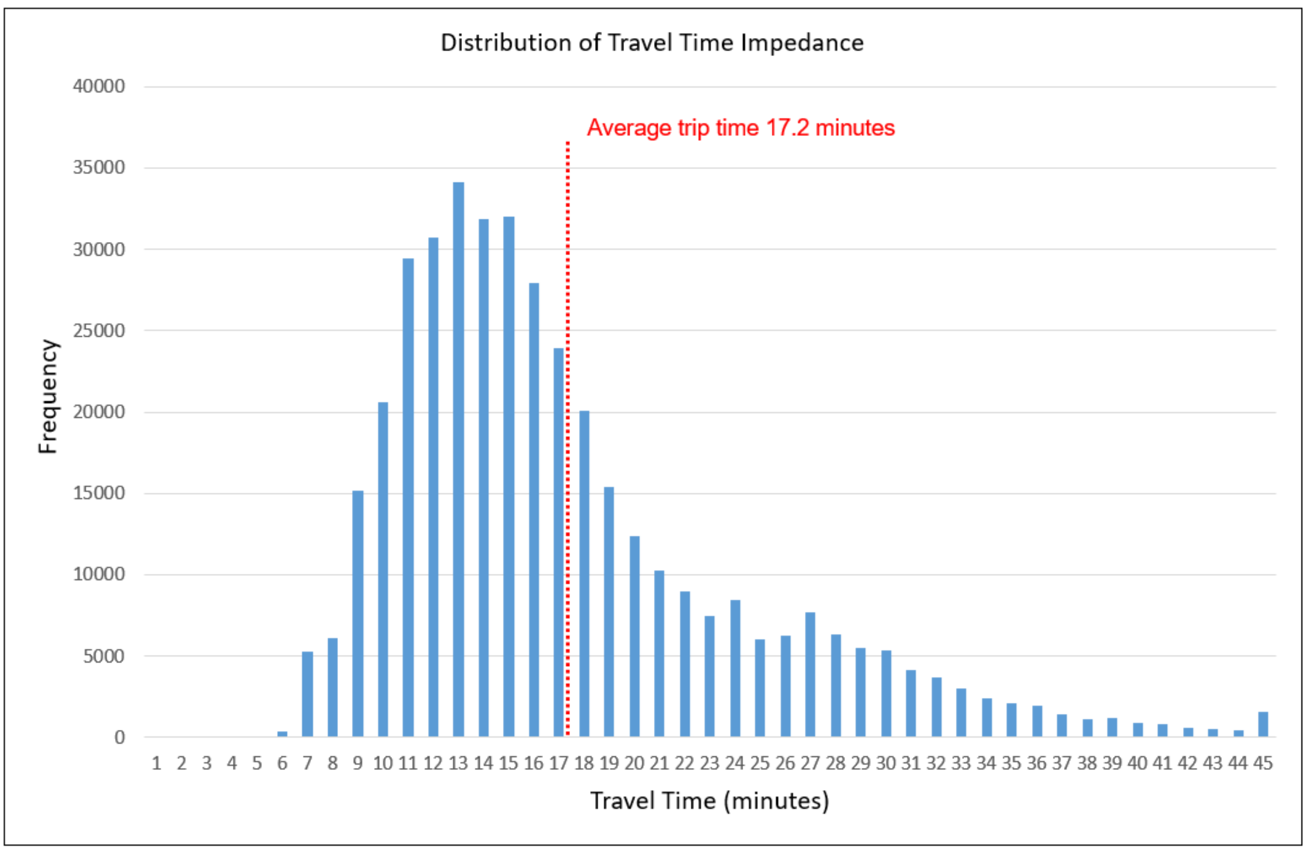


**Figure 16: Travel Time Maps for Trips Originating from TAZ 59 in Downtown Bloomington**

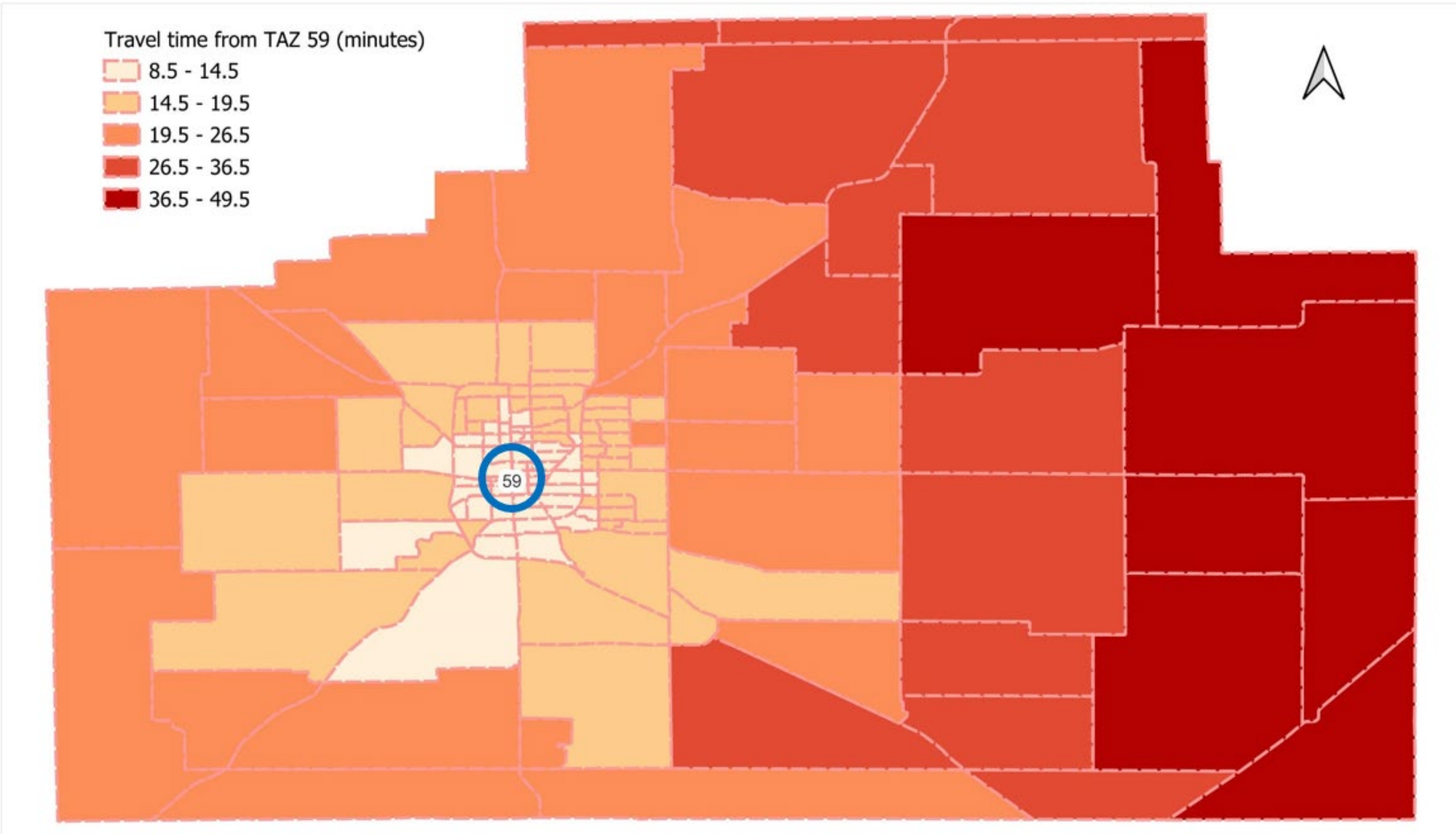


**Table 15: Intrazonal Trip Percentages by Trip Purpose**

| Purpose | HBW | HBSC | HBO | NHB | Total |
|---|---|---|---|---|---|
| Intra-Zonal Trip Percentage | 1.02% | 1.28% | 3.2% | 9.7% | 3.89% |

## 7.5 Auto Occupancy Rate

To convert person trips to vehicle trips as a preparation for traffic assignment process, auto occupancy rates are applied. The auto occupancy rates for trip purpose derived from the NCHRP Report 365 and the ILMUG TDM Guidelines Report were utilized in the MCRPC TDM. **Table 16** shows the auto occupancy factors for usedin the MCRPC TDM.

**Table 16: Auto Occupancy Factor used in the MCRPC TDM**

| Trip Purpose | HBW | HBSC | HBO | NHB |
|---|---|---|---|---|
| Auto-Occupancy Rate | 1.11 | 1.44 | 1.67 | 1.66 |

# 8 Trip Assignment

In this last step of the modeling process, model trips are loaded onto the roadway network. The auto (vehicle) trips were assigned to the roadway network. The trips were assigned by time-of-day or daily, using the User Equilibrium method. Here, it is noteworthy to mention that the MCRPC TDM does not cover the mode choicestep because the model does not include the existing transit system.

## 8.1 Time of Day Factors

This component of the travel demand model is used to distribute the model trips throughout the day. Incorporating the time of day factors in the travel demand model enables the analysis of both daily and peak hour conditions. The HBW and HBSc trips travel during the peak hour; whereas the HBO and NHB trips tend to travel during off-peak hours. The time-of-day factors are used to separate the vehicle trips over a 24-hour period. The estimation of travel over specific periods of the day is necessary for certain transportation planning studies, such as peak hour congestion, emission analyses, and transit services. The daily traffic assignment is not sensitive to these requirements.

In the MCRPC TDM, the daily O/D trip tables are factored into time periods using hourly factors derived from the NCHRP Report 365 and the ILMUG TDM Guidelines. **Table 17** and **Figure 17** present the hourly distributionof trips for each trip purpose used in the MCRPC model.

**Figure 17: Time-of-Day Factors used in the MCRPC TDM**

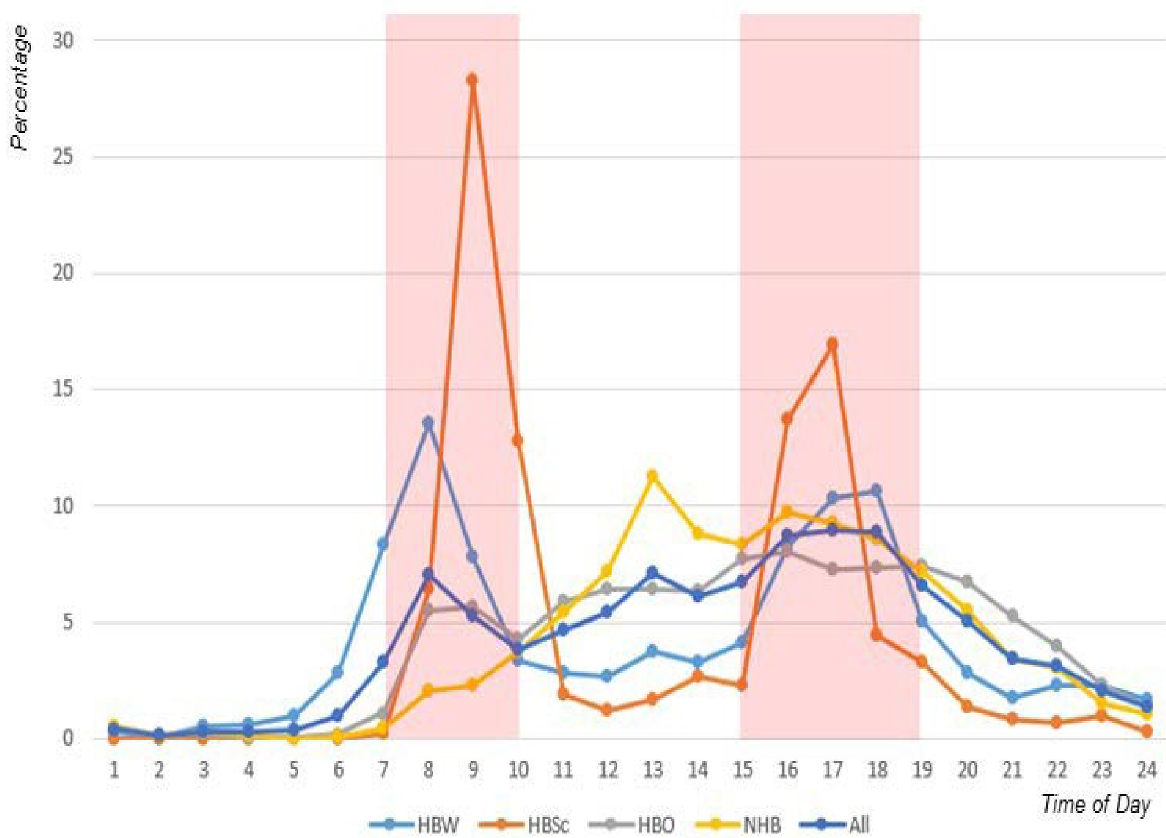


**Table 17: Time-of-Day Factors used in the MCRPC TDM**

| Hour | HBW | HBSc | HBO | NHB | All |
|---|---|---|---|---|---|
| 0-1 | 0.33 | 0 | 0.4 | 0.49 | 0.41 |
| 1-2 | 0.07 | 0 | 0.17 | 0.12 | 0.12 |
| 2-3 | 0.5 | 0 | 0.23 | 0.27 | 0.33 |
| 3-4 | 0.61 | 0 | 0.07 | 0.12 | 0.27 |
| 4-5 | 1 | 0 | 0.08 | 0 | 0.36 |
| 5-6 | 2.79 | 0 | 0.18 | 0.06 | 1.01 |
| 6-7 | 8.34 | 0.2 | 1.1 | 0.46 | 3.3 |
| 7-8 | 13.57 | 6.4 | 5.53 | 2.07 | 7.06 |
| 8-9 | 7.84 | 28.3 | 5.64 | 2.27 | 5.25 |
| 9-10 | 3.36 | 12.8 | 4.27 | 3.76 | 3.8 |
| 10-11 | 2.79 | 1.9 | 5.86 | 5.4 | 4.68 |
| 11-12 | 2.65 | 1.2 | 6.44 | 7.22 | 5.44 |
| 12-13 | 3.72 | 1.7 | 6.4 | 11.26 | 7.13 |
| 13-14 | 3.26 | 2.7 | 6.34 | 8.77 | 6.12 |
| 14-15 | 4.12 | 2.3 | 7.7 | 8.31 | 6.71 |
| 15-16 | 8.3 | 13.7 | 8.06 | 9.74 | 8.7 |
| 16-17 | 10.31 | 16.9 | 7.25 | 9.28 | 8.95 |
| 17-18 | 10.66 | 4.4 | 7.32 | 8.56 | 8.85 |
| 18-19 | 5.01 | 3.3 | 7.44 | 7.19 | 6.55 |
| 19-20 | 2.79 | 1.4 | 6.71 | 5.52 | 5.01 |
| 20-21 | 1.72 | 0.8 | 5.24 | 3.46 | 3.47 |
| 21-22 | 2.3 | 0.7 | 3.95 | 3.06 | 3.1 |
| 22-23 | 2.26 | 1 | 2.25 | 1.55 | 2.02 |
| 23-24 | 1.7 | 0.3 | 1.37 | 1.06 | 1.36 |

## 8.2 Auto Trip Assignment

The User Equilibrium process is based on Wardrop's principle which considers equilibrium to be reached when no traveler can reduce the travel time below a specified value between two zones by switching to an alternate path. In this method, the traveler uses the fastest possible route between the origin and destination. This is the most common process used in trip assignment. Other trip assignment algorithms/methods include stochastic equilibrium, all-or-nothing, and incremental capacity-restrained assignment.

In the user equilibrium process, the auto trips are loaded on the shortest path between the origin and destination. Based on the assigned volume from the 1st iteration, the congested travel times are calculated using the Bureau of Public Roads (BPR) curves. The model trips are then reloaded on the model network using the new congested travel times. This process is followed until the check for convergence is satisfied. A convergence criterion of 0.05% was used for the MCRPC travel demand model. The turn penalty data was included in the trip assignment process for the MCRPC model.

### Volume-Delay Function (BPR Curves)

The BPR curves present the relationship of the assigned volume and resulting delay on the roadway link due to congestion. The BPR curves estimate the change in travel time with respect to the change in the volume to capacity ratios. As the free flow speed increases, travel time decreases. The BPR equation is given as follows:

$$T_c = T_0 * \left[1 + a\left(\frac{v}{c}\right)^b\right]$$

*Where,*

$T_c$ = congested travel time

$T_0$ = link travel time for free-flow speed or previous iteration

v = assigned link volume

c = link capacity

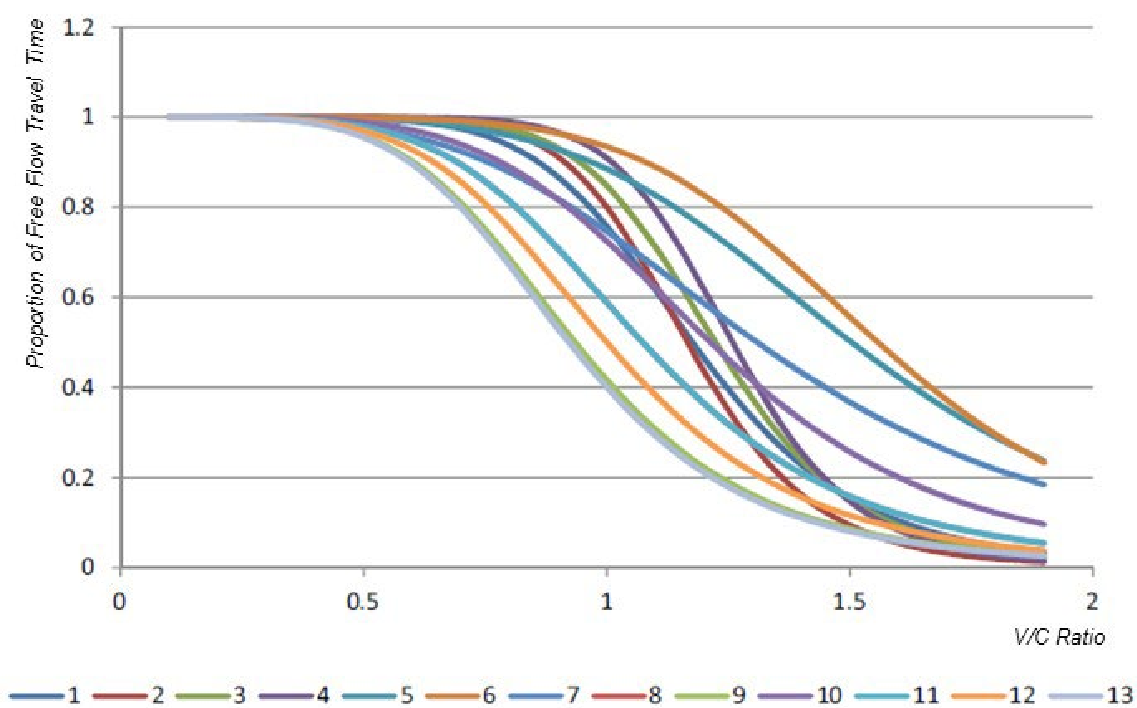
a, b = volume/delay coefficients

The facility types were further classified into 13 different categories (SPD_CRV) to calculate the BPR functions, based on the number of lanes and the free flow speed. Each link class was assigned a BPR curve. The parameters for the BPR curve for each link class were chosen based on the 2010 Highway Capacity Manual (HCM) and calibrated during the modeling process. **Table 18** shows the link classification and BPR coefficients used in the MCRPC travel demand model. **Figure 18** shows the BPR curve for each of the link classes.

**Table 18: Volume Delay parameters used in the MCRPC TDM**

| Link Class | Facility Type | Area | Lanes | Free Flow Speed (mph) | Alpha (α) | Beta (β) |
|---|---|---|---|---|---|---|
| 1 | 7 | Any | Any | > 65 | 0.32 | 7.0 |
| 2 | 7 | Any | Any | 65 | 0.25 | 9.0 |
| 3 | 7 | Any | Any | 60 | 0.18 | 8.5 |
| 4 | 7 | Any | Any | 55 | 0.10 | 10.0 |
| 5 | 5 - 6 | Any | Any | Any | 0.13 | 5.0 |
| 6 | 4 | 5 | > 1 | 50 - 55 | 0.07 | 6.0 |
| 7 | 4 | 5 | 1 | 50 - 55 | 0.34 | 4.0 |
| 8 | 4 | 2 - 4 | Any | 35 - 50 | 0.70 | 5.0 |
| 9 | 4 | 1 | Any | 35 | 1.40 | 5.0 |
| 10 | 0 - 3 | 5 | Any | 25 - 55 | 0.38 | 5.0 |
| 11 | 0 - 3 | 4 | Any | 25 - 45 | 0.70 | 5.0 |
| 12 | 0 - 3 | 2 - 3 | Any | 15 - 35 | 1.00 | 5.0 |
| 13 | 0 - 3 | 1 | Any | 15 - 35 | 1.50 | 5.0 |

**Figure 18: BPR Curves for Each Link Class in the MCRPC TDM**



## 8.3 Trip Assignment Validation

Validation checks for trip assignment are important since it not only addresses the assignment process but also the entire model. The following checks were performed to validate the trip assignment step of the modeling process. Maps are created to visualize the loaded traffic volumes, Volume-Capacity (V/C) Ratio (**Figure 19** and **20**).

### Traffic Volumes

In the trip assignment validation process, the model assignment is compared against the observed regional data to ensure that the model reasonably replicates the observed traffic patterns. The observed traffic counts were manually obtained from the "Getting Around Illinois" Website managed by the Illinois Department of Transportation. The estimated model volumes were compared against the observed traffic counts in the study area. The model estimated volumes were further validated using the Root Mean Square Error (RMSE), %RMSE, and the coefficient of determination ($R^2$).

#### Coefficient of Determination ($R^2$)

The model estimated volumes were compared against the observed link volumes to estimate the coefficient of determination ($R^2$). The linear regression coefficient between the two variables can be measured from 0 to 1, with 1 being a prefect correlation. The correlation coefficient check is important to verify the assignment of trips on different facility types and highlights any network link coding errors. **Figure 21** presents the $R^2$ between the model estimate volume and the observed traffic count data (in 2019). The MCRPC TDM shows an $R^2$ value of 0.80, which is well within the acceptable range. It is noteworthy to mention that $R^2$ value can be improved when the model estimate volume is compared with the same year traffic and socioeconomic data and detailed network characteristics (i.e., traffic signal data).

**Figure 19: MCRPC TDM Loaded Traffic Volume**

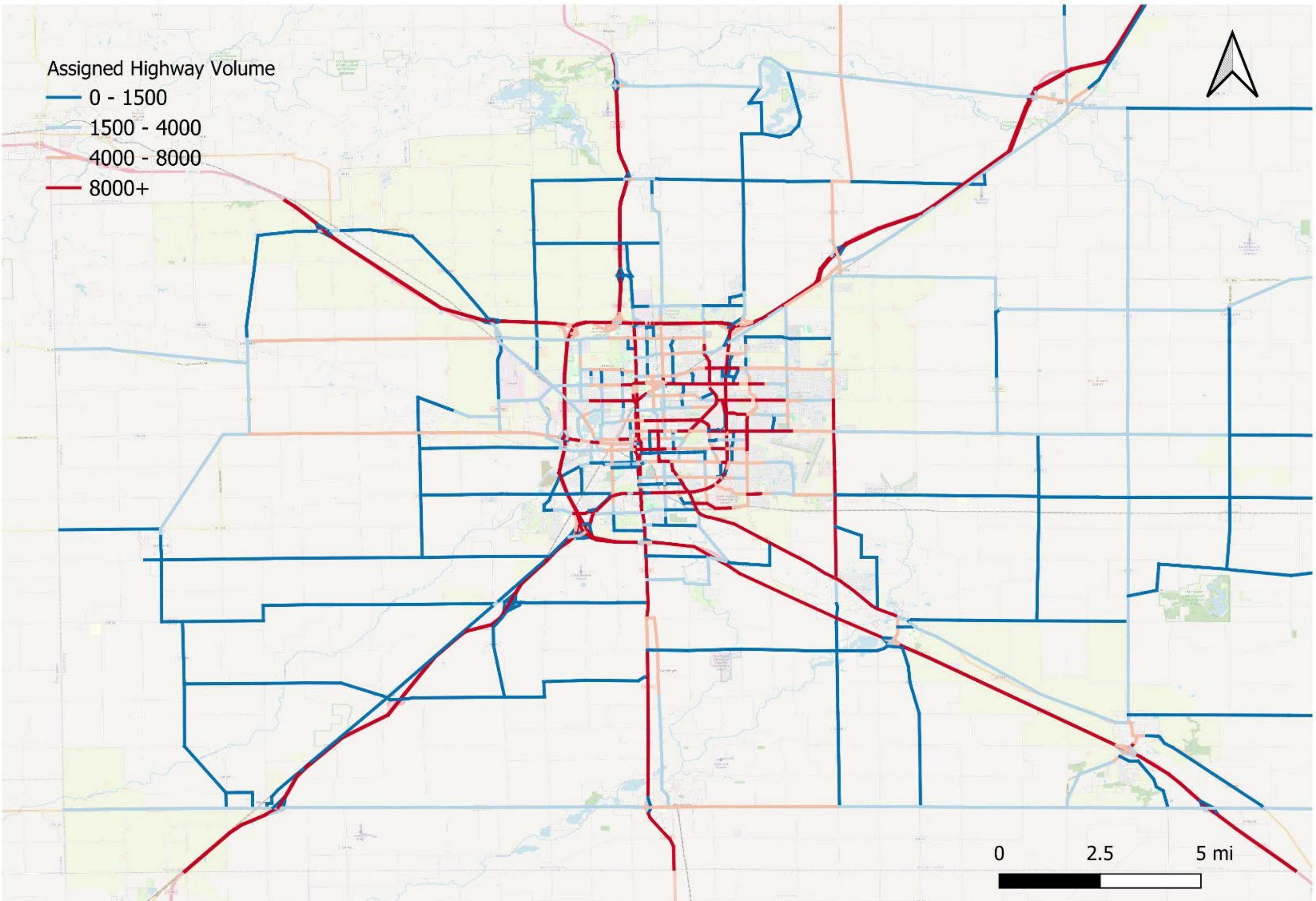


**Figure 20: MCRPC TDM V/C Ratio**

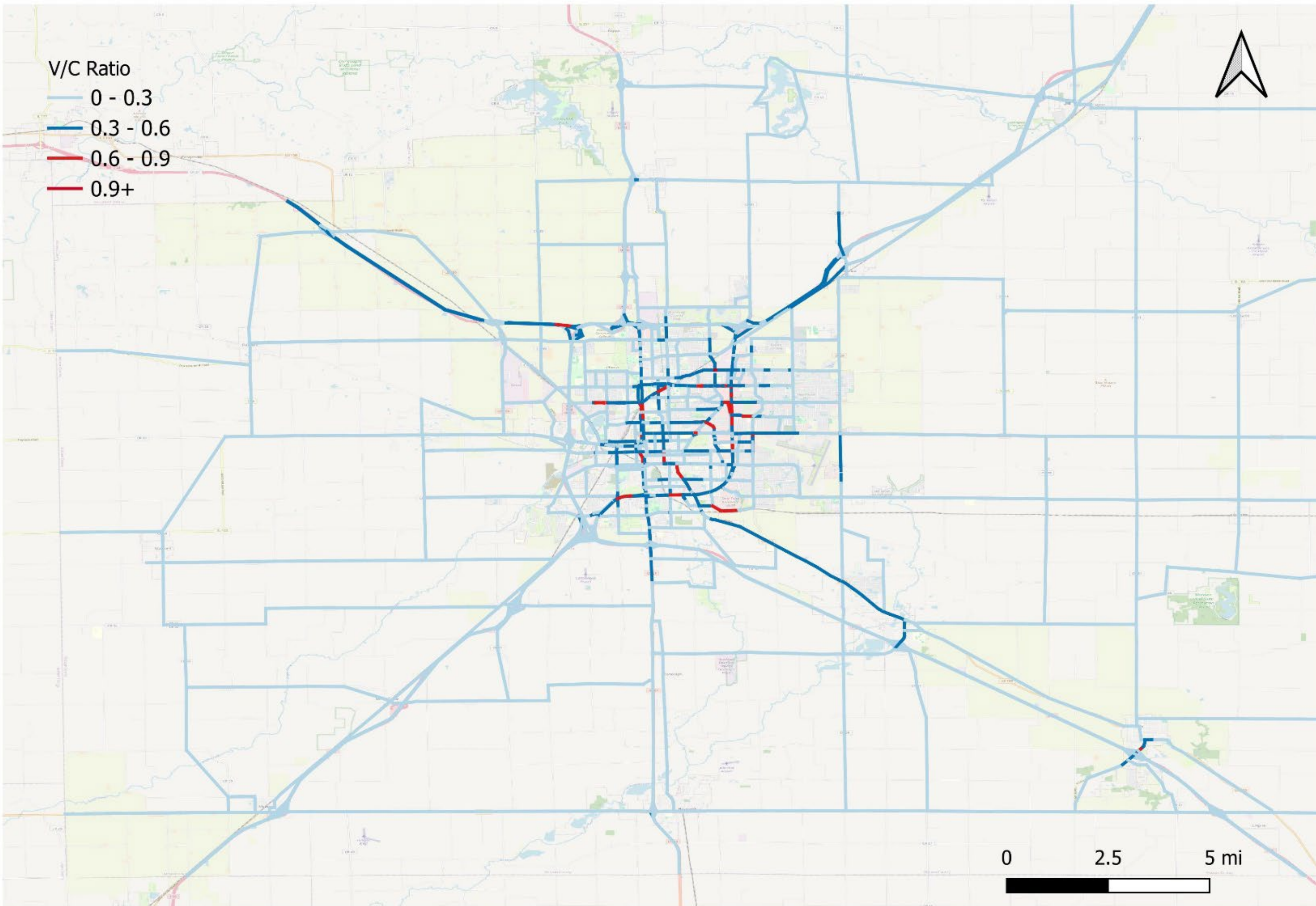
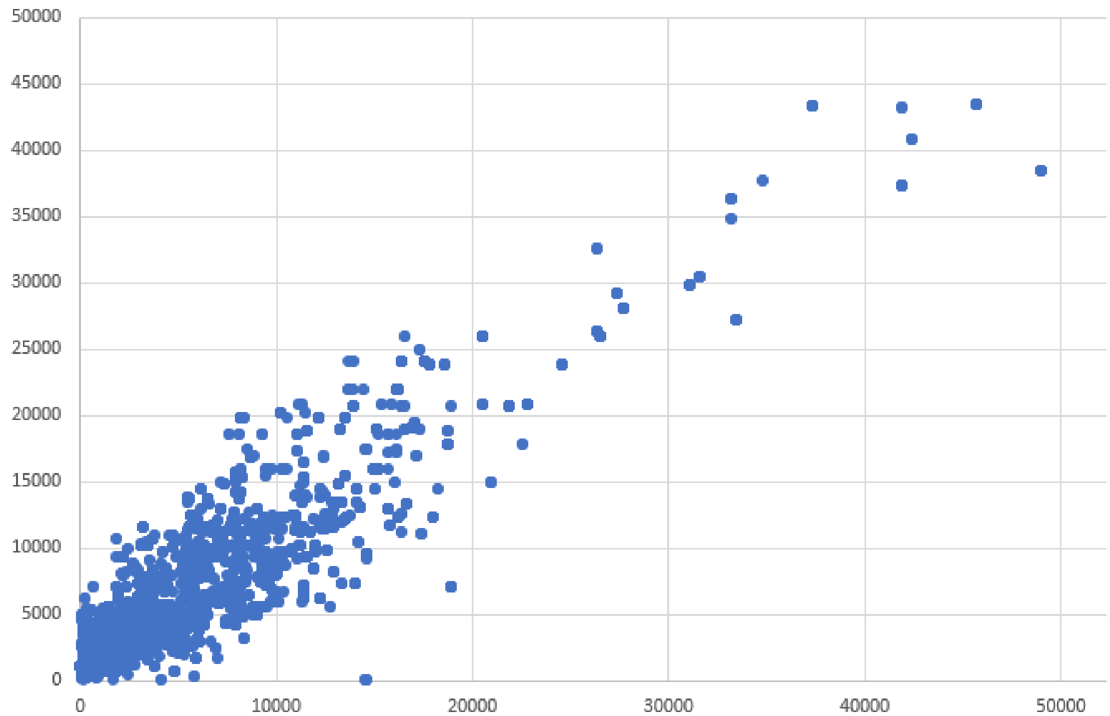


**Figure 21: Scatterplot of Model Volume vs. Observed Traffic Volumes**




## Percent Root Mean Square Error (%RMSE)

RMSE and %RMSE measure the average error between the observed and the model traffic volumes. The RMSE and %RMSE are calculated using the following formula. **Table 19** shows the RMSE and %RMSE for the MCRPC model by facility type.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}[(Count_i - Model_i)^2]}{N}}$$

$$\%RMSE = \frac{RMSE}{\left(\frac{\sum_{i=1}^{N} Count_i}{N}\right)} * 100$$

**Table 19: RMSE for the MCRPC TDM by Facility Type**

| Facility Type | RMSE | %RMSE |
|---|---|---|
| Interstates | 4,836.8 | 33.2 |
| Major Arterials | 4,019.04 | 29.3 |

## Vehicle Miles Traveled (VMT)

The vehicular travel in the model can be validated by comparing the model VMT against the observed VMT. The VMT checks for the MCRPC model were made by facility type. **Table 20** shows the VMT difference by facility type. The percentage difference between modeled and observed VMT were compared against the FHWA recommended targets. It was determined after comparing the values that the VMT by facility type were within the acceptable parameters.

Observed VMT data is collected from the Illinois Travel Statistics 2019 (https://idot.illinois.gov/transportation-system/network-overview/highway-system/reports/illinois-travel-statistics.html). Facility types of a few roadway segments were coded differently in the MCRPC TDM than the IDOT's classification (based on MCRPC staff's expertise and local knowledge). This was taken into consideration while comparing the model VMT with the IL travel statistics numbers.

**Table 20: Model VMT vs. Observed VMT difference for the MCRPC TDM**

| Facility Type | % Difference | FHWA Target |
|---|---|---|
| Interstates | -1.9% | +/- 7% |
| Major Arterial | 3.5% | +/- 10% |
| Minor Arterial | 0.3% | +/- 15% |
| Collectors | -1.9% | +/- 20% |

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