



Appendix D

Travel Demand Model Documentation

Lincoln MPO Travel Model

Technical Documentation

final report

prepared for

Lincoln MPO

prepared by

Cambridge Systematics, Inc.

with

Felsburg Holt & Ullevig

final report

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1.0 Introduction

The Lincoln Metropolitan Planning Organization (MPO) and member jurisdictions use the Lincoln MPO Travel Demand Model as a tool to forecast traffic and travel in Lancaster County and the Lincoln area. The primary purpose of the travel model is to support the 2050 Long Range Transportation Plan (LRTP) and Lincoln Mobility Plan (LMP). In addition, the model can support evaluation of proposed roadway and transit projects, help evaluate potential impacts of proposed development projects, and support various other studies of the region, subareas, corridors, and other planning activities. The updated model was prepared and customized using TransCAD version 10.0 (build 409695), in order to provide an up-to-date and user-friendly model. Newer builds of TransCAD 10.0 may also work. The model has been calibrated to reflect a base year of 2024 and contains future year data reflecting forecast 2036 and 2050 conditions. This model update builds on the previous model update which had a base year of 2019. Parameters remain consistent with the previous model update unless adjustment to match the new 2024 base year traffic counts and transit ridership was required. The Lincoln MPO Model is an adaptation of the standard 4-step modeling process that is common in many small and medium-sized communities in the United States. A flow chart of the model is shown in Figure 1.

1.1 Uses and Outputs

The traditional use of a travel demand model is to evaluate systematic congestion on the regional roadway system and provide a tool for considering improvements. This provides a useful planning tool for analysis of the Lincoln MPO's long range plan scenarios as both the impacts of roadway network changes and demographic growth or reallocation are demonstrated by the resulting shifts in travel.

The Lincoln MPO Model can provide a variety of outputs to demonstrate these travel results. Information that can be obtained from the model includes forecast traffic volumes, changes in traffic patterns due to changes in the roadway network, forecast changes to transit ridership based on system changes, and changes in travel demand due to changes in land use. An example map showing base year roadway congestion is included in Figure 2. As different scenarios are considered, similar maps can be created and compared to identify key outcomes.

Figure 1 Model Flow Chart

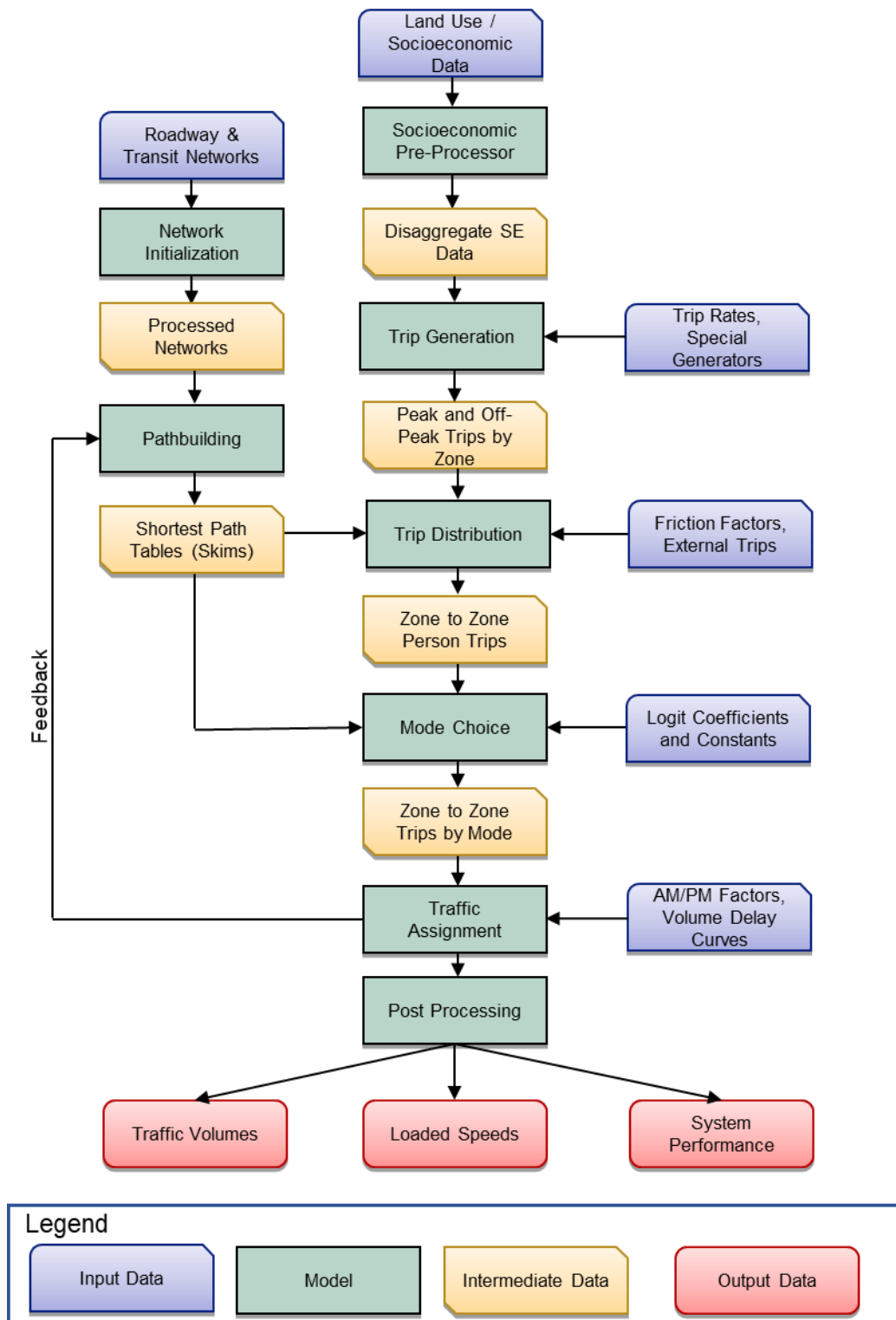
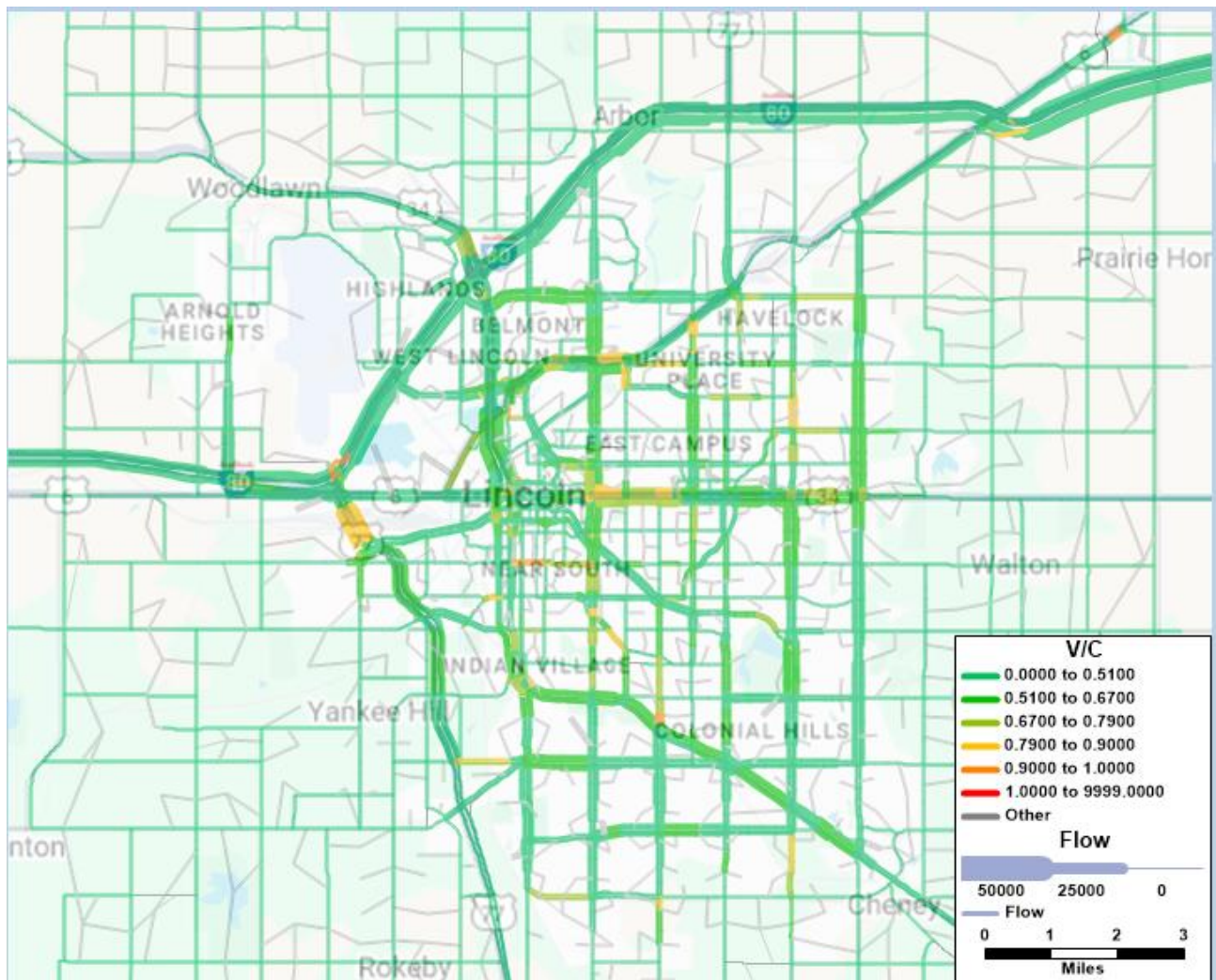


Figure 2 2024 Roadway Congestion

1.2 Location Based Services (LBS) Data

Location-based services (LBS) data collected passively from mobile devices are becoming an increasingly valuable source of information about travel patterns. LBS data are collected by GPS applications running either in the background or foreground on cellular devices, where the device user has opted to allow the app to access the device's geographic location. LBS data are spatially more accurate than other forms of cellular data because they collect locations using GPS technology.

These data can provide detailed information about how people are moving, where they are going, and when their travel is occurring. Compared to household surveys, LBS data can be collected for longer periods of time, at more regular intervals, and from a larger sample size. As a result, these datasets are massive in size, often containing millions of records collected over a period of months, rather than the typical 1- to 2-day travel diary often collected by travel surveys. Not only does this generate a larger overall sample, but travel patterns of individual devices can be measured over a period, while maintaining sufficient degrees of privacy since the device ID cannot be tied to any demographic or personally identifiable information.

Vehicle trip tables based on Spectus LBS data from 2022 were provided by the Nebraska Department of Transportation (NDOT) via the MPO at the Nebraska Statewide Model (NSM) TAZ level, a more aggregate geography than the MPO model. These tables were used in calibration and validation of trip generation and development of external / internal travel patterns. Intrazonal trips were not included with this data.

For the prior 2019 base year version of the model, person trip tables based on LBS data were developed for the Lincoln MPO region and were used for developing trip length distributions by purpose (work, UNL-related, and all other) during the calibration and validation of the travel model. These distributions were retained for the update, because the 2022 LBS data was unable to provide intuitive distinctions by trip purpose, due at least partly to the nature of the data (NSM zones, vehicle trips rather than person trips, and no intrazonal data).

2.0 Input Data

One of the critical components of any travel model is the input data. For the Lincoln MPO Model, this includes roadway and transit networks, land use/socioeconomic data at the traffic analysis zone (TAZ) level, and other factors (i.e. coefficients, peak hour factors and external trip data). This input data describes the travel conditions for the Lincoln MPO region and provides the foundation for evaluating system performance and future travel alternatives.

2.1 Roadway Network

The roadway network contains basic input information for use in the travel model and is used to distribute person trips and route vehicle trips throughout the region. Input network attributes used by the travel model include facility type, area type, number of lanes, speed limit, and direction of flow. The facility type assigned to the various roadways in the network follow the definitions shown in Table 2.1. Area types used in the model, listed in Table 2.2, are first calculated at the TAZ level based on zone density, and then applied to network links.

The model includes a roadway network data for the 2024 base year, 2036 and 2050 for existing plus committed conditions, and for two 2050 scenarios defined as part of the long range transportation plan development process, the “Transit-Friendly” (TF) and “Invest in Growth” (IG) scenario. The IG scenario is equivalent to the Fiscally Constrained scenario with respect to the travel demand model, because the only differences between those two scenarios consisted of non-modellable projects such as intersection geometry and paving. The TF scenario’s roadway network is very close to the IG scenario; most differences between the two are reflected in the TF scenario’s transit network assumptions.

Table 2.1 Facility Types

ID	Facility Type
1	Interstate/Freeway
2	Expressway
3	Principal Arterial
4	Minor Arterial
5	Collector
6	Major Rural Collector (State)
7	Major Rural Collector (County)
8	Minor Rural Collector
9	Local Street
10	Ramp
11	Freeway to Freeway Ramp
99	Centroid Connector

Table 2.2 Area Types

ID	Area Type
1	CBD
2	Urban
3	Suburban
4	Rural

Hourly capacities are assigned to each link based on facility type and area type using the lookup table shown in Table 2.3. Freeflow speeds are assigned based on facility type, area type and posted speed. For links without a posted speed, the model uses default speeds shown in Table 2.4. Freeflow speeds are then calculated by multiplying posted speed by the freeflow speed conversion factors shown in Table 2.5.

A small number of the values in Table 2.4 and Table 2.5 were adjusted from the 2019 model to aid in the validation of traffic counts; in particular, the freeflow conversion factors for freeways and principal arterials were increased to address under-assignment of vehicles on these roads.

Table 2.3 Capacity Lookup Table

Facility Type	CBD	Urban	Suburban	Rural
Interstate/Freeway	2000	2000	2000	1900
Expressway	1100	1200	1200	1200
Principal Arterial	930	1080	1120	1120
Minor Arterial	740	860	900	900
Collector	560	710	740	740
Major Rural Collector (State)	560	710	740	740
Major Rural Collector (County)	560	710	740	740
Minor Rural Collector	560	710	740	740
Local Street	520	660	690	690
Ramp	740	860	900	900
Freeway to Freeway Ramp	930	1080	1120	1120
Centroid Connector	10000	10000	10000	10000

Table 2.4 Default Posted Speed Lookup Table

Facility Type	CBD	Urban	Suburban	Rural
Interstate/Freeway	65	65	75	75
Expressway	65	65	75	75
Principal Arterial	35	45	55	65
Minor Arterial	30	35	40	45
Collector	25	30	35	45
Major Rural Collector (State)	35	45	55	65
Major Rural Collector (County)	35	45	55	65
Minor Rural Collector	25	30	35	45
Local Street	25	30	35	40
Ramp	20	25	35	45
Freeway to Freeway Ramp	35	45	45	45
Centroid Connector	15	20	20	35

Table 2.5 Posted Speed to Freeflow Speed Conversion Factors

Facility Type	CBD	Urban	Suburban	Rural
Interstate/Freeway	1.1	1.1	1.1	1.1
Expressway	0.9	0.95	1.0	1.0
Principal Arterial	0.8	0.9	0.95	1.0
Minor Arterial	0.8	0.9	0.95	0.9
Collector	0.75	0.9	0.95	0.9
Major Rural Collector (State)	0.75	0.85	0.9	0.9
Major Rural Collector (County)	0.75	0.85	0.9	0.9
Minor Rural Collector	0.75	0.85	0.9	0.85
Local Street	0.6	0.8	0.9	0.8
Ramp	0.8	0.8	0.8	0.8
Freeway to Freeway Ramp	1.0	1.0	1.0	1.0
Centroid Connector	1.0	1.0	1.0	1.0

2.2 Transit Networks

The travel model uses transit networks to build shortest transit paths between each zone pair, as well as to assign transit trips to individual transit routes. The Lincoln MPO Model uses information stored on the roadway network and a route system containing StarTran bus routes to represent the transit system. Routes and the associated service characteristics are converted into a series of links and nodes or stops. Transit route systems are directly connected to the roadway network so it is important to maintain this consistency

when using the Lincoln MPO Model. A listing of the routes included in the base year Lincoln MPO Model network and the corresponding headway assumptions are listed in Table 2.6.

Table 2.6 Route Headway Assumptions

Route	Peak Headway (minutes)	Off-peak Headway (minutes)
13 - South 13th	15	30
22 - NIC City	15	15
24 - Holdredge	10	20
25 - Vine	10	20
27 - North 27th	15	30
40 - Heart Hospital	15	60
41 - Havelock	15	30
42 - Bethany	30	60
44 - O Street	15	30
46 - Arnold Heights	30	30
48/54 - North 48th/Veteran's Hospital	60	60
49 - University Place	60	60
51 - West A	60	60
52 - Gaslight	60	60
53 - South Pointe	15	60
55 - Downtown Trolley	15	15
56 - Sheridan	15	60

2.3 Traffic Analysis Zone Structure

TAZs are ideally (but not always) sized and shaped to provide a relatively homogeneous amount and type of activity within each zone. TAZ delineations traditionally follow the boundaries that tend to segregate different land uses. These boundaries include water features, roads, railroads, and other lines that form logical boundaries. Jurisdictional and census boundaries often do not make for good TAZ definitions because they can be arbitrary in relation to the needs of the model, but they are usually desirable for data development and reporting functions.

The definition of TAZs has implications throughout the travel model. For roadway model components, TAZ resolution affects the amount of precision that can be achieved when loading vehicles onto the collector and arterial roadway network. This precision is obtained by increasing detail in the roadway network, TAZ structure, and socioeconomic data. The desire for increased detail must however be balanced with the ability to develop and maintain the data at the increased level of detail.

The TAZ layer is a polygon layer that divides the modeling area into internal zones and external stations. This layer is useful in developing socioeconomic data and as a guide when placing centroids and centroid connectors. It is only tangentially used by the travel model algorithms. Within the travel model, TAZs are

represented by centroids in the roadway network file. The TAZ-based data are stored in TransCAD binary table files rather than directly in the TAZ polygon layer.

Intermediate and output data at the TAZ level are also stored in either TransCAD binary table files or matrix files in the output directory for each scenario. Each of these output files can be joined to the TAZ polygon layer or to centroids in the roadway network. TAZ-based intermediate and output data includes terminal times, trip productions and attractions, trip matrices, and skim (shortest path) matrices. TAZ-based output data are discussed in detail in subsequent chapters describing the respective model components.

The TAZ structure has been extensively reviewed and refined in past model update efforts. For this update, the TAZ structure was reviewed and several changes were made to better align the TAZ layer with existing and forecast land uses. The MPO proposed the splitting of several TAZs to reflect recent development and roadway access. These changes were reviewed by CS with a couple minor adjustments. The overall number of TAZs in the model increased from 504 to 508 in the update.

The Lincoln MPO TAZs are shown in Figure 3.

Figure 3 Traffic Analysis Zone Structure



3.0 Trip Generation

Trip generation is the first phase of the traditional 4-step travel demand modeling process. It identifies the trip ends (productions and attractions) that correspond to the places where activities occur as represented by socioeconomic data (e.g., households, employment). Productions and attractions are estimated for each Traffic Analysis Zone (TAZ) by trip purpose, and then balanced at the regional level so that total productions and attractions are equal. In some cases, production and attraction allocation sub-models are applied to better represent the geographic distribution of trip-ends. The resulting productions and attractions by trip purpose and TAZ are subsequently used by the Trip Distribution model to estimate zone-to-zone travel patterns.

Trip generation rates are typically developed through analysis of household survey data. Since household survey data were not available for this effort, trip rates have been retained from the previous model.

3.1 Trip Production Rates

Trips productions are generated by trip purpose and household income group using the trip rates shown in Table 3.1 through Table 3.5. There are three income groups (low, medium, and high) and six trip purposes used in the Lincoln MPO Model as listed below:

- Home-Based Work (HBW): Trips between a traveler's residence and workplace.
- Home-Based Shop (HBS): Shopping trips starting or ending at the traveler's residence.
- Home-Based Other (HBO): All remaining trips starting or ending at the traveler's residence.
- Work-Based Other (WBO): Trips starting or ending at the workplace, but with neither end at the traveler's residence.
- Other-Based Other (OBO): Trips that do not start or end at the traveler's residence or workplace.
- Home-Based University (HBU): Trips between a traveler's residence and a University.

Many of the rates were adjusted from the 2019 model values to aid in validation – this was likely necessary due to trip-making patterns having changed. HBW and WBO rates decreased significantly, likely due to increased numbers of people working from home. HBS rates decreased as well, likely due to higher amounts of on-line shopping. Other rates also decreased but more moderately. Note that the HBU purpose does not have explicit production rates that vary by household income or size; those trips are balanced to attractions (discussed further in section 3.3).

Table 3.1 HBW Trip Production Rates

Income Group	1-Person	2-Person	3-Person	4-person	5+ Person
Low (\$0 – \$24,999)	0.522	1.451	1.451	1.451	1.451
Medium (\$25,000 - \$89,999)	0.929	1.921	3.397	3.397	3.397
High (\$90,000 and higher)	1.107	2.214	3.054	3.054	3.054

Table 3.2 HBS Trip Production Rates

Income Group	1-Person	2-Person	3-Person	4-person	5+ Person
Low (\$0 – \$19,999)	0.590	1.221	1.085	2.306	2.875
Medium (\$20,000 - \$74,999)	0.484	1.221	1.085	2.306	2.875
High (\$75,000 and higher)	0.432	0.979	1.78	1.695	2.875

Table 3.3 HBO Trip Production Rates

Income Group	1-Person	2-Person	3-Person	4-person	5+ Person
Low (\$0 – \$19,999)	1.419	3.699	8.733	12.348	21.267
Medium (\$20,000 - \$74,999)	1.368	3.699	8.733	12.348	21.267
High (\$75,000 and higher)	1.334	2.534	7.787	12.618	21.267

Table 3.4 WBO Trip Production Rates

Income Group	1-Person	2-Person	3-Person	4-person	5+ Person
Low (\$0 – \$19,999)	0.307	0.676	0.768	0.768	0.768
Medium (\$20,000 - \$74,999)	0.749	0.768	1.597	1.597	1.597
High (\$75,000 and higher)	1.113	1.413	2.073	2.073	2.073

Table 3.5 OBO Trip Production Rates

Income Group	1-Person	2-Person	3-Person	4-person	5+ Person
Low (\$0 – \$19,999)	1.323	1.343	3.127	5.133	9.177
Medium (\$20,000 - \$74,999)	1.481	2.117	3.127	5.133	9.177
High (\$75,000 and higher)	1.658	1.848	3.807	4.581	9.177

3.2 Trip Attraction Rates

Attraction rates define the ends of trips that occur at locations other than the trip-maker's home. For home-based trips, the attraction end of a trip occurs at a non-residential location, or occasionally at another person's home. For WBO trips, trip productions occur at the trip maker's workplace and the trip attraction occurs at the non-work end of the trip. For OBO trips, the trip production and attraction are synonymous with trip origin and destination. For non-home-based trip purposes, allocation models and special procedures are used to properly locate the production and attraction end of each trip.

Trip attraction rates used in the Lincoln model are based on land use categories and use the rates shown in Table 3.6 through Table 3.9. As with production rates, some adjustments were made to assist in model validation. All rates for office, service and industrial categories decreased significantly, almost certainly due to increased amounts of remote working

Table 3.6 HBW Trip Attraction Rates

	CBD	Urban	Suburban	Rural
Single Family	0.97	0.81	0.97	0.97
Multi Family	0.24	0.20	0.24	0.24
General Retail	2.25	1.49	1.37	1.12
Light Industrial	0.34	0.24	0.10	0.13
Office	1.80	1.00	0.59	0.75
Service	1.98	1.03	0.96	0.97
Industrial	30.16	11.31	7.46	5.91
Park	0.32	0.27	0.27	0.34
Elementary School	0.10	0.08	0.08	0.10
Secondary School	0.13	0.11	0.11	0.14
Community College	0.14	0.10	0.10	0.12
University	0.16	0.17	0.14	0.13

Table 3.7 HBS Trip Attraction Rates

	CBD	Urban	Suburban	Rural
General Retail	22.23	10.87	7.94	6.11

Table 3.8 HBO Trip Attraction Rates

	CBD	Urban	Suburban	Rural
Single Family	0.16	0.14	0.16	0.16
Multi Family	0.00	0.00	0.00	0.00
General Retail	4.26	2.48	2.50	2.59
Light Industrial	0.17	0.17	0.12	0.13
Office	1.79	1.44	1.45	1.51
Service	5.57	2.80	2.52	2.85
Industrial	0.00	0.00	0.00	0.00
Park	0.00	0.00	0.00	0.00
Elementary School	0.41	0.34	0.34	0.42
Secondary School	0.52	0.43	0.43	0.54

Community College	0.18	0.12	0.12	0.15
University	0.63	0.65	0.53	0.51

Table 3.9 WBO Trip Attraction Rates

	CBD	Urban	Suburban	Rural
Single Family	0.11	0.09	0.11	0.11
Multi Family	0.05	0.04	0.05	0.05
General Retail	3.03	1.38	1.18	1.18
Light Industrial	0.07	0.06	0.03	0.03
Office	0.78	0.48	0.34	0.34
Service	0.73	0.36	0.29	0.35
Industrial	4.45	1.67	1.10	0.87
Park	0.00	0.00	0.00	0.00
Elementary School	0.16	0.14	0.14	0.17
Secondary School	0.21	0.17	0.17	0.22
Community College	0.09	0.06	0.06	0.07
University	0.31	0.32	0.26	0.26

Table 3.10 OBO Trip Attraction Rates

	CBD	Urban	Suburban	Rural
Single Family	0.37	0.31	0.37	0.37
Multi Family	0.19	0.16	0.20	0.20
General Retail	7.89	3.59	3.06	3.06
Light Industrial	0.43	0.34	0.17	0.17
Office	4.63	2.87	2.03	2.00
Service	4.31	2.09	1.70	2.05
Industrial	5.60	2.10	1.38	1.10
Park	0.32	0.27	0.27	0.34
Elementary School	0.35	0.29	0.29	0.36
Secondary School	0.44	0.37	0.37	0.46
Community College	0.14	0.09	0.09	0.11
University	0.51	0.52	0.43	0.42

3.3 University Trip Generation and Production Allocation

Lincoln is home to the University of Nebraska Lincoln (UNL), which had a 2024 enrollment of 24,192 students. UNL includes a mix of students living on and off campus, with many off-campus students concentrated in housing near the university. This suggests that a separate university trip purpose and allocation model can improve representation of UNL in the travel model.

University Trip Purpose Definitions

Because universities do not fall into the normal trip patterns used by the model in the remainder of the region, some special considerations are given to trip types at UNL. In particular, the Home-Based University (HBU) trip purpose is defined as a trip by a university student or visitor between home and any location on the university campus. Trip ends at the university are associated with university faculty and staff, students living on campus, and students and visitors living off campus and described as follows:

- **HBW, HBS, and HBO Productions:** These production trip ends can occur only for students living on campus.
- **HBW Attractions and WBO Productions:** These trip ends can occur only for University faculty and staff.
- **WBO Attractions and all OBO Trips:** These trip ends can only occur for students and visitors living off campus.
- **HBS and HBO Attractions:** These trip ends cannot occur at the university. All home-based trips to the university by students and visitors are considered HBU trips and all home-based trips to the university by faculty and staff are considered HBW trips.
- **HBU Productions:** Trips within the university campuses are not modeled, so HBU productions cannot occur on campus.
- **HBU Attractions:** HBU attractions can occur only for students and visitors living off campus.

Special Generator Values

Trip rates are in units of trips per on-campus student, trips per off-campus student, or trips per employee. Total university enrollment was readily available for UNL. Employment and on-campus vs. off-campus students were estimated based on values obtained from UNL. Enrollment and employment data are shown in Table 3.11, with trip rates and special generator values shown in Table 3.12.

Table 3.11 Employment and Enrollment Data at UNL

Trip Generation Variable	Value
Total Students	24,192
On-Campus Students	9,677 (estimated)
Off-Campus Students	14,516 (estimated)
Employment (FTE)	6,173 (estimated)

Table 3.12 University Special Generator Values

Trip Purpose	Production / Attraction	Trip Rate	Unit	UNL Special Generator Value
HBW	Productions	0.22	On Campus Students	2,129
	Attractions	1.25	Total Employment	7,716
HBS	Productions	0.30	On Campus Students	2,903
	Attractions	n/a	n/a	0
HBU	Productions	n/a	n/a	0
	Attractions	3.00	Off Campus Students	43,547
HBO	Productions	0.30	On Campus Students	2,903
	Attractions	n/a	n/a	0
WBO	Productions	0.30	Total Employment	1,852
	Attractions	0.15	Off Campus Students	2,177
OBO	Productions	0.40	Off Campus Students	3,871
	Attractions	0.20	Off Campus Students	2,903

3.4 External Trips

In addition to the internal-internal trips that occur entirely within the modeling area, the model must include external travel from outside of the region. Trips with one end inside the modeling area and the other outside of the area are called Internal-External (IE) and External-Internal (EI) trips. Through trips, or External-External (EE) trips, are those that pass through the modeling area without stopping (or with only short convenience stops).

External travel is modeled explicitly at the external stations where roadways cross the model boundary. This external trip component of the Lincoln MPO Model is based on traffic counts available from NDOT and Lancaster County. The external stations in the Lincoln MPO model are shown in Figure 4.

External Station Volumes

The first step in estimating external travel for the model is to determine the average weekday traffic at each location in the base year. NDOT provided 2024 count data for some of the locations; prior counts were used those not provided – since those locations had very low amounts of traffic, using 5-to-10-year-old counts was not expected to reduce the model's accuracy. Next, it is necessary to determine the split between the EE and IE/EI trips at each external station. This was accomplished using LBS data provided by the MPO (originally from NDOT). The resulting base year traffic volumes and splits between EE and IE/EI trips for each external station are shown in Table 3.13. Many external stations are assumed not to carry EE trips.

Figure 4 External Station Locations

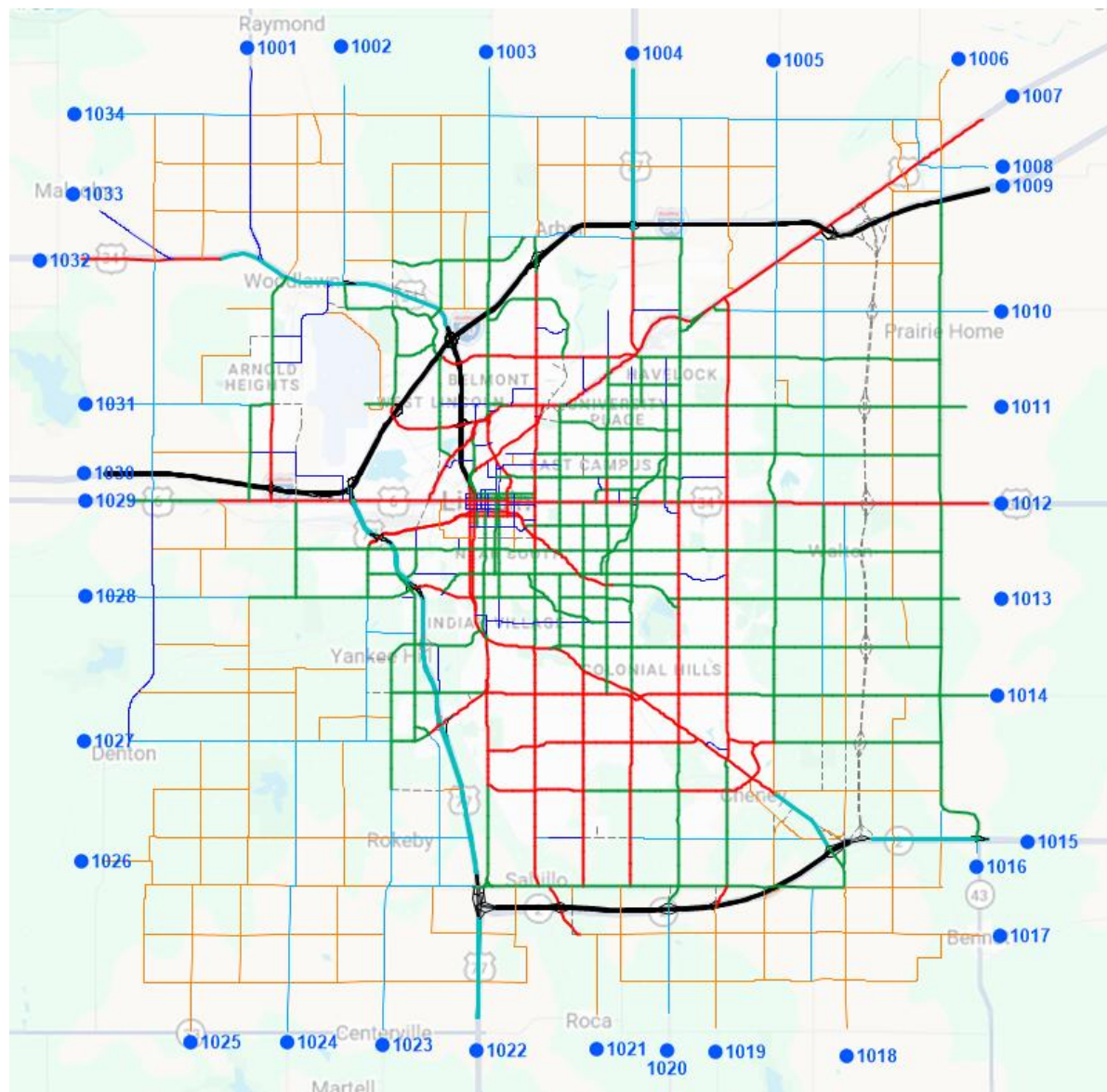


Table 3.13 External Travel Assumptions

Station	Location	Volume	%EE	%IE	EE Trips	IE/EI Trips
1001	56th North - SS79	2,465	12%	88%	297	2,168
1002	27th North	216	0%	100%	0	216
1003	14th North	3,703	0%	100%	0	3,703
1004	US 77- 56th North	8,845	14%	86%	1,248	7,597
1005	98th North	184	0%	100%	0	184
1006	148th North	230	0%	100%	0	230
1007	HWY 6 East	5,635	0%	100%	0	5,635
1008	Heywood/Bluff Rd	670	0%	100%	0	670
1009	I-80 East	51,180	32%	68%	16,255	34,925
1010	Fletcher	235	0%	100%	0	235
1011	Adams East	313	0%	100%	0	313
1012	US 34 - O Street East	7,735	10%	90%	779	6,956
1013	Van Dorn East	129	0%	100%	0	129
1014	Old Cheney East	779	0%	100%	0	779
1015	N2 - Rokeby East	13,389	33%	67%	4,473	8,916
1016	State Spur 43 South	6,315	5%	95%	345	5,970
1017	Bennet Rd	142	0%	100%	0	142
1018	120th South	184	0%	100%	0	184
1019	82th South	139	0%	100%	0	139
1020	68th South	4,600	7%	93%	300	4,300
1021	46th South	119	0%	100%	0	119
1022	Homestead Expy - US 77 South	15,430	32%	68%	4,915	10,515
1023	14th South	255	0%	100%	0	255
1024	42th South	85	0%	100%	0	85
1025	72th South	117	0%	100%	0	117
1026	Kolbrook	51	0%	100%	0	51
1027	Denton West	3,710	0%	100%	0	3,710
1028	Van Dorn West	500	0%	100%	0	500
1029	O Street West- HWY 6	2,075	0%	100%	0	2,075
1030	I-80 West	35,715	50%	50%	17,818	17,897
1031	Adams West	710	0%	100%	0	710
1032	Hwy 34 West	4,785	8%	92%	364	4,421
1033	State Spur 55-M	1,645	0%	100%	0	1,645
1034	Waverly Rd	95	0%	100%	0	95

4.0 Trip Distribution

Trip distribution is the second phase of the traditional 4-step demand model. Trip distribution is the process through which balanced person trip productions and attractions from the trip generation model are apportioned among all zone pairs in the modeling domain. The resulting trip matrix contains both intrazonal trips (e.g., trips that don't leave the zone) and interzonal trips to all other zone interchanges for each trip purpose.

The Lincoln MPO Model uses a gravity model equation and applies friction factors to represent the effects of impedance between zones. As the impedance (i.e., travel time) between a pair of zones increases, the number of trips between the zone pair decreases as represented by a decreasing friction factor. The trip distribution model also makes an assumption in that the number of trips between two zones is directly proportional to the number of productions and attractions contained in those zones. The gravity model used by trip distribution to estimate the number of trips between each zone pair is defined in the equation below.

$$T_{ij} = P_i \cdot \frac{A_j \cdot F_{ij} \cdot K_{ij}}{\sum_j A_j \cdot F_{ij} \cdot K_{ij}}$$

Where:

- T_{ij} = trips from zone i to zone j
- P_i = productions in zone i
- A_i = attractions in zone j
- K_{ij} = K-factor adjustment from i to zone j
- i = production zone
- j = attraction zone
- F_{ij} = friction factor (a function of impedance between zones i and j)

Friction factors represent the impedance to travel between each zone pair. Friction factors have been calibrated for each trip purpose based on a trip length frequency distribution (TLFD) generated from LBS travel data and roadway network shortest path matrices.

4.1 Roadway Network Shortest Path

The impedance portion of the gravity model equation is based on shortest paths between each zone pair. The Lincoln MPO Model finds the shortest path between each zone pair based on peak or off-peak congested travel time. Peak travel time is defined as the AM peak hour directional travel time, while off-peak travel time is defined as the off-peak period congested travel time. In the first speed feedback iteration, peak travel times are calculated based on congested speed lookup tables developed from INRIX and travel survey data. Initial off-peak speeds are identical to free flow speeds. In subsequent speed feedback iterations, travel times are calculated based on traffic assignment using a method of successive averages as described further in Section 6.2. Pathbuilding and travel time parameters used in this model update remain consistent with those derived for the previous model.

4.2 Friction Factors

Friction factors represent the impedance to travel between each zone pair. The Lincoln MPO Model applies the friction factors in the form of gamma functions for each trip purpose. The gamma function is defined by the equation below, with calibrated parameters shown in Table 4.1.

$$F_{ij} = \alpha t^{-\beta} e^{-\gamma t}$$

Where:

- F_{ij} = Friction factor between zones i and j
- t = travel time
- α, β, γ = calibration parameters

Friction factors for each trip purpose were calibrated by comparing a Trip Length Frequency Distribution (TLFD) generated by the travel model to a TLFD generated from a combination of observed trip OD pairs obtained from LBS data and the travel model shortest path matrix. The travel model was run iteratively with minor adjustments to calibration parameters alpha, beta, and gamma until the modeled and observed TLFD converged to a similar shape. The calibrated friction factors are shown in

Table 4.1 Calibrated Friction Factor Parameters

Trip Purpose	Alpha	Beta	Gamma
HBW	1000	0.25	0.17
HBS	1000	1.06	0.24
HBU	100	1.58	0.07
HBO	100	1.56	0.23
WBO	100	0.97	0.17
OBO	100	2.46	0.00

A comparison of observed TLFDs for peak and off peak periods shows minimal differences between time periods for all trip purposes. Therefore, separate calibration exercises were not performed for the peak and off-peak time periods.

The following figures show the trip length distribution curves, comparing the observed data and the validated base year model. The x axis corresponds to trip distance in one-mile ranges, and the y axis corresponds to the percentage of trips in each range. Figures 5 through 7 show the curves for HBW Trips, HBU Trips, and all other trips (including HBS, HBO, WBO and OBO) respectively.

Figure 5 Trip Length Distribution Curve, HBW Trips

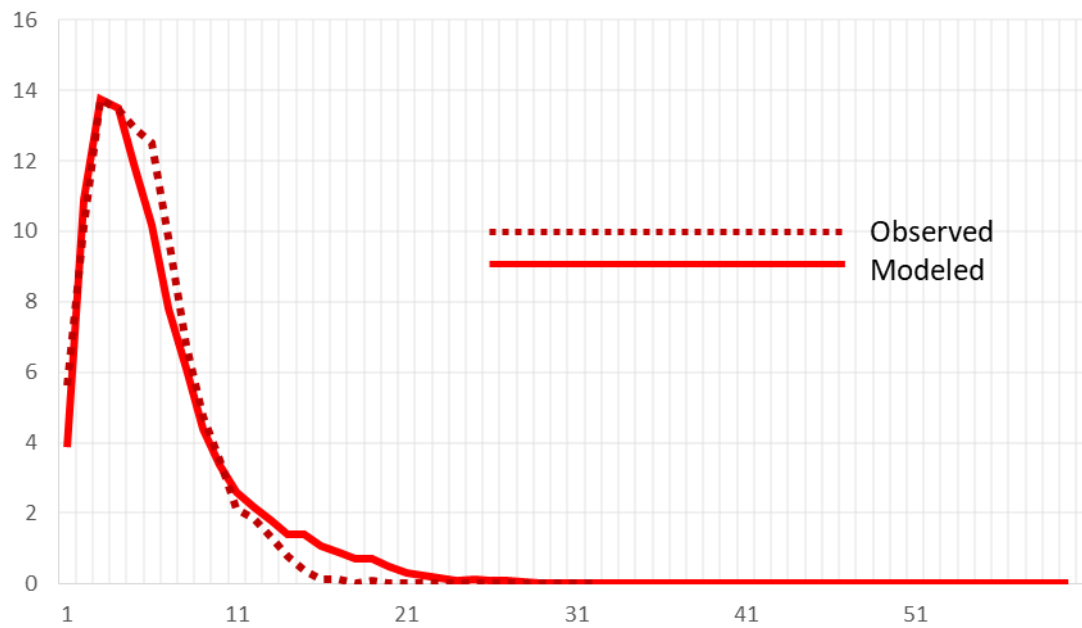


Figure 6 Trip Length Distribution Curve, HBU Trips

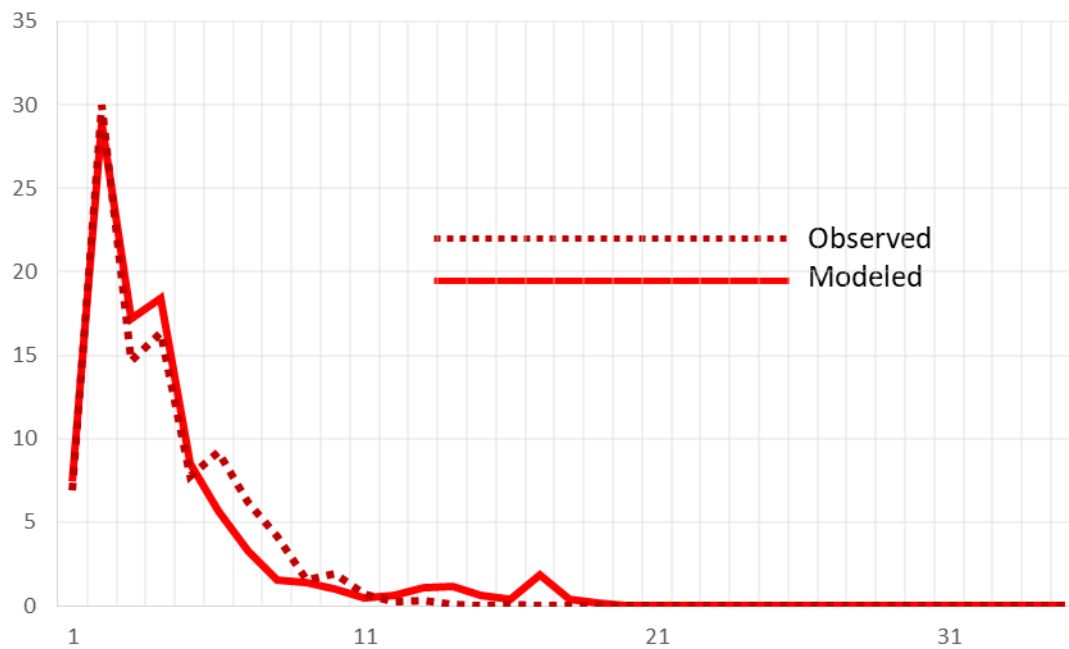
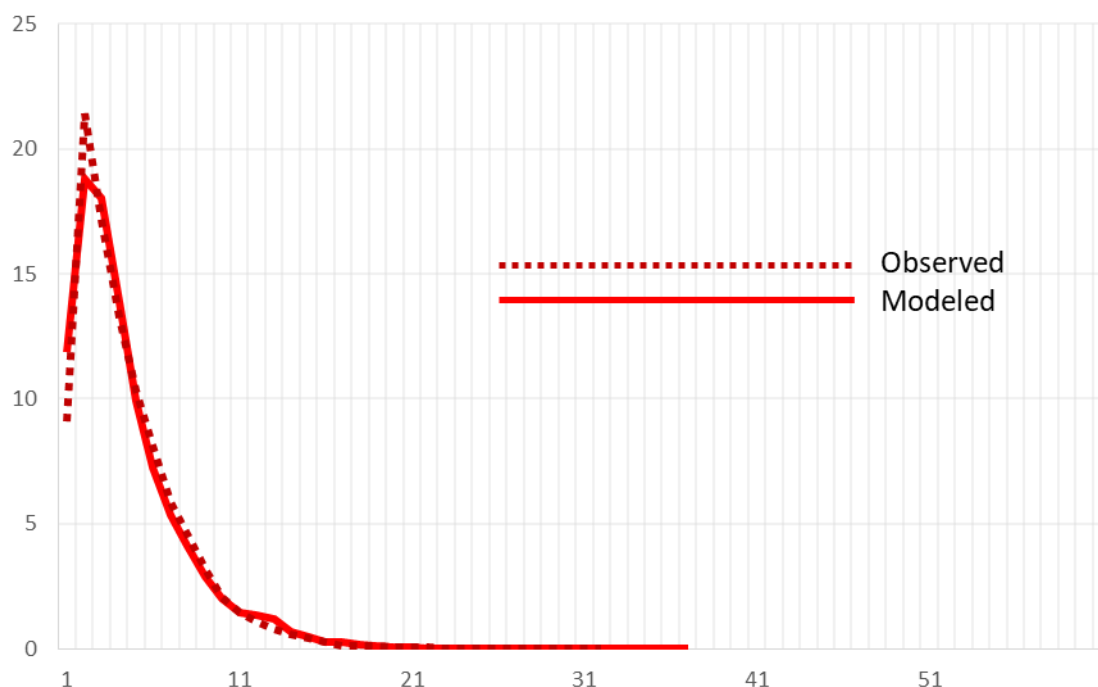


Figure 7 Trip Length Distribution Curve, All Other Trips

4.3 Peak and Off-Peak Period Definitions

Trips occurring during the AM and PM peak hours are distributed based on peak congested speeds and trips occurring during off-peak times are distributed based on off-peak congested speeds. Trip distribution is performed in Production-Attraction (PA) format rather than Origin-Destination (OD) format. This is because the majority of trips in the AM peak hour travel from production to attractions (e.g., to work) and the majority of trips in the PM peak hour travel from attraction to productions (e.g., from work).

The Lincoln MPO Model has the capability of generating trips by time of day, using factors representing the portion of trips occurring in the peak (combined AM and PM peak hours) and off-peak (all other times) period. Peak hour trips are further separated in the time of day step prior to traffic assignment.

The time of day factors were determined by analyzing the 2022-24 traffic count data within the City of Lincoln received from the MPO. Compared to the previous version of the model, the AM peak hour moved forward 15 minutes (starting at 7:15 AM) and the PM peak hour moved back 30 minutes (starting at 4:30 PM). The percentage of traffic occurring in the peak hours decreased slightly from the previous model, from 19% to 17%. The resulting share of trips in the peak by trip purpose are shown in Table 4.2.

Table 4.2 Peak and Off-Peak Trip Percentages by Purpose

Time Period	HBW	HBS	HBU	HBO	WBO	OBO
Peak 7:15 – 8:15 AM and 4:30 – 5:30 PM	22.3%	12.3%	17.8%	19.4%	17.2%	9.5%
Off-Peak All other times	77.7%	87.7%	82.2%	80.6%	82.8%	90.5%

5.0 Mode Choice

5.1 Mode Choice Model Structure

Because a household survey was not available, it was necessary to borrow many elements of the Lincoln MPO mode choice model from another region. While preference was given to local data sources, the mode choice model also draws from Federal Transit Administration (FTA) guidelines, consultant experience, and the mode choice model included in Colorado North Front Range (NFR) Regional Travel Model. The NFR mode choice model was selected as a source of information for this model update due to geographic proximity, similarity in community size, and the presence of a large university in both areas.

The Lincoln MPO Model applies a logit-based mode choice model for all internal trip purposes. The general equation describing a multinomial mode choice is shown in the equation below.

$$P_i = \frac{e^{U_i}}{\sum_m e^{U_m}}$$

Where:

- P_i = the probability of using mode i
- u_i = the utility of mode i
- u_m = the utility of mode m

The logit model is based on the concept of utilities (or disutilities) that describe the characteristics of travel by each mode. The utility function can be made up of impedance variables such as travel time, wait time, and cost as well as locational and socioeconomic variables. Each variable is multiplied by an estimated coefficient that describes the relative weight (positive or negative) of each variable. A mode constant that captures mode preferences not measured by the other utility variables is also added to the utility. Due to the relative nature of the mode constants, the mode constant for one mode must be set to zero. The utility equation applied to each mode is shown below.

$$u_i = c_1X_{1i} + c_2x_{2i} + c_3x_{3i} + \dots + c_nx_{ni}$$

Where:

- u_i = Utility for mode i
- $c_1, c_2, c_3, \dots, c_n$ = Estimated coefficients for variables 1 through n
- $x_{1i}, x_{2i}, x_{3i}, \dots, x_{ni}$ = Values for variables 1 through n

The Lincoln MPO Model uses a mode choice structure that nests multiple multinomial choices. At the bottom level of the nested logit structure, utility values are computed using the method described for multinomial application. Utilities at the upper level are computed as a combination of utilities for the nested modes (i.e., modes below the upper level choice). An example of a lower level mode is walk, while the corresponding upper level mode is non-motorized. Utilities for intermediate modes are based on the natural log of the sum of exponentiated sub-mode utilities. This term, referred to as the “logsum” variable, is computed as shown below.

$$LS_i = \ln \left(\sum_{j=1}^n e^{u_j} \right)$$

Where:

- LS_i = The logsum of intermediate mode i
- u_j = Utility terms for nested mode j
- n = The number of sub-modes under mode i

Once the logsum variables have been computed for all intermediate modes, mode probabilities are calculated in a manner similar to that described for multinomial logit models. However, for nested modes, utilities are replaced by the product of the logsum and a nesting coefficient as shown in the equation below. The nesting coefficient has a value between zero and one, where a nesting value of zero indicates sub-modes are identical and do not need to be included as separate modes and a nesting value of one indicates sub-modes are distinctly different and could be represented as separate non-nested modes.

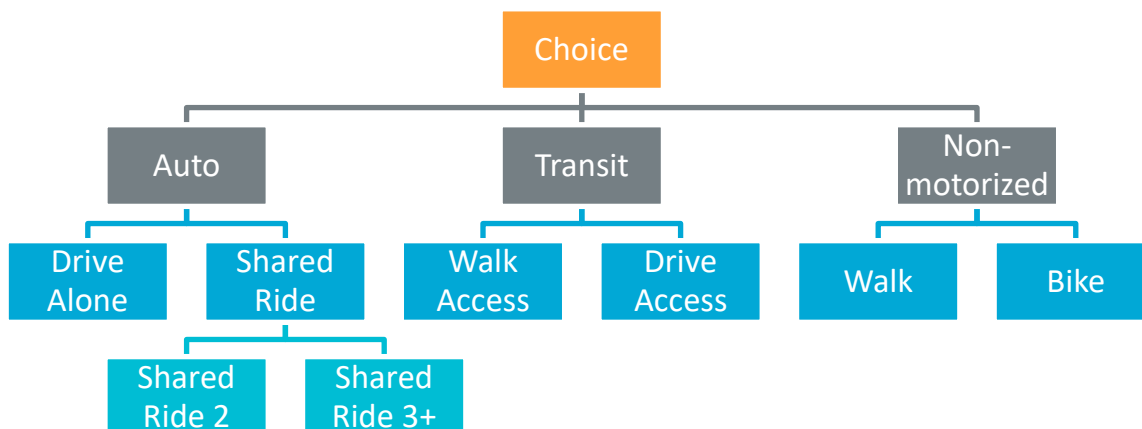
$$P_i = \frac{e^{\theta_i \cdot LS_i}}{\sum_{m=1}^n e^{\theta_m \cdot LS_m}}$$

Where:

- P_i = The probability of selecting intermediate mode i
- θ_i = The nesting coefficient for intermediate mode i
- θ_m = The nesting coefficient for mode m
- n = The number of modes at the same level as mode i

The structure for the Lincoln MPO mode choice models, shown in Figure 8, assumes modes, sub-modes, and access modes are distinctly different types of alternatives that present distinct choices to travelers. Within each nest, the model operates on the modes included in the nest as a multinomial logit model. Likewise, the model operates on nests included at a specific nesting level as a multinomial logit model. However, the competition between modes included in different nests or nesting levels is not in proportion to initial estimates of the mode shares. As a result, an important departure from multinomial logit models is “lower level” choices are more elastic than they would be in a multinomial logit model.

Figure 8 Nested Logit Mode Choice Structure



The nested logit model employs several multinomial logit models. The first is choice among primary modes: auto, transit, and non-motorized. The second model provides a choice between drive alone and shared ride followed by a choice between shared ride 2 and shared ride 3+. The next model provides a choice between walk and drive access to transit. Lastly, the model provides a choice between walk and bike.

In application, utilities are calculated at the bottom levels first and passed up through the nesting structure. When this is complete, the probabilities are estimated from the top of the structure down. Composite utilities are passed upward using “logsum” variables. For example, for the composite transit mode, the “logsum” would be based on walk and drive access modes. The logsum for transit is calculated as shown in the equation below.

$$LS_{transit} = -\ln(e^{u_{WalkAccess}} + e^{u_{DriveAccess}})$$

The logsum terms for the transit mode would then appear in the multinomial choice model for auto, transit, or non-motorized as follows:

$$P_{transit} = \frac{e^{\theta_1 \cdot LS_{transit}}}{e^{\theta_1 \cdot LS_{auto}} + e^{\theta_1 \cdot LS_{transit}} + e^{\theta_1 \cdot LS_{nonmotor}}}$$

Where:

$P_{transit}$ = the probability that a traveler will use transit
 θ_1 = the nesting coefficient for the upper level nest

While it is possible to estimate mode choice model coefficients and constants using a combination of household and on-board survey data, sufficient data are not available to estimate mode choice model coefficients in the region. Therefore, mode choice coefficients are consistent with guidance provided by the Federal Transit Administration (FTA). This guidance, summarized in Table 5.1, specifies allowable ranges for certain model coefficients.

Table 5.1 New Starts Coefficient Guidelines

Coefficient	Minimum Value	Maximum Value
In-Vehicle Travel Time (IVTT)	-0.030	-0.020
Out of Vehicle Travel Time (OVTT)	-0.090	-0.040

The Lincoln MPO Model uses a coefficient value of .0025 for in-vehicle travel time (IVTT) which falls mid-way between the minimum and maximum recommended coefficients, and -0.05 for out of vehicle travel time (OVTT), keeping consistent with the guidance that states that the coefficient for out of vehicle travel time should be between 2 and 3 times the in-vehicle travel time coefficient.

5.2 Mode Choice Model Specification

The utility equations for the Lincoln MPO mode choice model follow. The coefficient designations (e.g., C_{ivtt} for Coefficient of in-vehicle travel time) rather than the actual model coefficients are shown to aid in the understanding of the model specification. The actual model coefficients are shown in Table 5.2. Model constants will be calibrated to the mode choice targets documented in the subsequent section.

Drive Alone Utility:

$$U_{DA} = C_{IVTT} \cdot IVTT_{drive} + C_{OVTT} \cdot TTIME + C_{Cost(income)} \cdot (CPM \cdot Dist)$$

Shared Ride 2 Utility:

$$U_{SR2} = C_{IVTT} \cdot IVTT_{drive} + C_{OVTT} \cdot TTIME + C_{Cost(income)} \cdot (CPM \cdot Dist) + K_{SR2}$$

Shared Ride 3+ Utility:

$$U_{SR3p} = C_{IVTT} \cdot IVTT_{drive} + C_{OVTT} \cdot TTIME + C_{Cost(income)} \cdot (CPM \cdot Dist) + K_{SR3p}$$

Note: the cost terms for HBW trips are divided by 2 for SR2 and by 3.3 for SR3+. Cost terms for HBU trips are divided by 2 for SR2 and 3.5 for SR3+.

Walk to Transit Utilities:

$$U_{WalkTransit} = C_{IVTT} \cdot IVTT_{transit} + C_{OVTT} \cdot WalkAccessTime + C_{OVTT} \cdot WalkEgressTime + C_{OVTT} \cdot \min(WaitTime, 7.5) + C_{LWAIT} \cdot \max(WaitTime - 7.5, 0) + C_{OVTT} \cdot XferTime + C_{Cost(income)} \cdot Fare + K_{WalkTransit}$$

Drive to Transit Utilities:

$$U_{DriveTransit} = C_{IVTT} \cdot (IVTT_{transit}) + C_{IVTT} \cdot DriveAccessTime + C_{OVTT} \cdot WalkEgressTime + C_{OVTT} \cdot \min(WaitTime, 7.5) + C_{LWAIT} \cdot \max(WaitTime - 7.5, 0) + C_{OVTT} \cdot XferTime + C_{Cost(income)} \cdot (Fare + CPM \cdot Dist) + K_{DriveTransit}$$

Walk Utility:

$$U_{Walk} = C_{OVTT} \cdot WalkTime + K_{Walk}$$

Bike Utility:

$$U_{Bike} = C_{OVTT} \cdot BikeTime + K_{Bike}$$

Where:

$IVTT_{transit}$	= Transit in-vehicle travel time
$IVTT_{drive}$	= Drive in-vehicle travel time
$TTIME$	= Terminal time in minutes
CPM	= Auto operating cost per mile in cents
$Dist$	= Distance traveled in miles
$WalkAccessTime$	= Walk access time
$DriveAccessTime$	= Drive access time
$WalkEgressTime$	= Walk egress time
$WaitTime$	= Initial wait tie for transit in minutes
$XferTime$	= Transfer time in minutes (1/2 of the headway of the route being boarded, plus walk time if applicable)
$WalkTime$	= Direct walk time, assuming a 3 mph walk speed
$BikeTime$	= Direct bike time, assuming a 12 mph bike speed
$Fare$	= Transit fare in dollars (average rate paid by all riders)
C_x	= Coefficient for variable x, defined in Table 5.2
K_{TRN}	= Transit Constant
K_{DACC}	= Drive Access Constant
K_{mode}	= Constant for specified mode (i.e., express or premium)

Table 5.2 Mode Choice Model Coefficients

Coefficient	Value
In-Vehicle Travel Time (IVTT)	-0.025
Out of Vehicle Travel Time (OVTT)	-0.050
Long wait time (LWAIT)	-0.025
Cost (low income)	-0.621
Cost (med income)	-0.214
Cost (high income)	-0.121
Cost (not segmented)	-0.212
Walk Time	-0.050
Bike Time	-0.050
Nesting Coefficient (same for both levels)	0.5

Source: NFR Regional Travel Model, adjusted and transferred to the Lincoln MPO Model.

5.3 Mode Choice Targets

The Lincoln mode choice targets were prepared using a combination of the following data sources:

1. 2024 StarTran Farebox Ridership Data
2. 2019 StarTran On-Board Transit Survey, covering access and egress modes, transfer rate and trip purpose splits of riders¹
3. 2024 American Community Survey (ACS) mode choice splits for home based work trips in the MPO
4. 2015 NFR Mode Choice splits for other trip purposes

Transit Ridership

Table 5.3 shows the 2024 route boardings. The boardings reflect average weekday daily boardings using farebox data for all weekdays in 2024. For the three UNL-oriented routes (22, 24 and 25), months of zero or partial operation (January, May-August and December) were excluded; thus, the model reflects transit ridership when UNL is in session.

¹ At the time of model calibration, the 2019 StarTran Survey was still the most current survey available; the 2025 update was made available in early 2026, its key results were compared to 2019 and we determined they were close enough that no updated were warranted.

Table 5.3 Route Ridership

Route	Daily Boardings
13	676
22	248
24	1,380
25	1,283
27	873
40	411
41	457
42	306
44	702
46	562
48	183
49	349
51	210
52	303
53	523
54	221
55	188
56	157
Total (unlinked trips)	8,934
Transfer % (from 2019 survey)	21.2%
Total (linked trips)	7,453

Source: 2024 Farebox Data, received from StarTran.

On-Board Transit Survey

StarTran conducted an on-board transit survey on all fixed routes in mid-October 2019. The survey was meant to analyze travel patterns and transit use. There were 405 completed surveys. The survey provides information regarding on transfer rates and access and egress modes to/from transit.

Table 5.4 presents the transit access and egress mode splits as per the on-board transit survey report. To determine the 2019 linked transit trip target, the 2019 unlinked transit trips (boardings) are divided by the transfer rate. To that end, and in absence of more reliable information, we assumed that the average transfer rate in the region is the average of transfer access and egress rates, or 21.24%. Consequently, the linked transit trip target in the Lincoln MPO is **7,453 transit trips**.

Table 5.4 Transit Access and Egress Mode Splits

Access Modes	Percent of Respondents	Egress Modes	Percent of Respondents
Transfer	15.6%	Transfer	26.9%
Walk	72.6%	Walk	54.3%
Auto	5.4%	Auto	2.0%
Bike	2.0%	Bike	1.5%
Other	1.7%	Other	9.6%
N/A	2.7%	N/A	5.7%

Source: StarTran 2019 On-Board Transit Survey.

Also, Table 5.4 identifies the splits between walking to/from transit and driving to/from transit. We assumed that all access and egress modes aside from transfer and auto belong to the walk mode, whereas the auto mode belongs to the drive mode. Consequently, after adjusting the non-transfer modes to sum up to 100%, and averaging access and egress percentages, we find that 95.4% of transit trips are accessed/egressed via walking, whereas 4.6% of transit trips are access/egressed via driving.

Mode Choice Targets

To the extent possible, local data from the 2019 StarTran on-board survey and the 2024 American Community Survey (ACS) were used to develop mode choice targets. Where necessary, the available information was supplemented by information from the mode choice targets from the NFR Regional Travel Model. Non-transit mode targets are in percent, and sum up to 100%. Transit is split into Walk to Transit and Drive to Transit.

The 2019 on-board survey contains an overall trip purpose distribution, shown in Table 5.5.

Table 5.5 Trip Purpose Splits of Transit Ridership

Trip Purpose	Percent of Respondents
Work	27.9%
Shopping	41.5%
School	11.4%
Personal Business	8.9%
Medical & Dental	1.7%
Social & Recreational	2.2%
Other	4.2%
N/A	2.2%

Source: StarTran 2019 On-Board Transit Survey.

These trip purposes were mapped to the MPO model's trip purpose to the extent possible. Where detail was insufficient (e.g. income splits of work trips, distinction of WBO vs OBO), relative trip purpose splits were borrowed from the NFR Regional Travel Model.

The 2019 on-board survey also contains access and egress splits to transit, with 95.4% of respondents not making transfer saying they walked. This was used as a target for all trip purposes, except HBU, which was assumed to be 100% walking.

Overall mode split targets for the Lincoln region were available for HBW trips from the ACS, shown in Table 5.7.

Table 5.6 Regional Mode Splits of HBW Trips

Mode	Percent of Respondents
Drive Alone	83.0%
Carpool	10.6%
Transit	1.0%
Walk	3.1%
Bike	2.4%

Source: 2024 ACS 1-year estimates, Table B08141, Lincoln Area

In similar fashion to trip purpose, the additional detail necessary for the model's mode targets (splitting carpool into HOV2 vs HOV3+, relationship between income levels, and other purposes' mode splits) was borrowed from the NFR Regional Travel Model.

Table 5.7 presents the resulting Lincoln MPO mode choice targets. The percentages for all modes except transit add to 100%, with transit targets specified as ridership numbers (adding up to the 7,453 shown in Table 5.3).

Table 5.7 Lincoln MPO Mode Choice Targets (transit trips expressed as ridership numbers)

Purpose	Income	DA	SR2	SR3	Walk to Transit	Drive to Transit	Walk	Bike
HBW	Income 1	83.8%	6.6%	2.7%	1,591	76	6.7%	0.2%
HBW	Income 2	83.7%	8.0%	3.3%	1,181	57	3.3%	1.7%
HBW	Income 3	83.4%	7.7%	3.2%	179	9	2.4%	3.4%
HBS	All	43.3%	32.6%	17.7%	808	39	4.7%	1.8%
HBU	All	54.2%	14.4%	7.6%	2,080	0	11.7%	12.1%
HBO	All	33.7%	27.7%	24.8%	913	44	10.8%	3.0%
WBO	All	77.6%	7.8%	4.1%	137	7	8.3%	2.1%
OBO	All	36.8%	27.8%	24.9%	320	15	9.5%	1.0%

Table 5.8 shows the mode choice targets with transit targets converted to percentages, so that all modes add to 100%.

Table 5.8 Lincoln MPO Mode Choice Targets (all modes add to 100%)

Purpose	Income	DA	SR2	SR3	Transit	Walk	Bike
HBW	Income 1	78.6%	6.3%	2.6%	7.7%	4.6%	0.2%
HBW	Income 2	83.2%	8.1%	3.3%	0.7%	2.4%	2.3%
HBW	Income 3	82.6%	7.7%	3.2%	0.1%	1.8%	4.7%
HBS	All	43.2%	32.6%	17.6%	0.3%	4.7%	1.8%
HBU	All	51.6%	13.7%	7.3%	4.8%	11.1%	11.5%
HBO	All	33.7%	27.7%	24.8%	0.1%	10.8%	3.0%
WBO	All	77.5%	7.8%	4.1%	0.1%	8.3%	2.1%
OBO	All	36.8%	27.8%	24.9%	0.1%	9.5%	1.0%
Overall		47.3%	23.3%	18.4%	0.3%	8.2%	2.6%

6.0 Trip Assignment

The trip assignment model includes a time of day step followed by assignment of transit and vehicle trips to the transportation networks. In the time of day model component, the vehicle trip tables from the mode choice model are converted to Origin/Destination format and factored into time periods for assignment on the roadway network.

In the traffic assignment step, vehicle trip tables by time of day are assigned to the roadway network using an equilibrium procedure for the AM and PM peak hours and for the off-peak period. After traffic assignment is completed, resulting travel times are fed back to trip distribution and the model is run iteratively until speeds input to trip distribution are reasonably consistent with speeds resulting from traffic assignment.

After speed feedback has been completed, transit person trips are assigned to the transit route system. Transit trips are assigned separately for peak and off-peak periods and by drive and walk access. These individual assignment results are combined to form daily transit assignment results.

6.1 Time of Day

Based on the analysis of 2022-2024 traffic count data within the City of Lincoln received from the MPO, the AM and PM peak hours were defined as shown in Table 6.1.1. The peak hour definitions are consistent with the traditional morning and evening peaks observed in many similarly sized areas. One-hour peaks are often modeled in regions that don't experience significant congestion outside of rather short peak periods during typical weekdays. One-hour peaks also facilitate reporting of the common performance measure of peak hour level of service.

Table 6.1 Peak Period Definitions

Period Name	Period Definition
AM Peak Hour	7:15 AM – 8:15 AM
PM Peak Hour	4:30 PM – 5:30 PM
Off-Peak Period	All Remaining Time (22 hours)

Time of day processing is done in two steps in the Lincoln MPO Model. Factors are first applied in a pre-distribution time of day module that separates trips into peak and off-peak time periods but does not distinguish between different directions. These factors were shown in Table 4.2. After mode choice is complete, a second time of day process separates peak period trips into AM and PM trips and processes trip directionality. These factors are shown in Table 6.2Table 6.3. To interpret this table for HBW, for example:

- 48.9% of HBW *peak* trips are allocated to the AM peak hour, the remaining 51.1% to the PM peak hour.
- Of the 48.9% in the AM peak hour, most of them (46.2%) are traveling from home to work, so the production end of the trip is the origin, and the attraction end is the destination.

- The remaining 2.7% in the AM peak hour are traveling from work to home, so the attraction end of the trip is the origin, and the production end is the destination.
- Of the 51.1% in the PM peak hour, most of them (46.1%) are traveling from work to home, so the attraction end of the trip is the origin, and the production end is the destination.
- The remaining 5.0% in the PM peak hour are traveling from home to work, so the production end of the trip is the origin, and the attraction end is the destination.
- In the off peak (which does not need to be split into hours), 53.5% are traveling from home to work, and 46.5% are traveling from work to home.

Table 6.2 Peak Period AM / PM and Directionality Factors

Time Period	Hour and Direction	HBW	HBS	HBU	HBO	WBO	OBO
Peak	AM Peak Hour Depart	46.2%	13.2%	72.3%	51.0%	10.8%	15.4%
	AM Peak Hour Return	2.7%	1.1%	0.0%	6.8%	26.4%	15.4%
	PM Peak Hour Depart	5.0%	41.0%	8.0%	11.9%	53.5%	34.6%
	PM Peak Hour Return	46.1%	44.6%	19.7%	30.3%	9.3%	34.6%
Off-Peak	Depart	53.5%	41.1%	48.6%	47.1%	67.1%	50.0%
	Return	46.5%	58.9%	51.4%	52.9%	32.9%	50.0%

Combining the time of day factors in Table 4.2 with the AM/PM splits and directional factors from Table 6.2, the resultant overall time of day / directionality factors are shown in Table 6.3.

Table 6.3 Overall Time of Day Factors

Time Period	Direction	HBW	HBS	HBU	HBO	WBO	OBO
AM Peak Hour	Depart	10.3%	1.6%	12.9%	9.9%	1.9%	1.5%
	Return	0.6%	0.1%	0.0%	1.3%	4.5%	1.5%
PM Peak Hour	Depart	1.1%	5.1%	1.4%	2.3%	9.2%	3.3%
	Return	10.3%	5.5%	3.5%	5.9%	1.6%	3.3%
Off-Peak	Depart	41.6%	36.1%	40.0%	38.0%	55.5%	45.3%
	Return	36.1%	51.6%	42.2%	42.6%	27.3%	45.3%

6.2 Traffic Assignment

The Traffic Assignment step loads the travel demand represented by the vehicle trip tables onto the roadway network. The Lincoln MPO Model features a user equilibrium assignment method that accounts for traffic congestion and the associated rerouting of trips to avoid congestion. The equilibrium assignment process

minimizes the total travel time on the roadway network, representing a condition in which each highway user has perfect knowledge of traffic conditions in the region.

The impedance used for determining the shortest path in the Traffic Assignment step of the Lincoln MPO Travel Model includes travel time and auto operating cost. When including variables in addition to travel time, a generalized cost function converts all variables to a consistent cost using a value of time, as demonstrated in the equation below.

$$\text{Generalized Cost} = \text{Time} \cdot \text{ValueOfTime} + \text{OperatingCost}$$

A volume-delay function represents the effect of increasing traffic volume on link travel time in the assignment process. The Lincoln MPO Model uses the most common volume-delay function called the modified Bureau of Public Roads (BPR) function. The modified BPR function is shown below.

$$T_C = T_F \left(1 + \alpha \left(\frac{V}{C} \right)^\beta \right)$$

Where:

T_C = Congested travel time

T_F = Freeflow travel time

V = Traffic volume

C = Highway design capacity (i.e., upper limit level of service C capacity)

α = Coefficient alpha

β = Exponent beta

The coefficient alpha and the exponent beta are calibrated values that vary by facility type, shown in Table 6.4. They were developed by monitoring link speed and VMT balance by facility type during the model validation process. Most of these were unchanged from the previous model; the only exception was principal arterials, where beta was reduced from 10 to 7.

Table 6.4 Calibrated Friction Factor Parameters

	Alpha	Beta	Gamma
Freeway	0.83	5.5	1000
Expressway	0.71	2.1	1000
Principal Arterial	0.15	7	1000
Minor Arterial	0.15	7	1000
Urban Collector	0.15	7	1000
Major Rural Collector (State)	0.15	7	1000
Major Rural Collector (County)	0.15	7	1000
Minor Rural Collector	0.15	7	1000
Others (Local)	0.15	7	1000
Ramp	0.83	5.5	1000

Freeway/Freeway Ramp	0.83	1.40	1000
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Speed Feedback

The trip distribution and mode choice model steps rely on congested zone to zone travel time information to distribute trips and identify mode shares. The traffic assignment step produces estimated congested travel speeds based on traffic flows and application of the volume-delay function. The speeds input to trip distribution and mode choice are generally not consistent with the speeds output from traffic assignment. To rectify this inconsistency, results from traffic assignment are used to re-compute zone to zone travel times for input to trip distribution and mode choice. The model is re-run, and a comparison is then made between the initial and updated zone to zone travel times. If the travel times are not reasonably similar, the updated travel times are then fed back to trip distribution and mode choice. This process can be repeated iteratively until a convergence criterion or iteration limit is met.

Without speed feedback, overall regional travel demand remains constant regardless of the roadway network assumptions because trip distribution and mode choice patterns are not affected by changing congestion levels. When speed feedback is added to the model, heavy congestion results in slower speeds, thereby leading to shorter trip patterns in areas with heavy congestion. As roadway improvements are added to the model, the associated capacity increase results in faster travel speeds as localized congestion decreases. The higher speeds result in longer trip lengths, which has the effect of incrementally increasing overall travel demand. In the mode choice model, slower roadway speeds typically result in slower transit speeds as well, minimizing the effect of speed feedback on transit results. Speed feedback has a more notable effect on transit results when modeling transit options that do not experience speed degradation as traffic congestion increases. Inclusion of speed feedback is most important from a mode choice perspective when using the model to test options such as BRT, rail, or even improvements such as transit signal prioritization or queue jumps.

Application of Speed Feedback for Alternatives Analysis

Speed feedback ensures travel time consistency within the entire modeling structure. It was conceived as a model enhancement in the early 1990's largely in response to environmental lawsuits, although it is good practice and now considered a necessity. Generally, speed feedback is most noticeable when modeling network changes that provide a significant travel time improvement, such as a new freeway in a developing area. These types of alternatives warrant running the feedback process because they can affect regional travel patterns. Less significant improvements may not result in a significant change in trip distribution patterns.

For any and all interim milestone and horizon years, speed feedback should be executed to closure for the base network in each of these years. This base network could be defined as a no-build, existing plus committed, or build network for each of these future years. In any given year, speed feedback should generally be run when a scenario includes major changes to socioeconomic data assumptions or significant changes to the roadway network.

When comparing minor improvements, it is often best to run the model with speed feedback disabled. This will increase consistency between scenarios being compared.

6.3 Transit Assignment

Transit person trips resulting from the mode choice model are assigned to the transit route system. Each trip is assigned from zone centroid to zone centroid using walk or drive access links, transit routes, and walk egress links. The transit assignment step does not include capacity constraints, so increasing transit volumes do not result in diversion of transit trips to other transit services.

Transit assignment results include the total number of boardings at each transit stop, as well as transit volumes on all stop to stop transit route segments. Transit results are generally best evaluated at the systemwide or route group level. Individual route, stop, and segment values have not been validated to observed conditions in every case – however, CS did take steps to improve validation on the three UNL-related routes (22, 24 and 25) on a combined basis by segmenting them out from the rest of the routes in the parameter calibration procedure.

Many of the individual routes' modeled ridership does validate closely with 2024 ridership data, as shown below in Figure 9 Transit Ridership Comparison of Modeled to Target By Route

. Prior to using the model to support detailed transit corridor studies, a focused transit model calibration and validation effort may be recommended if more accuracy is desired.

Figure 9 Transit Ridership Comparison of Modeled to Target By Route



6.4 Assignment Validation

Roadway volumes resulting from traffic assignment were compared against traffic count data. This process, called traffic assignment validation, ensures that the model is reasonably representing observed traffic

patterns. Traffic counts obtained from Lincoln Transportation & Utilities, Lancaster County Engineering Office, and NDOT were placed on the roadway network. Travel model results were then compared to traffic count data using a variety of techniques, including regional comparisons, screenline comparisons, and visual inspection of individual link data.

Overall vehicle trip activity was validated by comparing count data to model results on all links where count data is available using two statistics: Model Volume as compared to Count Volume and Model VMT as compared to Count VMT. These statistics were reviewed at the facility type, area type, and regional level and are shown in Table 6.5.

While the model should accurately represent the overall level of activity, it is also important to verify the model has an acceptably low level of error. It is expected that the model will not perfectly reproduce count volumes on every link, but the level of error should be monitored. The plot shown in Figure 10 demonstrates the ability of the model to match individual traffic count data points. General guidelines suggest that % RMSE should be below about 40 percent region-wide, with values below 30 percent for high volume facility types such as freeways. The % RMSE measure tends to over-represent errors on low volume facilities, so values on collectors are not particularly meaningful. Table 6.6 shows % RMSE values by facility type and area type.

The Lincoln MPO Model includes 7 screenlines, shown in Figure 11. Screenlines capture distinct regional travel patterns, and can be useful in understanding the mode's trip generation and trip distribution characteristics. Screenlines have been drawn to cover links that either have observed traffic volumes or are known to carry very low traffic volumes. A comparison of model and count volumes across each screenline is provided in Table 6.7.

The validation summaries described above are limited to information on links where traffic count data are available. Total VMT and VHT on all links are presented in Table 6.8.

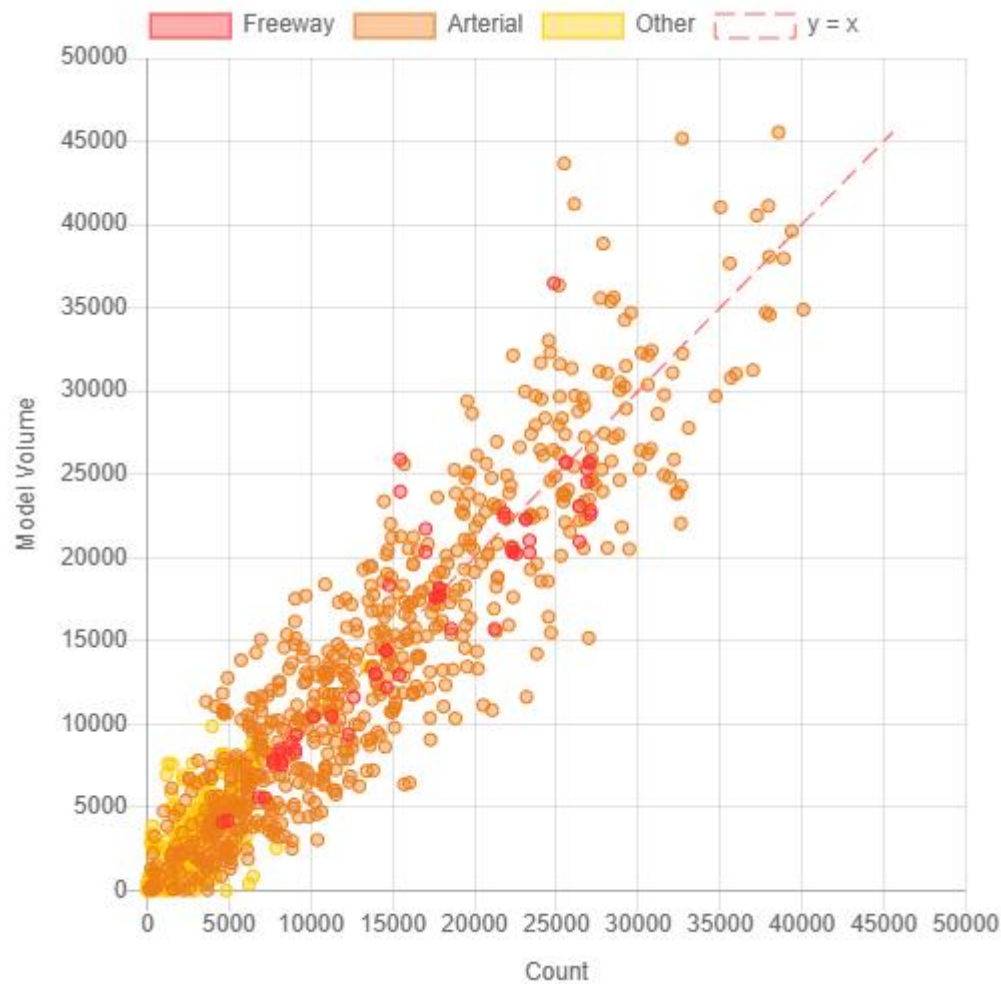
Table 6.5 Regional Volume and VMT Summary

Category	Model Volume / Count Volume	Model VMT / Count VMT	Target
Freeway	97.7%	94.0%	100% +/- 10%
Expressway	98.2%	97.8%	100% +/- 10%
Principal Arterial	102.2%	101.7%	100% +/- 10%
Minor Arterial	95.9%	93.4%	100% +/- 15%
Urban Collector	98.0%	86.1%	100% +/- 25%
Major Rural Collector(State)	104.5%	103.4%	100% +/- 25%
Major Rural Collector(County)	124.4%	104.1%	100% +/- 25%
Minor Rural Collector	53.1%	64.2%	100% +/- 25%
CBD	97.5%	97.2%	n/a
Urban	97.1%	95.3%	n/a
Suburban	106.1%	102.1%	n/a
Rural	98.4%	94.7%	n/a
Overall	100.5%	98.2%	100% +/- 5%

Note: Targets are a set of general guidelines shown for reference and are not a rule or regulation.

Table 6.6 Root Mean Square Error Summary

Category	RMSE	% RMSE
Freeway	3,646	17.2%
Expressway	2,760	20.3%
Principal Arterial	4,537	22.3%
Minor Arterial	3,351	38.4%
Urban Collector	2,252	70.2%
Major Rural Collector(State)	666	29.0%
Major Rural Collector(County)	1,540	113.7%
Minor Rural Collector	496	123.0%
CBD	3,002	30.2%
Urban	4,100	28.6%
Suburban	3,556	31.6%
Rural	1,572	35.8%
Overall	3,360	31.9%

Figure 10 Model Volume vs Count Volume**Table 6.7 Screenline Summary**

Screenline ID	Model Volume	Model Count	Vol/Count	Error	Number of Links
1	176,072	155,251	113.4%	13.4%	20
2	377,113	386,437	97.6%	-2.4%	32
3	318,265	300,355	106.0%	6.0%	31
4	151,906	152,851	99.4%	-0.6%	24
5	196,754	198,407	99.2%	-0.8%	23
6	330,219	302,120	109.3%	9.3%	24
7	197,324	204,938	96.3%	-4.7%	52

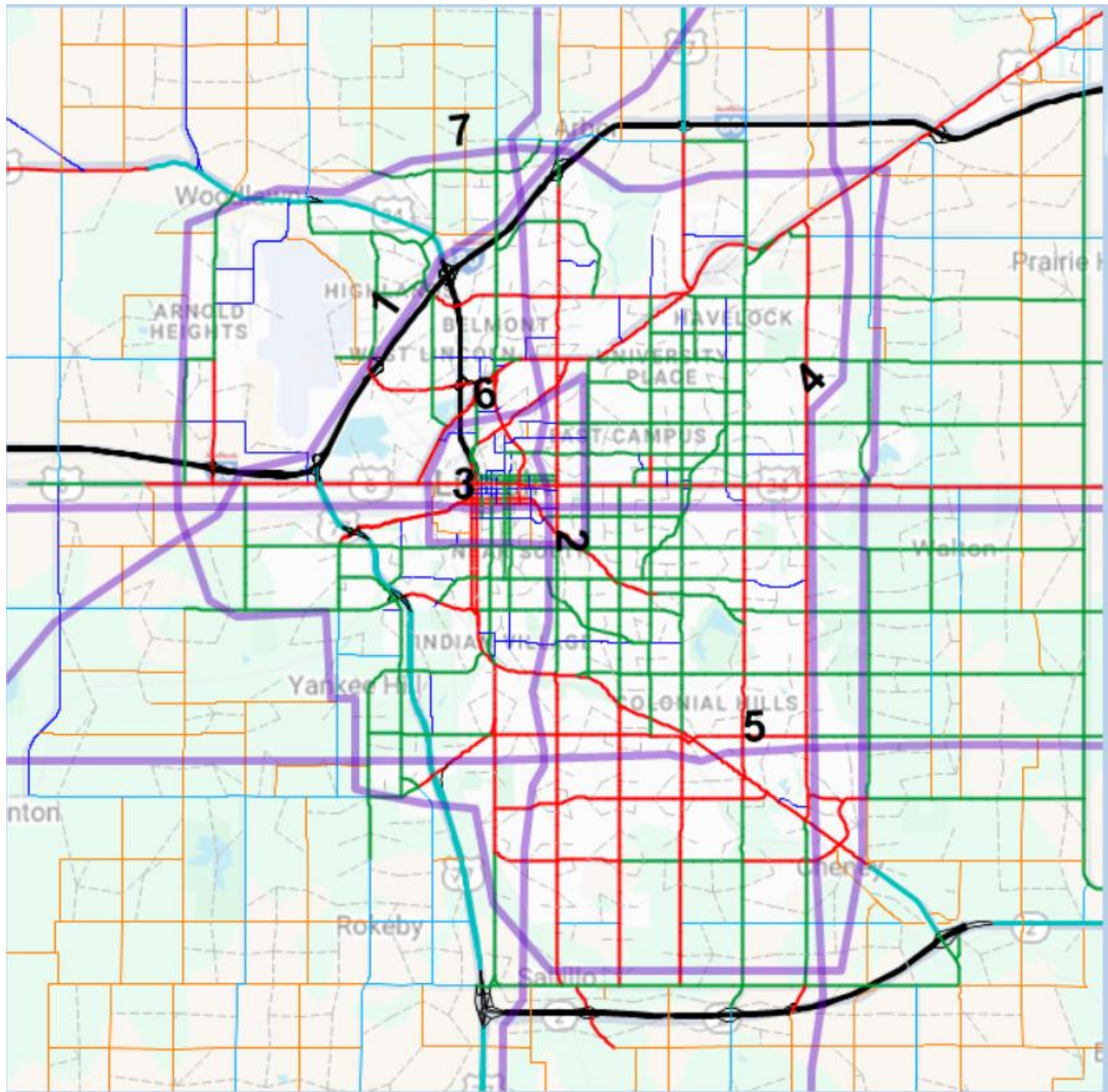
Figure 11 Screenline Locations

Table 6.8 Base Year VMT and VHT – Model Results for All Links

Category	Modeled VMT	Modeled VHT
Freeway	1,087,027	14,964
Expressway	413,976	7,578
Principal Arterial	2,365,406	59,455
Minor Arterial	1,358,040	39,676
Urban Collector	95,801	3,513
Major Rural Collector(State)	26,846	502
Major Rural Collector(County)	105,133	2,379
Minor Rural Collector	3,943	92
Local	55,864	1,551
Ramps	85,222	2,610
Freeway/Freeway Ramps	71,025	1,555
Centroid Connectors	743,646	34,725
CBD	111,169	5,167
Urban	1,849,928	59,277
Suburban	3,118,291	79,645
Rural	1,332,542	24,512
Total	6,411,929	168,600

6.5 Traffic Assignment Post Processing

The Lincoln MPO Model includes a post processing step that calculates adjusted volumes based on error in the validation year and assigns a level of service (LOS) to each link.

6.6 Link Volume Adjustment

For facility types 1 (Freeway), 2 (Expressway) and 3 (Principal arterial), the Lincoln Model produces adjusted link volumes based on guidance provided in National Cooperative Highway Research Program (NCHRP) Report 255 and re-iterated in NCHRP Report 765. These documents define the Ratio Method, Difference Method, and Average method, defined in the equations below.

$$AdjustedVolume_{Ratio} = ForecastVolume \cdot \frac{ValidationCount}{ValidationVolume}$$

$$AdjustedVolume_{Difference} = ForecastVolume + (ValidationCount - ValidationVolume)$$

$$AdjustedVolume_{Average} = \frac{(AdjustedVolume_{Ratio} + AdjustedVolume_{Difference})}{2}$$

The Lincoln Model applies the average method in most cases, but will instead use the difference method for links where any of the following conditions identified below are true. In these conditions, growth factor (GF) is defined as $ForecastVolume / ValidationVolume$ and error factor (EF) is defined as $ValidationCount / ValidationVolume$.

- $GF > 3$
- $GF > 4$ and $ForecastVolume \leq 1000$
- $EF > 2$ or $EF \leq 0.5$
- $(EF > 3 \text{ or } EF \leq 0.33)$ and $ForecastVolume \leq 3,000$
- $(EF > 4 \text{ or } EF \leq 0.25)$ and $ForecastVolume \leq 1000$

Link adjustments are only applied to links having either an actual traffic count or an estimated traffic count based on nearby traffic counts. Estimated traffic counts have been placed on all principal arterial, expressway, and freeway links where actual counts are not available. Furthermore, link adjustments have only been applied to principal arterials, expressways, and freeways. The adjustment routine has not been applied to minor arterials, collectors, local streets, local streets, ramps, or centroid connectors.

7.0 Sensitivity Tests

The base year calibration and validation measures described above and in the previous sections are critical in ensuring the validity of the model. These measures show that the model adequately reproduces observed trip generation, distribution, mode choice, and assignment patterns. However, the base year validation measures are *static* – they do not demonstrate the sensitivity of the model. The Lincoln MPO Model was run through a series of simple sensitivity tests to demonstrate that it provides appropriate sensitivity to variables that are important in the forecasting and planning process. These tests included:

- Socioeconomic Data Adjustments – both small scale and large scale changes were examined for reasonableness; and,
- Network Adjustments – critical links in both rural and urban areas were removed from the roadway network to ensure the Lincoln MPO Model reflected the expected diversion of traffic and congestion.
- Transit Service Adjustments – transit frequencies were increased to ensure that the model would respond by producing reasonable increases in transit ridership.