Louisville Southern Indiana Ohio River Bridges

Time-of-Day Travel Demand Model Phase 2

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List of Acronyms

HBW	Home Based Work Trips
HBO	Home Based Other Trips
NHB	Non Home Based Trips
EI	External – Internal Trips
EE	External Through Trips
KIPDA	Kentuckiana Regional Planning and Development Agency
WSA	Wilbur Smith Associates
LSIORB	Louisville Southern Indiana Ohio River Bridges
TOD	Time of Day
NEPA	National Environmental Policy Act
EIS	Environmental Impact Statement
CBD	Central Business District
M	Household Structure Type: Multi Family
S	Household Structure Type: Single Family
CTS	Community Transportation Services (a joint venture specifically for this project)
PUMS	Public Use Microdata Set
NAICS	North American Industrial Classification System
TAZ	Traffic Analysis Zone
PA	Production / Attraction
KYTC	Kentucky Transportation Cabinet
FDOT	Florida Department of Transportation
HCM	Highway Capacity Manual
MSA	Metropolitan Statistical Area
MSA	Method of successive averages
RMSE	Root Mean Square Error

TARC	Transit Authority of River City
GIS	Geographical Information System
ACS	American Communities Survey
FTA	Federal Transit Agency
NLM	Nested Logit Model
ODME	Origin Destination Matrix Estimation
QRFM	Quick Response Freight Manual
GC/aGC	Generalized Cost (aGC Generalized Cost field for assignment)
MMA	Multi-Modal Assignment
PCE	Passenger Car Equivalent
BPR	Bureau of Public Roads
TMIP	Travel Model Improvement Program
VMT	Vehicle Miles Traveled
PRMSE	Percent Root Mean Square Error
GISDK	GIS Developers Kit (TransCAD macro language)
SEIS	Supplemental Environmental Impact Statement
MTP	Metropolitan Transportation Plan
LRP	Long Range Plan
ADT	Average Daily Traffic
FAF	Freight Analysis Framework

1. Executive Summary

This document describes the development of a time-of-day travel demand model by Wilbur Smith Associates (WSA) for the Louisville-Southern Indiana metropolitan study area. WSA developed this project-specific travel demand model to support the NEPA analysis as well as provide the inputs to the future toll and revenue studies.

The project contained two phases.

1.1 Phase 1 TOD Model, Model Estimation and Data Collection

The first phase consisted of these tasks:

The development of an interim TOD model*:* This TOD model was used for interim decisions in the fall of 2010 regarding the tolling analysis. It was replaced entirely by the new TOD model and is not in use nor are the results of the model in use.

The model specification for an updated travel demand model*:* This model specification was for the final LSIORB TOD model and is described fully in the Phase 2 part of the executive summary. The model was significantly enhanced to include new trip generation, time-of-day modeling, truck modeling, traffic signals, transit modeling, feedback analysis, a user-friendly modeling interface.

The development and implementation of a data collection plan: Extensive data collection was performed for the travel demand modeling including vehicle classification counts at 61 locations including critical ramps and the Kennedy bridge along with origin-destination surveys at the interstates (I-65 in Indiana, I-65 in Bullitt County, I-71 in Oldham County, I-64 in Indiana and I-64 in Shelby County). The origin-destination surveys gave important information on through trips including truck trips.

The update of the model datasets: The new LSIORB used a base year of 2007 and a future year of 2030. New data was collected for the following areas: the highway network, the socio-economic data (needed to interpolate between 2000 and 2009 data from KIPDA), traffic count data, signal data and transit data. The traffic counts used for the new model increased from the original 200+ counts to nearly 1,400 count locations which included truck counts and 24-hour counts to be used for the time-of-day modeling. Traffic signal information was gathered at over 1,100 locations which gave much more accurate modeling assignments. The transit network included 48 routes and over 1,300 stops. The highway network was updated to include new projects including the latest alternatives used for the tolling analysis.

For clarification, definitions are given to the three models referenced in this document.

- **Existing KIPDA Model**: This is the basis for the INTERIM TOD Model and LSIORB Regional TOD Model. This model is the current model of record and was used for the long range transportation plan.
- **Interim TOD Model**: This model was completed as part of Task 1 within the first phase. The model is based on the existing KIPDA model including the same base and

forecast year assumptions. The existing model is being enhanced with the addition of period specific capacities and period traffic assignments.

- **LSIORB Regional TOD Model**: Enhanced model based on the existing model structure but enhanced to support the project analysis. The specification for this model and development of the datasets was completed in Phase 1. The model estimation, scripting and validation was completed in Phase 2. It should be noted that the LSIORB Regional TOD Model is a new model, and is not what was used for the Toll Evaluation study recently completed.

WSA used several sources of information to develop the model structure. First a workshop was held at the KIPDA offices on September 24, 2010 in order to get feedback from the project model stakeholders which included the Kentucky Transportation Cabinet, the Bi-State Authority, CTS and KIPDA. This provided an invaluable source of information. This workshop pointed WSA to other sources such as the Purpose and Need Statement.

After doing the necessary research, WSA developed a specification that was included in the Phase I Final Report. The phase 1 report was completed on December 28, 2010.

1.2 Phase 2 Time of Day

The second phase consisted of the development of the time-of-day model, the model estimation, model validation and implementation tasks.

Estimation: As stated above, in the Phase 1 summary, the model specification occurred earlier. Essentially, the model specification is a process to develop the functionality of the model and determine the key features. This process included input from key stakeholders including the Bi-State Bridge Authority, the Kentucky Transportation Cabinet and KIPDA.

The key elements in the model estimation process included trip generation, the network, trip distribution, mode choice, the external model, the truck model, the time-of-day model, and traffic assignment. A short summary of each of these key elements follows:

- **Trip Generation** The LSIORB TOD model included a daily trip generation model that used the same trip purposes used by KIPDA: home based work, home based other, non home based and external – internal trips. The most important change between the KIPDA model and the LSIORB project model is to include income disaggregation of households which allowed tracking of trips based on income categories.
- **Network** The LSIORB TOD model is a multi-model network that includes highway links and drive/walk access to support transit routes. The free flow speeds were changed from the KIPDA model using a combination of posted speed limits, default speeds, free flow adjustments and signalization.
- **Trip Distribution** The LSIORB is a traditional gravity model. Enhancements include a generalized cost function for impedance and the implementation of congestion in trip distribution.
- **Mode Choice** The LSIORB TOD model developed a mode choice model that adds several new modes to be modeled including local bus, premium bus/express bus, walk

and bike. This was a massive modeling exercise that built on the data collection activities in Phase 1.

- **External Model** There are two components to this model, external-external trips (or "through trips") and external – internal trips. The origin-destination data collected in Phase 1 was used to develop these trips.
- **Truck Model** A truck model was developed for the LSIORB model. This model was based on over 550 vehicle classification counts, the external truck flows from the origin-destination data (mentioned in the external model) and local truck trips generated using the Quick Response Freight Manual.
- **Time-of-Day Model** Perhaps this is one of the most important features of the model. The model now makes assignments for peak periods instead of just daily trips. The periods used were the AM period, the mid-day period, the PM period and the overnight period. Data from the KIPDA household survey and 24-hour counts were used to develop this TOD model feature. The TOD feature allowed much more sensitive analysis of congestion.
- **Traffic Assignment** The LSIORB model used a generalized cost assignment and more accurate values of time in the assignment process. This was very important for use in the tolling analysis. In order to get the maximum accuracy, the convergence was set to allow as many as 100 iterations (meaning the model could run that many times to keep improving the accuracy). Also, the model used different volume-delay functions which allows for more sensitivity to congestion and better results on different highway facility types such as interstate highways.

Validation: The purpose of validation is to improve model results against observed behavior (for instance traffic counts) and to test the ability of the model to predict future behavior. The model include went through exhaustive validation adjustments for trip generation, trip distribution and traffic assignment. Validation results were generated by daily assignments and period assignments. Finally, the model went through extensive sensitivity testing of multiple scenarios for individual model parameters.

- **Validation Adjustments** An example of the type of adjustments used in the model were adjustments to trip rates in Floyd County (Indiana) to improve trip generation. This County under produced trips which led to additional trips being generated. The trip distribution for this large study area also needed tweaking which resulted in K-factors being developed between the counties for all of the trip purpose categories. Finally, speed and capacity adjustments were changed in certain locations to improve validation.
- **Validation Results** One metric used to measure the validation results is the Root Mean Square Error. This statistic basically compares the traffic assignments (all of them) from the model to the ground counts which are considered to be the "truth." The WSA team tracked the results of the model over 60+ runs in order to isolate what the impact of the modeling changes were. The final RMSE was around 35% which is considered to be quite good for a large regional multi-county model. Other model metrics included comparing county to county flows to Journey to Work Data (a Census Data Set); Volume

Groups within each County and Daily River Crossings by Bridge. Finally, the vehicle miles traveled by period and period distribution were used with excellent results.

Implementation: In order to manage modeling input and output files, a graphical user interface was developed for the LSIORB model. This interface was written in the programming language of the model software, TransCAD. The GUI had a scenario manager, a scenario model run function and scenario outputs. These features made the model much more repeatable and user friendly.

1.3 Conclusion

This Phase 2 Time-of-Day Model document reports on the development of the LSIORB TOD Model including the parameter calibration, model validation and final development of forecast model inputs. Information regarding the development of the Phase II Model Inputs is included in the Phase I Final Report. Information on the use of the travel demand model to produce traffic forecasts for the tolling analysis and SEIS is included in the LSIORB Traffic Forecast document.

2. Introduction

As part of the Louisville – Southern Indiana Ohio River Bridge Time of Day Model Project, WSA has been charged with the development of a project specific travel demand model that will be used to support the NEPA analysis as well as provide the inputs to the future toll and revenue studies.

WSA used several sources of information to develop the model structure. First a workshop was held at the KIPDA offices on September 24, 2010 in order to get feedback from the project model stakeholders which included the Kentucky Transportation Cabinet, the Bi-State Authority, CTS and KIPDA. This provided an invaluable source of information. This workshop pointed WSA to other sources such as the Purpose and Need Statement.

After doing the necessary research, WSA developed a specification that was included in the Phase I Final Report.

This document reports on the development of the LSIORB TOD Model including the parameter calibration, model validation and final development of forecast model inputs. Information regarding the development of the Phase II Model Inputs is included in the Phase I Final Report.

Throughout the development of the model, WSA worked closely with KIPDA staff to ensure consistency in the inputs and assumptions. The Kentuckiana Regional Planning and Development Agency (KIPDA) serves as the staff agency for the Louisville Metropolitan Planning Organization. The term 'KIPDA' has been used interchangeably to mean 'Louisville MPO' in this report.

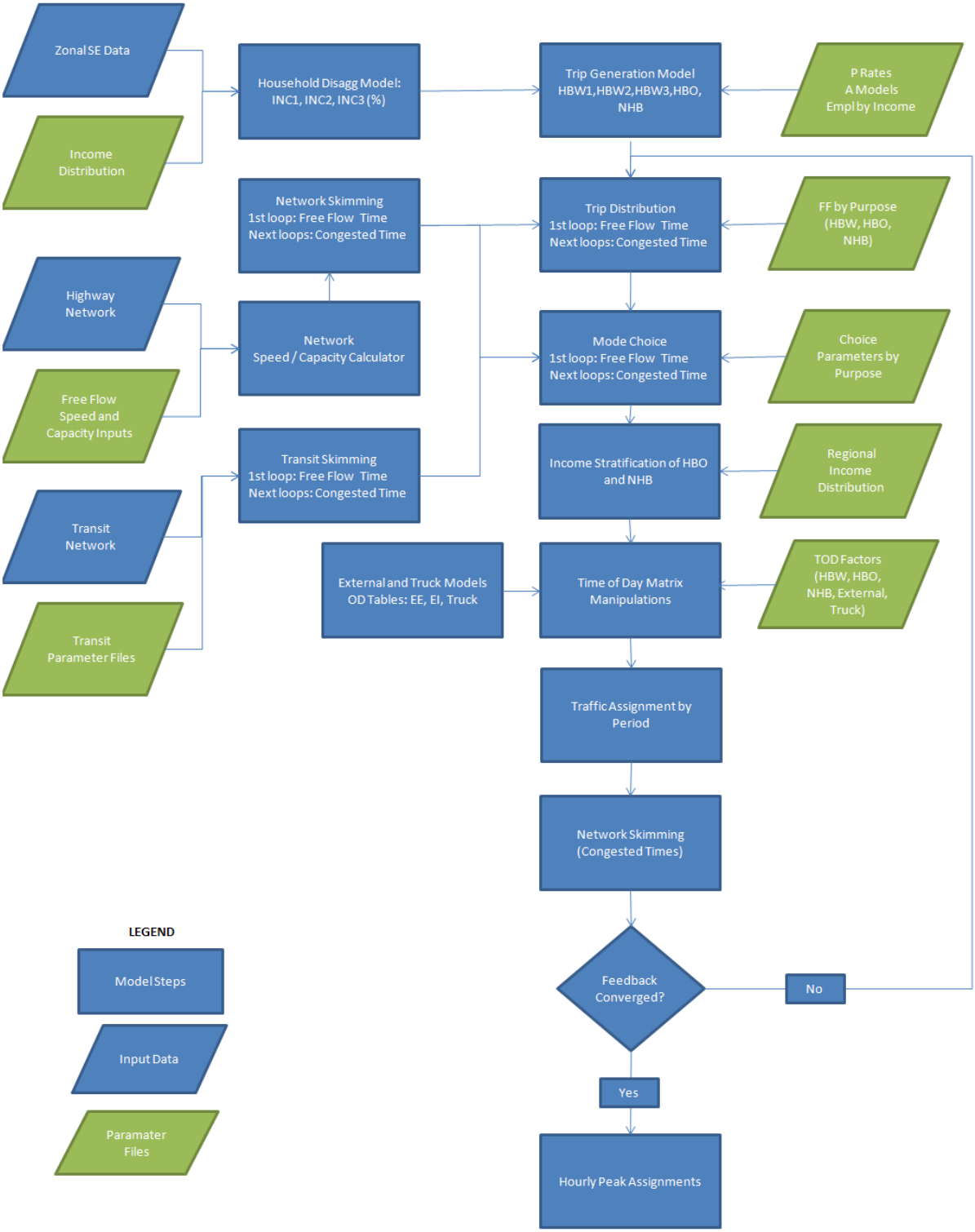
2.1 Model Structure

The LSIORB TOD Model includes five areas of enhancement as compared to the KIPDA Regional Model. Those areas include:

- Trip purpose stratification
- Time of day structure including feedback
- Mode choice
- Truck model
- Traffic assignment

Figure 2.1 provides an overall schematic of the operation of the LSIORB TOD Model including the input of data and parameters and the integration of the time of day and feedback structures. The functionality of each model step is discussed in greater detail in Section 3 of this report.

Figure 2.1: LSIORB TOD Model



3. Estimation

3.1 Trip Generation

The LSIORB TOD Model includes a daily person trip generation model that creates the productions and attractions for the following purposes:

- Home Based Work (HBW) – Work trips made to / from home to work
- Home Based Other (HBO) – Non work trips made to / from home
- Non-Home Based (NHB) – trips made from non-home locations
- External – Internal (EI_Work and EI_NonWork) – trips with one end inside the study by originating outside the study area or vis versa

The trip purpose taxonomy is similar to that used by the KIPDA regional model with the exception being the LSIORB disaggregates work trips by income. The trip generation model is aggregate in nature meaning the trips generated represent the total zone.

3.1.1 Trip Generation Parameters

The basis for the LSIORB TOD Model trip generation parameters was the 09PLANA KIPDA Model. The following tables provide the production rates by household size, structure type and vehicle ownership. The models are applied as cross-classification models based on the household disaggregation discussed in the next section. The trip rates as used by the KIPDA model include all travel by personal auto, transit and non-motorized trips.

Table 3.1: HBW Production Rates

Household Size	Structure Type	Vehicles Owned by Household			
		0	1	2	3
1	M (Multi Family)	0.268	0.66	0.8	1.317
2		0.92	1.104	1.275	1.323
3		1.047	1.636	1.877	2.134
4		1.359	2.654	2.93	2.734
5		2.669	3.52	3.008	3.549
1	S (Single Family)	0.232	0.598	0.703	0.795
2		0.419	1.152	1.156	1.206
3		0.89	1.554	1.558	1.647
4		2.336	2.41	2.298	2.493
5		2.7	3.042	3.151	3.181

Table 3.2: HBO Production Rates

Household Size	Structure Type	Vehicles Owned by Household			
		0	1	2	3
1	M (Multi Family)	0.726	1.792	2.172	3.572
2		2.495	2.994	3.459	3.589
3		2.841	4.44	5.092	5.789
4		3.686	7.201	7.949	7.416
5		7.241	9.548	8.159	9.628
1	S (Single Family)	0.723	1.866	2.192	2.478
2		1.306	3.591	3.603	3.76
3		2.775	4.845	4.856	5.136
4		7.282	7.515	7.165	7.771
5		8.419	9.485	9.824	9.917

Table 3.3: NHB Production Rates

Household Size	Structure Type	Vehicles Owned by Household			
		0	1	2	3
1	M (Multi Family)	0.288	0.711	0.862	1.418
2		0.99	1.188	1.373	1.424
3		1.127	1.762	2.021	2.297
4		1.463	2.858	3.155	2.943
5		2.873	3.789	3.238	3.821
1	S (Single Family)	0.285	0.736	0.865	0.978
2		0.515	1.417	1.421	1.484
3		1.095	1.911	1.916	2.026
4		2.873	2.965	2.827	3.066
5		3.321	3.742	3.876	3.912

The trip attraction models are applied based on the zonal total households, employment and whether the zone is within the CBD area of the model.

Table 3.4: LSIORB Trip Attraction Parameters

Socioeconomic Variable		HBW	HBO	NHB
Households		0	0.9	0
Other	Central Business District	1.45	0.5	0.5
Retail		1.45	2	1.4
Service		1.45	1.7	1.2
Other	Non CBD	1.45	0.5	0.5
Retail		1.45	7	2.7
Service		1.45	1.7	1.2

3.1.2 Income Disaggregation of Households

The LSIORB TOD Model includes a feature to estimate the number of trips generated by income group and trip purpose. The disaggregation of trip purposes is carried through mode choice and traffic assignment. The rationale for including an income dimension to the trip purposes is the following:

- By including income in the HBW purpose, high income employment can be linked to high income households, thus improving the trip distribution patterns in the model
- Mode choice segments the market for transit by trip purpose by income. Income is used to approximate auto availability and willingness to use transit for choice riders
- The assignment model uses a generalized cost approach that includes operating cost and tolls in the future. Segmenting trips by income allows for the testing of values of time that are based on income groups

To apply the income based trip generation models it is necessary to add a fourth dimension to the existing household disaggregation model applied by KIPDA. The existing KIPDA models disaggregate the zonal households by dwelling type (multi-family and single family), household size and vehicle ownership. This results in the zonal total households be distributed into 40 categories.

Table 3.5 provides the 2007 household distribution from the KIPDA 10PLANA socioeconomic dataset. This data set was the basis for the LSIORB TOD Model.

Table 3.5: 2007 KIPDA 10PLANA Household Distribution

Structure	Household Size	Vehicles				Total
		0	1	2	3	
M (Multi Family)	1	9,248	21,843	17,430	6,237	54,757
	2	4,656	11,987	9,945	3,598	30,186
	3	1,705	4,341	3,655	1,319	11,019
	4	1,013	2,533	2,177	797	6,521
	5	538	1,365	1,172	410	3,486
	Total	17,160	42,069	34,378	12,361	105,968
S (Single Family)	1	4,832	23,319	29,755	13,758	71,664
	2	6,165	32,169	45,033	21,865	105,232
	3	3,163	17,087	25,094	12,505	57,849
	4	2,516	14,112	21,818	11,146	49,593
	5	1,413	8,001	12,453	6,376	28,242
	Total	18,090	94,688	134,153	65,650	312,581
Grand Total		35,249	136,757	168,531	78,011	418,549

The KIPDA 10PLANA household distribution was based on a statistical model derived from the 2000 Census and applied as a static input in the KIPDA model. The forecast allocation was not based on a model, but instead an adjustment of the base year using information from the local

planning and economic development entities. For consistency, it was decided that the LSIORB TOD Model would utilize the same zonal distribution of households by size and structure type. The income disaggregation would be based on applying a distribution to each of the existing household disaggregation categories.

3.1.2.1 Definition of Income Categories

To define the income groupings, the Public Use Microdata (PUMS) was utilized from the 2000 Census. The PUMS was utilized to because it includes not only the income of the household, but the NAICS of the worker in each household as well. Using this information for each household it is possible to understand the income distribution of households in the region, but also the associated employment types by income group.

From the following figures, the PUMS geography that covers the Louisville model area were selected.

Figure 3.1: Louisville Surrounding PUMS Geography

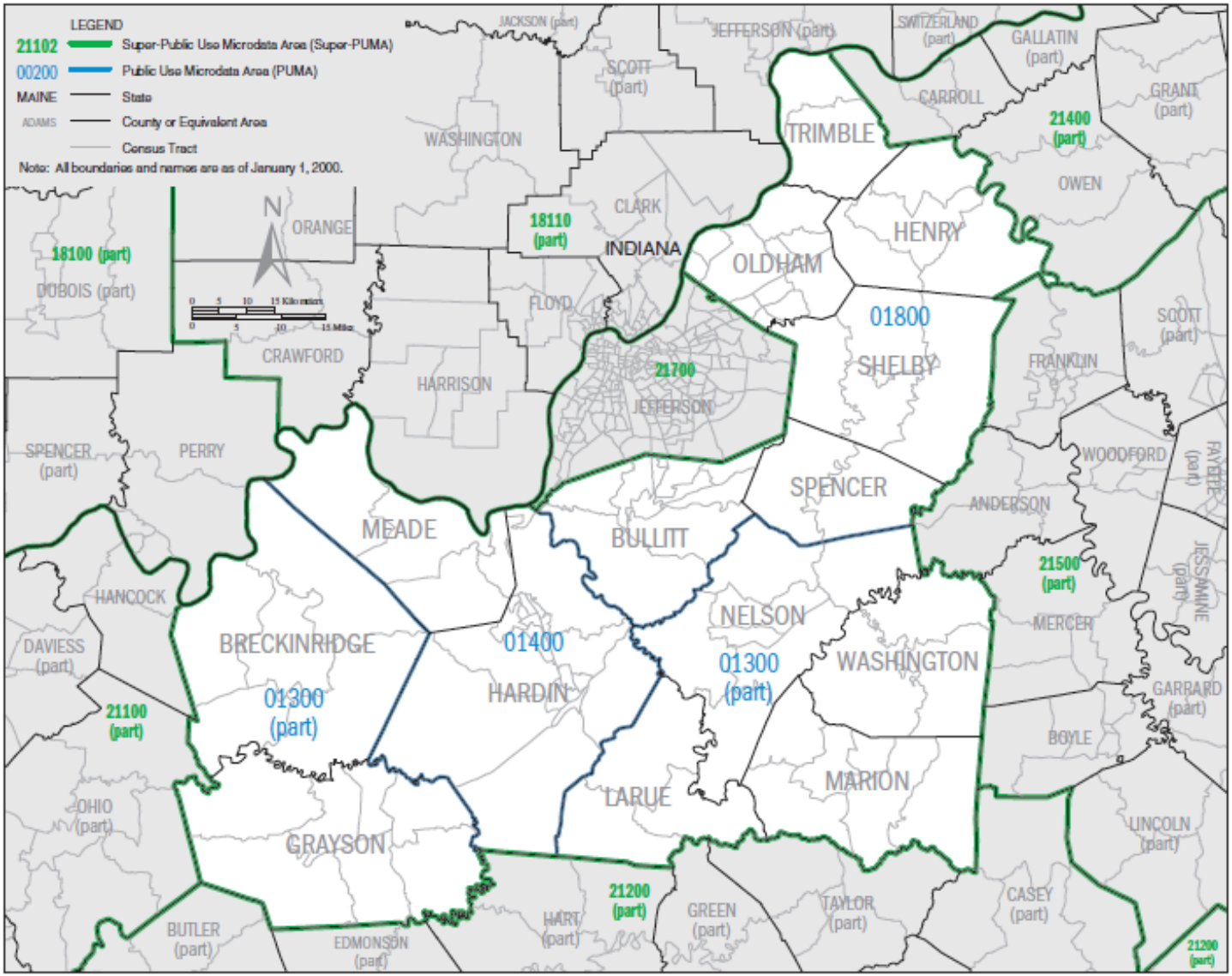


Figure 3.2: Louisville Urban PUMS Geography

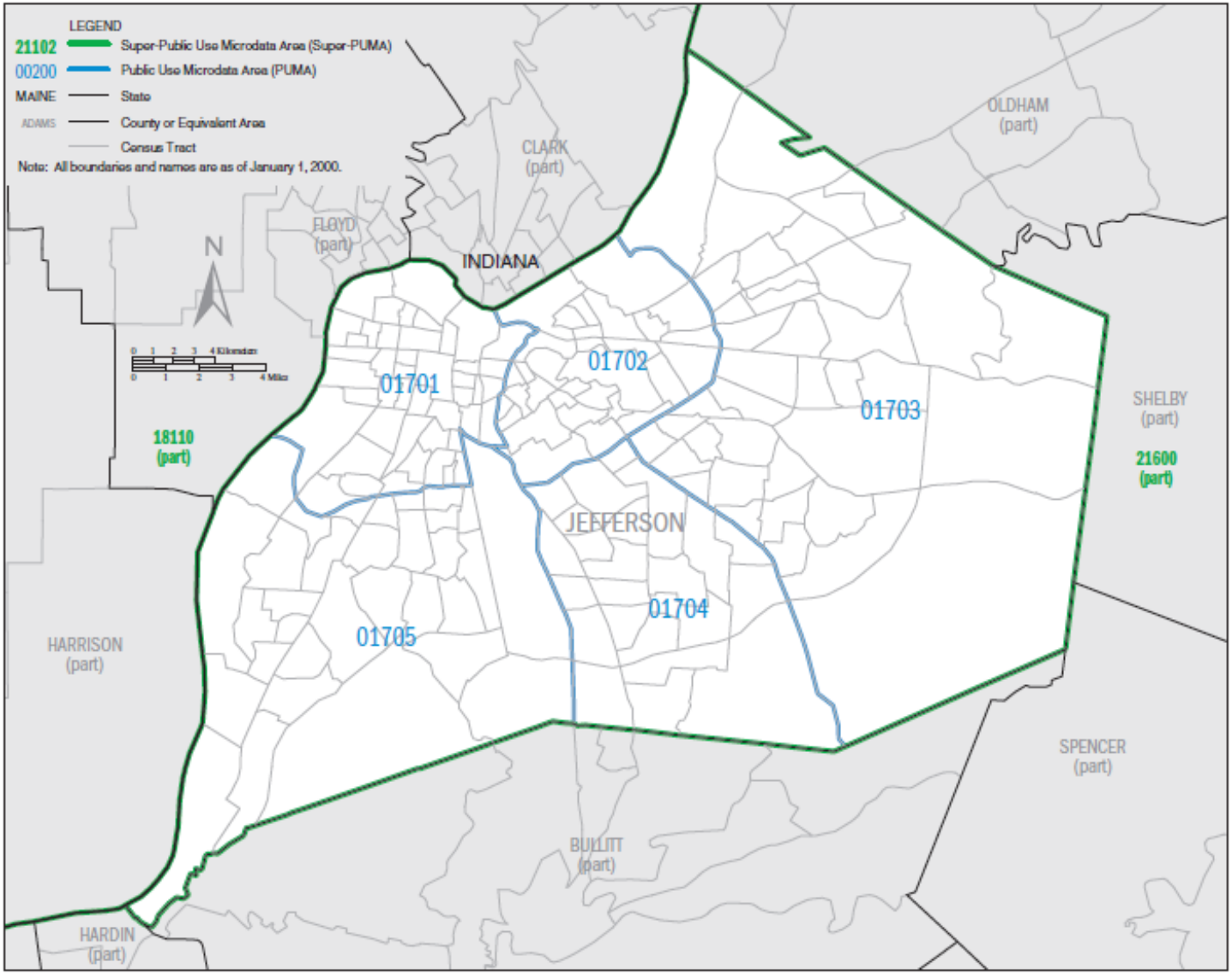
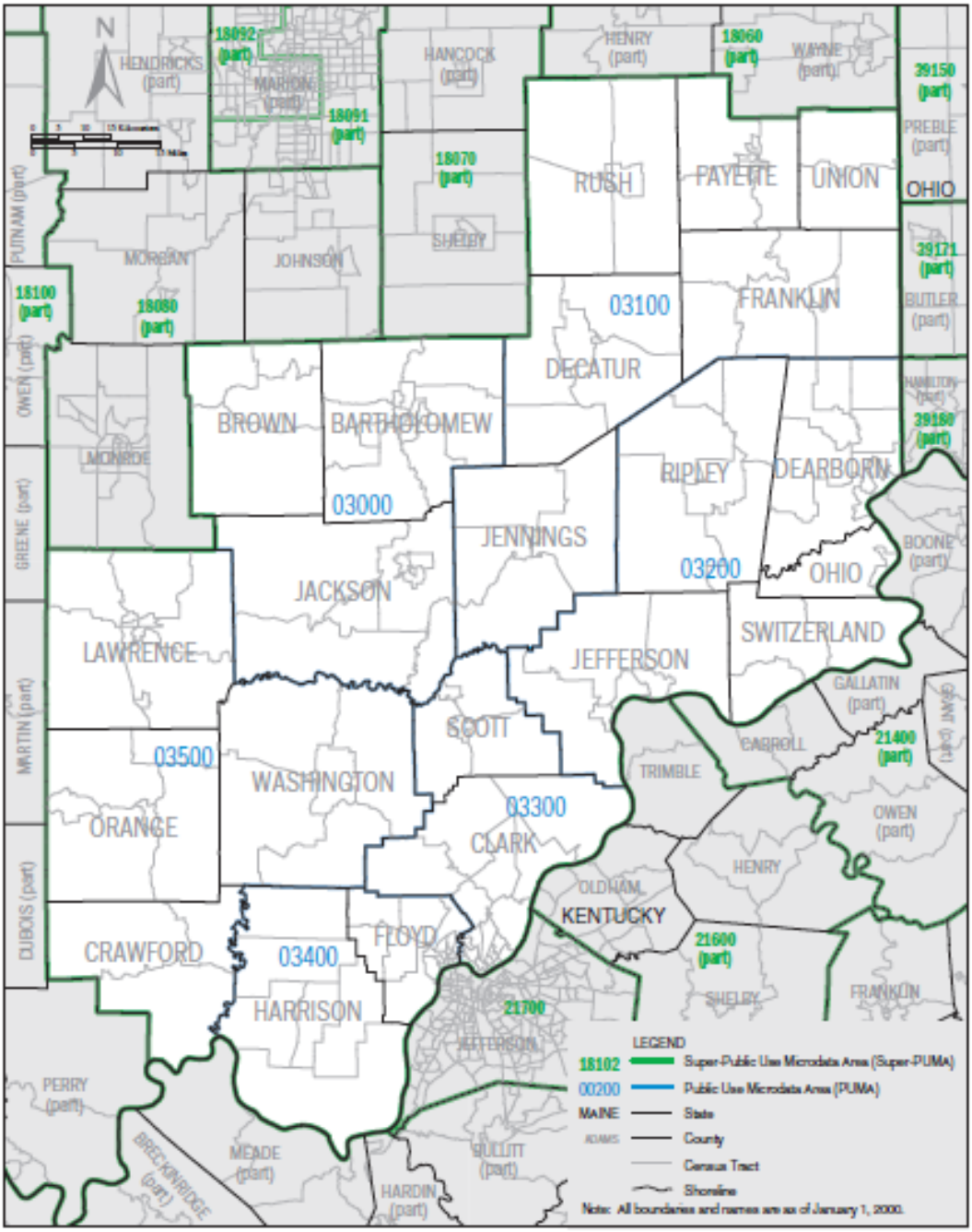
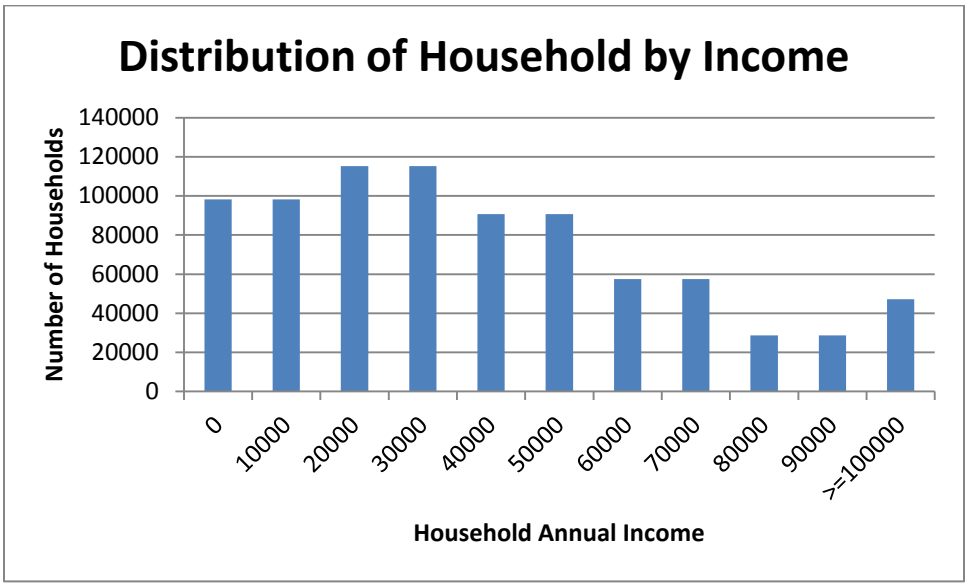


Figure 3.3: Indiana PUMS Geography



Based on the above geography, the distribution of households by total income was calculated and is shown in Figure 3.4.

Figure 3.4: Distribution of Households by Income



From the above distribution several schemes were considered of how to aggregate the distribution data. For consistency with the definition of income in other components of the EIS, it was decided that three income groups would be defined: $0 to $40,000, $40,000 to $60,000 and greater than $60,000.

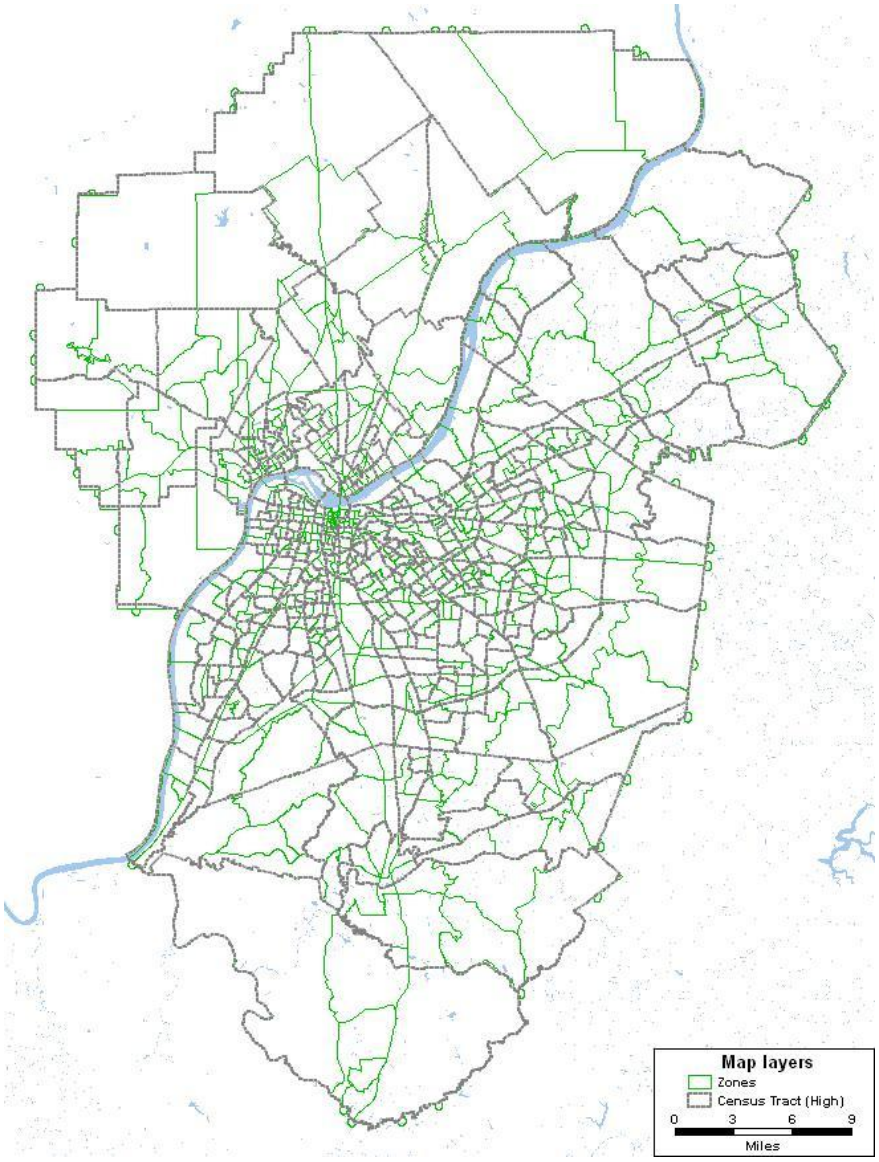
Table 3.6: Number of Households by Income and Grouping

INC	HH	CUMTOT	QUAR	TRI
0	16791	16791	1	1
10000	52505	69296	1	1
20000	58535	127831	2	1
30000	60378	188209	2	1
40000	51332	239541	3	2
50000	47677	287218	3	2
60000	34417	321635	4	3
70000	28931	350566	4	3
80000	20641	371207	4	3
90000	13835	385042	4	3
100000	10721	395763	4	3
110000	8494	404257	4	3
120000	5871	410128	4	3
130000	4267	414395	4	3
140000	3335	417730	4	3
150000	19873	437603	4	3

Using the three categories, the Census Tract data from 2000 was utilized to establish the distribution of households in each Tract in the region. The region is represented by 230 census

tracts as shown in the figure below. The TAZs within the tract are assigned the income distribution of the tract. The income distribution is then applied to each household category.

Figure 3.5: Louisville region Census Tracts vs Traffic Analysis Zones



The resulting total household distribution by income group in 2007 is reported in Table 3.7.

Table 3.7: 2007 Household Distribution by Income

	INC1	INC2	INC3	Total
Households	91166.2	108675.7	218707.2	418549.2
Distribution	21.8%	26.0%	52.3%	100.0%

3.1.3 HBW by Income

The trip generation model estimates a unique set of productions by purpose for each income group in the model. For HBW, the model uses this information to link the household income to appropriate job types in the region. To accomplish this, the distribution of the KIPDA employment types by household income was required.

Using the PUMS data discussed in the previous section, the household income distribution of the NAICS employment type was developed for the region. The resulting distribution is provided in Table 3.8.

Table 3.8: Distribution of Household Income by NAICS Employment

NAICS			INCOME GROUP (PWEIGHT)			INCOME GROUP (Percent)		
2 DIGIT	DESC.	MODEL	1	2	3	1	2	3
11	AGR	OTH	2901	1036	1472	53.6%	19.2%	27.2%
21	MINING	OTH	411	203	398	40.6%	20.1%	39.3%
22	UTILITY	OTH	1021	1366	3677	16.8%	22.5%	60.6%
23	CONST	OTH	17793	11190	17236	38.5%	24.2%	37.3%
31	MANUF	OTH	4745	4082	6739	30.5%	26.2%	43.3%
32	MANUF	OTH	9901	7636	12836	32.6%	25.1%	42.3%
33	MANUF	OTH	17229	15699	28844	27.9%	25.4%	46.7%
42	WHOLES	RETAIL	7716	6782	11120	30.1%	26.5%	43.4%
44	RETAIL	RETAIL	18991	11344	20262	37.5%	22.4%	40.0%
45	RETAIL	RETAIL	10228	6039	8735	40.9%	24.2%	34.9%
48	TRANSP	OTH	5886	4816	7099	33.1%	27.1%	39.9%
49	TRANSP	OTH	6003	4987	8400	31.0%	25.7%	43.3%
51	INFO	SERV	4246	3687	6981	28.5%	24.7%	46.8%
52	FININS	SERV	9637	7431	17486	27.9%	21.5%	50.6%
53	REAL	SERV	3240	2100	4781	32.0%	20.7%	47.2%
54	PROF	SERV	7018	4157	16587	25.3%	15.0%	59.7%
55	MANG	SERV	131	159	400	19.0%	23.0%	58.0%
56	ADM	SERV	11558	5074	6556	49.8%	21.9%	28.3%
61	ED	SERV	13299	10487	22970	28.4%	22.4%	49.1%
62	HEALTH	SERV	26598	18751	34680	33.2%	23.4%	43.3%
71	ARTS	SERV	5045	3352	4810	38.2%	25.4%	36.4%
72	ACCOM	SERV	22045	10229	14703	46.9%	21.8%	31.3%
81	OTHER	SERV	14367	8558	11975	41.2%	24.5%	34.3%
92	PUB	SERV	7997	7460	11237	30.0%	27.9%	42.1%
99			1612	530	516	60.6%	19.9%	19.4%

Based on the relationship of each NAICS employment category to the categories used by KIPDA's socioeconomic dataset, a distribution was developed for each category (Table 3.9).

Table 3.9: Distribution of Employment by Model Income Variables

	INCOME GROUP (PWEIGHT)			INCOME GROUP (Percent)		
Variable	1	2	3	1	2	3
OTH	65890	51015	86701	32.4%	25.1%	42.6%
RETAIL	36935	24165	40117	36.5%	23.9%	39.6%
SERV	125181	81445	153166	34.8%	22.6%	42.6%

In application, the income group percentages are applied to each employment type and the attraction coefficient for HBW trip attractions to calculate the income attractions.

3.1.4 HBO and NHB by Income

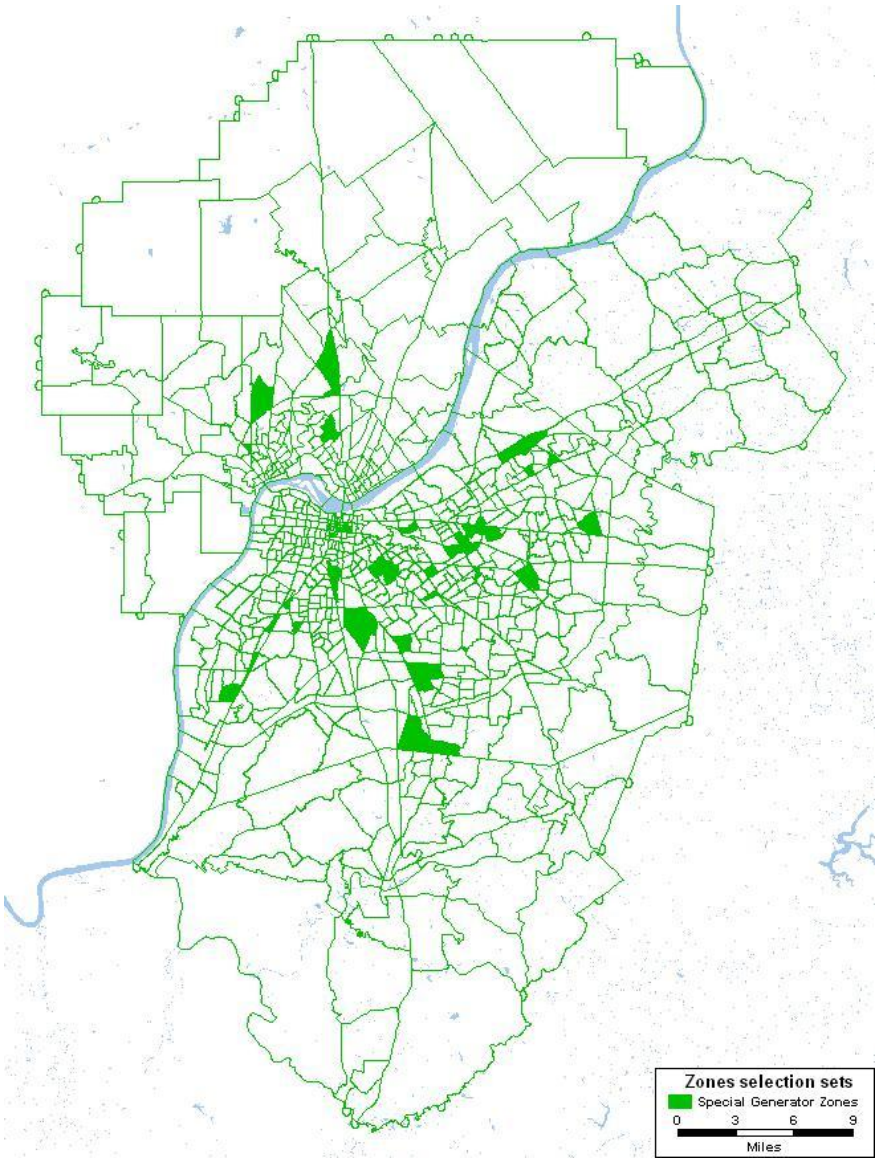
The disaggregation of attractions is only applied to the HBW purposes. A different approach was taken to accommodate the income disaggregation of the HBO and NHB trip purposes for mode choice and traffic assignment.

For HBO trips, the disaggregation of the trips is performed post distribution to the PA format person trip table. The income distribution of the zonal households is applied to the trip table row to create the income 1, 2 and 3 HBO trips. These trips are then used in mode choice. Because the home end of the trip is not none for NHB trips, the regional distribution of income categories is applied to all zones to create the three income NHB trip tables.

3.1.5 Special Generators and Trip Balancing

The LSIORB TOD Model applies the same special generator methodology as used by the KIPDA model including the location and magnitude of the special generators.

Figure 3.6: 2007 LSIORB TOD Special Generators



The final step in the trip generation model is the balancing of the production and attractions. For HBW trips, the income group attractions are balanced to the specific income productions. Because the income disaggregation for HBO and NHB purposes are applied later in the model, the productions and attractions are balanced in the typical method. This means for NHB trips, the attractions are adjusted to the total NHB productions and then productions are set equal to attractions.

3.2 Network

The LSIORB Phase II TransCAD network is a multi-modal travel demand model network that includes highway links as well as drive and walk access links to support the transit routes used in the mode choice step.

The LSIORB GISDK code populates the link attributes required for traffic assignment including the free flow travel times, link capacities, alpha and beta parameters and the generalized cost for auto and truck purposes.

3.2.1 Free Flow Speeds

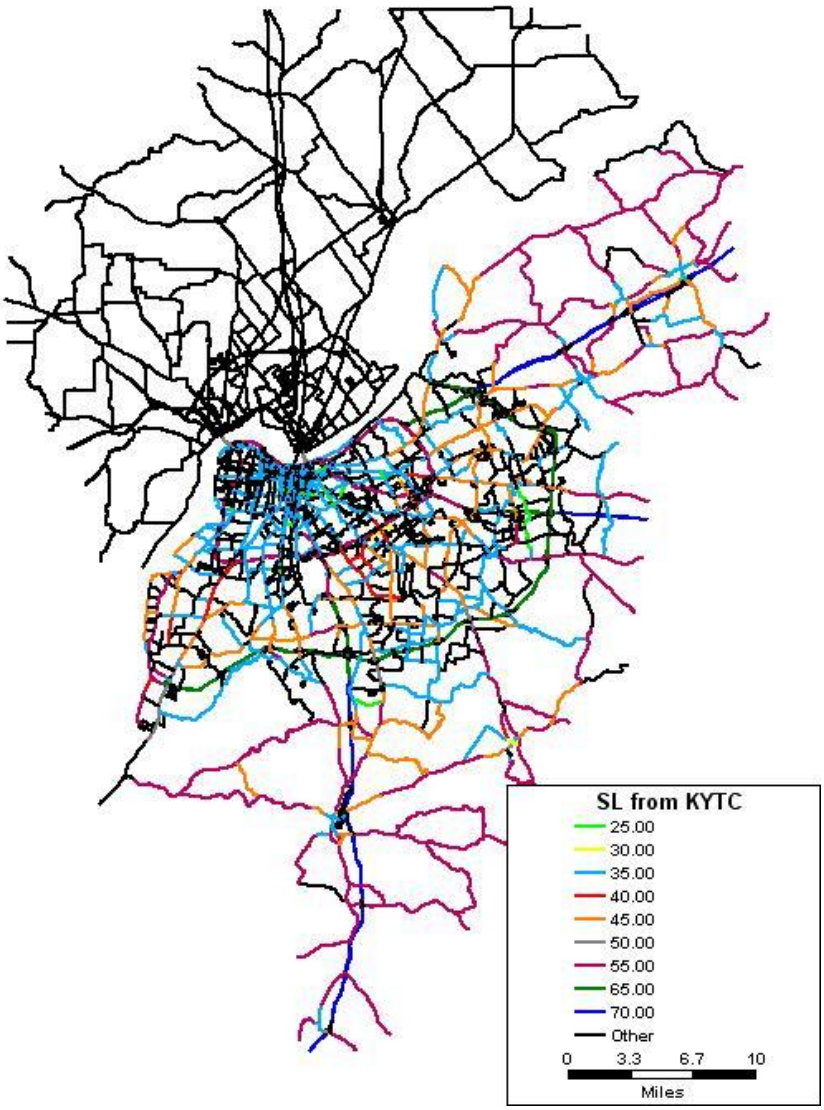
As part of the development of the LSIORB Phase II Model, WSA has changed the free flow speed logic from that used by KIPDA in the previous model. The free flow speed is a function of the following:

- Posted speed limit
- Default speeds in the absence of speed limits
- Free flow adjustments
- Signalization

3.2.1.1 Posted Speed Limit

The Kentucky Highway Information System was utilized to identify the posted speed limits on the state maintained routes in the Kentucky portion of the study area. Similar information was not made available from Indiana.

Figure 3.7: Posted Speed Limits (Kentucky Highway Information System)



3.2.1.2 Default Speeds

The posted speed limit data was not complete, and it was necessary to develop default values for facilities where posted speed limit data was not available. Using the links in the network with information, an analysis was completed evaluating the typical posted speed limit by facility type and area type. Those values were then used to populate the default speed table used in the model. The LSIORB Model scripts read the default values for links that do not have a posted speed limit attribute value.

Table 3.10: Default Posted Speed Limit

FACILITY TYPE	AREA TYPE									
	11	12	21	31	41	43	45	51	53	55
11	50	50	55	65	70	70	70	70	70	70
12	50	50	55	65	70	70	70	70	70	70
17	50	50	55	65	70	70	70	70	70	70
21	55	55	55	55	55	55	55	55	55	55
22	45	45	45	45	45	45	45	45	45	45
23	35	35	35	50	55	55	55	55	55	55
24	35	35	35	45	50	55	55	55	55	55
25	35	35	35	45	45	45	45	45	45	45
31	35	35	35	35	45	45	55	55	55	55
32	35	35	35	35	45	45	55	55	55	55
33	35	35	35	35	45	45	55	55	55	55
34	35	35	35	35	45	45	55	55	55	55
35	35	35	35	35	45	45	55	55	55	55
36	35	35	35	35	45	45	55	55	55	55
37	35	35	35	35	45	45	55	55	55	55
38	35	35	35	35	45	45	55	55	55	55
41	35	35	35	35	35	35	35	35	35	35
43	35	35	35	35	35	35	35	35	35	35
45	35	35	35	35	35	35	35	35	35	35
46	35	35	35	35	35	35	35	35	35	35
49	25	25	25	25	25	25	25	25	25	25
51	10	10	10	15	15	15	15	20	20	20
52	10	10	10	15	15	15	15	20	20	20
61	35	35	35	35	35	35	35	35	35	35
62	35	35	35	35	35	35	35	35	35	35
63	35	35	35	35	35	35	35	35	35	35
64	35	35	35	35	35	35	35	35	35	35
65	35	35	35	35	35	35	45	50	50	50
66	35	35	35	35	35	35	45	50	50	50
67	35	35	35	35	35	35	45	50	50	50
68	35	35	35	35	35	35	45	50	50	50
71	35	35	35	35	40	40	40	40	40	40
72	25	25	25	25	30	30	30	30	30	30
73	45	45	50	50	50	50	50	50	50	50
74	35	35	40	40	40	40	40	40	40	40

Note: Facility Type and Area Type are link attributes. The Facility type defines the type of roadway (freeway vs. arterial), while Area Type is a measure of the density and activity in a zone. Facility Type and Area Type are defined in the Phase I Final Report.

Based on the revalidation of the model in May of 2011, the default speeds were updated for key links in Indiana and Kentucky. Areas that were evaluated included the I-64 corridor from the western entry to the Kennedy Interchange as well as I-265 and I-65 in Indiana. In addition speeds through the urbanized areas in Indiana were evaluated. The resulting speeds were coded with the speed limit as discussed in section 3.2.1.1.

3.2.1.3 Free Flow Speed Adjustment

There has been considerable work on the estimation of free flow speed. In the case of the LSIORB Phase II Model, we have adopted the FHWA methodology of factoring the posted speed limit depending on the speed. The factors applied are as follows:

- FFS = (0.88 * Speed Limit) + 14 (>50mph)
- FFS = (0.79 * Speed Limit) + 12 (<= 50mph)

3.2.1.4 Impact of Signalization

An additional enhancement to the LSIORB Phase II Model is the addition of capturing the uniform delay from traffic signals as part of the free flow time. Extensive work was completed in Phase I and Phase II identifying the locations of signals in the study area, and making assumptions regarding the cycle length. In the end, several assumptions were made regarding the signal delay including:

- Equal green time split by approach
- Signal length based on known information and generalization for area type
- No reduction in signal delay from progression

The delay related to signalization was calculated by direction on each link based on the location of the signals. The formula used for estimating the uniform delay was:

$$d = 0.5C\left(1 - \frac{g}{C}\right)^2 \cdot PF$$

where,

d = delay per vehicle,
g = effective green time,
C = cycle length, and
PF = progression adjustment factor.

The resulting delay was added to the free slow speed to develop the final adjusted free flow travel time.

3.2.1.5 Time Penalties

As part of the validation process, it is anticipated that time penalties maybe added to some or all of the bridge crossings to improve traffic volumes. For this reason, it is recommended that the CUBE assignment allow for the flexibility to read a time penalty associated with the crossings by direction.

3.2.2 Capacity

Link level capacities are based on the look up table developed by KIPDA for the 09PlanA and 10PlanA regional models. The capacity logic used by KIPDA is borrowed from FDOT and is well documented and based on sound HCM methodologies. The mid-day and overnight period capacities were estimated by dividing the daily capacity by a factor that is the inverse of the percent of traffic observed in the period.

Table 3.11: Capacity Factors by Period

Period	Hours	Factor
Mid Day	9am to 3pm	- 19.45 % of daily traffic - 5.14 * Hourly Capacity
Overnight	6pm to 6am	- 21.9 % of daily traffic - 4.55 *Hourly Capacity
AM and PM Peak Hours	8am to 9am	- Daily Capacity / 10
	5pm to 6pm	

3.2.3 Generalized Cost Impedance

As part of the design considerations for the LSIORB to increase sensitivity to tolling, the trip distribution and mode choice steps use generalized cost impedance. The inclusion of cost as part of the impedance function ensures that the distance of the trip is considered as well as the travel time. For the LSIORB, cost is included in two components. The first is vehicle operating cost in $/mile and the second is tolls in the future year scenarios. The time component of the generalized cost function is converted to cost using a value of time in $/min that is unique for auto and truck trips.

For traffic and revenue estimates at the SEIS planning level, it is common to use area socioeconomic data, national travel planning data, experience from other regions and facilities, and fundamental research on these topics to select appropriate values of time and vehicle operating costs.

For this study, socio-economic data available from the US census regarding household income, number of households, and number of hours worked covering the five-county greater Louisville area was used to calculate an appropriate value of time (VOT) for automobiles. This information was checked against values of time from other regions where more extensive research and data is available, including accounting for differences in median income. This resulted in a rate of $0.21 per minute VOT for automobiles. Setting a VOT for trucks considers time based operating costs such as driver wages and business related schedule costs. For the SEIS study, national experience elsewhere indicated a $0.55 per minute value for trucks was appropriate.

Vehicle operating costs need to reflect that part of total vehicle operating costs (VOC) a driver would take into account when making a routing decision. Consequently, this process assumes vehicle capital and insurance costs are essentially fixed and vehicle operating costs are the costs of fuel and routine maintenance such as tires and oil changes. For automobiles, baseline information from the AAA is available. Also, in 2003, an academic study of per mile operating costs for automobiles and trucks was conducted by the Minnesota DOT. In this study, a methodology was presented to estimate VOCs. Using the AAA baseline information, information from the academic study, and updating both for the greater Louisville region and current fuel prices, vehicle operating cost at $0.19 per mile for automobiles and $0.65 per mile for trucks were selected.

As the financing progresses for the LSIORB project, it is likely the value of time and vehicle operating costs for the region and project will be examined in more detail and adjustments made.

The values being used in the LSIORB Phase II model are as follows:

Table 3.12: Value of Time and Operating Cost Values

Parameter	Auto	Truck
Value of Time ($/min)	0.21	0.55
Operating Cost ($/mile)	0.19	0.65

The value of time and vehicle operating costs described above were selected for use in travel demand modeling for this study to determine impacts of tolling on forecasted traffic flows. Different techniques and parameters would be applied for other assessments outside of travel demand modeling, such as a cost-benefit analysis.

The LSIORB network has unique toll fields allowing the toll rates to be specified by peak period vs mid day, and by vehicle occupancy as well as for trucks. The tolls should be coded at the toll collection location in $. The model combines the appropriate operating cost with the toll value and inputs this into the generalized cost function at the appropriate steps in the model. The Generalized Cost is calculated for all links based on the operating cost and adds the toll value for only the links with a toll cost added as a link attribute.

Table 3.13: Generalized Cost Components

Generalized Cost Value	Toll Field	Operating Cost (GUI Parameter)
GC_pkDA	TOLL_pkDA	Auto
GC_pkSR2	TOLL_pkSR2	
GC_pkSR3	TOLL_pkSR3	
GC_mdDA	TOLL_mdDA	
GC_mdSR2	TOLL_mdSR2	
GC_mdSR3	TOLL_mdSR3	
GC_LtTRK	TOLL_LtTRK	Truck
GC_HvTRK	TOLL_HvTRK	

3.3 Trip Distribution

The LSIORB utilizes a traditional gravity model formulation for the trip distribution step in the model. Enhancements to the typical gravity model include the following elements:

- Use of a generalized cost function for impedance
- Implementation of feedback to account for congestion in trip distribution

3.3.1 Friction Factor Calibration

Because of the difference in definition of impedance in the LSIORB TOD Model and the use of a congested feedback model, the friction factors had to be estimated. The 2000 KIPDA household travel survey was used. Since the 2000 survey used the 1990 traffic analysis zones, the first step was to equate the trip ends to the new zone structure. Once that step was

complete, the composite congested time was assigned to each survey trip and an average value was computed from the survey as well as the distribution of trips over time. The congested travel time was based on preliminary runs of the model.

The friction factors were iteratively estimated by comparing the output trip length distribution to the survey output and adjustments were made. A curve was then fit to the adjusted friction factors and the model was rerun. This process was completed until the average values from the survey were replicated within 10% or a difference of less than 2 minutes.

Figure 3.8 provides a comparison of the survey and estimated model average composite travel times by purpose at the end of the calibration process. Figure 3.9, Figure 3.10, and Figure 3.11 display the distribution from the survey (_S) and the calibrated model (_M) by purpose.

Figure 3.8: Survey vs. LSIORB TOD Model: Average Composite Time

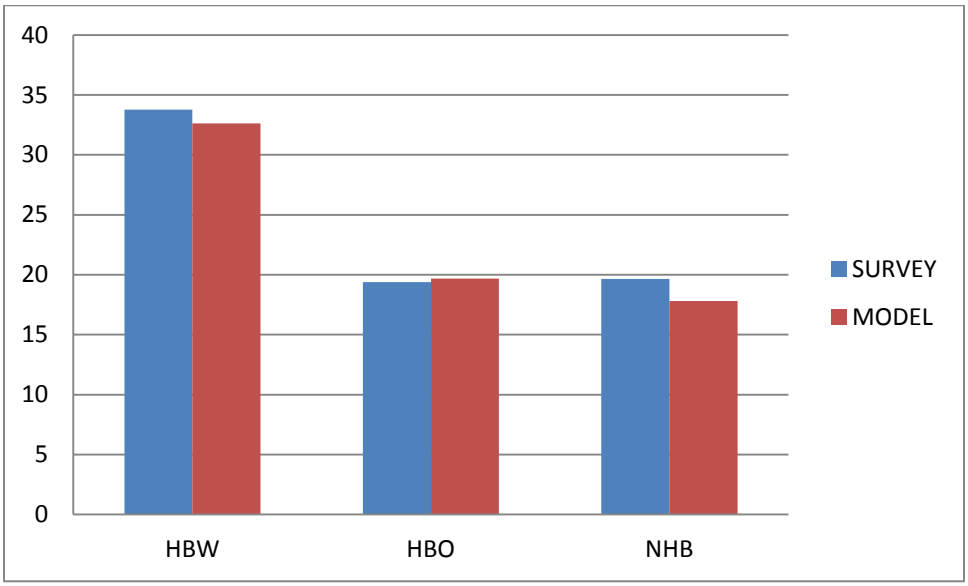


Figure 3.9: Survey vs. LSIORB TOD Model: HBW Composite Time Distribution

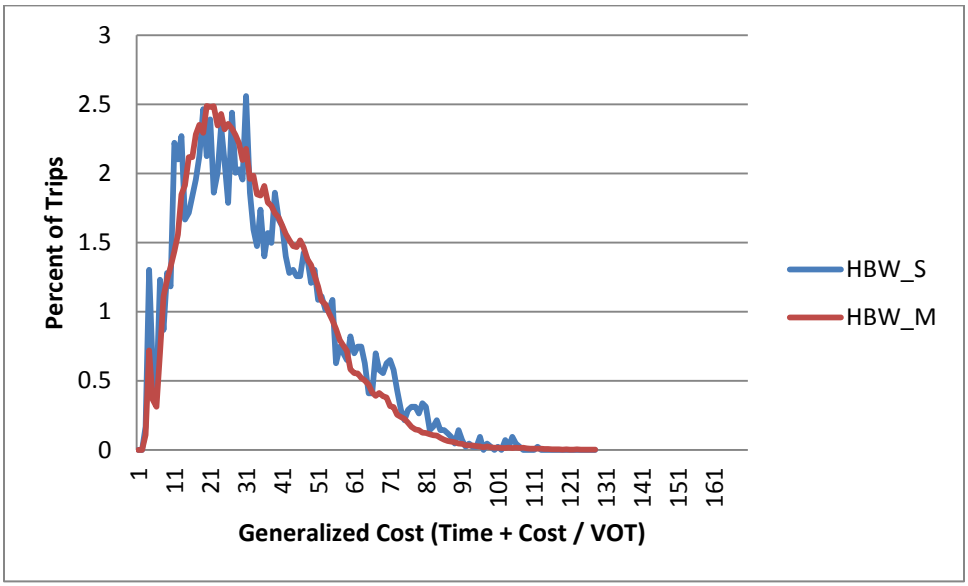


Figure 3.10: Survey vs. LSIORB TOD Model: HBO Composite Time Distribution

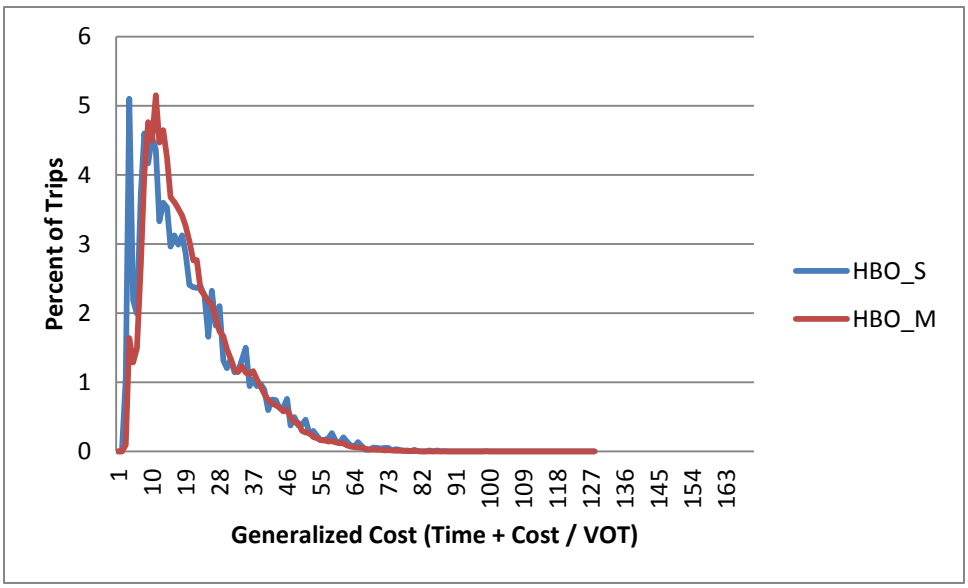
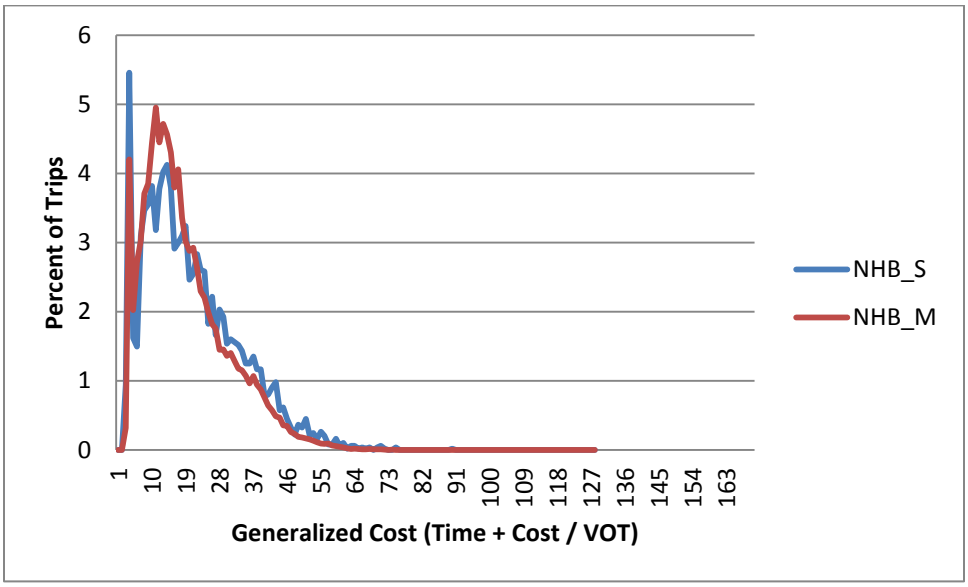


Figure 3.11: Survey vs. LSIORB TOD Model: NHB Composite Time Distribution



Based on the observed and modeled distributions, the coincidence ratio was calculated for each purpose. The coincidence ratio, a measure recommended by the TMIP Model Validation and Reasonableness Checking Manual, is a measure of the difference between two distributions. A value of 1.0 implies the distributions are the same.

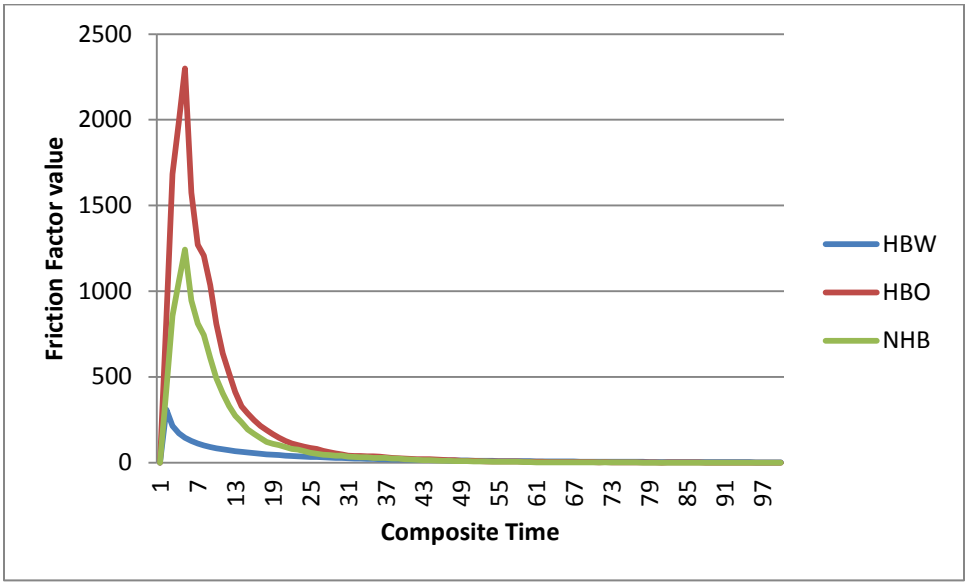
Table 3.14: Trip Distribution Calibration Results

Purpose	Observed Average	Model Average	Coincidence Ratio
HBW	33.77681	33.16751	0.836225
HBO	19.37822	19.88649	0.818359
NHB	19.65853	17.87851	0.813566

Note: Observed Average and Model Average are average trip length in minutes for the generalized cost function (time + cost / vot)

The resulting friction factors are shown Figure 3.12. The relative relationship between the trip purposes is consistent with the expected response to travel time by trip purpose. HBW has a higher willingness to travel as seen in the shallow slope of the curve as compared to HBO and NHB that fall off quickly.

Figure 3.12: LSIORB TOD Friction Factors

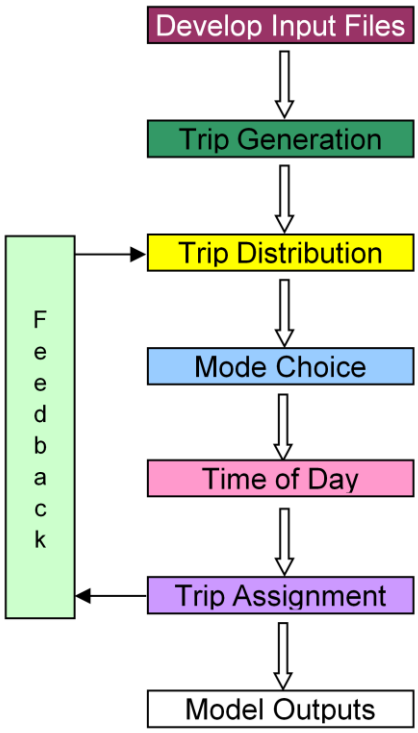


3.3.2 Feedback

The LSIORB model uses feedback procedures to "feed back" congested travel times into the modeling process. This is to ensure that inputs into earlier steps of the model are consistent with the model outputs at later stages.

The purpose of a feedback mechanism is to make use of more accurate times from the assignment stage into the earlier stages (trip distribution, mode choice, and time of day), and loop this way iteratively until there is more consistency between the time values being used for each of the model stages. **Figure 3.13** shows a flowchart of the feedback process.

Figure 3.13: Feedback Model Flowchart



Feedback loops between the assignment and trip distribution stages are used for calibrating speeds by taking congested highway impedance skims from the assignment process, feeding them back through the model and then repeating highway assignment using the new congested trip tables and free flow time. The feedback used in the LSIORB model is the method of successive averages (MSA) approach. This approach weights together the output volumes from trip assignment for the current and previous loops using an MSA function to produce a set of adjusted link volumes for the current loop (called "MSA_Flow"). Adjusted congested times ("MSA_Time") are then calculated based on the normal volume-delay relationship. This adjusted congested time is then fed back to the skimming procedures in trip distribution.

3.3.2.1 Convergence Methodology

The feedback loops can be terminated based on two criteria, the root mean square error (RMSE) for convergence and the number of feedback iterations specified by the user.

The loops terminate based on whichever of the two criteria is met first. RMSE measures the square root of squared cell differences, applied either to skims (the "cost" of travel) or trip tables. This is a better approach than a single global parameter because it measures convergence at the origin-destination (*ij*) pair level. The RMSE convergence measure is based on the current and previous iteration of peak congested travel time skims in the LSIORB model. The peak congested travel times are an average of the AM and PM peak periods and are used for the home-based work trip purposes. Mid-day congested travel time for off peak periods, which are

used for the HBO and NHB trip purposes are also calculated and fed back through the model but are not used to test convergence of model stability.

3.3.2.2 Convergence Criteria

The measure of convergence can be set by the model user but a default value was chosen to be less than to 0.1 RMSE. Caliper recommends a convergence threshold of 0.1 percent of RMSE between the current and previous loops' travel time skims. This measure is suggested to be detailed enough to appropriately measure convergence. The LSIORB model convergence was tested based on this threshold and the model converged in six feedback iterations.

By default the maximum number of feedback iterations is set to 100 in the LSIORB model but can be adjusted by the user. **Figure 3.14** and **Table 3.15** shows the number of feedback iterations verse the RMSE. The model reaches the 0.1 RMSE threshold at iteration six but becomes fairly stable starting at iteration four and little benefit is obtained after the fourth iteration in the 2007 model. Thus, iterations after the fourth may not warrant the additional time sacrificed for the minimal convergence improvements.

Figure 3.14: Feedback Convergence Plot

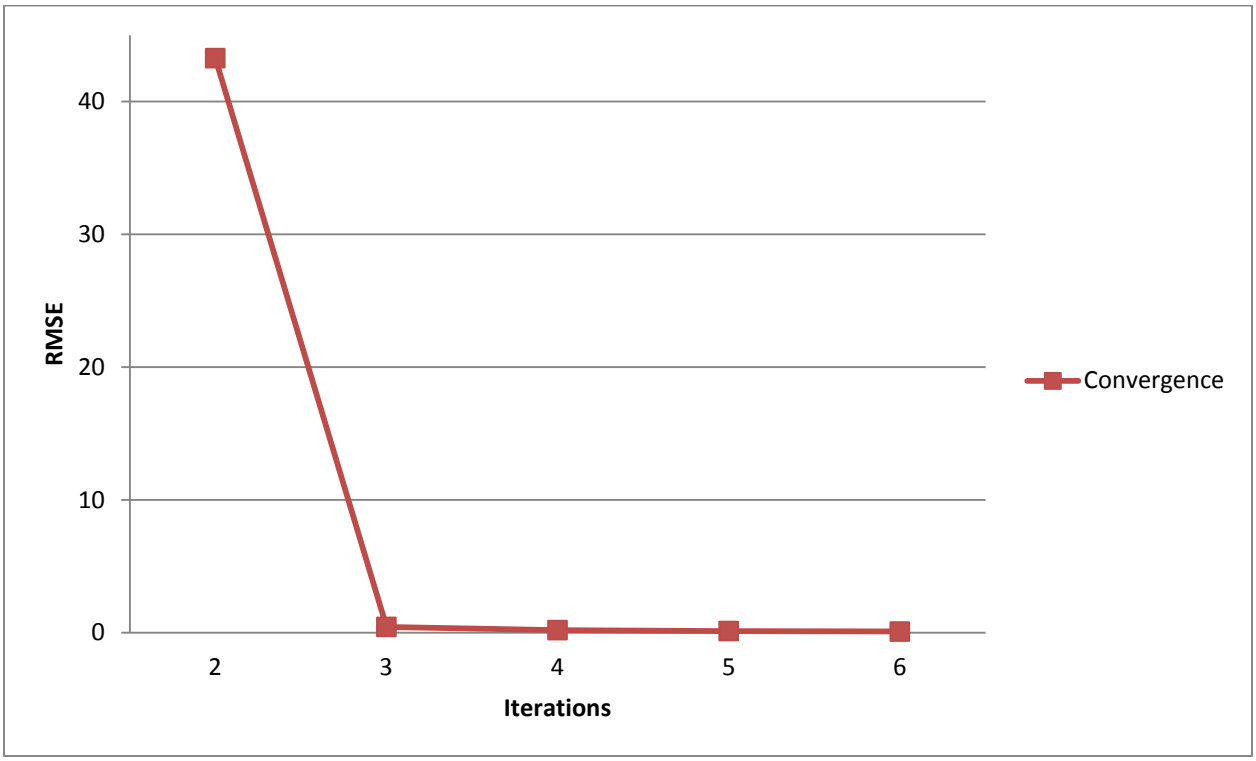


Table 3.15: Feedback Convergence Table

Iteration	RMSE
1	Free Flow
2	43.26
3	0.43
4	0.19
5	0.12
6	0.08

Future land use and network scenarios were tested and show a similar feedback convergence pattern but at a much higher initial RMSE. Thus, it is recommended to run more than four feedback iterations for future year scenarios. Analysis was performed on the output volumes after iteration four to evaluate the magnitude of volume change between these iterations.

3.4 Mode Choice

This section describes the data and methodology used to develop mode choice trip shares of the LSIORB study area. The share of trips by mode are developed using a transit system, transit markets, transit impedances, and a nested logit model. Mode choice is preformed for daily trips and includes toll and generalized cost components. The mode choice model includes the following modes:

- Private Vehicle
  - Drive Alone
  - Shared Ride – 2-person
  - Shared Ride – 3+-person
- Public Transit
  - Local Bus
  - Premium/Express Bus
- Non-Motorized
  - Walk
  - Bike

3.4.1 Transit System

The LSIORB transit system consists of several features including routes, stops, access links, and underlying highway line and node layers. Forty-seven fixed local and express routes operated by Transit Authority of River City (TARC) were coded on the LSIORB highway network. Each route was coded by direction and by segment considering that the routes service different areas at different times of the day. Each stop corresponding to each of the routes was code in the transit system and linked to the highway node database by node identification number.

All park-and-ride facilities were coded to the transit system based on highway node characteristics. Finally, walk and drive access links connecting the highway network centroid nodes to the transit stops and park-and-ride lots were coded in the transit system. **Figure 3.15** shows an image of the transit system.

The following tables provide the transit related attributes coded to the routes (**Table 3.16**

Table **3.16**.), stops (**Table 3.16**), highway nodes (**Table 3.18**) and highway links (**Table 3.19**).

Figure 3.15: Transit System

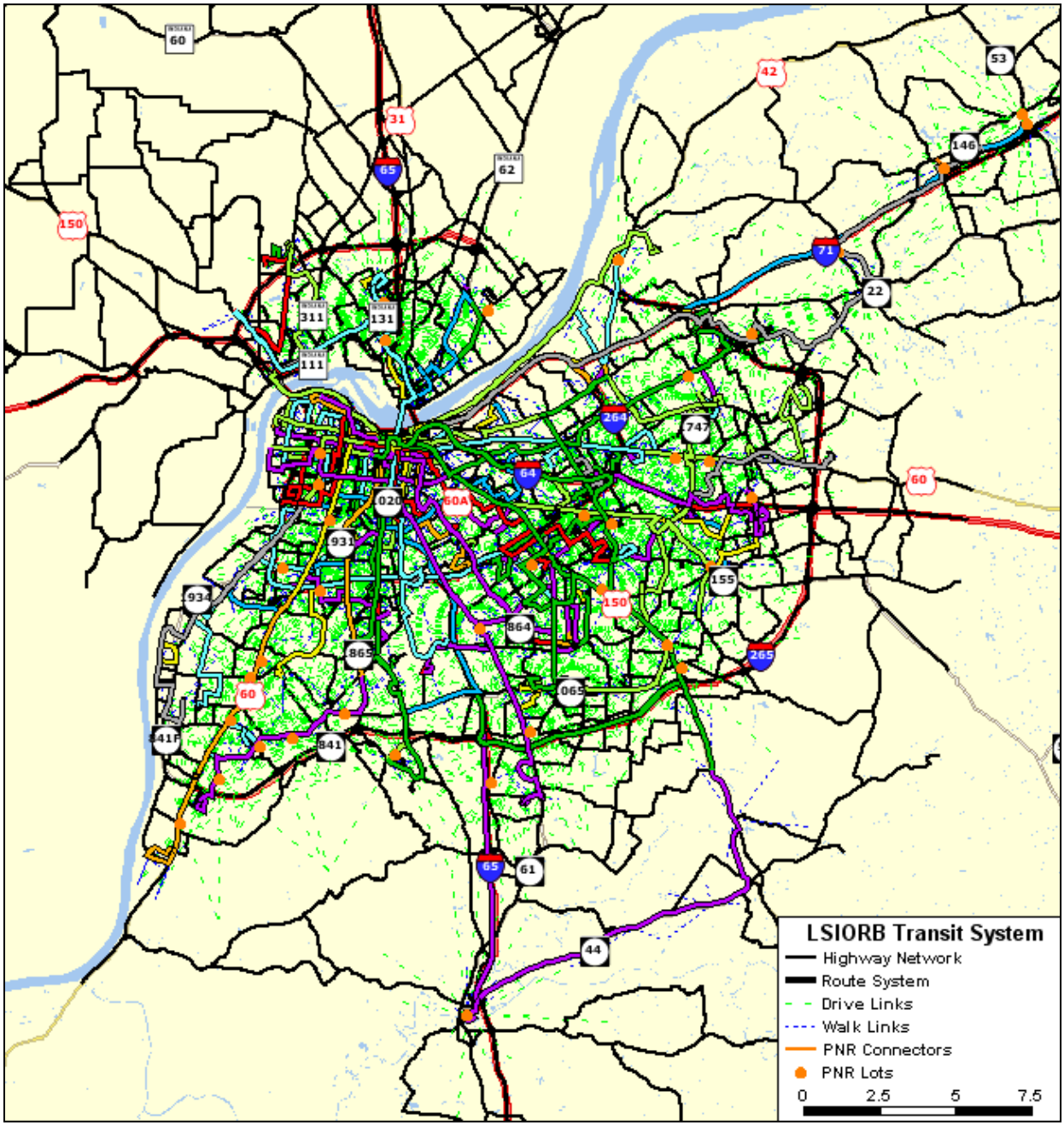


Table 3.16: Transit Route Attribute Data

Field	Type	Description
Route_ID	Integer	Generated by TransCAD
Route_Name	Character	Route Name based from TARC schedules
MODE	Integer	1 = Local Bus | 2 = Express Bus / Premium Transit
RouteNumber	Character	Route Number from TARC schedules
Route_Description	Character	Route Description from TARC schedules
Run_Number	Integer	Number of route variations within a day
Year_Start	Integer	Year route in service
PK_Headway	Real Number	Headway for the Peak (AM + PM) period
**_Headway	Real Number	Headway fields for the morning, mid-day, evening, and night periods
Fare	Real Number	Route Fare
TransferCOST	Real Number	Transfer Cost
Service Time	Integer	TARC schedule time
TYPE	Character	Route type (Local, Express, Flex, Circulator, etc)

Table 3.17: Route Stop Attribute Data

Field	Type	Description
ID	Integer	Generated by TransCAD
Route_ID	Integer	Generated by TransCAD
Milepost	Real	Generated by TransCAD
STOP_ID	Integer	Generated by TransCAD
NODE_ID	Integer	Tagged from the node layer
Year_Start	Integer	Year stop in service

Table 3.18: Node Layer Transit Attributes

Field	Type	Description
ID	Integer	Generated by TransCAD
PNR	Integer	1 = PNR node
Year_Start	Integer	Year PNR in service
PNRTime	Real	filled by model (actual highway travel time between the PNR and the centroid node)
ParkingGarage	Integer	1=Parking Garage Cost (inactive)
CBD_Zone	Integer	1=CBD zone

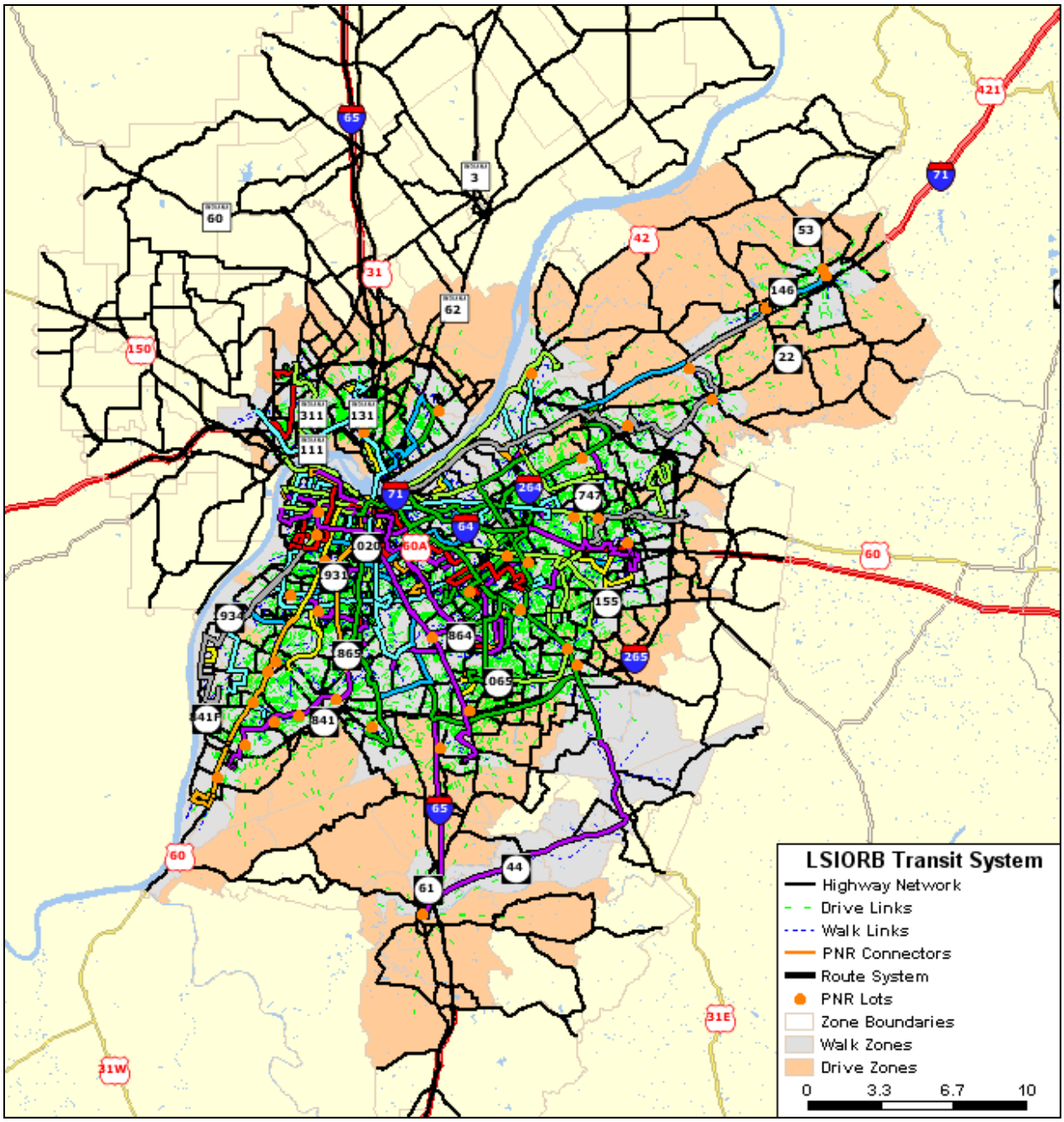
Table 3.19: Highway layer transit attributes

Field	Type	Description
MODE_ID	Integer	Walk Only Links = 30 | Drive Links = 40
NODE ID	Integer	Node ID of the Centroid Node connected to the Access links
Dtwn_WalkLinks	Integer	Downtown walk links = 1 | PNR drive connector = 2 | Centroid connector walk link = 3
PNR_CC	Integer	Park and Ride Lot ride access link = 1 | otherwise = 0
Node_ID	Integer	Identification of centroid node for drive access links only

GIS procedures were used to connect the centroid nodes of all zones fully or partially within one third mile of any bus stop. These zones reflect the transit walk access zones.

The link between the centroid node and the bus stop reflect the walk access links. Similarly, GIS procedures were used to connect centroid nodes of those zones within a 3-5 mile radius of park and ride stations. These zones reflect the transit drive access zones. The link between the centroid node and the park-and-ride lot reflect the ride access links. **Figure 3.16** shows the zones accessible to transit by walk and drive access.

Figure 3.16: LSIORB Walk and Drive Access Zones



Transit travel times by route were developed based on traditional transit time factors and calibrated to the route schedules. Transit in-vehicle travel time is the highway travel time divided

by a transit factor to reflect the slower speeds of transit busses and the frequency of stops. The transit factors were obtained from similar areas with comparable transit systems and then calibrated with the service times from the route schedules. **Table 3.20** shows the calibrated transit factors of the LSIORB model.

The route model time is the coded travel time in minutes from the start of the route to the end of the route by direction. The transit factor is based on facility type and area type and it accounts for delay due to the nature of the road (signals, access, and median type) and the location of the road (downtown or not downtown).

Table 3.20: Transit Time Factors

Functional Class	Description	Transit Factor
0	Road is not included in highway network model	1.00
11	Freeways	0.60
12	HOV Lanes	0.60
13	Freeways with restricted shoulders	0.60
17	Collector – Distributor Roads	0.40
21 -23	Divided Arterial I - III	0.40
24 - 25	Divided Arterial VI - V	0.35
31 - 38	Undivided Arterial I - II	0.40
41 - 46	Collectors / Local Roads	0.35
49	Side Streets used for Busses	0.40
51 - 52	Centroid Connectors	0.35
61 - 64	One-way Streets	0.60
65 - 68	Frontage Roads	0.60
71 - 74	Ramps	0.35
88	US 31 bridge	0.35
101	Walk Only Links	1.00
102	Drive Only Links	1.00
103	Transit Only	1.0

Additionally, transit walk access times were developed based on a three mile per hour speed assumption and a maximum walk time of ten minutes to transit service.

3.4.2 Transit Markets

Transit markets were specified in the LSIORB model to develop transit potential trips by household type (zero car households and one or more car households) and by access to transit (drive access and walk access) for each trip purpose. The trip purposes include home-based work, home-based other and non-home based. The disaggregation of households in trip generation provides the percent of households by auto ownership type. The percent of zonal area within the walk and drive access buffers provide the market share of transit potential trips by access type. By combining these data the percent of transit potential trips by auto ownership and transit access type market can be obtained. A list of transit potential markets is listed below.

- Zero Car – Walk Access

- 1+ Car – Walk Access
- 1+ Car – Drive Access
- Non-Transit Potential

3.4.3 Transit Skimming

Transit paths and impedance skims are created for each combination of transit mode, access type, and time of day. The transit modes include local and premium transit; the access types include walk and drive access to transit; and the time of day periods include peak and mid-day periods. The peak period skims are used for the home-based work trip purpose in the mode choice models and the mid-day skims are used for the home-based other and non-home based trip purposes in the mode choice models. The transit skims created in the LSIORB model include:

- Peak period, Walk access, Local transit
- Peak period, Drive access, Local transit
- Peak period, Walk access, Premium transit
- Peak period, Drive access, Premium transit
- Mid-day period, Walk access, Local transit
- Mid-day period, Drive access, Local transit
- Mid-day period, Walk access, Premium transit
- Mid-day period, Drive access, Premium transit

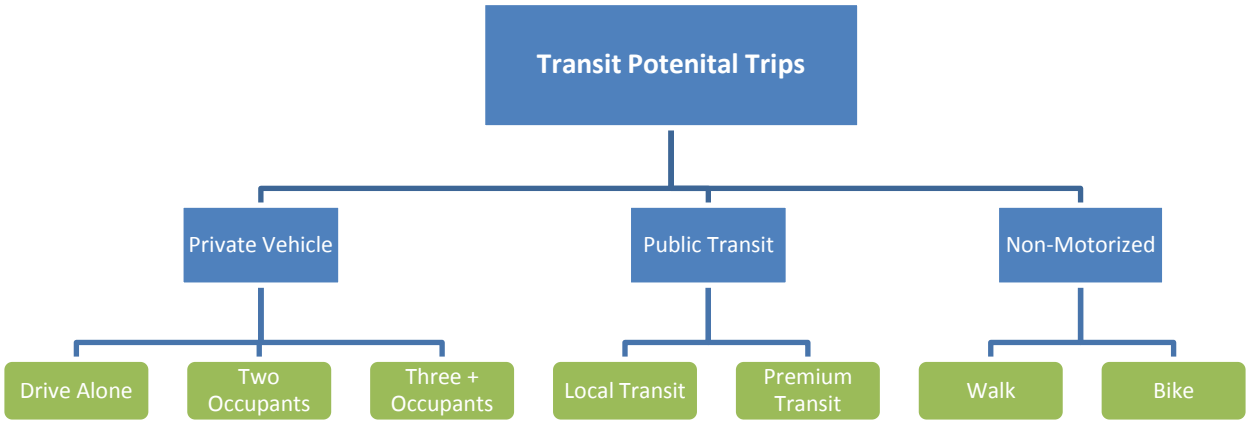
The transit paths are skimmed based on the impedances of generalized, fare and transfer cost (regular cost and peak period discount), travel time, number of transfers, distance (in-vehicle and drive access), and CBD flag. Such travel times include in-vehicle and out of vehicle travel time where the out of vehicle travel time includes transit walking and driving access time, wait time for initial boardings and transfers, and transfer time. Toll costs are included in the generalized travel time based on values of time by vehicle occupancy. Fare costs are included with transfer and drive access operating costs. There is a 25% reduction in fare costs for work trips due to the number of discounted “frequent user” fares.

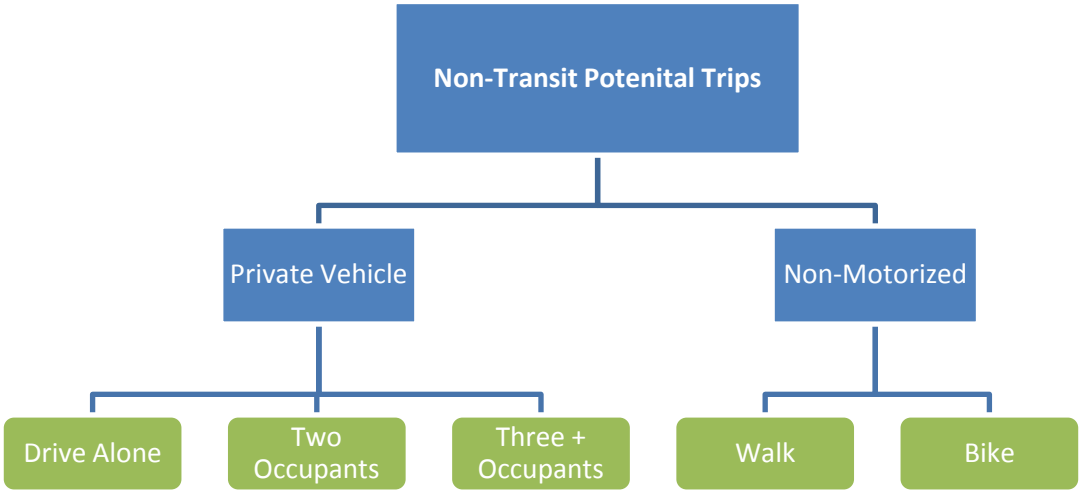
3.4.4 Mode Choice Model

Mode choice nest logit models (NLMs) were developed based on trip purpose and major transit markets to determine the share of trips by mode. The top level nest consists of private vehicle, public transit, and non-motorized modes that compete with each other. Within each of those major modes more detailed modes compete at the next level nest. Express bus services run parallel to and, to some extent, compete with local bus services. Therefore, there is a choice offered between lower cost, slower local service and higher cost, faster premium service. On the private vehicle side there is also a need to estimate private vehicle occupancy and how it might change in response to the implementation of toll charges by vehicle occupancy. The nesting structures of the NLMs for transit potential trips as well as non-transit potential trips are shown in **Figure 3.17**. These NLM nesting structures are applied by trip purpose and by the following markets.

- Car owning walk potential
- Non-car owning walk potential
- Car owning drive potential

Figure 3.17: Nested Logit Model Structures





The NLMs disutility variables and model constants and coefficients were developed based on guidance from FTA and commonly used data. These data were verified or adjusted based on observations from the American Community Survey (ACS) data. The traditional disutility variables were used to describe the alternative travel modes. These included:

- In-vehicle travel time
- Out-vehicle time (waiting for initial boarding as well as transfers and walking/driving access)
- Out of pocket costs (on a person trip basis including toll, parking, fare and operating cost for those driving to transit)
- Number of Transfers
- CBD or employment density dummy variable
- Modal bias constants

These variables are the most sensitive in determining mode shares. As expected time (in-vehicle, wait, transfer, and access times), cost (toll, fare, parking and operational costs), and the number of transfers have a negative effect on the utility equation and the CBD or employment density dummy variable has a positive effect. Peak travel times and costs are used for home based work trips. Mid-day times and costs are used for home based other and non-home based trips. **Table 3.21** shows the disutility variables and corresponding skimmed model data by mode used for each trip purpose.

Table 3.21: Transit Disutility Variables

	Variable				
Mode	**IVTT**	**OVTT**	**COST**	**Transfers**	**CBD**
Private Vehicle	Drive Time	Terminal Time	Parking Cost (currently inactive), Generalized Cost for Peak (HBW) and Mid-day (HBO, NHB) based on vehicle occupancy 1, 2, 3	N/A	Flag for CBD zone
Transit	Transit Time	Wait, Transfer, Access, and Egress Time	Auto Operating Cost * Distance + Fare Cost. Operating cost is only applied for the drive access. Fare cost is discounted by 25% for HBW.	Number of Transfers	Flag for CBD zone
Non-Motorized	Walk Time	Terminal Time	N/A	N/A	Flag for CBD zone

FTA suggests a set of reasonableness guidelines that should be followed in mode choice model structure and constant/coefficient estimation. These may be summarized as follows:

Unusual In-Vehicle Travel Time (IVTT) coefficients – guidance suggests that without compelling evidence to the contrary IVTT (in minutes) coefficients should be in the range -0.03 to -0.02. The LSIORB model IVTT coefficient is -0.025.

Mode specific IVTT coefficients – guidance suggests that without compelling evidence to the contrary mode specific IVTT coefficients should not be used. In the LSIORB model the IVTT coefficient is the same for all modes.

Unusual ratios of in-vehicle travel time to Out-Vehicle Travel Time (OVTT) (walking, waiting, access) coefficients – guidance suggests that without compelling evidence to the contrary the OVTT/IVTT coefficient ratio should be in the range 2.0 to 3.0. The OVTT/IVTT coefficient ratio in the LSIORB model is 2.52.

Wide Variation in LogSum coefficients – guidance suggests that without compelling evidence to the contrary LogSum coefficients should be in the range 0.7 to 1.0. The LSIORB model LogSum coefficients are in the range of 0.7.

Wide variation of mode choice value of time – guidance suggests that without compelling evidence to the contrary model implied value of time should be in the range average income /4 to average income / 3. The LSIORB model uses standard values provided by FTA guidance and recently preformed traffic and revenue studies of the region.

Non-logit decision rules – examples are no trip shorter than 3 minutes, no trips with auto access greater than transit in vehicle time. Guidance is to avoid these types of model structure. Accept some degree of model inaccuracy instead of over-defined model structure.

Bizarre Alternative Specific Constants – Guidance is that bias constants should be explainable. A simplified model structure is often desirable to a very complicated structure for which accurate observed data is not available.

The resulting LSIORB mode choice model coefficients and constants are presented in **Table 3.22**. The mode constants are reported in Table 3.23 are reported by purpose and market.

Table 3.22: Nested Logit Model Parameter Values

Parameters		**Value**
Parameter Coefficients	IVTT	-0.0250
	OVTT	-0.0630
	TRANSFER	-0.2500
	CBD	0.2500
	COST (work)	-0.0023
	COST (other)	-0.0012
	Walk Time	-0.0250
LogSum Coefficents		0.7000

Table 3.23: Mode Choice Mode Constants

Parameters		0 Car - Walk	1+ Car - Walk	1+ Car - Drive	1+ Car - Drive (non-trn)
Vehicle_Theta		0.7000	0.7000	0.7000	0.7000
Auto ASC	HBW	-1.1500	0.7500	1.6000	1.6000
	HBO	-1.1500	0.7500	1.6000	1.6000
	NHB	-1.1500	0.7500	1.6000	1.6000
Drive Alone ASC	HBW	-1.0000	2.0000	2.0000	2.0000
	HBO	-2.5000	0.2500	0.0000	0.0000
	NHB	-3.0000	0.8500	0.5000	0.5000
Shared Ride (2 person) ASC	HBW	1.0000	1.0000	0.2500	0.2500
	HBO	2.0000	0.7500	0.5000	0.5000
	NHB	3.0000	1.2500	0.7500	0.7500
Shared Ride (3+ person) ASC	HBW	1.0000	0.0000	-1.0000	-1.0000
	HBO	1.2500	-0.5000	-1.0000	-1.0000
	NHB	2.5000	-0.5000	-1.0000	-1.0000
Transit_Theta		0.7000	0.7000	0.7000	--
Transit ASC	HBW	2.5000	2.0000	1.5000	--
	HBO	0.0000	0.0000	-2.0000	--
	NHB	0.5000	0.0000	-1.0000	--
Local ASC	HBW	1.5000	0.0000	0.0000	--
	HBO	1.7000	-0.8000	-0.5000	--
	NHB	1.0000	-0.2500	0.0000	--
Premium ASC	HBW	1.0000	0.0000	1.5000	--
	HBO	-1.0000	-1.0000	1.0000	--
	NHB	-1.0000	-1.0000	1.0000	--
Non-Motorized_Theta		0.7000	0.7000	0.7000	0.7000
Non-Motorized ASC	HBW	-0.5000	1.9000	-1.0000	-1.0000
	HBO	-0.5000	2.7500	0.0000	0.0000
	NHB	0.4000	2.2000	-0.5000	-0.5000
Walk ASC	HBW	2.0000	0.7500	0.1500	0.1500
	HBO	1.7000	-0.2500	-0.8000	-0.8000
	NHB	1.0000	0.0000	-0.2500	-0.2500
Bike ASC	HBW	-1.0000	-0.2500	0.8500	0.8500
	HBO	-1.0000	-1.0000	-1.1500	-1.1500
	NHB	-1.0000	-1.0000	-1.2000	-1.2000

Initial applications of models were used to revise mode bias constants. Results were compared to ACS mode split data and other areas of similar size for the counties of Clark, Bullitt, Floyd, Jefferson, and Oldham. The home-based work split of shares between modes compared to ACS data is shown in **Table 3.24**. These results show a close match of the distribution of observed and modeled work trips by mode. The modeled transit distribution is 0.2% higher than the observed distribution but the number of work transit trips modeled is less than 1,000 trips greater than the observed at 23,600 modeled home-based work trips.

Table 3.24: Mode Split Trip Distribution

ACS 3 Year Data (2006 – 2008)	Observed Distribution	Modeled Distribution
Total:	100.0%	100.0%
Drove alone	84.5%	81.1%
In 2-person carpool	7.9%	9.3%
In 3+-person carpool	1.9%	2.0%
Public transportation	3.1%	3.3%
Walked	0.1%	1.2%
Bicycle	2.3%	2.5%

The split of transit shares by trip purpose compared to the observed survey data from the Charleston Area Transportation Study is shown in **Table 3.25**.

Table 3.25: Transit Trip Distribution by Trip Purpose

Trip Purpose	LSIORB Distribution	CHATS Distribution
HBW	57.5%	56.4%
HBO	33.8%	32.4%
NHB	8.7%	11.1%
Total Trips	100%	100%

3.5 External Model

The LSIORB TOD Model has an external sub-model that includes the following components:

- External – Internal
  - Auto
  - Truck
- External – External
  - Auto
  - Truck

The first step in the application of the external sub-model is the development auto and truck volumes at the cordon line. The 2007 data is reported in Table 3.26 and includes the distribution of the auto and truck into the EI and EE components. The distribution is based on the findings from the external OD survey discussed in section 3.5.1.

Table 3.26: LSIORB TOD 2007 External Volumes

TAZ	County	State	Count ID	Route	EI_AUT	EI_LTRK	EI_HVT	EE_AUT	EE_TRK	AUT	TRK	TOTAL
841	Jefferson	KY	508	US 31W	20,214	0	1,975	0	0	20,214	1,975	22,189
842	Bullitt	KY	E11	KY 434	923	59	16	0	0	923	75	998
843	Bullitt	KY	503	I-65	26,303	3,080	4,803	6,189	10,231	32,492	18,114	50,606
844	Bullitt	KY	529	KY 61	5,200	271	252	0	0	5,200	523	5,723
845	Bullitt	KY	272	KY 733	425	0	0	0	0	425	0	425
846	Nelson	KY	750	KY 245	9,824	573	765	0	0	9,824	1,338	11,162
847	Bullitt	KY	257	KY 480	2,237	0	0	0	0	2,237	0	2,237
848	Spencer	KY	779	US 31E	6,706	360	173	0	0	6,706	534	7,240
849	Spencer	KY	767	KY 44	2,948	208	67	0	0	2,948	275	3,223
850	Bullitt	KY	31	KY 1319	1,134	0	0	0	0	1,134	0	1,134
851	Jefferson	KY	373	KY 155	11,108	301	243	0	0	11,108	544	11,652
852	Jefferson	KY	369	KY 148	2,187	127	38	0	0	2,187	165	2,352
853	Jefferson	KY	19	I-64	38,310	720	3,382	3,743	5,201	42,053	9,303	51,356
854	Jefferson	KY	119	US 60	8,328	0	568	0	0	8,328	568	8,895
855	Jefferson	KY	131	KY 1531	4,096	0	0	0	0	4,096	0	4,096
856	Oldham	KY	267	KY 362	2,157	60	17	0	0	2,157	77	2,234
857	Oldham	KY	270	KY 1408	1,211	0	0	0	0	1,211	0	1,211
858	Oldham	KY	282	KY 1315	705	0	0	0	0	705	0	705
859	Shelby	KY	753	KY 53	1,696	0	0	0	0	1,696	0	1,696
860	Oldham	KY	253	KY 22	1,993	74	37	0	0	1,993	111	2,104
861	Oldham	KY	289	KY 712	1,348	0	0	0	0	1,348	0	1,348
862	Oldham	KY	315	I-71	16,633	1,225	5,870	4,321	7,408	20,954	14,503	35,457
863	Henry	KY	538	KY 146	2,715	0	0	0	0	2,715	0	2,715
864	Henry	KY	750	US 42	1,543	0	0	0	0	1,543	0	1,543
871	Clark	IN	?	Paynesville Rd	95	2	3	0	0	95	5	100
872	Clark	IN	?	Marble Hill Rd	319	13	37	0	0	319	50	369
873	Jefferson	IN	G1	SR-62	3,693	198	290	0	0	3,693	489	4,182

TAZ	County	State	Count ID	Route	EI_AUT	EI_LTRK	EI_HVT	EE_AUT	EE_TRK	AUT	TRK	TOTAL
874	Clark	IN	?	S Westport Rd	230	8	1	0	0	230	9	239
875	Clark	IN	1P	SR-203	876	0	0	0	0	876	0	876
876	Clark	IN	3H	SR-3	1,567	33	67	0	0	1,567	100	1,667
877	Clark	IN	?	S Slate Ford Rd	270	0	0	0	0	270	0	270
878	Clark	IN	10F	US 31	4,508	125	118	0	0	4,508	242	4,750
879	Clark	IN	1B	I-65	14,193	0	8,978	6,518	7,284	20,710	16,262	36,973
880	Clark	IN	?	S Bloomington Trl Rd	527	13	1	0	0	527	14	541
881	Clark	IN	1N	SR-160	1,912	23	12	0	0	1,912	34	1,946
882	Clark	IN	?	Pixley Knob Rd	134	1	1	0	0	134	1	135
883	Clark	IN	1J	SR-60	8,067	181	401	0	0	8,067	582	8,649
884	Floyd	IN	?	Martinsburg Knob Rd	367	0	0	0	0	367	0	367
885	Floyd	IN	2M	SR-335	1,210	15	35	0	0	1,210	50	1,260
886	Floyd	IN	1C	US 150	6,768	188	316	0	0	6,768	504	7,272
887	Floyd	IN	?	Bradford Rd	0	0	0	0	0	0	0	0
888	Floyd	IN	?	Nadorff Rd	0	0	0	0	0	0	0	0
889	Floyd	IN	1H	SR-64	7,806	107	179	0	0	7,806	286	8,092
890	Floyd	IN	?	Old Lanesville Rd	0	0	0	0	0	0	0	0
891	Floyd	IN	1A	I-64	18,470	0	5,031	4,214	5,170	22,685	10,201	32,885
892	Floyd	IN	1E	SR-62	2,603	34	13	0	0	2,603	48	2,651
893	Floyd	IN	1D	SR-11	602	10	5	0	0	602	15	617
894	Floyd	IN	1J	SR-111/River Rd	11,362	138	89	0	0	11,362	227	11,589

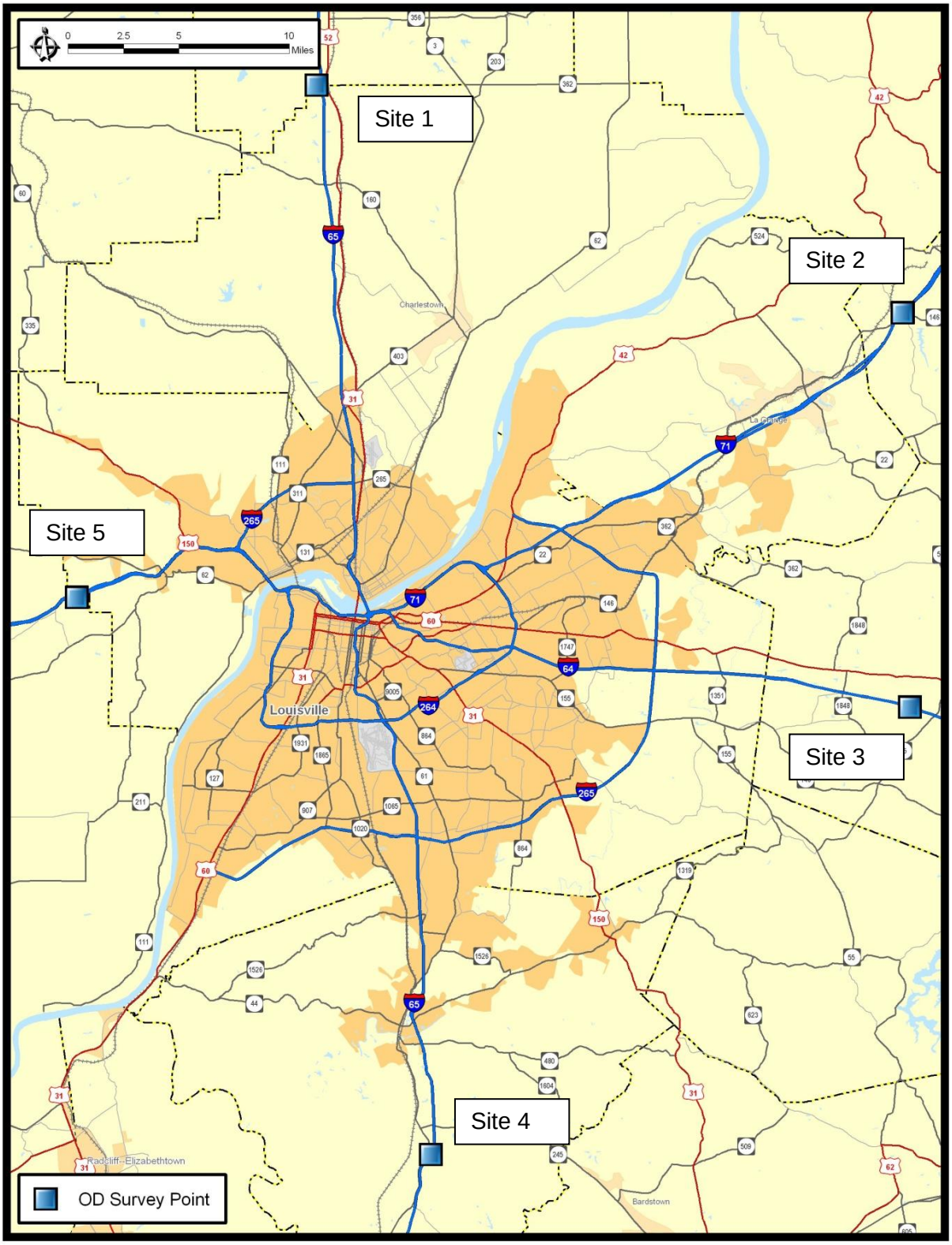
3.5.1 Through Demand Data Collection

This section describes the data and methodology used to develop external-to-external through trips for five major external stations of the LSIORB study area. The external-to-external through trips are developed based on origin-destination survey data and traffic counts collected by The Traffic Group, Inc. in September of 2010. For each external station surveyed, traffic counts and license plate counts as well as the plate-to-count ratio are reported for total vehicles, passenger vehicles, and heavy vehicles. This data is shown in the Table 3.27 and the locations follow in .Figure 3.18.

Table 3.27: Observed Traffic Counts and Recorded License Plates

Station		Traffic Count via Sensor			Plates Recorded & Used			Count / Plates - Expansion		
		Total Count	Passenger Count	HV Count	Total Plates	Passenger Plates	HV Plates	Total Factor	PC Factor	HV Factor
1N	I-65	18,317	10,008	8,309	11,934	6,547	5,387	1.535	1.529	1.542
1S	North	18,445	10,423	8,022	12,526	6,982	5,544	1.473	1.493	1.447
2N	I-71	28,167	16,066	12,101	23,288	18,300	4,988	1.210	0.878	2.426
2S	East	29,095	20,403	8,692	21,867	17,386	4,481	1.331	1.174	1.940
3E	I-64	25,730	19,080	6,650	22,124	18,635	3,489	1.163	1.024	1.906
3W	East	25,309	18,376	6,933	20,338	16,739	3,599	1.244	1.098	1.926
4N	I-65	25,582	15,752	9,830	21,646	14,486	7,160	1.182	1.087	1.373
4S	South	26,081	15,101	10,980	12,246	12,246	6,402	2.130	1.233	1.715
5E	I-64	15,920	10,210	5,710	9,823	7,433	2,390	1.621	1.374	2.389
5W	West	15,826	11,657	4,169	8,680	6,493	2,187	1.823	1.795	1.906
Total		**228,472**	**147,076**	**81,396**	**164,472**	**125,247**	**45,627**	**1.389**	**1.174**	**1.784**

Figure 3.18: Origin Destination Survey Locations



Results from the license plate recognition and matching survey were adjusted for study area inbound and outbound movements and factored to match the recorded traffic count data. Expansion factors and the fratar process are used to adjust the survey license plate data into balanced external through movements between the five external stations for both passenger vehicles and heavy vehicles. Note that heavy vehicles include both light and heavy trucks. The below sections describe the procedures for developing external-to-external through trips for passenger and heavy vehicles.

3.5.2 Through Passenger Vehicles Demand

The origin-destination survey conducted by The Traffic Group, Inc. provided data on external trip movements by direction including external-to-external (EE) and external-to-internal (EI) movements for passenger vehicles. This data is shown in the Table 3.28. The license plates were matched for at the first and last location only throughout the 24-hour period. Thus, some illogical movements between the directional external stations are recorded. For example, the southbound trips from external station 1 (1S) going to southbound station 2 (2S) or to northbound station 4 (4N) is not a direct movement but there are other external-to-internal movements not recorded within these two endpoints that compose this trip chain. Therefore, these trips are considered EI trips. Similarly, the matrix diagonal highlighted in light orange are EI trips where a license plate was recorded initially but no match was found. In other words, a trip entered or exited the study area but did not return.

Table 3.28: Directional External Passenger Vehicle Matched License Plates

	1N	1S	2N	2S	3E	3W	4N	4S	5E	5W	Total
1N	4,844	778	142	79	151	105	82	110	101	155	6,547
1S	906	3,580	141	59	817	80	67	920	107	305	6,982
2N	176	56	13,278	4,048	124	136	82	147	95	158	18,300
2S	210	61	6,897	8,291	262	103	101	1,005	92	364	17,386
3E	209	60	163	117	13,029	4,605	101	115	85	151	18,635
3W	716	55	268	93	5,980	8,754	67	157	85	564	16,739
4N	1,131	74	1,328	94	225	91	7,806	3,494	81	162	14,486
4S	176	55	226	63	134	72	2,434	8,886	88	112	12,246
5E	369	113	423	76	614	97	70	128	4,009	1,534	7,433
5W	198	66	138	61	130	65	58	76	1,063	4,638	6,493
Total	8,935	4,898	23,004	12,981	21,466	14,108	10,868	15,038	5,806	8,143	125,247

There are a total of 125,247 passenger vehicle trips recorded by the origin-destination license plate matching survey. In comparison to Table 3.27, the sum of the rows (productions) match the number of plates recorded for passenger vehicles. The sum of the columns (attractions) does not match the number of plates recorded and shows an imbalance of trips. The trip imbalance could be a result of the low plate matching rate for external station five. Additional details can be seen in the Automatic License Plate Recognition and Origin & Destination Study report developed by The Traffic Group, Inc.

The directional external passenger vehicle trips were condensed to only the logical external station movements between the five external stations. Based on the location of the stations, the locations of 1S, 2S, 3W, 4N, and 5E are entry points to the study area and the locations of 1N,

2N, 3E, 4S, and 5W are exit points to the study area. A matrix table was developed that includes the survey external trips from entry points to exit points for passenger vehicles. This table is shown in Table 3.29.

Table 3.29: External Passenger Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	906	141	817	920	305	3,089
2S	210	6,897	262	1,005	364	8,738
3W	716	268	5,980	157	564	7,685
4N	1,131	1,328	225	3,494	162	6,340
5E	369	423	614	128	1,534	3,068
Total	3,332	9,057	7,898	5,704	2,929	28,920

The external passenger vehicle trips were further condensed to only the EE trips between the five external stations and all EI trips were removed. See Table 3.30.

Table 3.30: External to External Passenger Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	0	141	817	920	305	2,183
2S	210	0	262	1,005	364	1,841
3W	716	268	0	157	564	1,705
4N	1,131	1,328	225	0	162	2,846
5E	369	423	614	128	0	1,534
Total	2,426	2,160	1,918	2,210	1,395	**10,109**

The EE trips were then expanded to match the observed counts using expansion factors. The expansion factors are shown in Table 3.27 as the count-to-plate ratios. Table 3.31 shows the expansion of the EE productions and attractions. Note that external station 2N has a decreasing expansion rate. The issue of the decreasing expansion rate for station 2N (attraction) as well as the imbalance of the attraction trip totals (Table 3.30) to the matched plates (Table 3.28) results in some uncertainty with the attraction trips. Therefore, due to more confidence in the production data, the expanded external trip productions are used to fratar the survey EE passenger trips to the expanded EE trips to be used in the LSIORB travel demand model.

Table 3.31: Expanded Passenger Vehicle External to External Trip Productions and Attractions

Productions				Attractions			
	Survey EE Trips	Expansion Factor	Expanded Productions		Survey EE Trips	Expansion Factor	Expanded Attractions
1S	2,183	1.473	3,259	**1N**	2,426	1.529	3,708
2S	1,841	1.174	2,160	**2N**	2,160	0.878	1,896
3W	1,705	1.098	1,872	**3E**	1,918	1.024	1,964
4N	2,846	1.087	3,095	**4S**	2,210	1.233	2,725
5E	1,534	1.374	2,107	**5W**	1,395	1.795	2,504
Total	**10,109**	n/a	**12,493**	**Total**	**10,109**	n/a	**12,798**

The TransCAD modeling software was used to fratar the raw survey data of EE trips (Table 3.30) with the sum of the expanded EE productions (Table 3.31) for passenger vehicles. The result of the fratar procedure is a daily external-to-external trip matrix. As shown in Table 3.32 there are approximately 12,500 external through trips for passenger vehicles in the LSIORB study area.

Table 3.32: LSIORB Passenger Vehicle External to External Trips

	1	2	3	4	5	Total
1	0	187	870	1,558	644	3,259
2	275	0	191	1,167	527	2,160
3	805	209	0	157	701	1,872
4	1,484	1,211	165	0	235	3,095
5	695	553	645	214	0	2,107
Total	3,258	2,160	1,872	3,095	2,107	**12,493**

3.5.3 External – Internal Trip Making (EI)

Auto External – Internal trip making is divided into two components: work and non-work related. The LSIORB TOD Model requires a total auto EI at each external station. The model distributes the EI traffic volume into a work and non-work component based on a fixed factor that is used in the KIPDA regional model. The distribution is applied to all external stations. The attractions are allocated based on the internal HBW and HBO attractions and balanced to the external productions at the cordon line. The distribution of the EI trips is based on the application of a gravity model that utilizes the same friction factors applied to the internal trip purposes.

3.5.4 External Truck Trips

The origin-destination survey conducted by The Traffic Group, Inc. provided data on external trip movements by direction including external-to-external (EE) and external-to-internal (EI) movements for heavy vehicles. Heavy vehicles include both light and heavy trucks. This data is shown in the Table 3.33. As with the passenger vehicle trips, the heavy vehicle license plates were matched for at the first and last location only throughout the 24-hour period. Thus, illogical movements between the directional external stations are recorded. For example, the

southbound trips from external station 1 (1S) going to southbound station 2 (2S) or to northbound station 4 (4N) is not a direct movement but there are other external-to-internal movements not recorded within these two endpoints that compose this trip chain. Therefore, these trips are considered EI trips. Similarly, the matrix diagonal highlighted in light orange are EI trips where a license plate was recorded initially but no match was found. In other words, a trip entered or exited the study area but did not return.

Table 3.33: Directional External Heavy Vehicle Matched License Plates

	1N I-65 IN	1S I-65 IN	2N I-71 KY	2S I-71 KY	3E I-64 KY	3W I-64 KY	4N I-65 KY	4S I-65 KY	5E I-64 IN	5W I-64 IN	Total
1N I-65 IN	4,733	240	55	29	68	29	57	109	21	46	5,387
1S I-65 IN	496	2,351	142	40	681	52	59	1,517	29	177	5,544
2N I-71 KY	65	42	4,291	286	34	25	58	122	20	44	4,987
2S I-71 KY	125	36	484	1,920	75	27	72	1,448	32	261	4,480
3E I-64 KY	98	35	53	28	2,688	415	27	51	21	73	3,489
3W I-64 KY	739	45	109	22	388	1,732	34	133	28	369	3,599
4N I-65 KY	1,685	82	1,844	72	115	58	2,785	409	28	82	7,160
4S I-65 KY	154	55	174	48	46	38	388	5,446	29	24	6,402
5E I-64 IN	199	30	420	28	403	28	20	60	1,005	197	2,390
5W I-64 IN	87	20	86	18	45	17	18	19	147	1,730	2,187
Total	8,381	2,936	7,658	2,491	4,543	2,421	3,518	9,314	1,360	3,003	45,625

There are a total of 45,625 heavy vehicle trips recorded by the origin-destination license plate matching survey. In comparison to Table 3.28, the sum of the rows (productions) match the number of plates recorded for heavy vehicles. The sum of the columns (attractions) does not match the number of plates recorded and shows an imbalance of trips. The trip imbalance could be a result of the low plate matching rate for external station five. Additional details can be seen in the Automatic License Plate Recognition and Origin & Destination Study report developed by The Traffic Group, Inc.

The directional external heavy vehicle trips were condensed to only the logical external station movements between the five external stations. Based on the location of the stations, the locations of 1S, 2S, 3W, 4N, and 5E are entry points to the study area and the locations of 1N, 2N, 3E, 4S, and 5W are exit points to the study area. A matrix table was developed that includes the survey external trips from entry points to exit points for heavy vehicles. This table is shown in Table 3.34.

Table 3.34: External Heavy Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	496	142	681	1,517	177	3,013
2S	125	484	75	1,448	261	2,393
3W	739	109	388	133	369	1,738
4N	1,685	1,844	115	409	82	4,135
5E	199	420	403	60	197	1,279
Total	3,244	2,999	1,662	3,567	1,086	12,558

The external heavy vehicle trips were further condensed to only the EE trips between the five external stations and all EI trips were removed. See Table 3.35.

Table 3.35: External to External Heavy Vehicle Matched License Plates

	1N	2N	3E	4S	5W	Total
1S	0	142	681	1,517	177	2,517
2S	125	0	75	1,448	261	1,909
3W	739	109	0	133	369	1,350
4N	1,685	1,844	115	0	82	3,726
5E	199	420	403	60	0	1,082
Total	2,748	2,515	1,274	3,158	889	**10,584**

The EE trips were then expanded to match the observed counts using expansion factors. The expansion factors are shown in Table 3.28 as the count-to-plate ratios. Table 3.36 shows the expansion of the EE productions and attractions. Similar to the issues with the heavy vehicle trip attractions and due to more confidence in the production data, the expanded external trip productions are used to fratar the survey EE heavy trips to the expanded EE trips to be used in the LSIORB travel demand model.

Table 3.36: Expanded Heavy Vehicle External to External Trip Productions and Attractions

Productions				**Attractions**			
	Survey EE Trips	**Expansion Factor**	**Expanded Productions**		**Survey EE Trips**	**Expansion Factor**	**Expanded Attractions**
1S	2,517	1.447	3,642	**1N**	2,748	1.542	4,239
2S	1,909	1.940	3,704	**2N**	2,515	2.426	6,103
3W	1,350	1.926	2,601	**3E**	1,274	1.906	2,428
4N	3,726	1.373	5,115	**4S**	3,158	1.715	5,416
5E	1,082	2.389	2,585	**5W**	889	1.906	1,695
Total	**10,584**	n/a	**17,647**	**Total**	**10,584**	n/a	**19,880**

The TransCAD modeling software was used to fratar the raw survey data of EE trips (Table 9) with the sum of the expanded EE productions (Table 10) for heavy vehicles. The result of the

fratar procedure is a daily external-to-external trip matrix. As shown in Table 3.37 there are approximately 17,600 external through trips for heavy vehicles in the LSIORB study area.

Table 3.37: LSIORB Heavy Vehicle External to External Trips

	1	2	3	4	5	Total
1	0	148	1,028	2,071	395	3,642
2	158	0	150	2,623	773	3,704
3	1,003	162	0	259	1,176	2,601
4	2,111	2,535	229	0	241	5,115
5	371	860	1,193	161	0	2,585
Total	3,643	3,705	2,601	5,113	2,585	**17,647**

3.6 Truck Model

The previous section discussed the development of the external-external truck movements. The LSIORB TOD Model includes the movement of trucks that are internal to the region and External-Internal which we are calling the truck model. The development of the Sub-Model included the following steps:

- Development of seed truck trip table
- Matrix adjustment using ODME

For the LSIORB TOD Truck Model, all trucks are combined into one vehicle type. The trucks modeled include multi unit vehicles, or heavy trucks, and single unit vehicles with more than 4 tires. The truck model does not include the movement of commercial vehicles which are represented in the model as part of the NHB trip purpose.

3.6.1 Seed Truck Trip Table

The first step in the development of the Internal and External-Internal Truck trip tables was the development of a seed trip table for 2007.

3.6.1.1 Internal Truck Movements

The zonal generation of the single unit, and multi unit truck trips is estimated using regression models that input the zonal demographics and calibrated parameters. The productions and attractions use the same model coefficients.

The current state of the practice for truck models is to use the Quick Response Freight Manual II, FHWA (2007) for trip generation. These coefficients were originally calibrated from data collected in Phoenix, Arizona in the 1990s. The QRFM coefficients are shown in Figure 3.19.

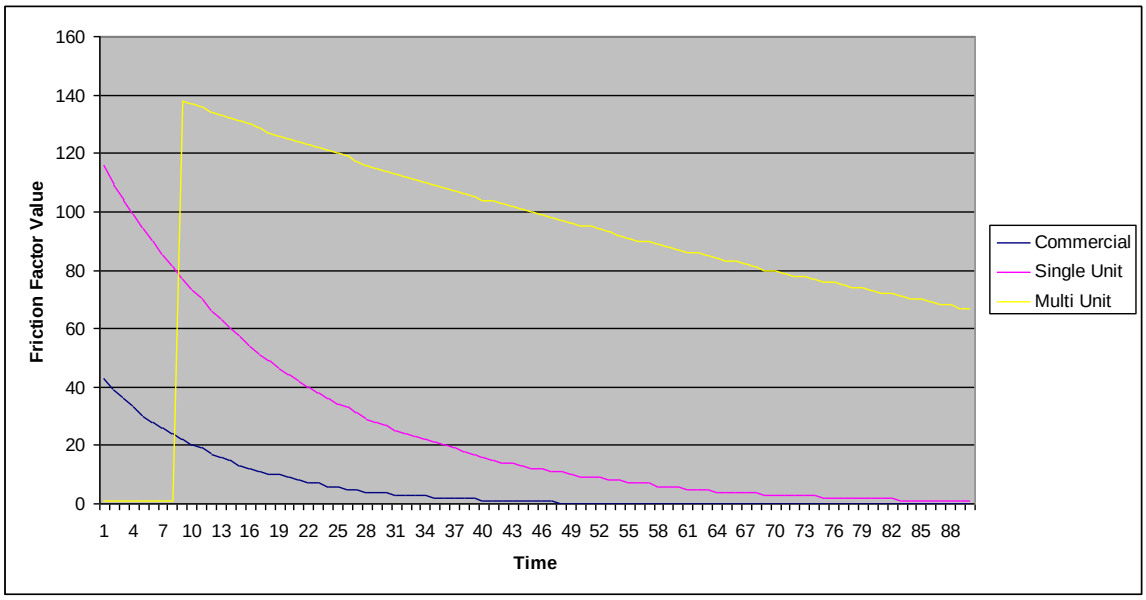
Figure 3.19: Quick Response Freight Manual - Generation Rates (Source: QRFM, Table 4.1)

Generation Variable (Employment or Households)	Four-Tire Trucks	Single Unit Trucks (6+ Tires)	Combination Trucks
Agriculture, Mining, and Construction	1.110	0.289	0.174
Manufacturing, Transportation/ Communications/Utilities, and Wholesale	0.938	0.242	0.104
Retail Trade	0.888	0.253	0.065
Office and Services	0.437	0.068	0.009
Households	0.251	0.099	0.038

The second phase of the internal purpose was trip distribution, similar to a person model. In the distribution phase, the zonal productions is linked to an attraction using a vehicle specific gravity model. The gravity models differ in the friction factors used by vehicle type.

The shape of the curves is different by vehicle type to differentiate the types of trips made. Typically, commercial trips are shorter and thus the curve decreases at a faster rate as compared to the single unit trucks. Trips made by multi unit trucks within a region are generally longer (distribution center based deliveries rather than door to door for example) and thus the curve allows for longer trips. No local information is available to calibrate the models, but QRFM provides some guideline average trip lengths by vehicle type to show the relative differences.

Figure 3.20: QRFM Friction Factor Functions by Truck Type and Average Trip Length (Source: QRFM, Table 4.2)



	Light Truck	Medium Truck	Heavy Truck
Observed Trip Length (Miles)	No data	27.51	30.81
Modeled Trip Length (Miles)	22.34	27.53	28.29

3.6.1.2 External – Internal Truck Trips

As with the EI auto trips, the volume at the external station serves at the productions for the movement of trucks with one end of the trip internal to the LSIORB region. The attraction models use the same parameters as the internal truck movements and are balanced to the total external volume.

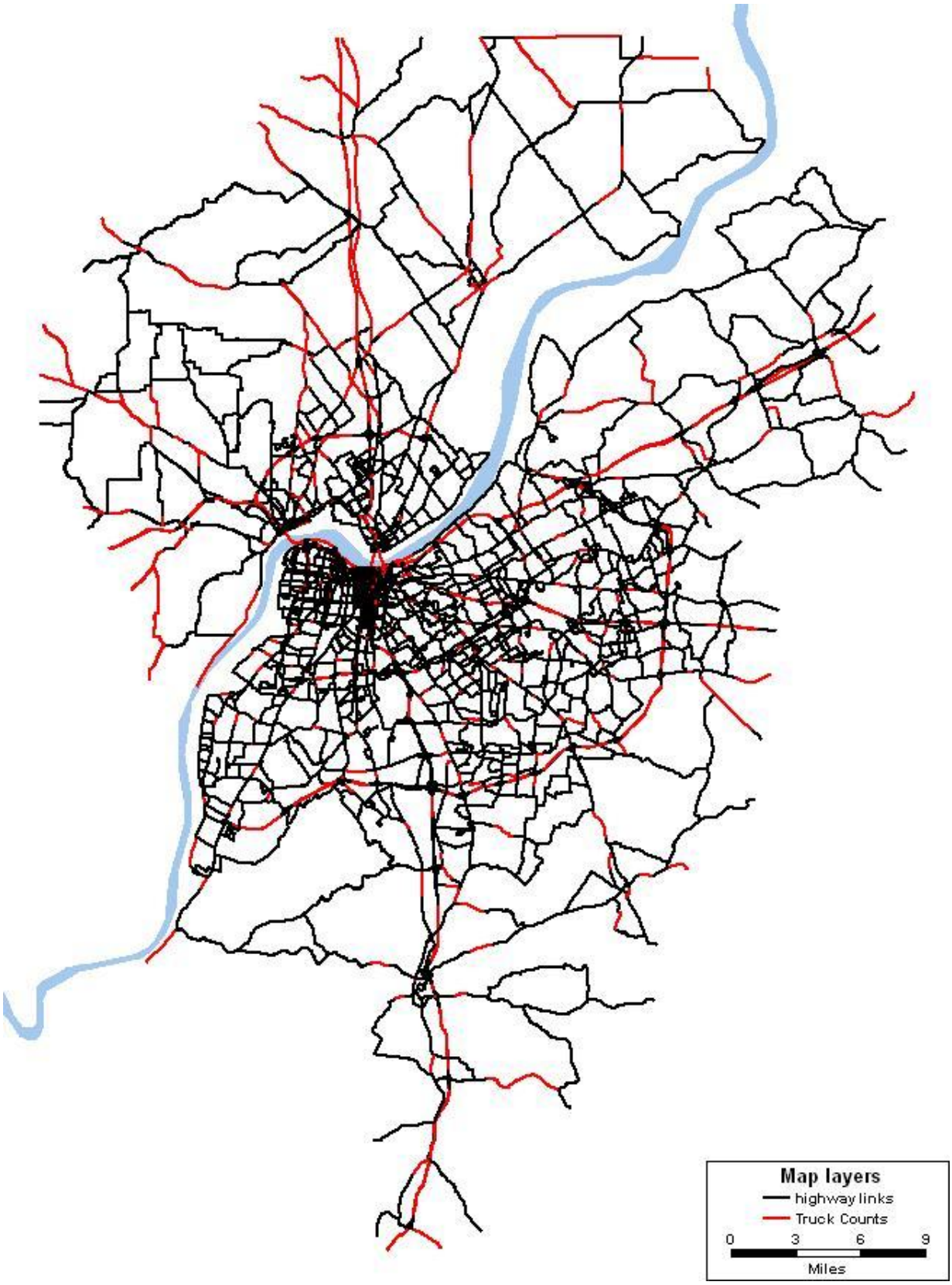
3.6.1.3 Total Trip Table

The internal, external-internal and external-external truck trips were aggregated to a single truck trip table. In the development of the LSIORB TOD Model, this trip table was disaggregated in to time periods (See Section 3.7) and assigned simultaneously with the auto trips. The generation and distribution parameters were adjusted as part of a coarse validation.

3.6.2 Matrix Adjustment

Based on the modeled truck trip table developed for 2007, an ODME process was completed to create a more accurate truck trip table for assignment in the model. In total, over 550 truck counts were identified as part of the count database created in Phase I. Because of inconsistency in the reporting of truck data between Indiana and Kentucky, it was only possible to develop a combined truck count rather than distinguish between single unit and multi unit vehicles (Figure 3.21).

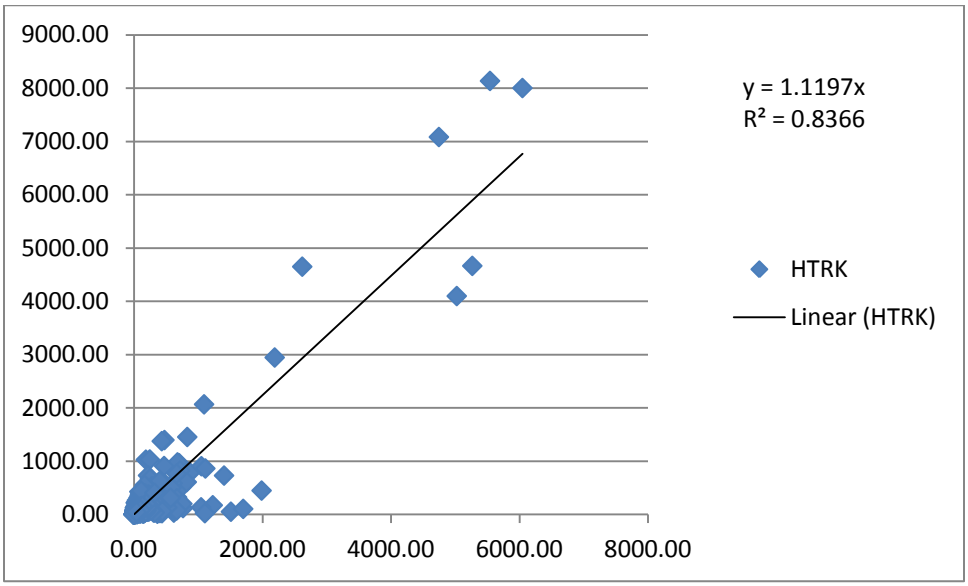
Figure 3.21: LSIORB 2007 Truck Count Locations



The resulting intra and external-internal truck trip tables were added to the external through trips and applied to the ODME process using the identified counts. The external through and external-internal productions were held constant allowing the internal end of the EI and internal trips to change.

An assessment was made of the resulting ODME trip table versus the zonal generation results. The resulting trip table marginals from the ODME and modeled trip table were compared and the resulting r-squared was greater than 0.8.

Figure 3.22: ODME vs. Modeled Trip Table Marginals



3.7 Time of Day Model

A key feature of the LSIORB TOD Model is the disaggregation of the daily trip tables created by mode choice into time of day periods for traffic assignment. The benefit to this design is that congestion in the system is better represented and the impact on route choice. Further, it provides for additional policy sensitivity in the model.

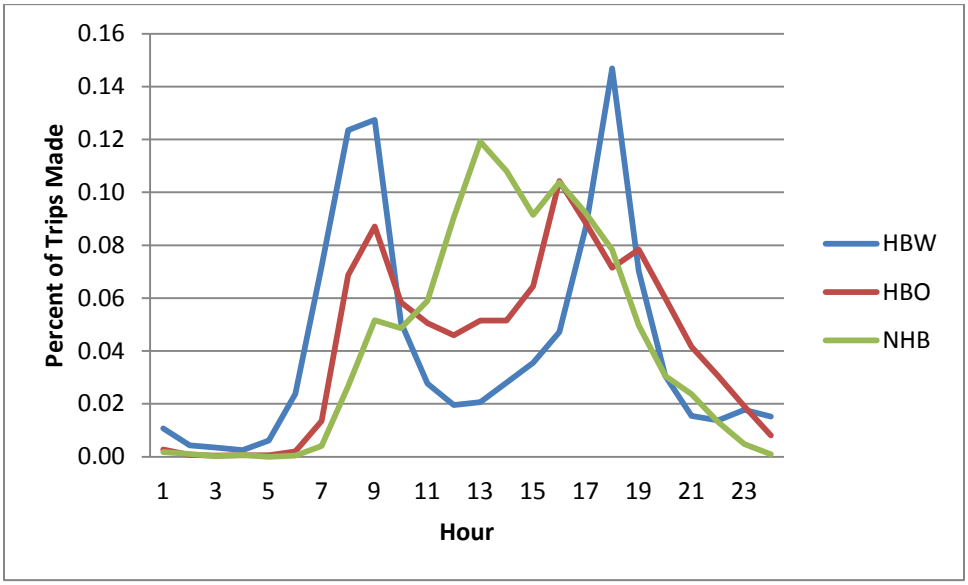
3.7.1 Period Definition

In defining periods for a Time of Day Model, the standard approach is to define a period to be at least one hour in length. In the case of the LSIORB TOD Model, the periods were defined based on the following criteria:

- Capturing majority of directional commuting trips
- Period allowed for all trips to be completed (period longer than longest trip)
- Capturing activities of trip purposes

Figure 3.23 shows the distribution of trips by trip purpose. From the graph, the prominence of work trips being made in the am peak and pm peak periods becomes clear. As well, the high activity of NHB and HBO activity being made between the peak periods becomes clear.

Figure 3.23: Distribution of Internal Trips by Hour (Source: 2000 KIPDA Household Survey)



Based on a review of the information presented above, the following periods were identified for the LSIORB TOD Model:

- AM Period: 6am to 9am (3 Hours)
- Mid – Day: 9am to 3pm (6 Hours)
- PM Period: 3pm to 6pm (3 Hours)
- Overnight: 6pm to 6am (12 Hours)

Through the development of the LSIORB TOD Model, it was decided that the AM and PM periods would be further disaggregated to individual hours to fully capture the peak congestion in the system.

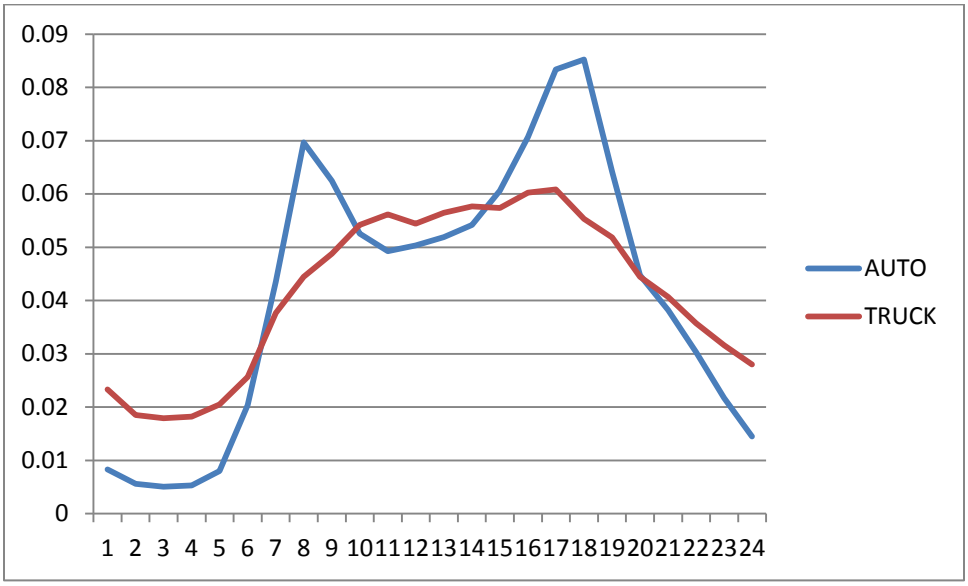
Based on these periods, the directionality of the trips were defined using the household travel survey data. For home based trips, the orientation of trips from home to attraction and attraction to home were defined. This creates the directional movement of trips observed in reality in the model. Table 3.38: Directional Trip Purpose Diurnal Factors provides the distribution by direction by purpose. When reviewing the information, the direction of travel from home to work (DEP) for HBW appears in the AM Period with very low percentages of trips in the work to home (RTN) direction. In the PM period, this pattern is reversed as expected.

Table 3.38: Directional Trip Purpose Diurnal Factors (Source: 2000 KIPDA Household Survey)

Hour	HBW	HBO	NHB	DEP_HBW	RTN_HBW	DEP_HBO	RTN_HBO	TOTAL
0	1.07%	0.27%	0.17%	0.16%	0.91%	0.03%	0.24%	0.41%
1	0.43%	0.07%	0.11%	0.04%	0.40%	0.00%	0.07%	0.15%
2	0.34%	0.04%	0.02%	0.11%	0.24%	0.01%	0.03%	0.10%
3	0.25%	0.06%	0.06%	0.18%	0.07%	0.02%	0.04%	0.10%
4	0.62%	0.06%	0.00%	0.54%	0.07%	0.05%	0.01%	0.16%
5	2.37%	0.20%	0.05%	2.14%	0.24%	0.18%	0.01%	0.61%
6	7.19%	1.34%	0.40%	6.78%	0.42%	1.28%	0.06%	2.32%
7	12.36%	6.87%	2.67%	11.85%	0.51%	6.56%	0.30%	6.98%
8	12.74%	8.70%	5.16%	12.25%	0.49%	7.69%	1.01%	8.68%
9	5.07%	5.84%	4.87%	4.66%	0.42%	4.86%	0.98%	5.45%
10	2.77%	5.05%	5.90%	2.17%	0.60%	3.69%	1.37%	4.79%
11	1.96%	4.60%	9.05%	1.23%	0.72%	2.80%	1.79%	5.12%
12	2.07%	5.15%	11.92%	0.80%	1.27%	2.37%	2.78%	6.14%
13	2.81%	5.15%	10.80%	1.56%	1.25%	2.28%	2.87%	6.03%
14	3.55%	6.45%	9.14%	1.81%	1.74%	2.64%	3.81%	6.50%
15	4.71%	10.43%	10.38%	1.32%	3.39%	2.26%	8.16%	9.24%
16	8.70%	8.83%	9.20%	1.49%	7.21%	2.36%	6.47%	8.89%
17	14.69%	7.15%	7.82%	0.98%	13.71%	2.31%	4.84%	8.87%
18	7.03%	7.84%	4.97%	0.54%	6.49%	3.53%	4.32%	6.98%
19	3.06%	5.99%	3.05%	0.56%	2.50%	2.83%	3.16%	4.68%
20	1.54%	4.16%	2.37%	0.25%	1.29%	0.82%	3.33%	3.19%
21	1.38%	3.05%	1.32%	0.27%	1.11%	0.41%	2.65%	2.29%
22	1.78%	1.91%	0.48%	0.65%	1.12%	0.28%	1.62%	1.54%
23	1.52%	0.80%	0.09%	0.56%	0.96%	0.09%	0.71%	0.78%

A similar process was completed for the external auto and truck trips. Based on the counts collected as part of the video OD survey, a distribution of auto and truck trips entering the region was defined and used to generate the period factors for external – external auto and truck as well as the external-internal auto and truck trips.

Figure 3.24: External Auto and Truck Hourly Distributions



3.8 Traffic Assignment

The LSIORB Phase II Model uses a multi-class user equilibrium traffic assignment that relies on a generalized cost impedance function. As described previously in this memo, the free flow travel time is specified in the network as is the generalized cost for each link. The generalized cost is the operating cost per mile plus any tolls added to the network links if included in the scenario. The TransCAD graphical user interface allows the opportunity to apply unique values of time by income group, and for trucks. Operating cost is applied by Auto and Truck. Unique toll rates can be applied for Auto by occupancy and for trucks for peak periods and for mid-day / overnight.

3.8.1 Assignment Fields

The tables below indicate the fields used for each period assignment.

Table 3.39: Assignment Parameters

Field	AM (1 – 3)	MD	PM (1-3)_	NT
Free Flow Time	AB_AFF_Time / BA_AFF_Time			
Capacity	AB_HR_CAP / BA_HR_CAP	AB_MD_CAP / BA_MD_CAP	AB_HR_CAP / BA_HR_CAP	AB_NT_CAP / BA_NT_CAP
Alpha	ALPHA			
Beta	BETA			

Field Descriptions: AB_AFF_Time / BA_AFF_Time: Adjusted free flow travel time based on speed limit, FHWA free flow adjustment plus uniform signal delay.
AB_HR_CAP / BA_HR_CAP: Directional hourly capacity.
AB_MD_CAP / BA_MD_CAP: Mid-Day (6 hour) capacity
AB_NT_CAP/ BA_NT_CAP: Overnight (12 hour) capacity
Alpha and Beta: Volume Delay Function parameters

The LSIORB TOD Model was modified to allow the user to test the sensitivity of tolls only in the assignment process and not in the feedback through distribution and mode choice. To accommodate this in the network fields, a second set of generalized cost fields (aGC_*) was added. When tolls are not considered as part of the scenario, either in distribution and mode choice and assignment, the parameters shown in Table 3.40 are appropriate.

If tolling is considered in the distribution and mode choice as well as assignment, the parameters in

Table 3.41 are read by the model. When tolling is only considered as part of assignment, the model reads the GC fields for trip distribution and mode choice and aGC for assignment. Finally, when a free scenario, the GC and aGC fields are equal.

Table 3.40: No Toll Generalized Cost by Trip Purpose

Core Name	AM / PM Peak Periods	MD / NT Periods
HBW1_DA (6-9)	GC_pkDA	GC_mdDA
HBW1_SR2 (6-9)	GC_pkSR2	GC_mdSR2
HBW1_SR3 (6-9)	GC_pkSR3	GC_mdSR3
HBW2_DA (6-9)	GC_pkDA	GC_mdDA
HBW2_SR2 (6-9)	GC_pkSR2	GC_mdSR2
HBW2_SR3 (6-9)	GC_pkSR3	GC_mdSR3
HBW3_DA (6-9)	GC_pkDA	GC_mdDA
HBW3_SR2 (6-9)	GC_pkSR2	GC_mdSR2
HBW3_SR3 (6-9)	GC_pkSR3	GC_mdSR3
EIIEW (6-9)	GC_pkDA	GC_mdDA
EIIEO (6-9)	GC_pkDA	GC_mdDA
LtTRK (6-9)	GC_LtTRK	GC_LtTRK
HvTRK (6-9)	GC_HvTRK	GC_HvTRK
EI_LtTRK (6-9)	GC_LtTRK	GC_LtTRK
EI_HvTRK (6-9)	GC_HvTRK	GC_HvTRK
HBO1_DA (6-9)	GC_pkDA	GC_mdDA
HBO1_SR2 (6-9)	GC_pkSR2	GC_mdSR2
HBO1_SR3 (6-9)	GC_pkSR3	GC_mdSR3
HBO2_DA (6-9)	GC_pkDA	GC_mdDA
HBO2_SR2 (6-9)	GC_pkSR2	GC_mdSR2
HBO2_SR3 (6-9)	GC_pkSR3	GC_mdSR3
HBO3_DA (6-9)	GC_pkDA	GC_mdDA
HBO3_SR2 (6-9)	GC_pkSR2	GC_mdSR2
HBO3_SR3 (6-9)	GC_pkSR3	GC_mdSR3
NHB1_DA (6-9)	GC_pkDA	GC_mdDA
NHB1_SR2 (6-9)	GC_pkSR2	GC_mdSR2
NHB1_SR3 (6-9)	GC_pkSR3	GC_mdSR3

Core Name	AM / PM Peak Periods	MD / NT Periods
NHB2_DA (6-9)	GC_pkDA	GC_mdDA
NHB2_SR2 (6-9)	GC_pkSR2	GC_mdSR2
NHB2_SR3 (6-9)	GC_pkSR3	GC_mdSR3
NHB3_DA (6-9)	GC_pkDA	GC_mdDA
NHB3_SR2 (6-9)	GC_pkSR2	GC_mdSR2
NHB3_SR3 (6-9)	GC_pkSR3	GC_mdSR3
Auto EE	GC_pkDA	GC_mdDA
Truck EE	GC_HvTRK	GC_HvTRK

Table 3.41: Toll Generalized Costs by Trip Purpose

Core Name	AM / PM Peak Periods	MD / NT Periods
HBW1_DA (6-9)	AGC_pkDA	AGC_mdDA
HBW1_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
HBW1_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
HBW2_DA (6-9)	AGC_pkDA	AGC_mdDA
HBW2_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
HBW2_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
HBW3_DA (6-9)	AGC_pkDA	AGC_mdDA
HBW3_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
HBW3_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
EIIEW (6-9)	AGC_pkDA	AGC_mdDA
EIIEO (6-9)	AGC_pkDA	AGC_mdDA
LtTRK (6-9)	AGC_LtTRK	AGC_LtTRK
HvTRK (6-9)	AGC_HvTRK	AGC_HvTRK
EI_LtTRK (6-9)	AGC_LtTRK	AGC_LtTRK
EI_HvTRK (6-9)	AGC_HvTRK	AGC_HvTRK
HBO1_DA (6-9)	AGC_pkDA	AGC_mdDA
HBO1_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
HBO1_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
HBO2_DA (6-9)	AGC_pkDA	AGC_mdDA
HBO2_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
HBO2_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
HBO3_DA (6-9)	AGC_pkDA	AGC_mdDA
HBO3_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
HBO3_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
NHB1_DA (6-9)	AGC_pkDA	AGC_mdDA
NHB1_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
NHB1_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
NHB2_DA (6-9)	AGC_pkDA	AGC_mdDA
NHB2_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2

Core Name	AM / PM Peak Periods	MD / NT Periods
NHB2_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
NHB3_DA (6-9)	AGC_pkDA	AGC_mdDA
NHB3_SR2 (6-9)	AGC_pkSR2	AGC_mdSR2
NHB3_SR3 (6-9)	AGC_pkSR3	AGC_mdSR3
Auto EE	AGC_pkDA	AGC_mdDA
Truck EE	AGC_HvTRK	AGC_HvTRK

3.8.2 Value of Time and Passenger Car Equivalents

The TransCAD MMA Generalized Cost assignment methodology converts the link level travel time to a cost using the value of time by matrix core. The graphical user interface allows the use of unique values of time by income group for the auto trips, and unique values of time for light truck and heavy truck flows.

A passenger car equivalent is used for the truck purposes including the LtTRK and HvTRK flows. The default PCE parameter is 2.0 which is reflective of the relatively flat geography in the Louisville region.

3.8.3 Assignment Convergence

Each period assignment is set to have a convergence closure of 0.001 and to be reached by 100 iterations. Through the validation process, the assignments have been converging before the maximum iteration.

3.8.4 Volume Delay Functions

The LSIORB TOD Model utilizes a traditional volume delay function using the BPR formulation with the Alpha and Beta parameters. To enhance the model's sensitivity to congestion, the traditional 0.15 and 4.0 parameters were replaced with recommended values from the Highway Capacity Manual (HCM 2000, Exhibit C30-1 and C30-2).

Table 3.42: Volume Delay Function Parameters

Facility Type	Description	Alpha	Beta
11	Freeway	0.25	9
12	HOV	0.25	9
13	Low Capacity Freeway	0.1	10
17	Collector – Distributor	0.25	9
21	Divided Arterial	0.34	4
22		0.34	4
23		0.75	5
24		1.16	6
25		1.16	6
31	Undivided Arterial	0.7	5
32		0.7	5
33		0.7	5
34		0.7	5

Facility Type	Description	Alpha	Beta
35		0.7	5
36		0.7	5
37		0.7	5
38		0.7	5
41	Collector	0.7	5
43		0.7	5
45		0.7	5
46		0.7	5
49		0.7	5
51	Centroid Connectors	0.15	4
52	Externals	0.15	4
61	One Way Roads	0.38	5
62		0.7	5
63		1	5
64		1	5
65		0.34	4
66		0.74	5
67		0.74	5
68		1.16	6
71	High Speed – Freeway to Surface	0.1	10
72	Low Speed – Freeway to Surface	0.1	10
73	High Speed – Freeway to Freeway	0.1	10
74	Low Speed – Freeway - Freeway	0.1	10
88	Clark Memorial	6	10

4. Validation

The process of model validation is different from model calibration. The previous sections of this report have provided information on the model design and calibration of the model parameters. The Model Validation and Reasonableness Checking Manual, TMIP (2010) defines the validation process as:

> Model Validation: In order to test the ability of the model to predict future behavior, validation requires comparing the model predictions with information other than that used in estimating the model. This step is typically an iterative process linked to model calibration. It involves checking the model results against observed data and adjusting parameters until model results fall within an acceptable range of error. (Source: Validation Manual, pg 1-2)

For purposes of model validation, we have identified independent data sources for the trip distribution and traffic assignment phases of the model.

The results of the comparisons are presented in Section 4.2.

4.1 Validation Adjustments

The validation process is an iterative process where all elements of the model must be reviewed for reasonableness and comparison to predefined evaluation criteria. As part of the validation process, several of the calibrated parameters were adjusted to improve the validation and forecast ability of the model.

4.1.1 Trip Generation

Because trip generation has the biggest influence on regional traffic volumes, this step in the model is often the focus of adjustment for global level validation adjustments. Two areas of trip generation were considered during the validation and they include the production rates and trip making in Floyd County.

4.1.1.1 Production Rates

The source of the trip production rates in the LSIORB TOD Model was the 2000 KIPDA Household Survey and subsequent analysis by KIPDA staff. The production rates are the same as those used in the 09PLANA KIPDA regional model. During the validation effort, the VMT error by county was evaluated, and it was found that the original rates were creating significant error in VMT by county. As a result, a set of adjustment factors were developed and applied to the internal trip productions by county until more reasonable county level VMT error was established.

Table 4.1: Production Adjustment Factors

COUNTY		STATE	HBW	HBO	NHB
18019	CLARK	IN	1.35	1.35	1.35
18043	FLOYD	IN	1.35	1.35	1.35
21029	BULLITT	KY	1	0.5	0.5
21111	JEFFERSON	KY	1.5	1.5	1.5
21185	OLDHAM	KY	1.25	1	1

4.1.1.2 Floyd County

During the validation of the traffic assignment phase of the model, I-265 in Indiana between I-65 and I-64 was observed to be low compared to count as were the north / south routes providing access to the freeway. To account for the lower model demand compared to county with Floyd County, IN, the attractions within the county were factored up prior to trip balancing. This made the have a heavier weighting in the balancing process since the number of trips was not impacted. For all trip purposes, the attractions were increased by 25%.

4.1.2 Trip Distribution

The results of the trip distribution model were evaluated based on comparing the home based work distribution to the ACS JTW for the five county region and a set of screen lines defined for the region. Using the Journey to Work data for 2006 to 2008, the pattern of work trips within the county were identified and are presented in Table 4.5. The K-factors were adjusted based on improving the JTW comparison and the screen line validation while maintaining reasonable values.

Typically K-factors are considered a “last resort” of adjustment for the adjustment of trip distribution model once all other variables have been considered. The Louisville region does present a unique case because of its, boundary to travel formed by the Ohio River and focus of jobs and other opportunities in Jefferson County. In future updates to the LSIORB TOD Model, varying the trip generation rates or friction factors by geography in the region may reduce the need for k-factors.

The validated K-factors are presented in Table 4.2. The difference between the methodologies of K-factors used by KIPDA in the regional model is the addition of a K-factor for external – internal trips entering the study area on I-65 to improve loadings on the I-65 river crossing.

Table 4.2: LSIORB TOD Distribution K-Factors

HBW

COUNTY	Jefferson	Bullitt	Oldham	Clark	Floyd
Jefferson	1.5	1.5	1.5	0.32	0.23
Bullitt	1.5	1.5	1.5	0.32	0.23
Oldham	1.5	1.5	1.5	0.32	0.23
Clark	0.32	0.32	0.32	1	1
Floyd	0.23	0.23	0.23	1	1.5

HBO

COUNTY	Jefferson	Bullitt	Oldham	Clark	Floyd
Jefferson	1.5	1.5	1.5	0.24	0.14
Bullitt	1.5	1.5	1.5	0.24	0.14
Oldham	1.5	1.5	1.5	0.24	0.14
Clark	0.24	0.24	0.24	1	1
Floyd	0.14	0.14	0.14	1	1.5

NHB

COUNTY	Jefferson	Bullitt	Oldham	Clark	Floyd
Jefferson	1.5	1.5	1.5	0.24	0.14
Bullitt	1.5	1.5	1.5	0.24	0.14
Oldham	1.5	1.5	1.5	0.24	0.14
Clark	0.24	0.24	0.24	1	1
Floyd	0.14	0.14	0.14	1	1.5

EX

	21111	21029	21185	18019	18043
I-65 (IN)	1	1	1	1	1
I-64 (IN)	0.5	0.5	0.5	1.5	1.5

4.1.3 Traffic Assignment

The calibration and validation of the trip generation and trip distribution parameters has focused on the regional and sub-regional validation. Validation of the traffic assignment phase of the model focuses on the local level or link by link basis. As part of the traffic assignment validation, the following parameters were considered:

- Adjustments to input speeds
- Capacity assumptions

4.1.3.1 Speed Adjustments

Section 3.2.1 has documented the assumptions and methodology for calculating the adjusted free flow speeds. The input to this process was an assumption regarding the speed limit for each link in the network. Since only speed limit data was available from KYTC and not INDOT,

initial runs of the LSIORB TOD Model used assumptions speed limits by facility type and area type where data was not available. During the validation, WSA staff made several fields visits to the study to provide existing posted speed limit data. Particular attention was paid to the I-64 and I-265 routes as well as within the Clarksville and New Albany areas.

4.1.3.2 Capacity Restrictions

The Louisville network has specific locations on the interstate system that are problem areas for congestion. These include:

- I-65
  - South of downtown ("Hospital Curve")
  - I-65 Memorial Bridge
- I-64
  - Cochran Tunnel
  - Sherman Minton Bridge
  - From I-264 to I-65 west of I-65
- CBD
  - Default speed was changed to all non-freeway links within the CBD to 25mph
- Clark Memorial
  - New facility type (FACT) was established for bridge that included a default speed change

For the above sections, a capacity analysis was completed to evaluate the impact of the increase weave sections and reduced lane width and shoulders. To account for the impact to capacity, different volume delay function parameters were applied to the facility type.

4.2 Validation Results

The validation of the LSIORB TOD Model was an iterative process that included completing in excess of sixty validation runs to the model. Figure 4.1 shows the improvement to the validation of the model by plotting the overall percent RMSE for each of the 60+ runs. Percent RMSE is a measure of relative error of the assignment compared to counts so is useful in showing the improvement of the validation.

Figure 4.1: Percent RMSE of LSIORB TOD Validation

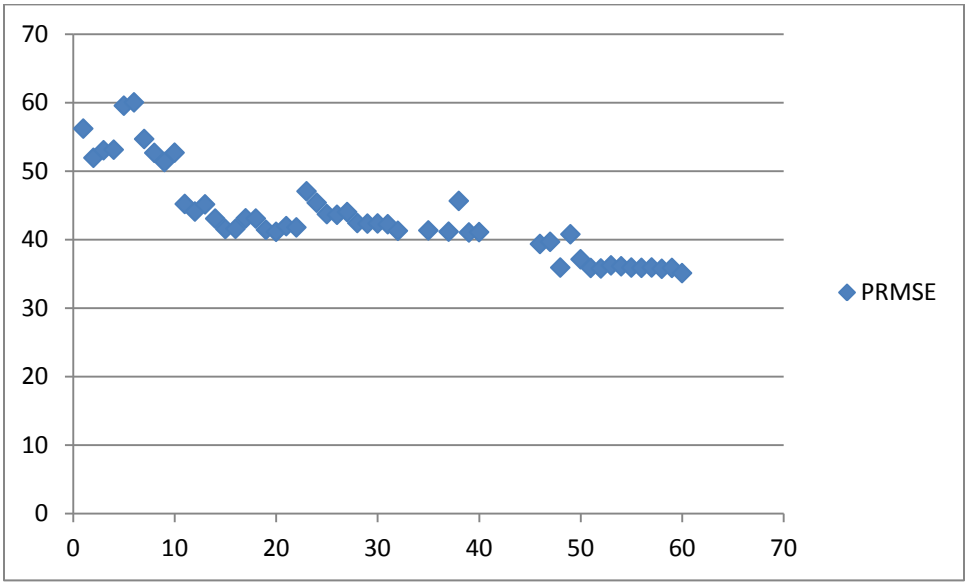


Table 4.3 and Table 4.4 provide a description of the parameters that were adjusted for each validation run. This information is provided to show the depth of the validation exercise and that all portions of the model were examined in a systematic way.

The traffic counts used for the validation of the LSIORB TOD Model are documented in the Phase I LSIORB Project Documentation. In total, over thirteen hundred counts were identified and used for validation purposes. Of that total, 558 included information about truck volumes and 843 included data about hourly traffic patterns.

Table 4.3: LSIORB TOD Validation (Part 1)

#	SE	Person Trip Rates	Truck Trip Rates	Auto FF	Truck FF	VDF	K-factors	Speeds	Externals	Counts	Penalties	Network	Dirunals	US31	Capacities
0		09PlanA		09PlanA	QRFM (SU & MU)										
1		09PlanA	QRFM (SU & MU)												
2		09Plan * 1.3				BPR	09PlanA								
3		09Plan * 1.3													
4		09PlanA					1								
5		09PlanA (Adjust to Bullitt and Oldham)					1								
6		09PlanA (Adjust to Bullitt and Oldham)													
7		09PlanA Increase to xBullit and xOldham													
8		09PlanA Increase to xBullit and xOldham			QRFM (SU)										
9		09PlanA changes to prod adj from ODME													
10	09PlanA	09PlanA changes to prod adj from ODME								count changes					
11	2007	09PlanA changes to prod adj from ODME	QRFM *.5		Adjusted to shorten					count changes	US31 and I-64 (5)				
12		Run11								count changes	US31 and I-64 (2.5)				
13		Adjusted Run11 (RUN12.DBF)								count changes	US31 and I-64 (2.5)				
14		Adjusted from Run 13 Result (RUN14)				HCM VDF Coefficients				count changes	US31 and I-64 (2.5)				
15		Adjusted from Run 13 Result (RUN14)				BPR				count changes	US31 and I-64 (2.5)				
16		Adjusted from Run 13 Result (RUN14)				HCM VDF Coefficients				count changes					
17		Adjusted from Run 13 Result (RUN14)				BPR	09PlanA			count changes					
18		Adjusted from Run 13 Result (RUN14)					RUN18			count changes	US31 and I-64 (2.5)				
19		Adjusted from Run 13 Result (RUN14)					RUN19			count changes	US31 and I-64 (2.5)				
20		Adjusted from Run 13 Result (RUN14)					RUN19			count changes	US31 and I-64 (2.5)	Revised VOT / OP			
21		Adjusted from Run 13 Result (RUN14)					21			count changes	US31 and I-64 (2.5)	Revised VOT / OP			
22	10PlanA 2007	09PlanA		Recalibrated using GC	ODME Trip Table	HCM VDF Coefficients	09PlanA	new default speed table	Updated to 2007	count changes		Revised VOT / OP	Interim Model	FACT=21	10 percent K / Hour Periods
23		Run23	ODME Trip Table							count		Revised			

#	SE	Person Trip Rates	Truck Trip Rates	Auto FF	Truck FF	VDF	K-factors	Speeds	Externals	Counts	Penalties	Network	Dirunals	US31	Capacities
										changes		VOT / OP			
24		RUN 24 Adjustments to Ps								count changes		Revised VOT / OP			
25		RUN 25 Adjustments to Ps								count changes		Revised VOT / OP			
26		RUN 26 Adjustments to Ps								count changes		Revised VOT / OP			
27		RUN 26 Adjustments to Ps					RUN 27			count changes	US 31 - 1.5 / 64 5	Revised VOT / OP			
28		RUN 26 Adjustments to Ps					RUN 28			count changes	None	Revised VOT / OP			
29		RUN 26 Adjustments to Ps	ODME Trip Table v2				RUN 28			count changes	US 31 - 1.5 / 64 5	Revised VOT / OP			
30		RUN 26 Adjustments to Ps	ODME Trip Table 2 * .75 Internal				RUN 28			count changes	US 31 - 1.5 / 64 5	Revised VOT / OP			
31		RUN 26 Adjustments to Ps	ODME Trip Table 2 * .75 Internal (balanced)				RUN 28			counts (3/22/11)	US 31 - 2.5 / 64 5	Revised VOT / OP			
32															
33															
34		RUN 26 Adjustments to Ps	ODME Trip Table 2 *.75 Int Bal Removal of EE				RUN 28			counts (3/22/11)	US 31 - 2.5 / 64 5	Revised VOT / OP			
35		RUN 26 Adjustments to Ps	ODME Trip Table 2 *.75 Int Bal Removal of EE				RUN 28			counts (3/22/11)	US 31 - 2.5 / 64 2.5	Revised VOT / OP	Revised HH Analysis		
36		RUN 26 Adjustments to Ps	ODME Trip Table 2 *.75 Int Bal Removal of EE				RUN 28			counts (3/22/11)	US 31 - 2.5 / 64 5	Revised VOT / OP			
37		RUN 26 Adjustments to Ps	ODME Trip Table 2 *.75 Int Bal Removal of EE				RUN 28			counts (3/22/11)	US 31 - 2.5 / 64 5	Revised VOT / OP			
38		RUN 26 Adjustments to Ps	ODME Trip Table 2 *.75 Int Bal Removal of EE		ODME Trip Table v2					counts (3/22/11)	None	Revised VOT / OP			
39		RUN 25 Adjustments to Ps	2007 Truck ODME		2007 Truck ODME					Counts 3/22/11	None	Revised VOT / OP			
LA		RUN 25 Adjustments to Ps	2007 Truck ODME		2007 Truck ODME					Counts 3/22/11	None	Revised VOT / OP		US 31 - FACT88	
40		RUN 25 Adjustments to Ps	2007 Truck ODME		2007 Truck ODME	BPR VDF	09Plan A	new def speeds / 25mph Core		Counts 3/22/11	None	Revised VOT / OP	Revised HH Analysis / II Trk uses Counts Dist	US 31 - FACT36 / 25 MPH	8 percent K / peak period factors

#	SE	Person Trip Rates	Truck Trip Rates	Auto FF	Truck FF	VDF	K-factors	Speeds	Externals	Counts	Penalties	Network	Dirunals	US31	Capacities
41		RUN 25 Adjustments to Ps	2007 Truck ODME		2007 Truck ODME					Counts 3/22/11	None	Revised VOT / OP		US 31 - FACT36 / 35 MPH	
42		RUN 25 Adjustments to Ps	2007 Truck ODME		2007 Truck ODME					Counts 3/22/11	None	Revised VOT / OP		US 31 - FACT88 / 35 MPH	
43		RUN 25 Adjustments to Ps	2007 Truck ODME		2007 Truck ODME					Counts 3/22/11	None	Revised VOT / OP		US 31 - FACT36 / 30 MPH	

Table 4.4: LSIORB TOD Validation (Part 2)

#		Person Trip Rates	Truck Trip Rates	Auto FF	Truck FF	VDF	Kfactors	Speeds	Externals	Counts	Network	Dirunals	US31	Capacities	Periods
44	10PlanA 2007							new def speeds / 25mph Core	Updated to 2007	Counts 3/22/11	Revised VOT / OP		US 31 - FACT88 / 30 MPH		4
A	10PlanA 2007					BPR VDF		new def speeds / 25mph Core	Updated to 2007	Counts 3/22/11	Revised VOT / OP		US 31 - FACT88 / 30 MPH		8
A	10Plan 2007					VDF		Core	to 2007	3/22/11	VOT / OP		MPH		8
B	10PlanA 2007							new def speeds / 25mph Core	Updated to 2007	Counts 3/22/11	Revised VOT / OP		US 31 - FACT88 / 30 MPH		8
C	10PlanA 2007							Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 3/22/11	Revised VOT / OP		US 31 - FACT88 / 30 MPH		8
D	10PlanA 2007			Recalibrated Using GC				Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 3/22/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8
E	10PlanA 2007						09PlanA	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 3/22/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8
F	10PlanA 2007						F	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 3/22/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8
G	10PlanA 2007	RUN 26 Adjustments to Ps					F	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 5/05/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8
H	10PlanA 2007	RUN H (floyd increase)					H	Indiana Speeds / new def speeds / 25mph Core	New I-64	Counts 5/06/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8
I	10PlanA 2007	RUN 26 Adjustments to Ps	2007 Truck ODME	Calibrated with new VOC	2007 Truck ODME	HCM VDF	I	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 5/06/11	NEW VOT / OP	Revised HH Analysis / II Trk uses Counts Dist	US 31 - FACT88 / 30 MPH	10 percent K / peak period factors	8

#		Person Trip Rates	Truck Trip Rates	Auto FF	Truck FF	VDF	Kfactors	Speeds	Externals	Counts	Network	Dirunals	US31	Capacities	Periods
J	10PlanA 2007						I	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 5/06/11	NEW VOT / OP		FACT 21		8
K	10PlanA 2007	RUN K					K	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 5/06/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8
L	10PlanA 2007	RUN 26 Adjustments to Ps (Floyd 1.25 A)					I	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 5/06/11	NEW VOT / OP		FACT 21		8
M	10PlanA 2007	RUN 26 Adjustments to Ps (Floyd 1.25 A)					M	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 5/06/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8
N	10PlanA 2007	RUN 26 + Floyd SG Zones					M	Indiana Speeds / new def speeds / 25mph Core	Updated to 2007	Counts 5/06/11	NEW VOT / OP		US 31 - FACT88 / 30 MPH		8

4.2.1 Trip Distribution

A comparison of the LSIORB TOD Model distribution pattern to that of the 2006 to 2008 ACS Journey to Work shows that for the largest county in the region, Jefferson County, the trend is consistent with over ninety percent of the work trips remaining inside the county. In comparing the number of work trips between the LSIORB TOD Model and JTW, the JTW data should be approximately one-half of the model output. This is because of the difference in the definition of a journey versus a travel demand model trip. The model includes both to work and return movement in Production / Attraction format where JTW is reporting only the trip to work. When taking this adjustment into consideration, the LSIORB TOD Model and JTW compare favorably.

Table 4.5: ACS JTW (2006-2008)

		WORKPLACE					
		Clark	Floyd	Bullitt	Jefferson	Oldham	
RESIDENCE		IN	IN	KY	KY	KY	Total
Clark	IN	24,275	6,755	140	18,020	295	49,485
Floyd	IN	6,655	14,910	95	12,615	115	34,390
Bullitt	KY	370	270	9,740	23,330	195	33,905
Jefferson	KY	6,365	2,015	3,215	305,805	2,745	320,145
Oldham	KY	235	70	50	15,595	8,190	24,140
Total		37,900	24,020	13,240	375,365	11,540	

		WORKPLACE					
		Clark	Floyd	Bullitt	Jefferson	Oldham	
RESIDENCE		IN	IN	KY	KY	KY	Total
Clark	IN	49.1%	13.7%	0.3%	36.4%	0.6%	100%
Floyd	IN	19.4%	43.4%	0.3%	36.7%	0.3%	100%
Bullitt	KY	1.1%	0.8%	28.7%	68.8%	0.6%	100%
Jefferson	KY	2.0%	0.6%	1.0%	95.5%	0.9%	100%
Oldham	KY	1.0%	0.3%	0.2%	64.6%	33.9%	100%
Total		100%	100%	100%	100%	100%	

Table 4.6: LSIORB JTW

		WORKPLACE					
		Clark	Floyd	Bullitt	Jefferson	Oldham	
RESIDENCE		IN	IN	KY	KY	KY	Total
Clark	IN	40,527	17,179	422	22,709	474	81,311
Floyd	IN	15,406	31,083	195	10,448	206	57,338
Bullitt	KY	1,021	412	8,360	32,222	750	42,765
Jefferson	KY	18,217	9,215	15,660	548,616	13,776	605,485
Oldham	KY	970	391	543	26,065	10,614	38,583
Total		76,141	58,280	25,180	640,060	25,820	

RESIDENCE		WORKPLACE					
		Clark	Floyd	Bullitt	Jefferson	Oldham	
		IN	IN	KY	KY	KY	Total
Clark	IN	49.8%	21.1%	0.5%	27.9%	0.6%	100%
Floyd	IN	26.9%	54.2%	0.3%	18.2%	0.4%	100%
Bullitt	KY	2.4%	1.0%	19.5%	75.3%	1.8%	100%
Jefferson	KY	3.0%	1.5%	2.6%	90.6%	2.3%	100%
Oldham	KY	2.5%	1.0%	1.4%	67.6%	27.5%	100%
Total		100%	100%	100%	100%	100%	

4.2.2 Daily Assignment Validation

The output of the traffic assignment validation for the 24-hour period includes the following metrics:

- Absolute VMT Error
  - Facility Type group
  - Area Type
  - County
- Percent RMSE
  - Volume Group
- Total Traffic Volume
  - Ohio River Bridges
  - Screenline Analysis

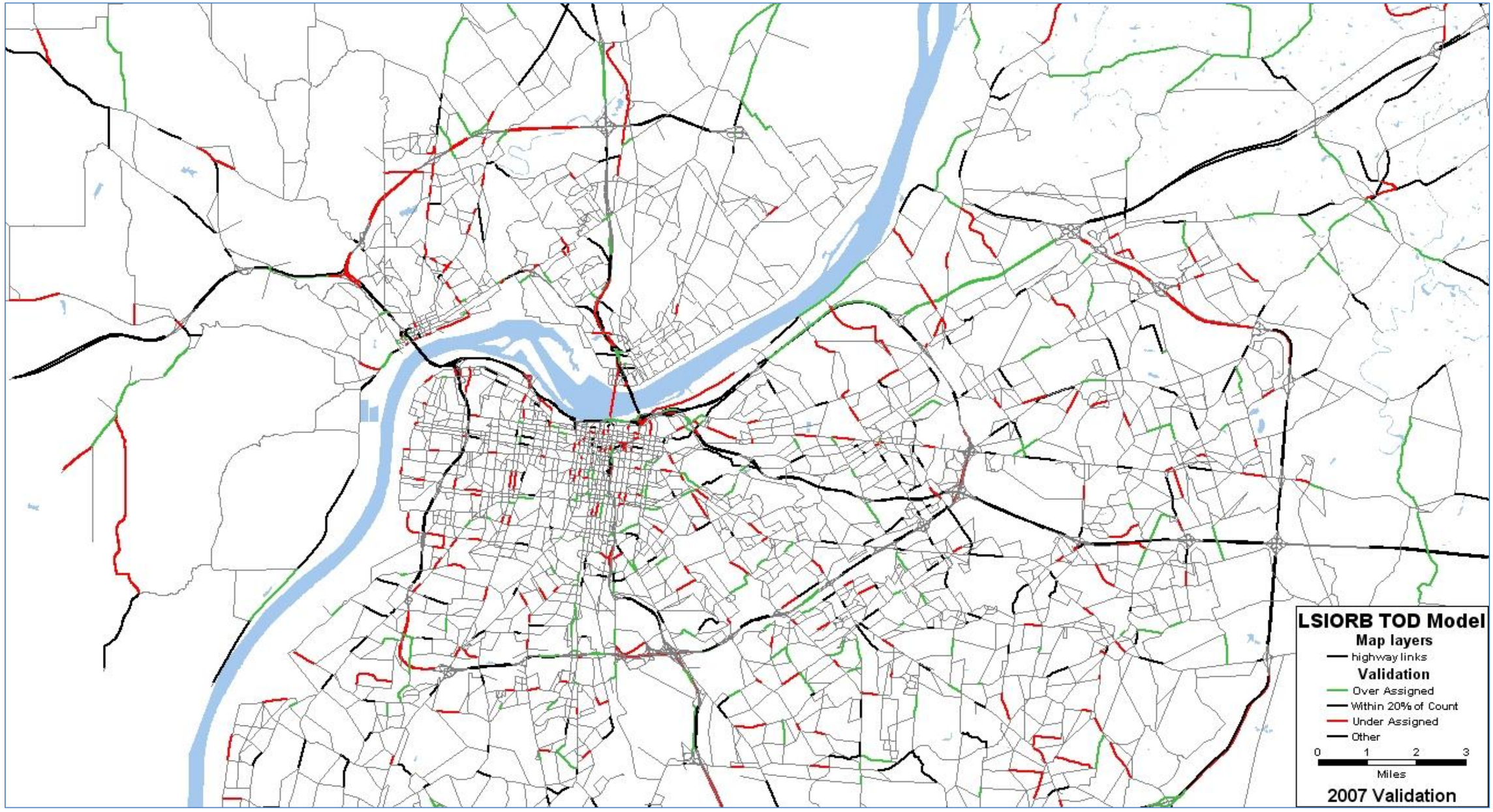
For each metric, the LSIORB TOD Model (TOD) is compared against a criteria and the 09PLANA Daily model (DAILY) and the 09PLANA Interim TOD Model (INTERIM). The distribution of counts by facility type, area type and county are shown in the following table.

Table 4.7: Number of Validation Counts by Facility Type, Area Type and County

Facility	Counts	Area Type	Count	County	Counts	Screenline	Counts
FREEWAY	181	11	44	Bullitt	98	1	2
DIV ART	180	12	12	Clark	184	2	7
UDIV ART	406	21	53	Floyd	120	3	7
LOCAL	350	31	211	Jefferson	772	4	9
ONE WAY	90	41	601	Oldham	92	5	18
RAMPS	58	43	61			6	7
		45	26			7	1
		51	6			8	2
		53	36				
		55	217				

The map below shows the over and under assigned volumes on a daily basis for the validation.

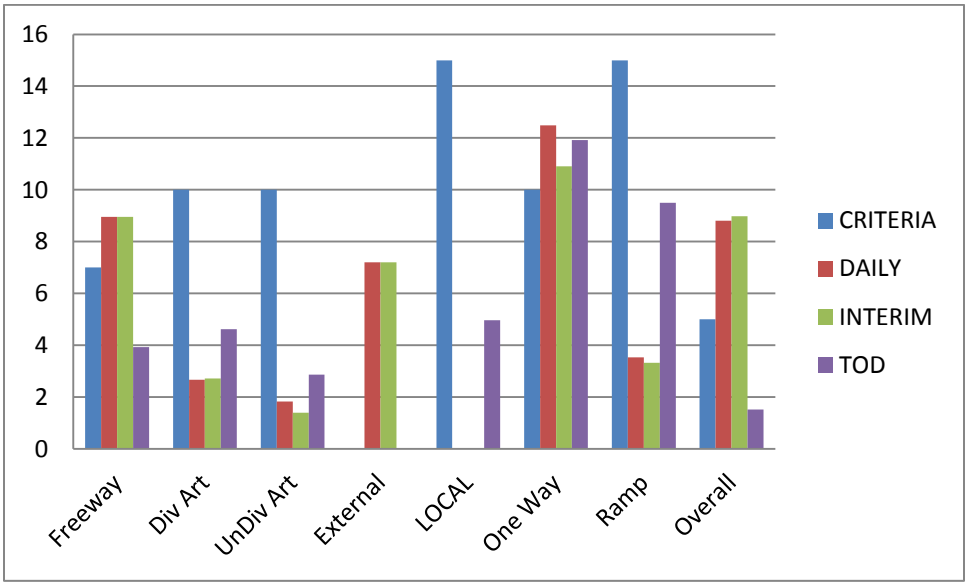
Figure 4.2: LSIORB TOD Model – Daily Validation



The criteria established for the facility type groups is based on FHWA and Ohio Department of Transportation guidelines for travel demand model validation. As the average roadway volume decreases for lesser facility types, the criteria is more relaxed. Figure 4.3 demonstrates that for all facility type groups with the exception of one way roadways, the LSIORB TOD Model is below the established criteria. One way roadways exceed the criteria (10% vs 12%).

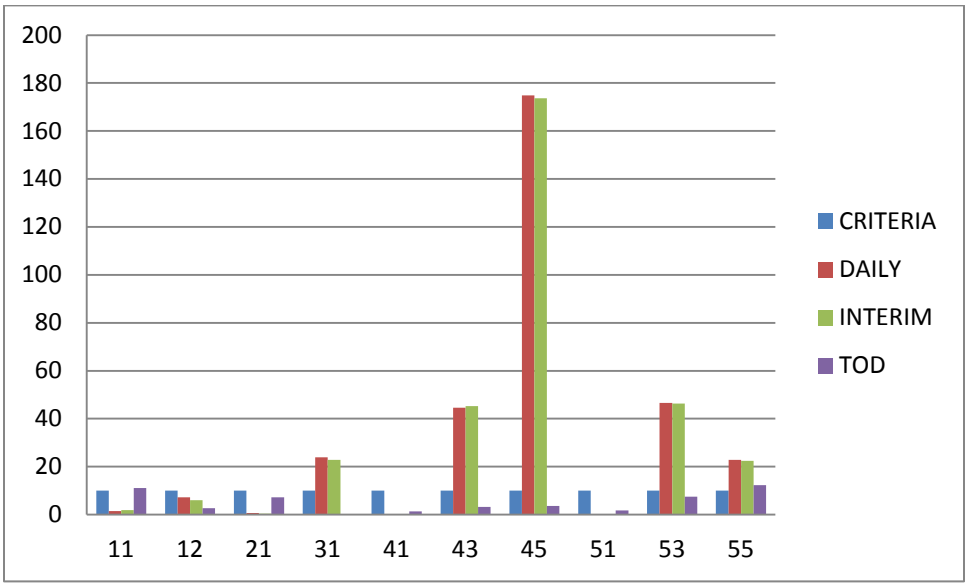
For each metric, the output from the LSIORB TOD Model was compared on links with observed traffic counts. As discussed above, approximately thirteen under unique count locations were identified from data that was obtained from KYTC, INDOT and KIPDA. More information on the source of counts and coverage is found in the Phase I final report.

Figure 4.3: Facility Type Group: Absolute VMT Error



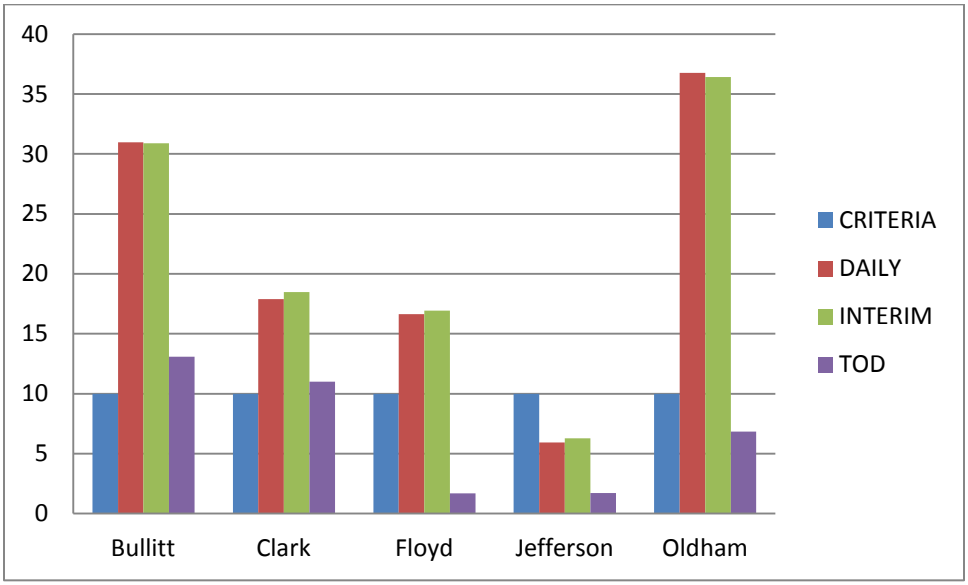
Area Type validation is based on the zonal area types assigned by the KIPDA 09PLANA Model. A criteria of 10% absolute VMT error was set for all area types. The LSIORB TOD Model improves the validation for nearly all area types with the exception of CBD.

Figure 4.4: Area Type: Absolute VMT Error



Similar to the area type validation, the absolute VMT error each of the five counties within the study area were computed and compared against a 10% absolute error criteria. The generation and distribution adjustments made during the validation process have improved these measures as compared to the 09PLANA Daily and Interim Models.

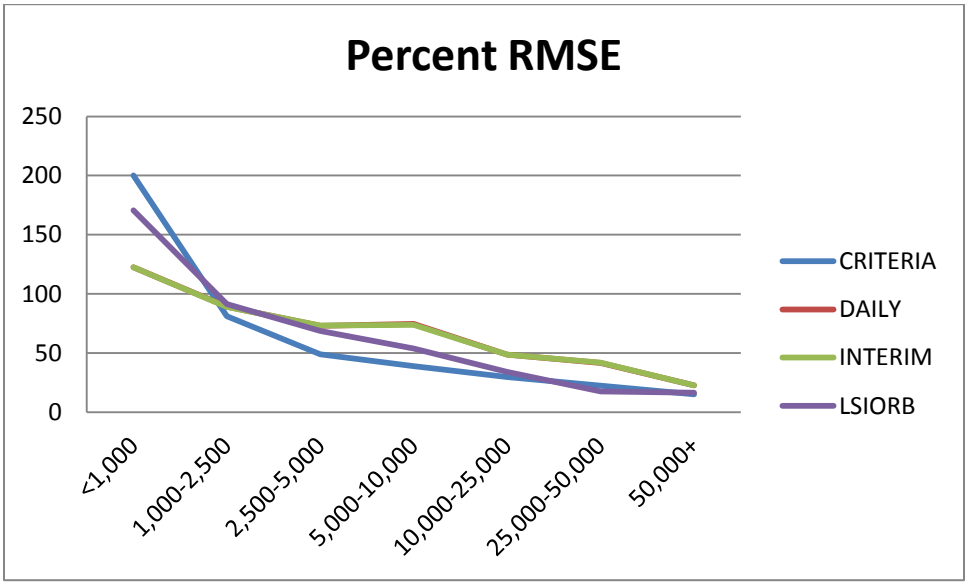
Figure 4.5: County: Absolute VMT Error



A common validation statistic applied to travel demand models is to compute the percent root mean square error for defined volume groups based on the observed count. Percent RMSE is a measure of relative error of the assignment compared to the ground counts. The application of percent RMSE to volume groups follows the “add a lane / drop a lane” philosophy where the assignment must be accurate enough to properly size the roadway. As volumes become

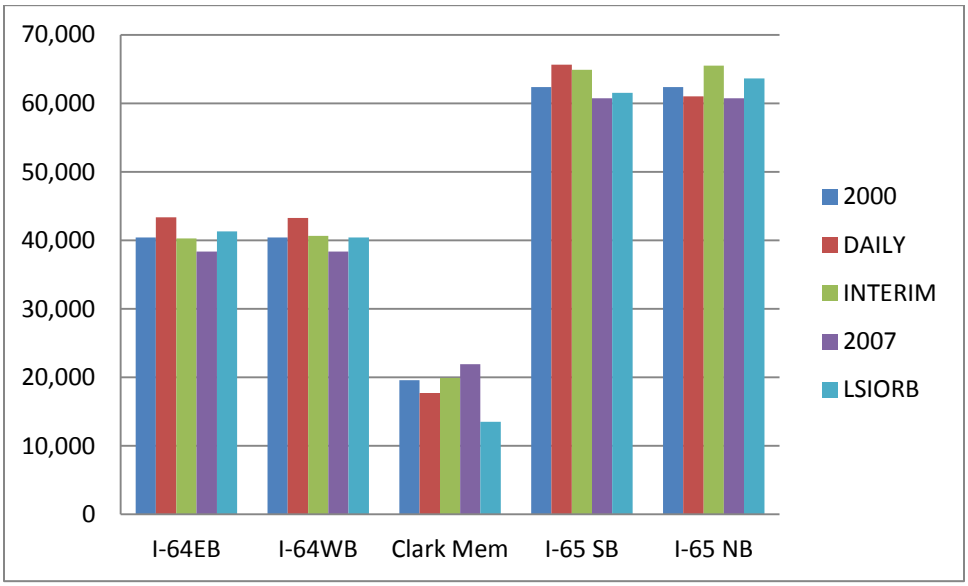
higher, the forecast must be more accurate. The criteria becomes more rigid as the volume group increases. The figure below compares the PRMSE to the criteria. Compared to the KIPDA and Interim models, the LSIORB TOD Model improves except for the very low volume groups.

Figure 4.6: Daily Percent RMSE by Volume Group



Perhaps the most visible validation comparison is the results of the various models on the Ohio River bridges. Figure 4.7 provides not only the results from the LSIORB TOD Model, but also the KIPDA Daily and Interim TOD Models compared to the 2000 traffic counts. The figure also provides a breakdown of traffic by direction on I-65 and I-64.

Figure 4.7: Daily River Crossings by Bridge



In conjunction with the Ohio River bridges, eight additional screenlines were identified to capture the movement of vehicles across the river and between counties in the region as well as trip in and out of the CBD. The screenlines as depicted in Figure 4.8 were developed based on the location of counts in the network.

Figure 4.8: Validation Screenlines

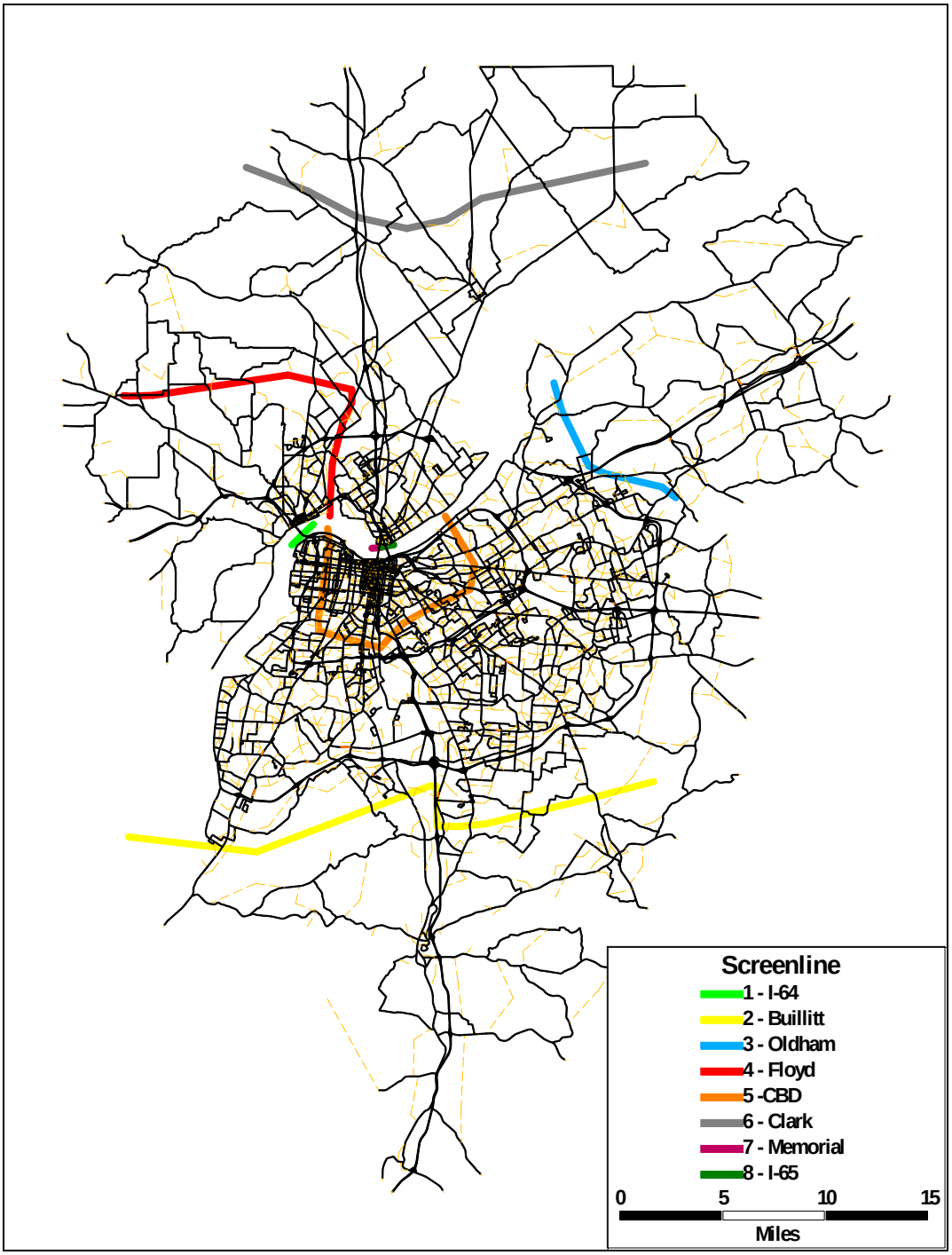


Table 4.8: Screen line Validation

SCREENLINE	DLY AADT	DLY ASSIGN	ERROR DLY	TRK AADT	TRK ASSIGN	ERROR TRK
1	76,740	81,709	6.48	8,440	9,873	16.97
2	157,255	215,782	37.22	56,175	50,698	-9.75
3	103,924	114,290	9.97	12,847	12,311	-4.18
4	97,396	102,913	5.66	5,980	6,295	5.26
5	454,133	434,839	-4.25	41,257	41,938	1.65
6	57,206	65,679	14.81	15,794	17,832	12.91
7	21,906	13,520	-38.28	175	164	-6.14
8	121,422	125,155	3.07	25,620	21,298	-16.87

4.2.3 Validation by Period

The validation statistics up to this point have focused on daily total traffic. Because the LSIORB TOD Model develops traffic by four time periods (AM, MD, PM and NT), it is important to assess the reliability of the period volumes as well.

From a global perspective, the distribution of internal trips is consistent with the distribution of traffic through the day as seen in Table 4.9. The difference between the total traffic in the model (MODEL) and the traffic generated by the internal trips is made up of the external and truck movements.

Table 4.9: Period Distribution of Traffic (Count vs. Model)

Period	HBW	HBO	NHB	All Internal Trips	COUNT	MODEL
AM (6 - 9)	21.9%	8.4%	3.1%	9.9%	17.9%	21.0%
Mid (9 - 3)	27.4%	34.5%	47.7%	36.2%	32.4%	30.6%
PM (3 - 6)	17.0%	25.7%	28.7%	24.6%	23.1%	25.4%
Overnight	33.7%	31.4%	20.5%	20.4%	26.6%	23.0%

Table 4.10 reports the total counted and modeled VMT by period and facility group along with the overall percent error by period. The number of counts used to generate the period validation is less than that used for the daily validation since not all count locations included hourly information.

Table 4.10. VMT Error by Facility Group by Period

PERIOD	COUNT	MODEL	ERROR
AM	1,586,154	1,807,673	14.0%
MD	2,875,568	2,627,821	-8.6%
PM	2,044,665	2,185,377	6.9%
NT	2,363,901	1,974,908	-16.5%
AM	COUNT	MODEL	ERROR
FREEWAY	1,119,990	1,248,030	11.4%
DIV ART	116,221	138,991	19.6%
UDIV ART	216,814	252,890	16.6%
LOCAL	86,035	119,695	39.1%
ONE WAY	14,950	15,279	2.2%
RAMPS	28,628	30,180	5.4%
Total	1,582,638	1,805,064	14.1%
MD	COUNT	MODEL	ERROR
FREEWAY	1,942,201	1,829,491	-5.8%
DIV ART	241,791	196,450	-18.8%
UDIV ART	437,709	373,491	-14.7%
LOCAL	163,164	161,962	-0.7%
ONE WAY	32,934	20,251	-38.5%
RAMPS	52,838	43,355	-17.9%
Total	2,870,637	2,625,001	-8.6%
PM	COUNT	MODEL	ERROR
FREEWAY	1,388,184	1,495,013	7.7%
DIV ART	163,808	174,937	6.8%
UDIV ART	305,050	307,476	0.8%
LOCAL	125,816	151,514	20.4%
ONE WAY	20,330	18,484	-9.1%
RAMPS	35,500	34,072	-4.0%
Total	2,038,689	2,181,496	7.0%
NT	COUNT	MODEL	ERROR
FREEWAY	1,651,006	1,383,570	-16.2%
DIV ART	182,689	145,715	-20.2%
UDIV ART	329,448	272,011	-17.4%
LOCAL	140,426	124,303	-11.5%
ONE WAY	19,719	14,772	-25.1%
RAMPS	36,713	32,539	-11.4%
Total	2,360,001	1,972,910	-16.4%

The following figures display the information from the above table graphically.

Figure 4.9: AM VMT by Facility Group (Count vs. Model)

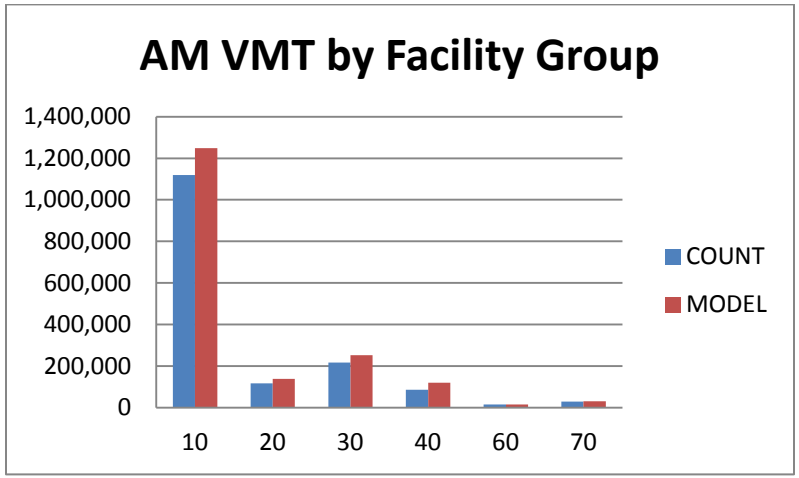


Figure 4.10: MD VMT by Facility Group (Count vs. Model)

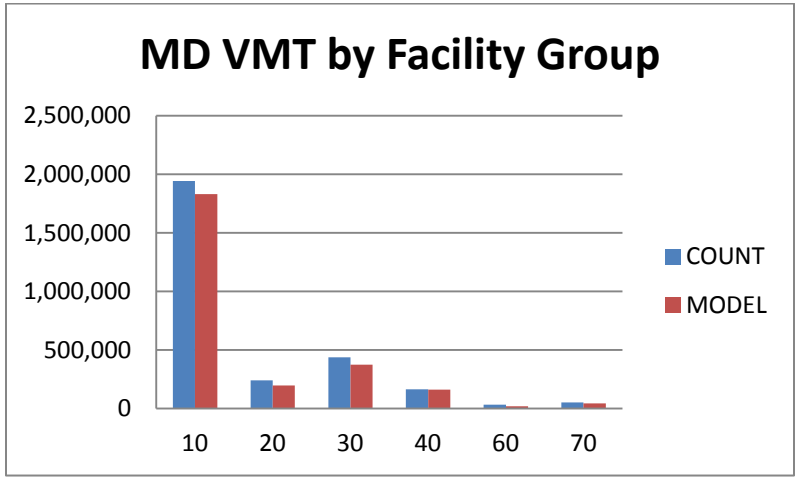


Figure 4.11: AM VMT by Facility Group (Count vs. Model)

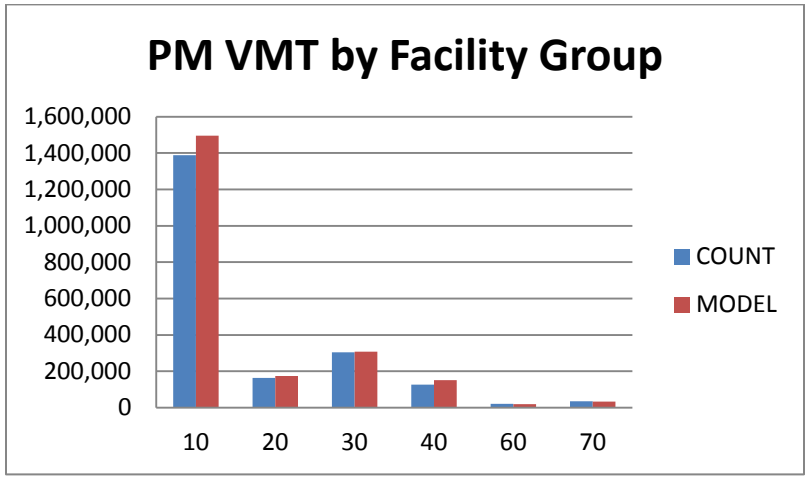
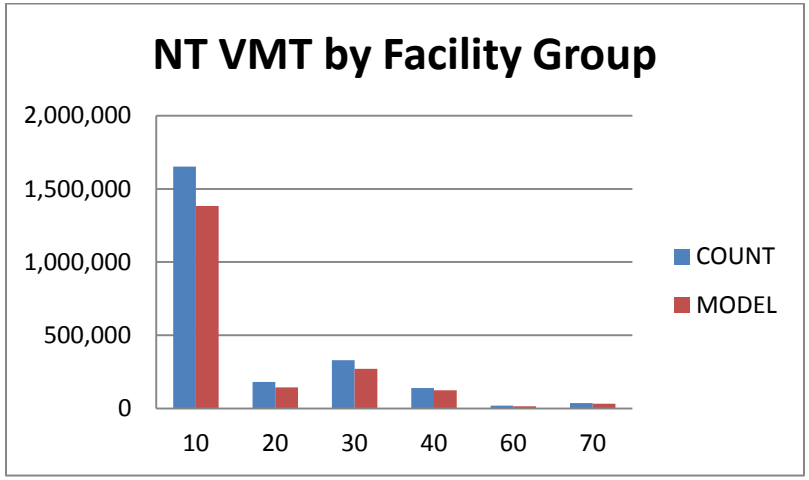


Figure 4.12: AM VMT by Facility Group (Count vs. Model)



5. Implementation

A GISDK script was developed along with a graphical user interface (GUI) to manage scenario input and output files as well as post processing model output data. The GISDK script includes all model processes from trip generation to traffic assignment plus post processing of the model output data and a customized graphical user interface for the LSIORB project. The GUI has three main components:

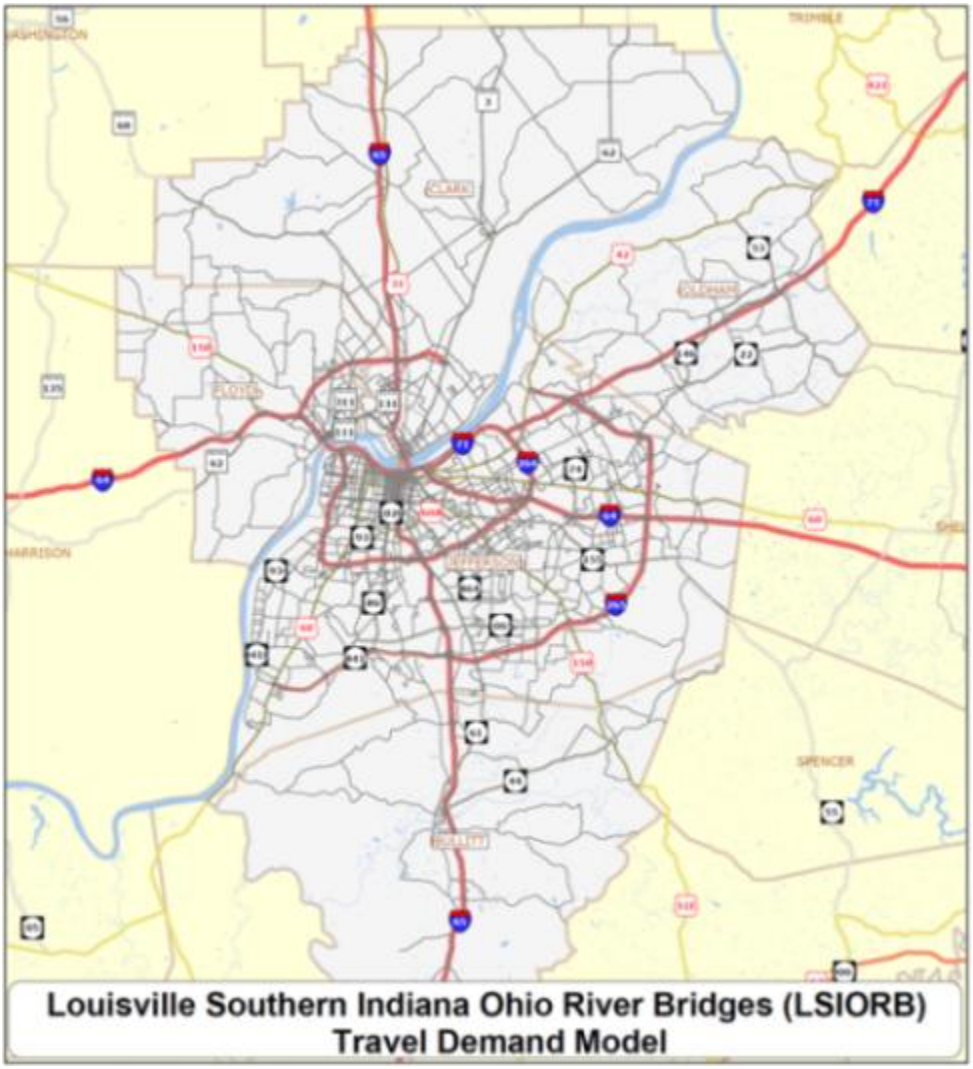
1. Scenario Manager
2. Scenario Model Run
3. Scenario Outputs

Each of these components contains various functions specific to managing, running, and analyzing the LSIORB travel demand model.

5.1 GISDK Interface

The LSIORB interface is a customized GISDK graphical user interface developed as an “Add-In” to the TransCAD program. The main screen of the LSIORB GUI is shown in **Figure 5.1**. This dialog box displays an image of the study area along with three sub dialog boxes available to the user. This box will allow the user to navigate to the three sub components of the GUI and it will be the “Home Screen” for the model. From this dialog box, the user will access the Scenario Manager, Scenario Model Run and Scenario Outputs boxes. For each of the three sub components, the user will specify a scenario which is defined by a scenario array file (.scn). This file contains all scenario specific descriptions, parameters, and input and output file names and locations.

Figure 5.1: LSIORB Interface Welcome Screen



The Scenario Manager component of the LSIORB interface allows the user to setup and manage scenarios, specify parameter values and specify input, interim, and output file names and locations. An image of the Scenario Manager is shown in **Figure 5.2**. There are six tabs within the Scenario Manager that allow the user to specify scenario features. These tabs include:

> The "Scenario Settings" tab allows the user to create, copy, delete, and load a predefined scenario. When creating a new scenario the scenario folder and input files will be based on a defined scenario located in the "Inputs" folder of the model files or copied based on an existing scenario. *Note that the highway and transit system are specific to each scenario. Thus, scenario specific input folder have been created.*

The “Global Parameters” tab allows the user to specify values and flags of various parameters and criteria including (1) trip generation factors by income level, (2) value of time and operating costs, (3) assignment and feedback iterations and convergence, (4) network criteria, and (5) various flags to turn on or off truck and tolling features.

The “Input Files” tab allows the user to specify the locations and file names of all input files to the LSIORB travel demand model.

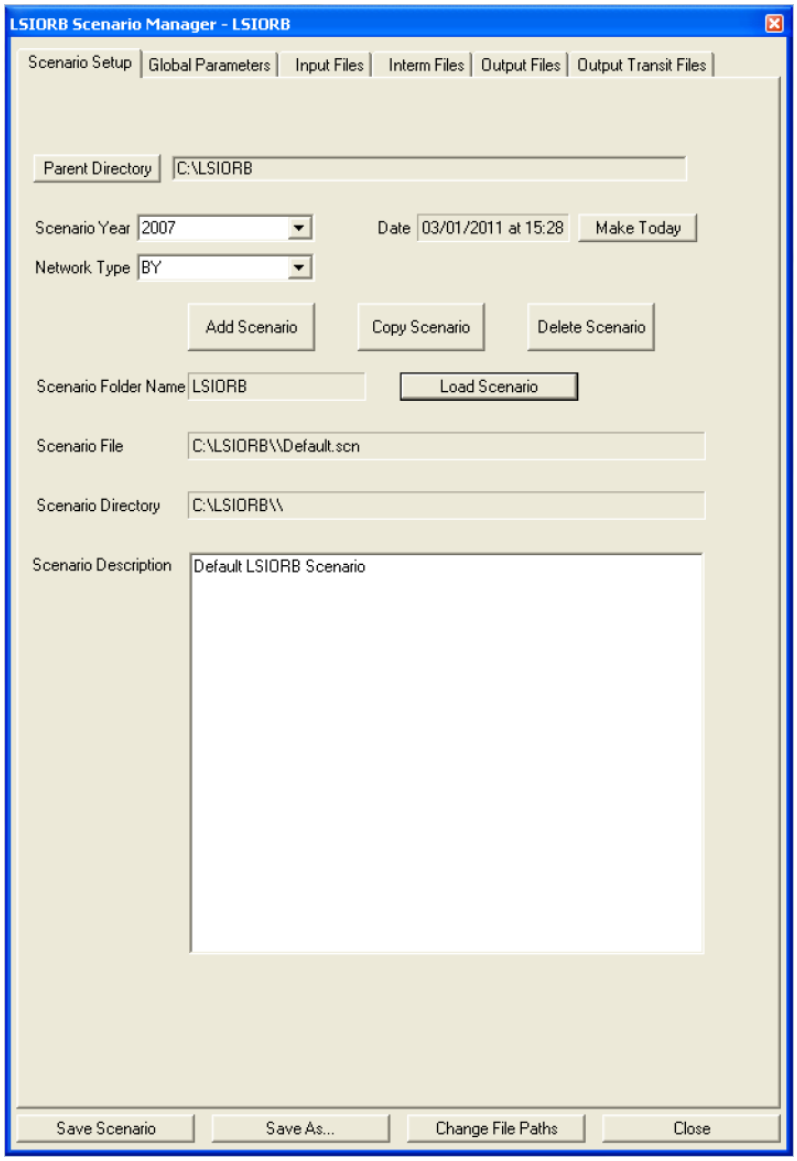
The “Interm Files” tab allows the user to specify the locations and file names of all intermediate files created from the LSIORB travel demand model.

The “Output Files” tab allows the user to specify the locations and file names of all output files created from the LSIORB travel demand model, except for those files created from the transit assignment step.

The “Output Transit Files” tab allows the user to specify the locations and file names of all transit assignment output files created from the LSIORB travel demand model.

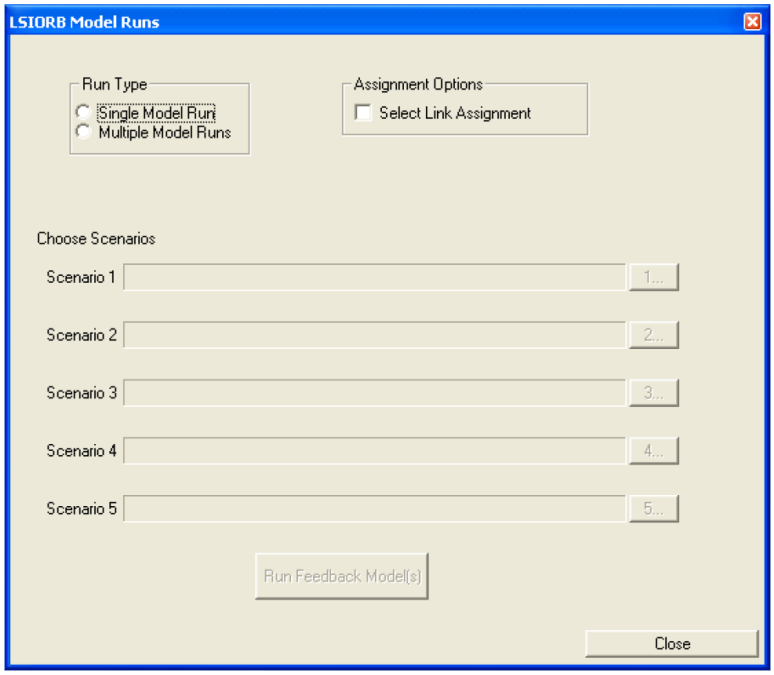
From each of the six tabs the user can at any time save the existing scenario, save the scenario as a new scenario, change the directory path of the input and output files (note that this is preformed for all tabs at once), and close out of the Scenario Manager to return to the main screen of the LSIORB interface.

Figure 5.2: LSIORB Scenario Manager



The Scenario Model Run component of the LSIORB interface controls the running of the model and allows the user to run a single scenario or multiple (up to five) scenarios at once using feedback. Additionally, an assignment option is provided to allow the user to run traffic assignment with select link analysis. An image of the Scenario Model Run dialog box is shown in **Figure 5.3**. Prior to a model run the user must select a run type (single or multiple model run) and load an existing scenario. The close option from this dialog box will close out of the Scenario Model Run to return to the main screen of the LSIORB interface.

Figure 5.3: LSIORB Scenario Model Run



The Scenario Outputs component of the LSIORB interface allows the user to view results of the validated model, post process output data, and view maps of the study area. An image of the Scenario Outputs dialog box is shown in **Figure 5.4**. There are three tabs within the Scenario Outputs dialog box that allow the user to view model outputs. These tabs include:

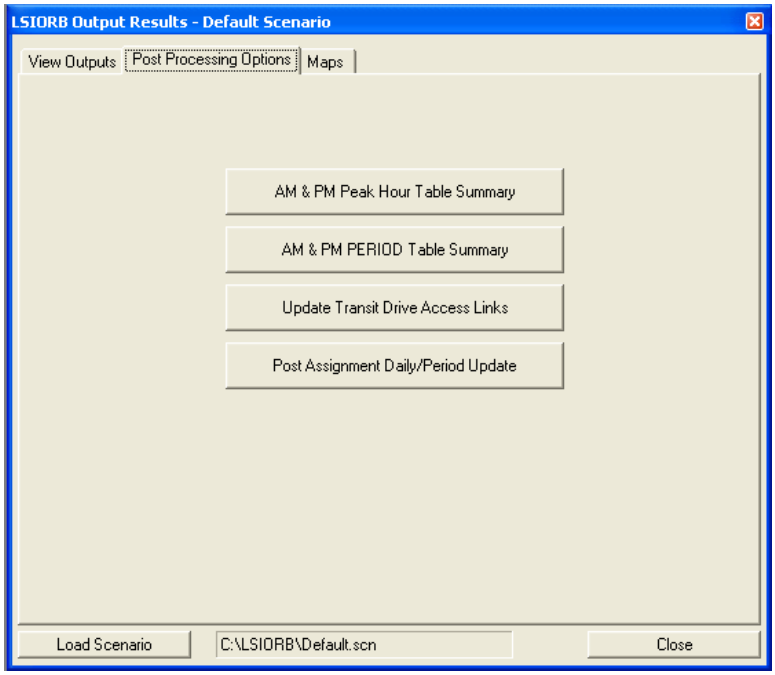
The "View Outputs" tab allows the user to perform various validation statistics for autos and trucks in the morning and evening peak periods as well as daily. Such validation statistics include count vs. model vehicle miles traveled and volume, root mean square error, NCHRP deviation curve, and screenline analysis.

The "Post Processing Options" tab allows the user to update and summarize output data from an existing model run. Such options include the (1) creation morning and evening peak hour and period table summaries of the free flow and congested speeds, truck percentages, and traffic counts, (2) the update of transit drive access links with connecting centriod node identification numbers so that the actual travel time from the centroid node to the park and ride lot can be updated in the model stream (*note that this only needs to be preformed if a new drive access link is created*), and (3) creation of daily, morning, and evening peak period assignment tables (*note that these steps are preformed within the model stream and thus will rarely be used in this capacity*).

The "Maps" tab allows the user to view various maps of the LSIORB model outputs including volume-to-capacity mpas, flow maps, and screenline maps.

Prior to processing any of the model outputs the user must load an existing scenario. The close option from this dialog box will close out of the Scenario Model Run to return to the main screen of the LSIORB interface.

Figure 5.4: LSIORB Scenario Outputs



6. Traffic Forecasts

As part of the implementation of the LSIORB TOD Model, 2030 traffic forecasts were developed that included the development of a 2030 EIS Preferred Network, Socioeconomic Forecast and External data.

6.1 Networks and Demographics

6.1.1 Network Development

The development of the forecasts for the LSIORB TOD Model included the development of several networks for 2030 to support the SEIS. The list of networks included:

- No Build
- East End Only
- Downtown
- EIS Preferred
- EIS Modified

Table 6.1 documents the assumptions used in defining the five networks as they relate to the East End Bridge, Kennedy Interchange and improvements to I-65. All networks include the projects outside of the study area from the 2030 Metropolitan Transportation Plan - the long range planning document of the Louisville MPO.

Table 6.1: LSIORB 2030 Networks

NETWORK NAME	East End Bridge (4 lanes) Includes all connecting roadways	East End Bridge (6 lanes) Includes all connecting roadways	New I-65 Second Span	EIS Interchange	Kennedy Interchange with only existing I-65 Bridge	Modified Interchange	2030 Plan Network (modified based on information in left columns)
2030 No Build	not included	not included	not included	not included	not included	not included	Included
2030 East End Only	not included	Included	not included	not included	Included	not included	Included
2030 Downtown Only	not included	not included	Included	not included	not included	Included	Included
2030 EIS Preferred	not included	Included	Included	Included	not included	not included	Included
2030 Modified	Included	not included	Included	not included	not included	Included	Included

6.1.2 Socio Economic Data

Socio-economic data were obtained from the Kentuckiana Regional Planning & Development Agency based on the 10PlanA data. **Table 6.2** shows the growth in 10PlanA socio-economic data between year 2007 and 2030. The growth in population and households is less than one percent per year and the growth in employment is around 1.5% per year, with service employment having the highest growth per year

Table 6.2: KIPDA 10PlanA Socio-Economic Data

Variable	**2007**	**2030**	**Growth/Yr**
Population	999,834	1,151,805	0.62%
Households	417,639	502,342	0.81%
Total Employment	564,675	803,844	1.55%
Retail Employment	97,188	130,635	1.29%
Service Employment	212,659	316,162	1.74%
Other Employment	254,846	357,047	1.48%

Additionally, the magnitude of change in the number of household and employment were plotted by traffic analysis zone in **Figure 6.1** and **Figure 6.2**. There is a decrease in households (yellow) in more urban areas and an increase in households (red zones) in more rural areas. On the other hand, there is a low increase in employment in rural areas of the region and major increases in employment in specific areas showing that in the future year there is more concentrated employment.

Figure 6.1: Change in Households

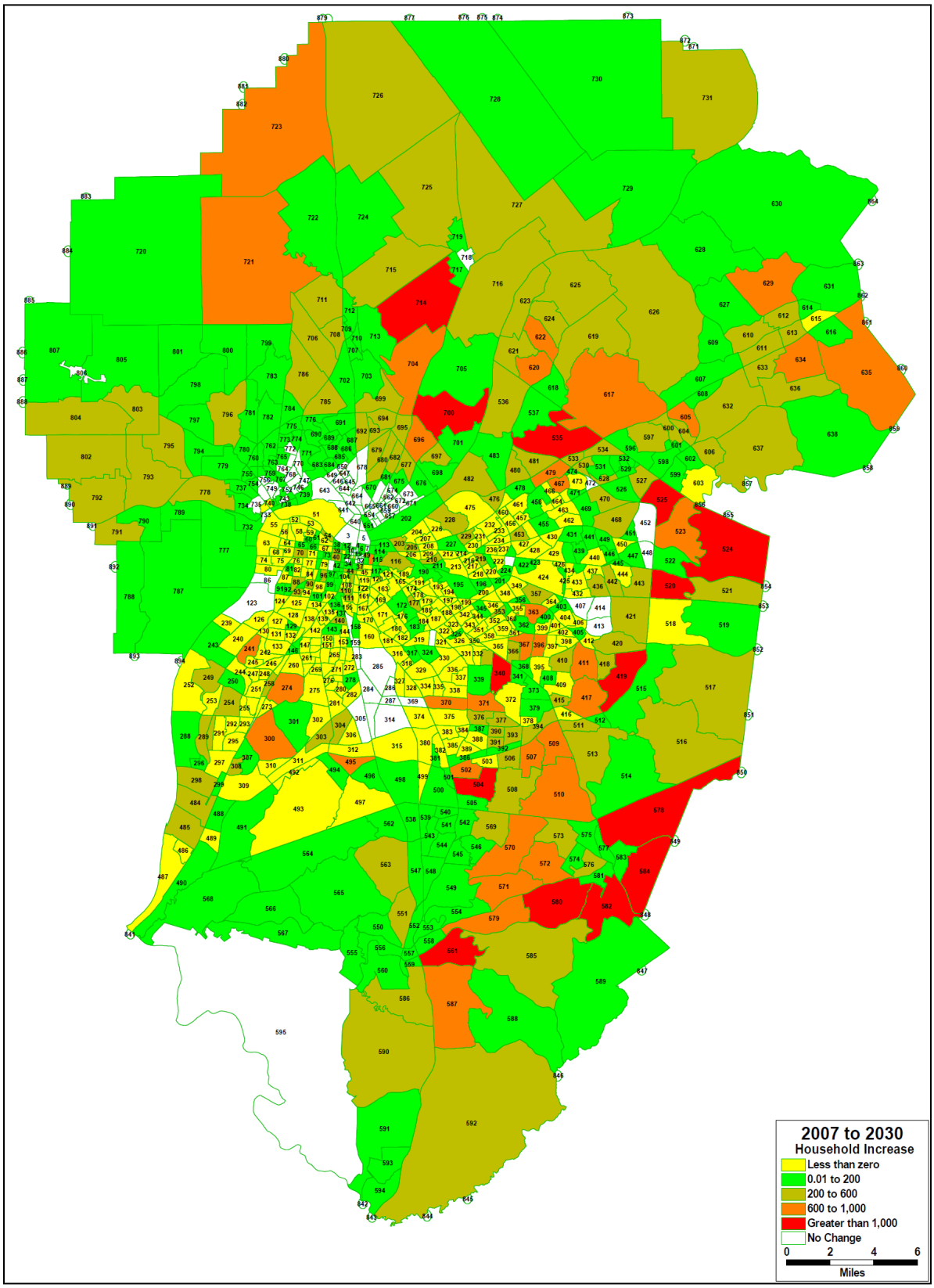
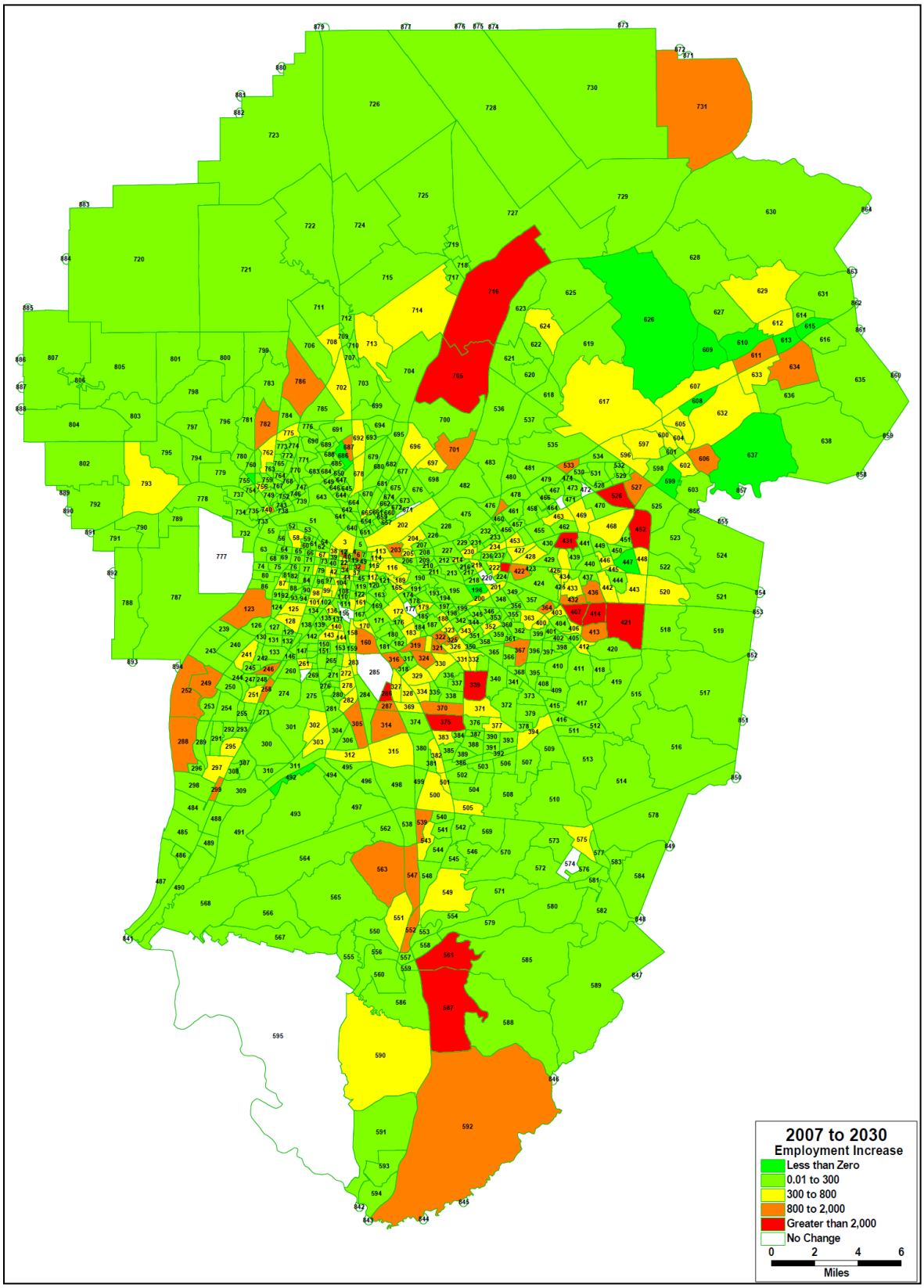


Figure 6.2: Change in Employment



6.2 External Forecasts

An important component of the future year forecasts is the growth at the external stations. To develop the external forecasts for the LSIORB model, WSA researched available historical data at each external station and then developed a regression based 2030 forecast volume. Observed average daily traffic (ADT) counts were obtained from the Kentucky Transportation Cabinet and the Indiana Departments of Transportations as well as field counts conducted by The Traffic Group, Inc. for each of the 48 external stations within the LSIORB travel demand model. This historical data from 1990 to 2010 were used to forecast year 2030 ADT. The distribution of traffic into external through vs. external-internal and auto vs. truck are based on the base year distribution assumptions.

Table 6.3 reports the available historic data for each external station from 1990 through 2010. Data are not available for each year and are limited for several of the study area external stations, especially in Indiana. Trend values were calculated for base year 2007 and forecast year 2030 in order to develop an annual growth rate. The trend annual growth rate was then applied to observed counts used in the base year 2007 LSIORB model. As a result of limited data, for several stations, trend data was not able to be obtained resulting in zero volume for the 2030 forecast. For these stations the “2030 KIPDA” forecast from the KIPDA travel demand model was used as the LSIORB forecast. Similarly, for external stations US 31 and US 150 in Indiana, the trend showed negative or very low growth between 2007 and 2030. For these stations (highlighted in dark grey) the “2030 KIPDA” forecast from the KIPDA travel demand model was used as the LSIORB forecast. **Table 6.4** reports the resulting forecasted volumes for the 2030 LISORB model. These values are shown in the “2030 Model” column.

All external stations increase in traffic between years 2007 and 2030 except for a slight decrease in traffic on S Bloomington Trail Rd in Clark County, Indiana. Overall, there is a yearly 2.13% increase in ADT for the external stations between years 2007 and 2030.

Table 6.3: Historical Count Data by External Station

TAZ	Route	County	State	Count ID	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
841	US 31W	Jefferson	KY	508		15600						20100				22800				22700			21700			20400			22200	22400
842	KY 434	Bullitt	KY	E11	1730						2040							1210				1020		914			998		930	881
843	I-65	Bullitt	KY	503						29500	30100	31900	25500	38700	38600	41200	43300	47800				41900		52100	53600		51700	50600	52800	53900
844	KY 61	Bullitt	KY	529	1030					2220												3780			3770			3790	3930	4040
845	KY 733	Bullitt	KY	272										310						333		297		383			425		403	401
846	KY 245	Nelson	KY	750		4650						6800						10200				10700		10800			12500		12800	13000
847	KY 480	Bullitt	KY	257							333									449		554				650			540	577
848	US 31E	Spencer	KY	779	3670							5000								7950			7750			8220			8060	8290
849	KY 44	Spencer	KY	767	1550							1810								2620			3110	2550			3220	3640	3120	2600
850	KY 1319	Bullitt	KY	31						747		680								1140		935					1130		1150	1150
851	KY 155	Jefferson	KY	373	2070									5050						8760		9690			10800			11700	12000	12200
852	KY 148	Jefferson	KY	369	1030								1640							1960		2080				2010			2350	2360
853	I-64	Jefferson	KY	19						30300	31200	37200	38700	38700	42000	40000	43100	41100				52200	52800	54700	51700	52000	53800	54500	51400	55600
854	US 60	Jefferson	KY	119	6060						7650							10500				8320			9640		9640	8900	9410	9740
855	KY 1513	Jefferson	KY	131	346											1340						1720			2970			4100	3920	3870
856	KY 362	Oldham	KY	267	663							1120								1210			1920			2460			2230	2310
857	KY 1408	Oldham	KY	270										609						1090			829				1210		1230	1270
858	KY 1315	Oldham	KY	282	325									514						668			776			719			705	745
859	KY 53	Shelby	KY	753			738												1250			1240				1370			1360	1400
860	KY 22	Oldham	KY	253					1470						1990						2150			2210			2100		2240	2260
861	KY 712	Oldham	KY	289	1060								1410							2160			1740			1430			1350	1480
862	I-71	Oldham	KY	315						25500	28400	31000	25200	25400	28400	27000	29100	33200	30400		29800	32700	34300	35200	35900	37700	38100	35300	35500	37800
863	KY 146	Henry	KY	538						1780						2010						2340		2690			2720		2810	2850
864	US 42	Henry	KY	750						758						1330						2970		1400			1540		1560	1550
871	Paynesville Rd	Clark	IN	?										0					0			0					0			
872	Marble Hill Rd	Clark	IN	?										0					0			0					0			
873	SR-62	Jefferson	IN	G1										3400				4030			3870						4182			
874	S Westport Rd	Clark	IN	?										0					0			0					0			
875	SR-203	Clark	IN	1P										830					750			750					876			
876	SR-3	Clark	IN	3H										1390					1520			1660					1551			
877	S Slate Ford Rd	Clark	IN	?										0					0			0					0			
878	US 31	Clark	IN	10F										4900					4540			4610					4260			
879	I-65	Clark	IN	1B					21040					35940				40380	41710	36960		38770			35750		36963			
880	S Bloomington Trl Rd	Clark	IN	?										0					0			0					0			
881	SR-160	Clark	IN	1N										1390					2020			1710					1823			
882	Pixley Knob Rd	Clark	IN	?										0					0			0					0			
883	SR-60	Clark	IN	1J										6520					9040			7350					8190			
884	Martinsburg Knob Rd	Floyd	IN	?										0					0			0					0			
885	SR-335	Floyd	IN	2M										560					1000			930					947			
886	US 150	Floyd	IN	1C										7730					6950			8100					7500			
887	Bradford Rd	Floyd	IN	?										0					0			0					0			
888	Nadorff Rd	Floyd	IN	?										0					0			0					0			
889	SR-64	Floyd	IN	1H										7250					8900			8640					8308			
890	Old Lanesville Rd	Floyd	IN	?										0					0			0					0			
891	I-64	Floyd	IN	1A					18730					29070				26720	27600			28760			30869		29897			
892	SR-62	Floyd	IN	1E										2410					2790			2750					2890			
893	SR-11	Floyd	IN	1D										550					720			580					655			
894	SR-111/River Rd	Floyd	IN	1J										3210					12240			12740					9738			

Table 6.4: Average Daily Traffic Volumes by External Station

TAZ	Route	County	State	Count ID	2007 Trend	2030 Trend	Trend Annual Growth	2007 Model	2030 Forecast	2030 KIPDA	**Updated Annual Growth**	**2030 Model**
841	US 31W	Jefferson	KY	508	22319	26856	0.63%	22189	25424	28276	**0.63%**	**25424**
842	KY 434	Bullitt	KY	E11	944	0	0.00%	998	0	2458	**6.36%**	**2458**
843	I-65	Bullitt	KY	503	52289	81451	2.42%	50618	78849	81063	**2.42%**	**78170**
844	KY 61	Bullitt	KY	529	3863	6441	2.62%	5723	9166	5516	**2.62%**	**9238**
845	KY 733	Bullitt	KY	272	389	559	1.90%	425	611	558	**1.90%**	**611**
846	KY 245	Nelson	KY	750	12268	20265	2.77%	11162	18266	20898	**2.77%**	**18266**
847	KY 480	Bullitt	KY	257	571	880	2.35%	2237	3448	1057	**2.35%**	**3374**
848	US 31E	Spencer	KY	779	8196	12603	2.23%	7240	10948	13059	**2.23%**	**10948**
849	KY 44	Spencer	KY	767	3033	4605	2.27%	3223	4908	5127	**2.27%**	**4908**
850	KY 1319	Bullitt	KY	31	1118	1647	2.05%	1134	1670	2238	**2.05%**	**1680**
851	KY 155	Jefferson	KY	373	11316	21082	3.78%	11652	21781	21842	**3.78%**	**21781**
852	KY 148	Jefferson	KY	369	2231	3375	2.09%	2352	3481	3323	**2.09%**	**3481**
853	I-64	Jefferson	KY	19	53972	81443	2.21%	51360	77502	72195	**2.21%**	**76017**
854	US 60	Jefferson	KY	119	9503	12217	1.02%	8895	10983	11094	**1.02%**	**10757**
855	KY 1531	Jefferson	KY	131	3368	6958	5.17%	4096	8964	6667	**5.17%**	**8964**
856	KY 362	Oldham	KY	267	2148	3779	3.41%	2234	3987	4211	**3.41%**	**3987**
857	KY 1408	Oldham	KY	270	1161	2043	3.30%	1211	2130	2070	**3.30%**	**2130**
858	KY 1315	Oldham	KY	282	736	1121	2.08%	705	1043	1278	**2.08%**	**1043**
859	KY 53	Shelby	KY	753	1362	2005	2.06%	1696	2424	2877	**2.06%**	**2424**
860	KY 22	Oldham	KY	253	2214	2942	1.43%	2104	2796	3719	**1.43%**	**2691**
861	KY 712	Oldham	KY	289	1591	1864	0.27%	1348	1431	2274	**0.27%**	**1431**
862	I-71	Oldham	KY	315	36065	50095	1.69%	35450	49241	48168	**1.69%**	**49615**
863	KY 146	Henry	KY	538	2709	4019	2.10%	2715	4027	4054	**2.10%**	**4054**
864	US 42	Henry	KY	750	1731	2479	1.88%	1543	2210	2188	**1.88%**	**1967**
871	Paynesville Rd	Clark	IN	?	0	0	0.00%	100	0	368	**11.65%**	**368**
872	Marble Hill Rd	Clark	IN	?	0	0	0.00%	369	0	971	**7.09%**	**971**
873	SR-62	Jefferson	IN	G1	4235	5432	1.23%	4182	5364	3612	**1.23%**	**5364**
874	S Westport Rd	Clark	IN	?	0	0	0.00%	239	0	417	**3.24%**	**417**
875	SR-203	Clark	IN	1P	823	901	0.41%	876	958	1177	**0.41%**	**958**
876	SR-3	Clark	IN	3H	1622	1947	0.87%	1667	2001	2675	**0.87%**	**2001**
877	S Slate Ford Rd	Clark	IN	?	0	0	0.00%	270	0	278	**0.13%**	**278**
878	US 31	Clark	IN	10F	4281	3233	-1.06%	4750	3587	5342	**0.54%**	**5342**
879	I-65	Clark	IN	1B	41241	56977	2.48%	36962	58061	64783	**2.48%**	**57303**
880	S Bloomington Trl Rd	Clark	IN	?	0	0	0.00%	541	0	417	**-1.00%**	**417**
881	SR-160	Clark	IN	1N	1907	2515	1.38%	1946	2565	2567	**1.38%**	**2565**
882	Pixley Knob Rd	Clark	IN	?	0	0	0.00%	135	0	249	**3.67%**	**249**
883	SR-60	Clark	IN	1J	8383	10533	1.12%	8649	10867	9809	**1.12%**	**10867**
884	Martinsburg Knob Rd	Floyd	IN	?	0	0	0.00%	367	0	695	**3.89%**	**695**
885	SR-335	Floyd	IN	2M	1035	1658	2.62%	1260	2018	2423	**2.62%**	**2018**
886	US 150	Floyd	IN	1C	7587	7646	0.03%	7272	7329	10271	**1.79%**	**10271**
887	Bradford Rd	Floyd	IN	?	0	0	0.00%	0	0	687	**0.00%**	**687**
888	Nadorff Rd	Floyd	IN	?	0	0	0.00%	0	0	417	**0.00%**	**417**
889	SR-64	Floyd	IN	1H	8748	10425	0.83%	8092	9643	12239	**0.83%**	**9643**
890	Old Lanesville Rd	Floyd	IN	?	0	0	0.00%	0	0	973	**0.00%**	**973**
891	I-64	Floyd	IN	1A	31524	43660	2.36%	29896	46150	48663	**2.36%**	**45713**
892	SR-62	Floyd	IN	1E	2933	3724	1.17%	2651	3366	3908	**1.17%**	**3366**
893	SR-11	Floyd	IN	1D	661	783	0.80%	617	731	967	**0.80%**	**731**
894	SR-111/River Rd	Floyd	IN	1J	12636	23795	3.84%	11589	21824	17400	**3.84%**	**21824**

These ADT percent increases are consistent with the truck growth between 2007 and 2030. The truck percent of total ADT is held constant between the base year and the forecast year. Similarly, the split between EE and EI trips are held constant between the base and forecast years. The percent trucks of total ADT is shown in **Table 6.5** along with the corresponding annual growth of truck traffic. Interstate 65 in Clark County, IN has the highest percentage of trucks at 44% of the total ADT. Similarly, Interstate 71 in Oldham County, KY has a high truck percentage of 41% of the total ADT.

Table 6.5: LSIORB Model Truck Percentages and Growth

Route	2007 Model	2030 Model	Percent Trucks	Model Growth/Yr
I-65 KY	19,282	28,213	36%	1.67%
I-64 KY	10,108	14,038	18%	1.44%
I-71 KY	15,473	20,146	41%	1.15%
I-65 IN	16,273	25,547	44%	1.98%
I-64 IN	9,300	14,307	31%	1.89%

Table 6.6 shows the Freight Analysis Framework (FAF) version 3 data of truck percentage of daily traffic and truck annual growth for the external stations. This table shows a higher growth in traffic than the historical counts, especially for the Indiana counts.

Table 6.6: Freight Analysis Framework Truck Percentages and Growth (Source: FAF3, 2040 Forecast)

Route	2007 FAF	2040 FAF	FAF 2040 % Trucks	FAF Growth/Yr
I-65 KY	21804	39035	49%	1.78%
I-64 KY	7960	12524	15%	1.38%
I-71 KY	13120	22574	39%	1.66%
I-65 IN	11705	21352	31%	1.84%
I-64 IN	5852	9355	20%	1.43%

The truck growth comparison between the FAF3 data and the model data shows that compared to the FAF data, the model closely reflects truck percentage of total ADT for I-64 and I-65 in Kentucky and I-65 in Indiana. The model under-estimates the I-71 truck percentage and over-estimates the I-64 truck percentages in Indiana compared to the FAF data. For the truck percent of total ADT the model tends to over-estimate interstate truck percentage of traffic in Indiana and under-estimate truck percentage on I-65 in Kentucky.

Appendix A

Comment	Description	Reviewer	Agency	Response
1	The document is written in a very technical format with little explanation of what many things are. While the experts in modeling can follow it easily enough, this document will be shared with the public and should include more explanation of what things are; for example, Section 2.1 Home Based Work (HBW), what exactly does that mean, another, in the charts on Pages 4-6, what does the "M" and "S" stand for, what is the "Size", the public would never be able to relate to any of this, not that need to fully, but a certain amount of explanation should be included.	Kevin Villier	CTS	List of acronyms added. Explanation added to the tables referenced in comment.
2	A list of all the abbreviations would be very helpful as a reference when reading the report	Kevin Villier	CTS	Added
3	Several of the Figures (maps) may be better at full pages to make them more legible in hard-copy	Kevin Villier	CTS	Readability improved by enlarging.
4	Table 2-10, in relation to Comment #1, an example of explanation for the layperson, what are the facility types, what do the numbers represent, what are the area types, what do the numbers mean, again, I'm trying to look at this with the public having access to the final report	Kevin Villier	CTS	See comment #1.
5	Page 18, at the top, on the %'s for Mid Day, Overnight, AM & PM peaks, could the hours from when to when be added that these %'s are based on	Kevin Villier	CTS	Hours of perods added and information converted to a table for clarity.
6	Figures 2-9 thru 2-12, denote the units for "cost" and "time"	Kevin Villier	CTS	Changed axis label to "Generalized Cost (Time + Cost / VOT)"
7	Many of the maps are very crowded with detail, some need to be quite a bit larger if possible for clarity on hard-copy	Kevin Villier	CTS	Readability improved by enlarging.
8	Page 25, in the second & third paragraphs the sentence e is incomplete, the "Table 2-15" should be at the end of the sentence of the 2nd paragraph, not the beginning of the 3rd	Kevin Villier	CTS	Paragraph corrected.
9	Page 36, Table 2-24 includes a list of "stations", is there a map that shows the location for these stations	Kevin Villier	CTS	Added a location description to table.
10	Page 55, 3.1.3.2, "Hospital Corner" should be "Hospital Curve"	Kevin Villier	CTS	Corrected
11	Page 55, 3.1.3.2, under the I-64 it shows "From I-264 to I-65", since I-64 connects to I-264 in western downtown and the east end, it should be denoted which of these sections it is referring to	Kevin Villier	CTS	Added "west of I-65" to denote section in question.
12	Page 71, Figure 4-1 is essentially illegible	Kevin Villier	CTS	Graphic is only to represent the "Welcome Screen" to the model.
13	Since this is a very technical document, a conclusion could be added that provides an overview of observations, analyses and conclusions that a non-technical person could understand	Kevin Villier	CTS	Report audience is intended to be technical in nature. A non-technical version of the document could be preopared if requested, but outside the scope of this report.
14	In my opinion, it would be a good idea for the introduction section (only that one) to spell out all acronyms used, similar to an Executive Summary writing style. Alternatively, an Executive Summary might be prepared.	Amy Thomas	FHWA	Executive Summary and List of Acronyms added to report.
15	Also, I have continuing concerns about using the term 'KIPDA' instead of 'Louisville MPO'. I suggest that a sentence is included in the introduction (and/or Executive Summary) that explains the relationship similarly to the following: "The Kentuckiana Regional Planning and Development Agency (KIPDA) serves as the staff agency for the Louisville Metropolitan Planning Organization. The term 'KIPDA' has been used interchangeably to mean 'Louisville MPO' in this report."	Amy Thomas	FHWA	Sentence added to introduction to make clarification.
16	An appendix page of acronyms might be helpful, for those wanting to be able to read the report more easily without having to flip back to prior sections. Some that might be helpful: NEPA, KIPDA, CTS, TOD, PUMS, NAICS, EIS, TAZ, HBW, HBO, NHB, PA, KYTC, FDOT, HCM, WSA, MSA – metropolitan statistical area (only if used in the report), MSA – method of successive averages, RMSE, TARC, GIS, CBD, ACS, FTA, NLM, EE, EI, ODME, QRFM, GC/aGC, MMA, PCE, BPR, TMIP, VMT, PRMSE, GISDK, SEIS, MTP (unused in report – replacing LRP, see #5), ADT, FAF, etc.	Amy Thomas	FHWA	List of acronyms added.
17	The acronym LSIORB is misspelled on page 15 and 17. The acronym 'NLM' is misspelled as 'NML' on page 29. WSA might want to complete a spell check and look at every acronym.	Amy Thomas	FHWA	Corrected
18	Page 76: The term 'Long Range Plan' has been changed to 'Metropolitan Transportation Plan' in federal law. A suggested change to the wording: "…the 2030 Metropolitan Transportation Plan – the long range planning document of the Louisville MPO…" I may have missed other references to 'LRP'; I suggest WSA search for that term and make appropriate changes.	Amy Thomas	FHWA	revised sentence accordingly.
19	I suggest a brief 'Conclusion' section be added that summarizes the validation of the TOD model, and why the model can be used with confidence for the projects' SEIS. Alternatively, this information could be included in an Executive Summary, if one were to be prepared.	Amy Thomas	FHWA	Included in ES.
20	On page 2, the figure shows roads in Indiana labeled as Indiana 111, 131, and 311. Most of the Indiana routes (or portions of them) inside I-265/IN 265 have been relinquished. The exception may be IN 111 between I-64 and the Floyd County/ Harrison County Line. The portions outside of I-265/IN 265 generally remain Indiana routes. You may want to contact INDOT to determine where your labels should be placed on the figure.	Randy Simon	KIPDA	Graphic is only to represent the "Welcome Screen" to the model and not should be used for route identification.

Comment	Description	Reviewer	Agency	Response
21	On page 6, the first sentence under Table 2-5 starts, 'Because the KIPDA 10PLANA household distribution was not based on a statistical model, but instead a manual allocation based on KIPDA's knowledge of the region and past demographic trends for each zone,'. The household distribution for 10PLANA was based on a statistical model, which was derived from the 2000 Census data. Furthermore, the overall forecasts—although not based on a model—were based on information from the local planning and economic development entities.	Randy Simon	KIPDA	Statement clarified in the report to imply that the KIPDA approach is not modeled, but instead a static input to the model based on Census data and local information.
22	On pages 6-10, please clarify the assumptions behind linking the household income to job industry types for the region.	Randy Simon	KIPDA	Additional language added to the section regarding the importance of linking income and job type.
23	On page 29, the last sentence in section 2.4.3 mentions a '25% reduction in fare costs for work trips due to the number of discounted "frequent user" fares.' Was this information provided by TARC or based on data from other areas? Further, because of the fare reductions for students, the elderly, etc., there could probably also be a reduction for trips for other purposes, although we do not have an estimate of what the reduction would be.	Randy Simon	KIPDA	The mode choice model and transit skimming were borrowed from another area where a transit on-board survey were used in model estimation. They were used in the KIPDA region for order of magnitude transit and non-motrozied demand. If results are to be used, additional effort should be placed on calibration of these model components.
24	On pages 34 (Table 2-23) and 83 (Table 5-4), TAZ 855 is listed as KY 1513. It should be KY 1531.	Randy Simon	KIPDA	Corrected
25	On pages 63-64, Absolute VMT error is reported. VMT error is usually based on the difference between observed and modeled VMT, and presumably that is the case on these pages. What are the sources of the observed Facility Type, Area Type, and County VMTs?	Randy Simon	KIPDA	Sentence added to clarify the comparsions are based on locations with counts and the source of the count data.
26	On page 84 (Table 5-6), please clarify the FAF3 data values utilized for the "FAF 2040 % Trucks" calculation.	Randy Simon	KIPDA	FAF3 was the source used.
27	Page 4: "The LSIORB TOD Model includes a daily person trip generation model…" Please confirm this includes non-motorized trips as they are needed based on the mode choice model specified in Figure 2-17.	Tony Pakeltis	CTS / Parsons	Verified with KIPDA that production rates were estimated using all trips including non-motorized. Sentence added to state this.
28	Tables 2-1, 2-2 and 2-3: Generally rates are what the data says they are. Was any statistical analysis to determine significant statistical differences between trip rates across stratifications. Rates for multi-family structure, 4 and 5 person households, 2 vehicles and single-family structures, 4 person households, 2 vehicles have production rates that do not follow logical increasing patterns across vehicle stratification. Also, these tables should be labeled better (e.g., use Household Size for the column heading, note what M and S stand for under Structure Type, indicate that the vehicles column means numbers of vehicles owned)	Tony Pakeltis	CTS / Parsons	Table labeling improved. Statistical analysis was not completed on trip rates because they were used directly from the KIPDA model for consistency. Had new trip rates been estimated, analysis would have been completed to identify whether stratification of structure type was warranted etc.
29	Page 6: "This results in the zonal total households be distributed into 30 categories." should be 40 categories	Tony Pakeltis	CTS / Parsons	Correction made
30	Figure 2-4: the number of households in the income brackets over $100,000 appears oddly balanced. Totaling across all brackets in the figure implies about 1,000,000 households.	Tony Pakeltis	CTS / Parsons	Graphic was corrected to represent households greater than >100,000 properly.
31	Page 9: The income distribution model simply transfers the census tract income distribution to the TAZs within the tract. More robust income distribution submodels exist.	Tony Pakeltis	CTS / Parsons	Agreed, but this approach was utlized because we were not able to develop new zonal demogrpahic variables. At a minimum would require zonal income which was not avaiable.
32	Page 10: "The resulting total household distribution by income group in 2007 is reported in Table 2-5." should be Table 2-7	Tony Pakeltis	CTS / Parsons	Cross reference corrected.

Comment	Description	Reviewer	Agency	Response
33	Table 2-7: As reported total households across the three income groups sum to 417638.9. This does not match the total reported in Table 2-5 or 2-6	Tony Pakeltis	CTS / Parsons	Table 2.7 corrected to match previous tables. Calculation error in table summary, model data is correct.
34	Page 15: Typo in the second to last line. LSIROB should be LSIORB	Tony Pakeltis	CTS / Parsons	See #17
35	Table 2-10: There should be an explanation of the facility type and area type codes.	Tony Pakeltis	CTS / Parsons	Note added to table with a brief description of codes and reference to Phase I Report.
36	Page 17: Typo in the second line. LSIROB should be LSIORB	Tony Pakeltis	CTS / Parsons	See #17
37	Table 2-11: What is the source of information or data to justify using the indicated values of time and operating cost? Value of time is equivalent to $12.60/hour and $33.00/hour for autos and trucks respectively.	Tony Pakeltis	CTS / Parsons	Added a description of the source and rationale.
38	Page 19: "This process was completed until the average values from the survey were replicated within an acceptable tolerance." What was the acceptable tolerance?	Tony Pakeltis	CTS / Parsons	Sentence modified to include converge tolerance used.
39	Figures 2-9, 2-10 and 2-11: need to show some calibration statistic such as the coincidence ratio. Curves appear to match observed.	Tony Pakeltis	CTS / Parsons	Coincidence ratio was added (all purposes greater than 0.8)
40	Page 21: "HBW has a higher willingness to travel as seen in the shallow slope of the curve as compared to HBW and NHB that fall off quickly." should be …as compared to HBO and NHB.	Tony Pakeltis	CTS / Parsons	Corrected
41	Page 23: "The model reaches the 0.1 RMSE threshold at iteration six but becomes fairly stable starting at iteration four and little benefit is obtained after the fourth iteration in the 2007 model. Thus, iterations after the fourth may not warrant the additional time sacrificed for the minimal convergence improvements." This may be true when analyzing daily or peak period output since the convergence is based off of an average of the AM and PM peak period travel times (for HBW). However the model may still have larger than acceptable iteration to iteration variance within a peak hour assignment. More iterations may be warranted when focusing on peak hour results.	Tony Pakeltis	CTS / Parsons	Agreed that in forecast application, additional iterations of the feedback process should be completed. An analysis was completed of the different volumes between iteration of feedback and very little differece was found after the 3rd iteration which is consistent with the literature.
42	Page 23: Third paragraph: replace LSIROB with LSIORB	Tony Pakeltis	CTS / Parsons	Corrected
43	Page 26: "GIS procedures were used to connect the centroid nodes of all zones fully or partially within one third mile of any bus stop.	Tony Pakeltis	CTS / Parsons	No comment raised.
44	Page 28: "Additionally, transit walk access times were developed based on a three mile per hour speed assumption and a maximum walk time of ten minutes to transit service." This equates to ½ mile maximum walk distance. It seems possible that a TAZ could be outside the 1/3 mile buffer used to create walk access links but still have a centroid within ½ mile walk distance.	Tony Pakeltis	CTS / Parsons	Yes, that could be possible. The first rule was to check if the zone boundary is within a third of a mile to the transit stop. This first rule governs because it is assumed that if the zone boundary is not within a third of a mile to the stop then most likely there would not be direct walk access to the stop from that zone.
45	Page 28: "Transit markets were specified in the LSIORB model to develop transit potential trips by household type (zero car households and one or more car households) and by access to transit (drive access and walk access) for each trip purpose." How are these transit markets used in the model?	Tony Pakeltis	CTS / Parsons	There are different logit models applied for each transit market in mode choice
46	Section 2.4.3: What are the transit settings, parameters and weights used in path building? They should be consistent with parameters used in mode choice.	Tony Pakeltis	CTS / Parsons	The same parameters used in transit path building settings and resulting skims are used in mode choice.
47	Page 31: "…and the number of transfers have a negative effect on the utility equation and the CBD or employment density dummy variable has a positive effect." Some professionals have argued against the use of geographic based coefficients (i.e. the CDB dummy variable).	Tony Pakeltis	CTS / Parsons	This point may be valid. However, the methodology assumed characteristics from similar areas where the CBD attracts more transit trips than other area types, especially for HBW trips.
48	Table 2-20: No mode constants are listed in the table	Tony Pakeltis	CTS / Parsons	Additional table added to report for mode constants by market segment and purpose.

Comment	Description	Reviewer	Agency	Response
49	Page 32: "…model implied value of time should be in the range average income /4 to average income /3." What are the average incomes and what are the models implied values of time?	Tony Pakeltis	CTS / Parsons	The VOT assumptions used in the model are consistent between all steps (trip distribution, mode choice and traffic assignment). See note # 23 above for more information about source of model parameters.
50	Table 2-20: The cost coefficients for Work and Other trips give a higher value of time to Other trips ($12.50/hr versus $6.52/hr). Typically, Work trips would be expected to have a higher value of time.	Tony Pakeltis	CTS / Parsons	The cost parameter coefficients for work and other in the NLM of Mode Choice are borrowed as described in the documentation. Local surveys were not used for calibration of the model. The model was validated to Journey-to-Work percent mode shares and transit trip by purpose data borrowed from similar areas with adjustment of the mode constants as is typical practice. When Ken Cervenka, FTA reviewed the source model (CHATS), he also acknowledges the lower HBW VOT. He states in an email "This doesn't mean you are wrong, but I am curious as to whether you have seen this type of VOT difference amongst purposes from other studies" beyond the CHATS On-Board study.
51	Page 38: "The issue of the decreasing expansion rate for station 2N (attraction) as well as the imbalance of the attraction trip totals (Table 2) to the matched plates (Table 1) results in some uncertainty with the attraction trips." What are Tables 2 and 1? Are they possibly 2-28 and 2-27 respectively?	Tony Pakeltis	CTS / Parsons	Corrected
52	Page 38: "The TransCAD modeling software was used to fratar the raw survey data of EE trips (Table 4) with the sum of the expanded EE productions (Table 2-28) for passenger vehicles." What is Table 4?	Tony Pakeltis	CTS / Parsons	Corrected
53	Page 51: "The graphical user interface allows the use of unique values of time by income group for the auto trips, and unique values of time for light truck and heavy truck flows." What values of time have been proposed for use with the forecasts?	Tony Pakeltis	CTS / Parsons	For the SEIS the VOT and VOC used in validation were applied for the forecast since constant dollars were assumed in the forecast. The GUI was created to allow flexibility for future applications. (Table 2-11)
54	Page 54, Table 3-2: "The K-factors were adjusted based on improving the JTW comparison and the screen line validation while maintaining reasonable values." What are reasonable values? A more rigorous standard for using K-factors includes using them sparingly and limited the range from 0.5 to 2.0 to ensure that they did not dominate the calibrated friction factors. The use of very large (or small) K-factors can have the tendency to fix the distribution and make it relatively insensitive to changes in the transportation network.	Tony Pakeltis	CTS / Parsons	In principle agree, but given the high proportion of employment in Jefferson County as compared to the rest of the region and geographic barriers (Ohio River), they may be warranted in this case. Future enhancements to the trip generation model (rates by district) may reduce the dependence on k-factors.
55	Figure 3-1: An overall goal for percent RMSE should be less than 30.	Tony Pakeltis	CTS / Parsons	An overall goal of a percent RMSE less than 30 is desirable, but it is not a "pass / fail" criteria in the literature. Further, by volume group, the LSIORB TOD Model is well under the TMIP Criteria (Figure 3-5).

Comment	Description	Reviewer	Agency	Response
56	Page 62: "Figure 3-2 demonstrates that for all facility type groups, the LSIORB TOD Model is below the established criteria." This is true except for the One Way class shown.	Tony Pakeltis	CTS / Parsons	Amended sentence to reflect one-way streets exceed by 2%.
57	Figures 3-2, 3-3, 3-4: It would be helpful to see how many count locations were available for each classification grouping.	Tony Pakeltis	CTS / Parsons	The distribution of 1265 counts is shown in a new table.
58	Figure 3-6: Clark Memorial Bridge volumes are considerably lower than counts. Is this a direct trade-off with the volumes on I-65 which closely match the counts?	Tony Pakeltis	CTS / Parsons	The trade off is based on a) the validation on I-65, and the relative distribution of traffic under forecast conditions when applying the model.
59	Table 3-7: Typically, it is desirable to match screenline crossings to within ±15 percent. It would also be helpful to see how many count locations were used to define each screenline.	Tony Pakeltis	CTS / Parsons	See #57
60	Section 3.2.3: It appears as the model has forecast too much traffic during the peak periods and to little in the off-peak periods. Again it would be helpful to see how many count locations were in each facility group by period.	Tony Pakeltis	CTS / Parsons	See #57 Further, the model was validated to AADT, and period validation was for order of magnitude check only. This is a typical comparsion based on the reporting time of trip departure vs count distributions in TOD Models.
61	You've referenced the 1997 validation manual, but not the 2nd edition dated September 24, 2010. Please reference the newer manual with additional documentation of the processes and results.	Scott Thomson	KYTC	Changed reference to 2nd edition, but sections used in the LSIORB Validation are unchanged between 1st and 2nd version.
62	2.3.1 Friction Factor Calibration….What was the range of values? Friction Factors can make the model insensitive to changes. Please document the range and frequency of values using a visual histogram.	Scott Thomson	KYTC	The friction factors are shown in Figure 4.12 in the report.
63	2.3.2.2 Convergence Criteria… You mention 0.1 RMSE as the threshold, but we're more accustomed to it as a numerical value. Is this the same as .001? Recent Caliper white papers have reference values of .0001 or better(smaller).	Scott Thomson	KYTC	The threshold applied was based on a review of the literature and our experince with feeedback models in Austin, TX. The model is achieving stability based on the converge calcuation and a comparsion of volumes by period after iteration #3.
64	2.5.1 Data Collection This and the following sections describe Stations as 1N, 1S, etc. however, no figure is provided or referenced. Please provide a map that highlights the stations and the nomenclature used in the tables. (so the previous Phase 1 document isn't a required reference.	Scott Thomson	KYTC	Map added.
65	3.2 Validation Results Figure 3-1 demonstrates a trend in the overall error (ie. RMSE) but doesn't provide an idea of the models overall performance when compared to data. Please include a figure where count vs flow is plotted relating to ADT's. Since this is a TOD model, can the hourly counts of the results be displayed in a similar manner?	Scott Thomson	KYTC	Provided a map of the daily validation results showing under and over assigned. Not appropriate to show peak validation since model validated to daily conditions.
66	3.2.2 Daily Assignment Validation FHWA criteria is mentioned. Please document the methodology used to establish the values. The link below includes a table, but doesn't appear to correlate with the 'Criteria' line in figure 3-5 http://tmip.fhwa.dot.gov/resources/clearinghouse/docs/FHWA-HEP-10-042/ch9.htm Figure 3-2 and 3-3 do not label the Y-axis (what are the units of VMT error?)	Scott Thomson	KYTC	Corrected the curve in the figure represent the correct curve from the TMIP Guide.
67	Table 3-9 VMT Error by Facility Group by Period. Convert the Facility Group labels from numbers (10,20,30,etc) to match the Facility Group labels used on figure 3-2	Scott Thomson	KYTC	Change made.

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