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Standardization of Travel Demand Models

The North Carolina Experience

TNMUG Meeting – November 14, 2013

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Background

- **North Carolina Profile**
  - 18 MPOs, 10 with population < 250,000
  - 20 Rural Planning Organizations
  - 1959 GS 136-66.2
  - 2001 revisions were made to GS 136-66.2

NCDOT
NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

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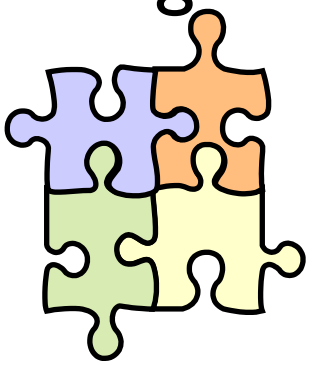
Current Challenges

- Changing workforce
- Changes in scope and responsibility
- Loss of experienced, knowledgeable staff leading to an erosion of modeling skills and loss of institutional knowledge in modeling practice



NCDOT's Efforts

- Broad scale effort to improve travel forecasting tools in NC
- Sponsored research to develop best practice guidelines for planning analysis tools (Tier 1 and 2 communities)
- Contracted with Parsons Brinckerhoff to develop standard modeling guidelines and procedures

  (Tier 3 communities)

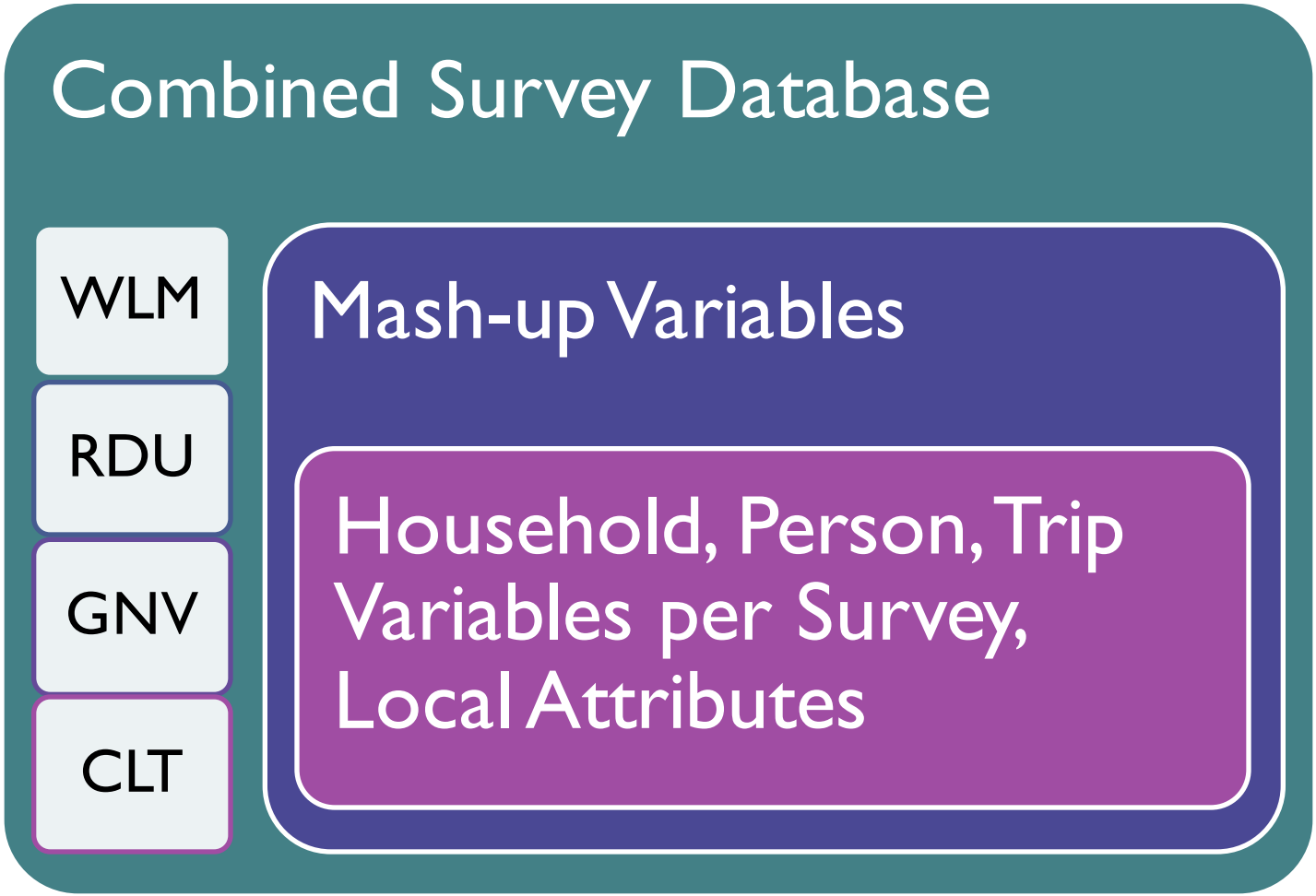
Outline

- North Carolina Combined Survey Database
- Model Structure
- Traditional Approach vs. Key Features of New Approach
- Graphical User Interface
- Benefits
- NCDOT – that was then, this is now

Combined Survey Database

- Household travel survey data from 4 MPOs across North Carolina
- Used to develop default rates and parameters
  - Household disaggregate curves
  - Production and attraction rates
  - Initial gamma coefficients
  - Mode split factors
  - Vehicle occupancy factors
  - Time of day distribution
- Starting point for communities with no observed travel survey data
- Future enhancement – NHTS add-on to adjust rates

Survey Data Mash-up



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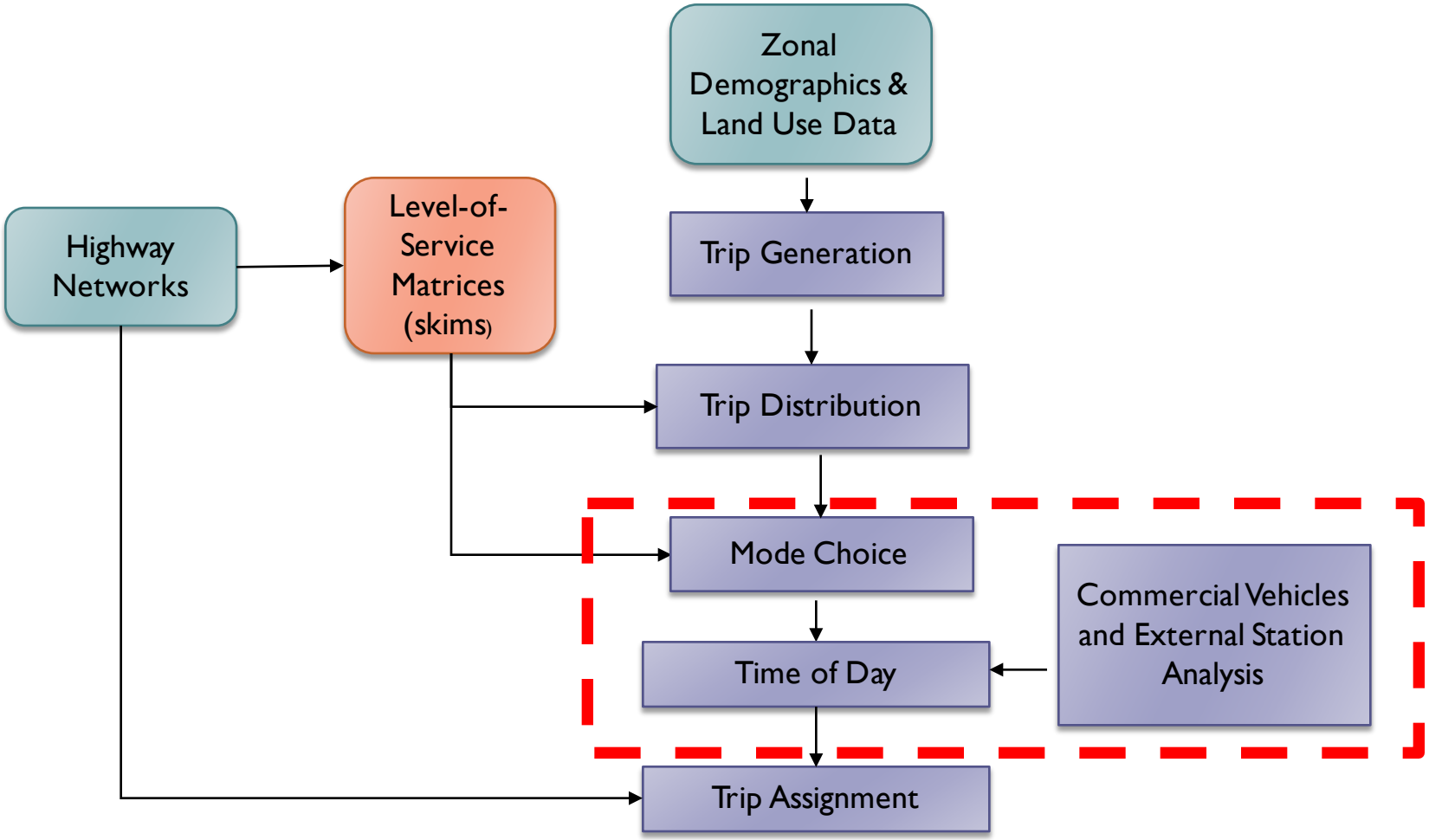
Model Structure

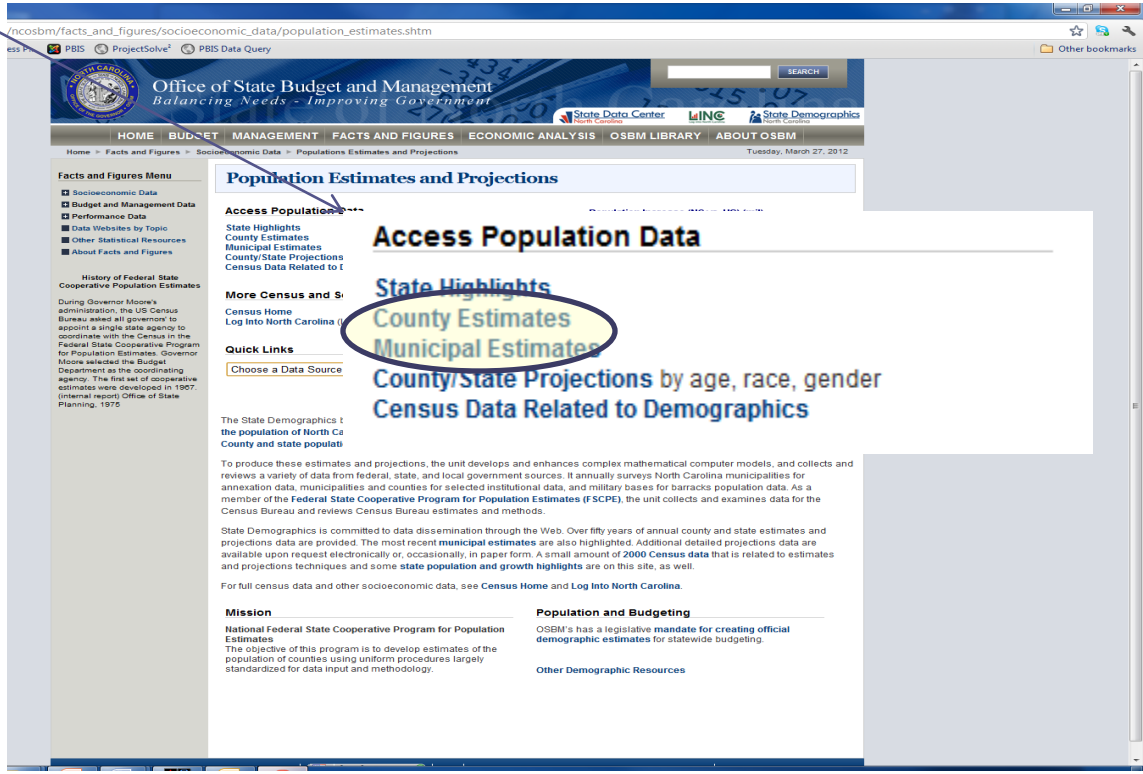


Data Collection

Traditional	Standardization
• 100% field inventory	• Census Data • Private Vendor Data

TAZ Census and Socio-Economic Data

- Total Population
- Total Households
- Total Autos
- School Enrollment



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TAZ Employment Groupings 3-digit NAICS

Employment Category	NAICS 3-digit codes
Industry	111-115, 211-213, 221, 236-238, 311-339, 424, 481-484, 486, 488, 491-493, 562
Retail	423, 441-444, 446, 448-453
High-traffic Retail	445, 447, 722
Service	485, 487, 532, 541, 561, 611, 621-624, 711-713, 721, 811- 814, 922, 923
Office	425, 454, 511-519, 521-525, 531, 533, 551, 921, 924-928

Highway Network

Traditional	Standardization
• No standard approach • No standard procedures for attributes • No standard procedures for capacity calculations	• Guidelines for selecting modeled roadways • Minimum required attributes • NCLOS program for capacity calculations

Standard Roadway Attributes

Attribute	Description
Posted Speed	
Facility Type	Predefined
Area Type	Predefined
Divided	Predefined
AB Lanes BA Lanes	Number of lanes by direction
Functional Class	Predefined
AB Capacity BA Capacity	Capacity Lookup Table
Initial Time	Initial link travel time, calculated from Posted Speed. Documented formula
Alpha	Predefined parameter used in the Volume Delay Function

Values of Facility Type

Value	Definition
Freeway	Roads with uninterrupted flow and fully restricted access including interstate facilities, freeways, and expressways.
Multi-lane Highway	Partial access control two-way facility. No traffic signals or with traffic signals spaced at least 2 miles apart. Directional traffic is divided or with a continuous turn lane.
Two-lane Highway	Rural, undivided, two-way highways. Intercity or commuting route serving longer trips in rural areas.
Urban Arterial I	Principal arterials of high speed design
Urban Arterial II	Most suburban designs, and intermediate designs for principal arterials.
Urban Arterial III	Generally urban design for principal arterials, intermediate design for minors
Urban Arterial IV	Minor arterials of intermediate or urban design
Collector	Urban suburban locations with lower speeds than arterials. Can be rural roadways with low free-flow speed or frequent interruptions.
Local Road	Coded to provide connectivity. Low speed collectors
Diamond Ramp	
Loop Ramp	
Freeway to Freeway Ramp	
Centroid Connector	

Values of Cross-Section

Divided	DIVIDED_CD	Definition
Undivided	1	Undivided roadway and centroid connectors
Divided	2	Divided roadway
CLTL	3	Continuous Left Turn Lane

Values of Functional Classification

Functional	FUNCL_CD
Not Classified	99
Rural Principal Arterial - Interstate	20
Rural Principal Arterial - Other	21
Rural Minor Arterial	22
Rural Major Collector	23
Rural Minor Collector	24
Rural Local / Rural Centroid Connectors	25
Urban Principal Arterial - Interstate	10
Urban Principal Arterial - Freeway/Expressway	11
Urban Principal Arterial - Other	12
Urban Minor Arterial	13
Urban Collector	14
Urban Local / Urban Centroid Connectors	15

Initial Travel Time Calculations

Description	Selection Set	Formula
CASE1: Higher level highways	Where Facility Type = "Freeway" or ((Facility Type = "Multi-lane Highway" or Facility Type = "Two-lane Highway") and Divided = "Divided")	Initial Travel Time = Length/(Posted Speed + 5.0)*60
CASE2: Lower level highways and arterials	((Where Facility Type = "Multi-lane Highway" or Facility Type = "Two-lane Highway") and Divided = "Undivided" or Divided = "CLTL") or Facility Type contains "Urban Arterial"	Initial Travel Time = Length/(Posted Speed - 5.0)*60
CASE3: Local Roads, collectors, ramps and other links	Where Facility Type= "Centroid Connector" or Facility Type= "Collector" or Facility Type= "Diamond Ramp" or Facility Type= "Loop Ramp" or Facility Type= "Local Road" or Facility Type= "Freeway to Freeway Ramp"	Initial Travel Time = Length/Posted Speed*60

Alpha Parameter by Facility Type

Facility Type	Alpha
Freeway	10
Multi-Lane Highway	8
Two-lane Highway	6
Urban Arterial I	6
Urban Arterial II	6
Urban Arterial III	6
Urban Arterial IV	6
Collector	4
Local Road	4
Diamond Ramp	8
Loop Ramp	8
Freeway to Freeway Ramp	8
Centroid Connector	NA

Example Capacity Lookup Table

Facility Type	Area Type	Divided	Capacity(Hourly/Lane)
Freeway	CBD	Divided	2,100
Freeway	Rural	Divided	2,100
Freeway	Urban	Divided	2,100
Multi-lane Highway	CBD	Divided	1,700
Multi-lane Highway	CBD	Undivided	1,400
Multi-lane Highway	Rural	Divided	1,700
Multi-lane Highway	Rural	Undivided	1,400
Multi-lane Highway	Urban	Divided	1,700
Multi-lane Highway	Urban	Undivided	1,400
Two-lane Highway	Rural	Divided	1,200
Two-lane Highway	Rural	Undivided	1,000
Two-lane Highway	Urban	Divided	1,200
Two-lane Highway	Urban	Undivided	1,000
Freeway to Freeway Ramp	CBD	Divided	2,100
Freeway to Freeway Ramp	Rural	Divided	2,100
Freeway to Freeway Ramp	Urban	Divided	2,100
Loop Ramp	CBD	Divided	1,000
Loop Ramp	Rural	Divided	1,000
Loop Ramp	Urban	Divided	1,000
Urban Arterial I	CBD	Divided	1,500
Urban Arterial I	CBD	Undivided	1,400
Etc…			

Peak Hour Factors – Small Areas

Period	Peak Hour Factor	Period Limits	Period Length
AM	0.40	6 AM – 10 AM	4 hours
MD	0.24	10 AM – 3 PM	5 hours
PM	0.29	3 PM – 7 PM	4 hours
OP	0.30	7 PM – 6 AM	11 hours

Peak Hour Factors – Large Areas

Period	Peak Hour Factor	Period Limits	Period Length
AM	0.37	6 AM – 10 AM	4 hours
MD	0.23	10 AM – 3 PM	5 hours
PM	0.30	3 PM – 7 PM	4 hours
OP	0.35	7 PM – 6 AM	11 hours

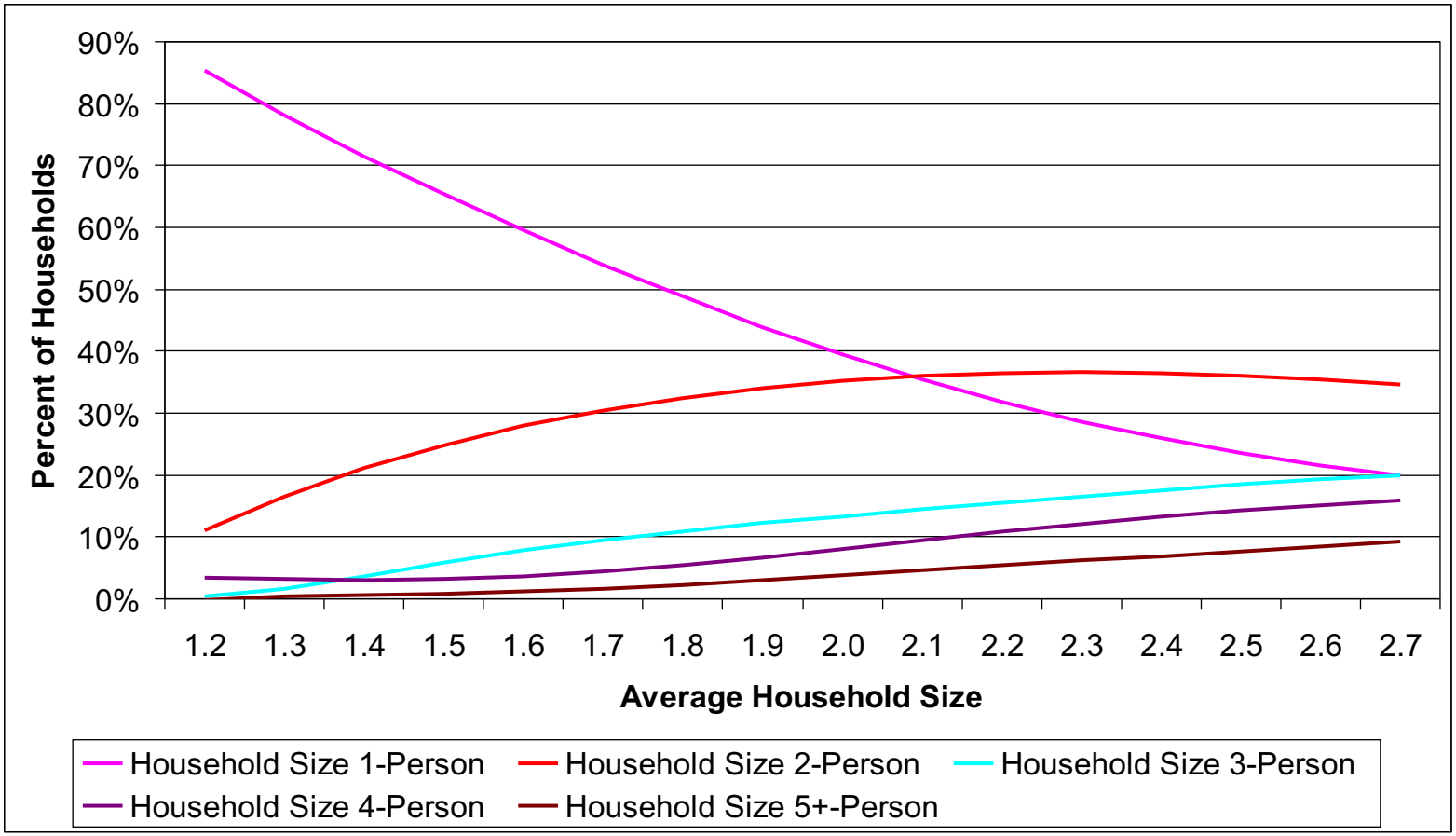
Rates and Parameters

Traditional	Standardization
• Borrowed from other areas • No guidelines for transferability • Used classification of households on a scale of excellent to poor	• Default rates from combined survey database • Separate rates for small and large areas • Standard variables designed to best capture travel behavior

Trip Generation Submodels

Traditional	Standardization
• Not used	• Default household size curves • Default auto ownership curves • Default seed matrix • All data derived from census data for communities covered in combined survey database

Example Trip Generation Submodel



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Trip Generation

Traditional	Standardization
• 3 trip purposes • (HBW,HBO,NHB) • Productions by 5 dwelling unit classes • Attractions by 5 employment categories • Vehicle trips	• 5 trip purposes • Productions by household size and auto ownership (20 classes) • Attractions by 5 employment categories • Person trips

Person Trip Production Rates and Standard Deviation (1 person households)

Field Name	Description	HBW	HBO	HBSCH	NHBW	NHBO
hhp1a0	1 person, 0 auto	0.222	1.442	0.01	0.101	0.638
	Standard Deviation	*0.69*	*1.28*	*0.15*	*0.5*	*1.88*
hhp1a1	1 person, 1 auto	0.777	1.891	0.033	0.597	1.009
	Standard Deviation	*0.96*	*1.6*	*0.23*	*1.18*	*1.45*
hhp1a2	1 person, 2 auto	0.777	1.891	0.033	0.69	1.009
	Standard Deviation	*0.93*	*1.7*	*0.1*	*1.4*	*1.76*
hhp1a3	1 person, 3 auto	0.777	1.891	0.033	0.690	1.009
	Standard Deviation	*0.86*	*2*	*0.36*	*0.97*	*1.3*

Person Trip Attraction Rates

Employment Type	HBW	HBO	HBSCH	NHBW	NHBO
Total Employment	1.06				
Industry		0.57		0.38	0.25
Retail		5.78		1.69	3.57
Highway Retail		5.78		1.69	3.57
Service		0.46		0.30	0.18
Office		0.32		0.24	1.16
Households		1.89			0.82
Student Enrollment			0.78		

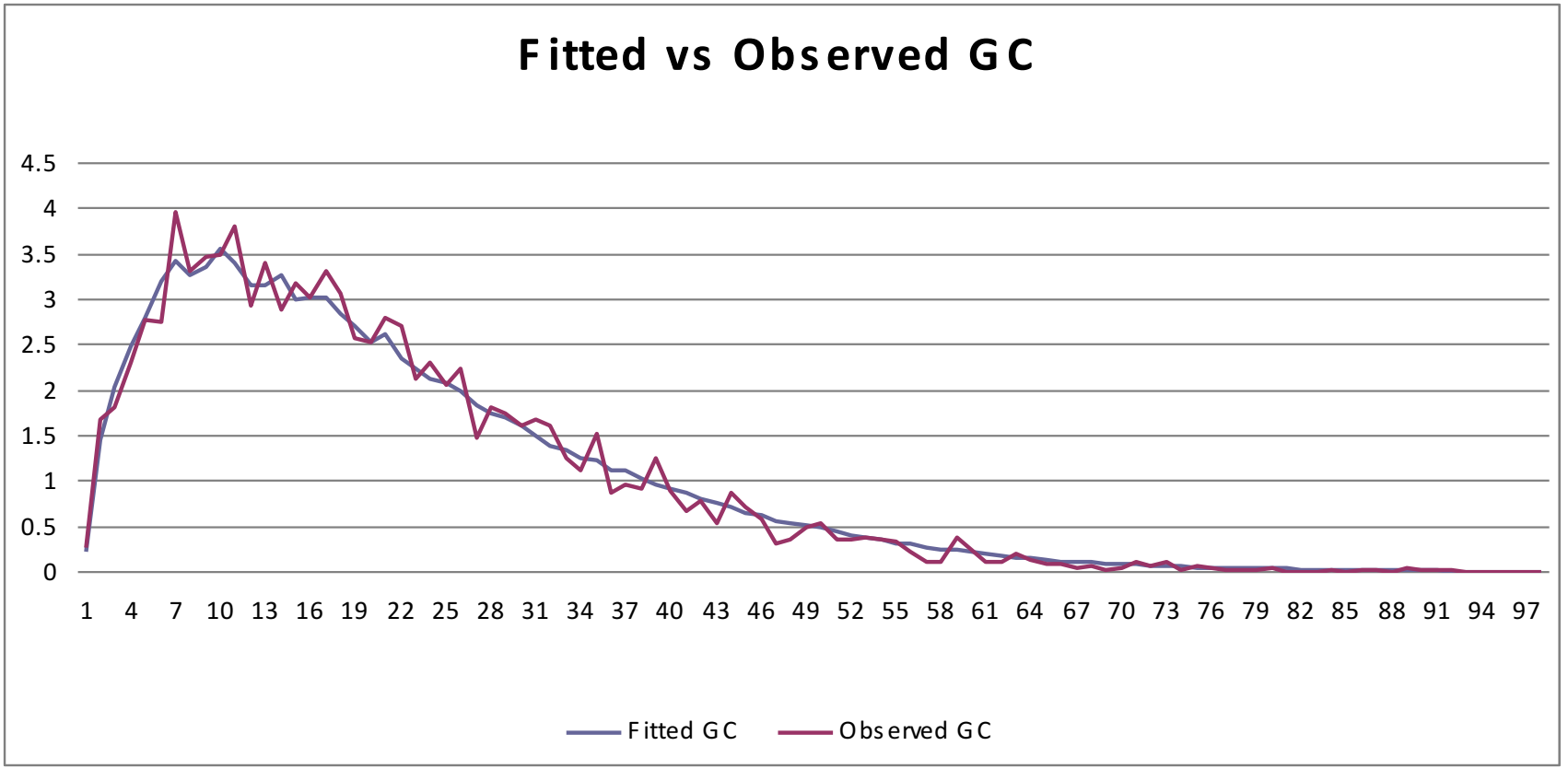
Person Trip Attraction Rates – Standard Deviation

Employment Type	HBW	HBO	HBSCH	NHBW	NHBO
Total Employment	0.027				
Industry		0.11		0.04	0.06
Retail		0.42		0.18	0.24
Highway Retail		0.83		0.36	0.48
Service		0.09		0.04	0.05
Office		0.07		0.14	0.18
Households		0.13			0.07
Student Enrollment			0.10		

Trip Distribution

Traditional	Standardization
• Friction factor table • Impedance = initial travel time	• Gamma Function • Impedance = Generalized Cost

Combined Survey – HBW TLD GC



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Range of Trip Lengths

- Highlighted the need to develop separate factors for small and large areas

Purpose	Range of Mean Travel Time	Range of Mean Trip Length	Range of Mean Generalized Cost
HBW	8.58 – 15.30	6.13 – 11.04	12.68 – 21.70
HBO	7.08 – 9.87	4.97 – 6.55	13.74 – 17.40
HBSCH	8.44 – 9.61	5.19 – 6.26	13.95 – 16.80
NHBW	5.65 – 10.49	3.90 – 7.37	9.22 – 16.17
NHBO	4.47 – 8.87	3.03 – 6.04	7.19 – 13.53

Standard Gamma Coefficients

Trip Purpose	a	b	c
HBW (large area)	93.2694	0.7903	0.0616
HBW (small area)	10.5936	1.0250	0.0000
HBO	811.0232	1.0645	0.0832
HBSCH	354.0846	0.5874	0.1291
NHBW (large area)	470.3996	0.9334	0.0678
NHBW (small area)	2.3286	0.7694	0.0000
NHBO (large area)	2983.1686	1.0461	0.0782
NHBO (small area)	4.6750	0.2916	0.1390
CV1 (large area)	2983.1686	1.0461	0.0782
CV1 (small area)	4.6750	0.2916	0.1390
CV2 (large area)	2983.1686	1.0461	0.0782
CV2 (small area)	4.6750	0.2916	0.1390
CV3 (large area)	2983.1686	1.0461	0.0782
CV3 (small area)	4.6750	0.2916	0.1390
IX (large area)	2983.1686	1.0461	0.0782
IX (small area)	4.6750	0.2916	0.1390

Mode Split

Traditional	Standardization
• None	• Mode factors applied to person trip tables

Mode Shares by Trip Purpose

	Small Study Area		Large Study Area	
Purpose	Auto	Non-Auto	Auto	Non-Auto
HBW	96.9	3.1	96.4	3.6
HBO	93.2	6.8	93.7	6.3
HBSCH	98.4	1.6	93.7	6.3
NHBW	96.3	3.7	94.6	5.4
NHBO	95.8	4.2	95.2	4.8

Commercial Vehicles

Traditional	Standardization
• Trip rate applied to total commercial vehicles per zone • CV trips combined with NHB trips for distribution	• Separate production and attraction equations for 3 classes of commercial vehicles • 3 classes maintained through time of day • Commercial Autos/Vans (CV1) • Commercial Pickups (CV2) • Large Trucks (CV3)

Commercial Vehicle Production Rates

Production Rates	Industry CV	Retail CV	HwyRet CV	Service CV	Office CV
Autos/Vans (CV1)	2.49	2.89	2.89	3.43	3.43
Pickups (CV2)	4.19	5.81	5.81	4.32	4.32
Trucks (CV3)	6.62	7.86	7.86	7.44	7.44

Commercial Vehicle Attraction Rates

	Industry EMP	Retail EMP	HwyRetail EMP	Service EMP	Office EMP	Households
Autos/Vans (CV1)	0.20	0.33	0.25	0.10	0.12	0.0200
Pickups (CV2)	0.30	0.40	0.33	0.25	0.13	0.0120
Trucks (CV3)	0.75	0.67	0.50	0.21	0.23	0.039

External Station Analysis

Traditional	Standardization
• SYNTH program to synthesize through trip table based on ADT, facility type, and % trucks • Borrowed attraction rates for IE/EI trips	• No change

SYNTH PROGRAM

- Uses regression equations and matrix balancing techniques to synthesize through trips
- Requires: planning area population, external station count, percent trucks, functional classification, and information on route continuity

External Station Attraction Rates

	Households	Industry	Retail	HwyRetail	Service	Office
IX	0.33	0.34	0.49	0.28	0.28	0.28

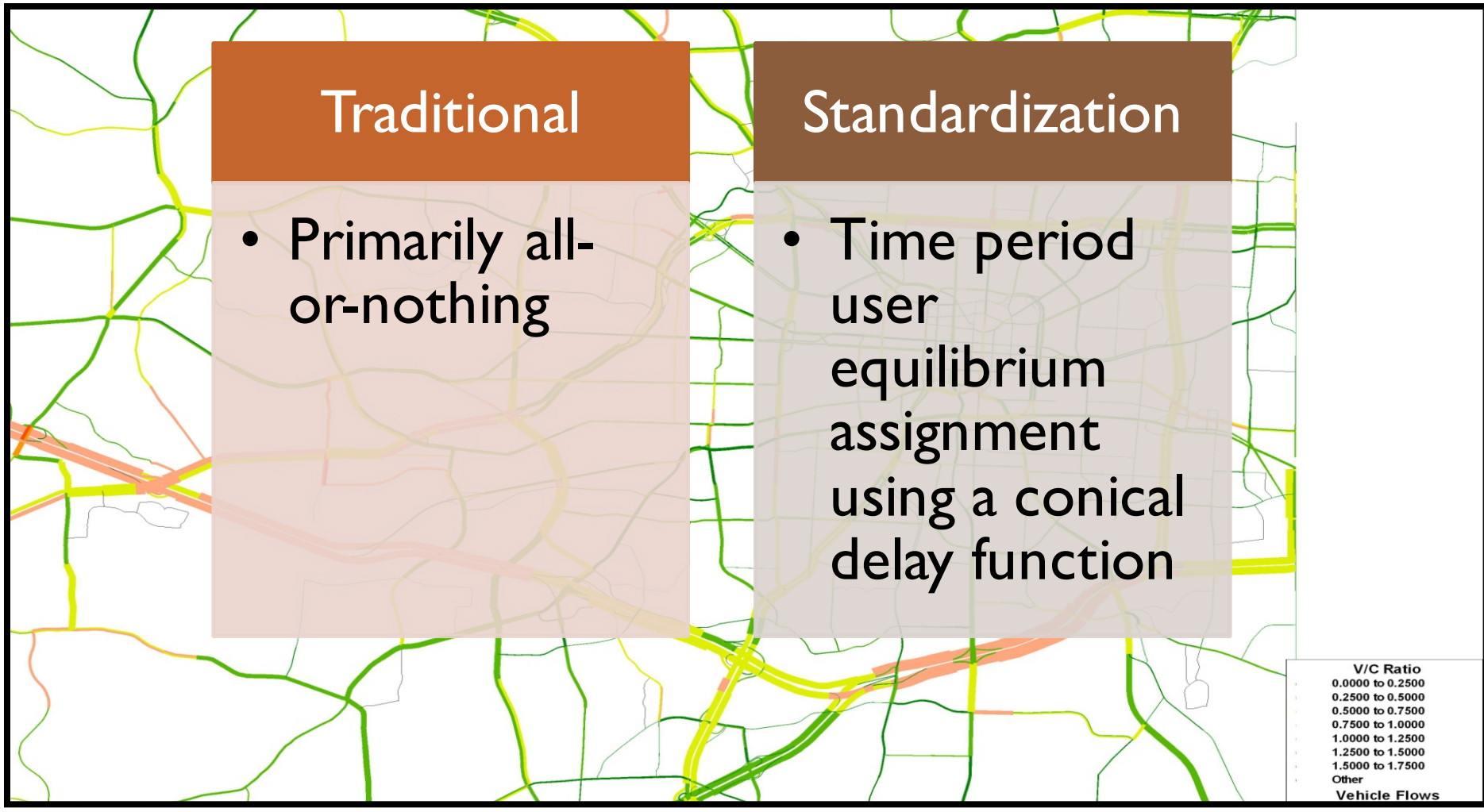
Time of Day

Traditional	Standardization
• Daily Model	• AM, Midday, PM, and Night • Time of day distributions developed from combined survey • Vehicle occupancy factors from combined survey

Time of Day Distribution by Purpose

Hour	dep_hbw	ret_hbw	dep_hbsch	ret_hbsch	dep_hbo	ret_hbo	dep_nhbw	ret_nhbw	dep_nhbo	ret_nhbo	dep_all	ret_all	% FLOW ALL
0	0	0.63	0	0	0	0.29	0	0	0	0	0	0.22	0.22
1	0.28	1.3	0	0	0.07	0.36	0.06	0	0.1	0.1	0.13	0.41	0.54
2	0	0.11	0	0	0	0.06	0	0	0	0	0	0	0
3	0.11	0.11	0	0	0	0	0	0	0	0	0.02	0.04	0.06
4	0.34	0	0	0	0.11	0	0.13	0	0	0	0.12	0.02	0.14
5	2.5	0.3	0	0	0.27	0.05	0.12	0.6	0	0	0.61	0.12	0.73
6	5.83	0.07	0	0	1.08	0.05	0.12	1.03	0.17	0.17	1.59	0.17	1.76
7	14.86	0.86	5.48	0	3.49	0.59	0.13	5.83	0.78	0.78	4.53	1.14	5.67
8	10.12	0.98	17.7	0	5.56	2.44	1.28	15.19	2.57	2.57	5.28	3.24	8.52
9	2.52	0.33	9.79	0.8	4.58	1.9	2.13	1.74	2.67	2.67	3.37	1.84	5.21
10	1.07	0.21	1.39	0	4.7	2.77	1.76	2.16	4.51	4.51	3.46	2.78	6.24
11	1.36	1.19	2.09	3.02	3.8	2.28	3.8	1.88	4.12	4.12	3.37	2.7	6.07
12	0.89	2.04	1.14	5.52	2.21	3.68	6.67	3.89	6.12	6.12	3.73	4.28	8.01
13	2.42	1.58	0.63	4.83	2.92	2.42	4.97	8.9	6.33	6.33	4.12	4.22	8.34
14	1.61	1.31	0	4.54	2.62	3.55	3.01	3.57	2.94	2.94	2.5	2.95	5.45
15	1.64	3.08	2.31	10.83	3.54	3.96	5.76	2.18	4.97	4.97	3.87	4.16	8.03
16	1.13	8.89	1.04	5.59	2.91	3.92	6.23	1.59	3.31	3.31	3.05	4.46	7.51
17	1.32	11.99	3.26	3.17	2.8	4.94	7.69	0.55	3.73	3.73	3.42	5.4	8.82
18	0.33	7.46	4.09	1.23	3.36	4.77	3.81	0.33	2.71	2.71	2.62	4.09	6.71
19	0.61	2.38	0.53	1.66	3.8	2.78	0.55	0.4	1.89	1.89	2.05	2.17	4.22
20	0.03	1.94	0.55	1.79	1.3	2.95	0.26	0	1.06	1.06	0.82	1.85	2.67
21	0.28	1.02	0	1.06	0.32	3.2	0.97	0	1.2	1.2	0.68	1.79	2.47
22	0.17	1.2	0	5.96	0.36	1.92	0.55	0	0.58	0.58	0.4	1.25	1.71
23	0.58	1.02	0	0	0.2	1.12	0	0.16	0.24	0.24	0.26	0.7	0.9

Highway Assignment



Traditional

- Primarily all-or-nothing

Standardization

- Time period user equilibrium assignment using a conical delay function

Auto Occupancy Factors by Purpose

	Small Study Area Factors				Large Study Area Factors			
Purpose	AM	MD	PM	OP	AM	MD	PM	OP
HBW	1.07	1.10	1.07	1.09	1.05	1.07	1.05	1.05
HBO	1.36	1.30	1.43	1.45	1.48	1.31	1.52	1.52
HBSCH	1.27	1.13	1.23	1.30	2.07	1.58	1.99	1.23
NHBW	1.05	1.11	1.08	1.14	1.09	1.18	1.09	1.10
NHBO	1.32	1.27	1.45	1.73	1.57	1.39	1.61	1.73

Validation and Reasonableness Checking

Traditional	Standardization
• Primarily performed at highway assignment using screenline and coverage counts	• Reasonableness checks at each step in the process using secondary sources of data • Best practice highway assignment validation checks including %RMSE

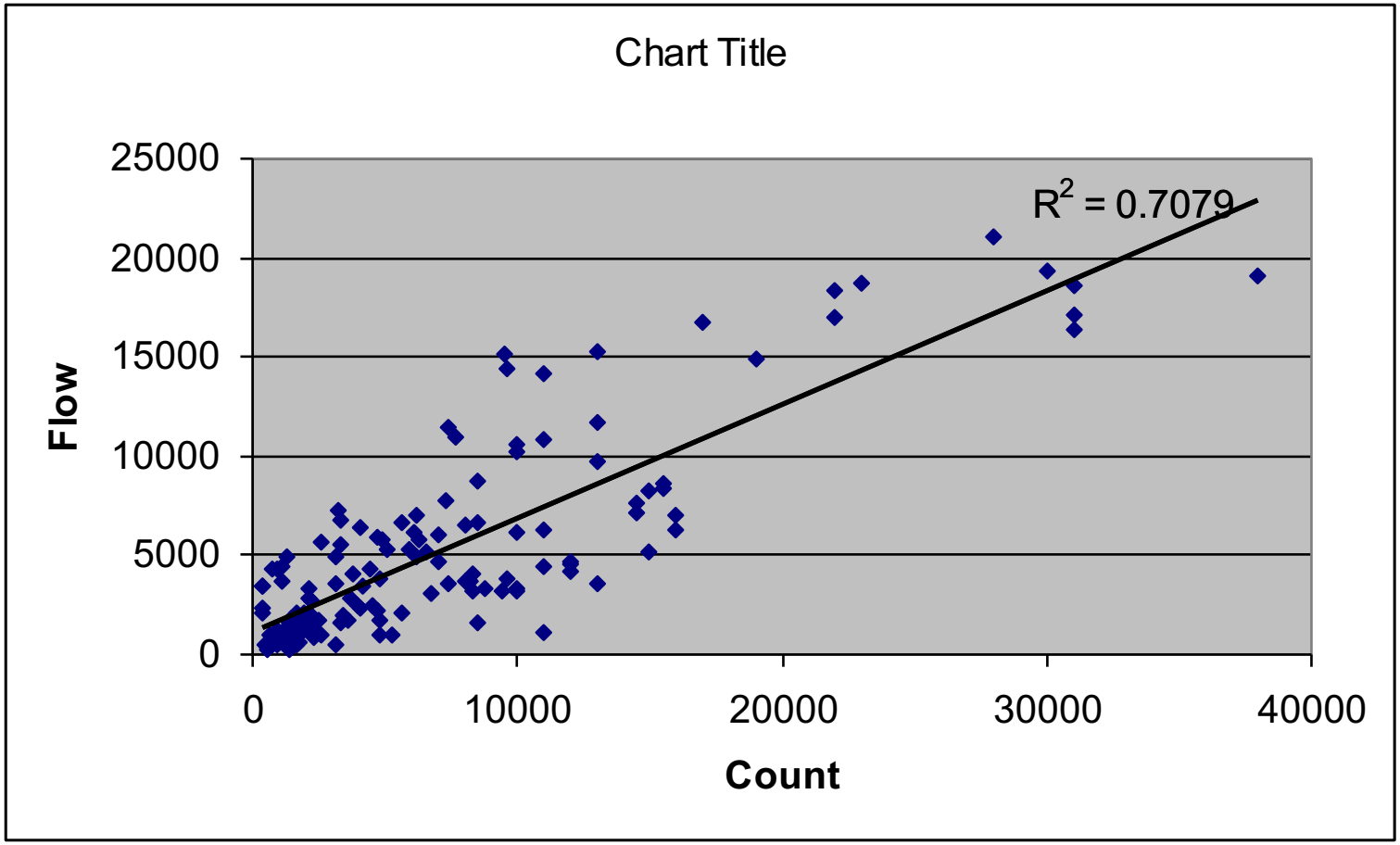
Target Percent Root Mean Square Error

Facility Type	Approximate % RMSE
Interstate	25%
Freeway/Expressway	40%
Arterials	50%
Collector	65%
Total	30 – 40%

FHWA Standards for Acceptable Deviation by Volume Group

Daily 2-way Volume	Desirable Percent Deviation
< 1,000	60%
1,000 to 2,500	47%
2,500 to 5,000	36%
5,000 to 10,000	29%
10,000 to 25,000	25%
25,000 to 50,000	22%
> 50,000	21%

Example Scatter Plot



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Highway Assignment Review EXAMPLE

VMT Summaries (Count Links Only)

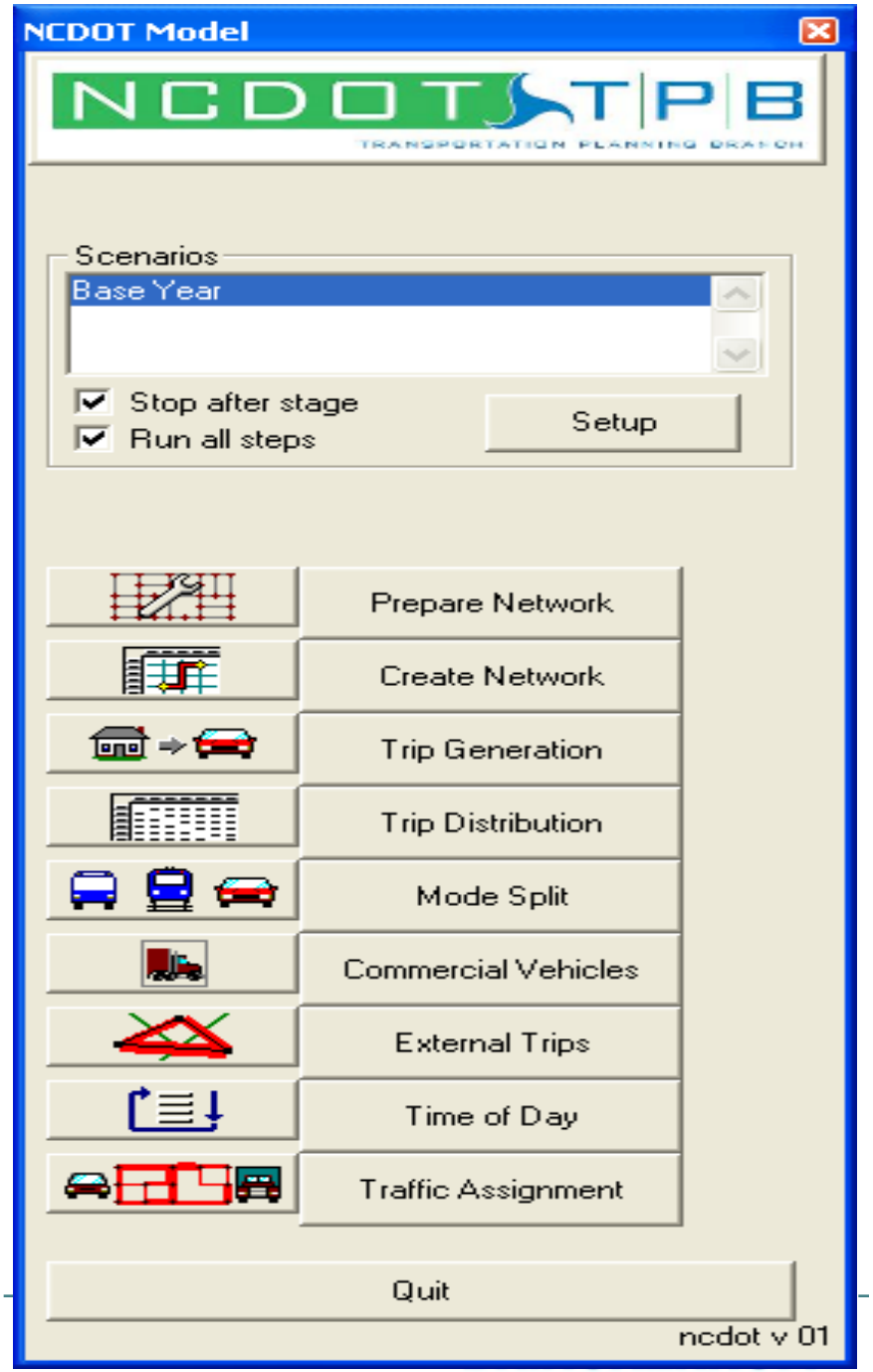
Facility Type	TOT VMT	Count VMT	% Deviation
Freeway	117,521	171,418	-31
Multilane Highway	155,958	222,517	-30
Urban Arterial I	29,088	37,129	-22
Urban Arterial II	51,243	46,056	-11
Urban Arterial III	21,138	24,641	-14
Urban Arterial IV	68,145	86,733	-21
Two-lane Highway	43,682	28,344	54
Collector	21,939	26,684	-18
All	508,714	643,522	-21

Highway Assignment Assessment Example

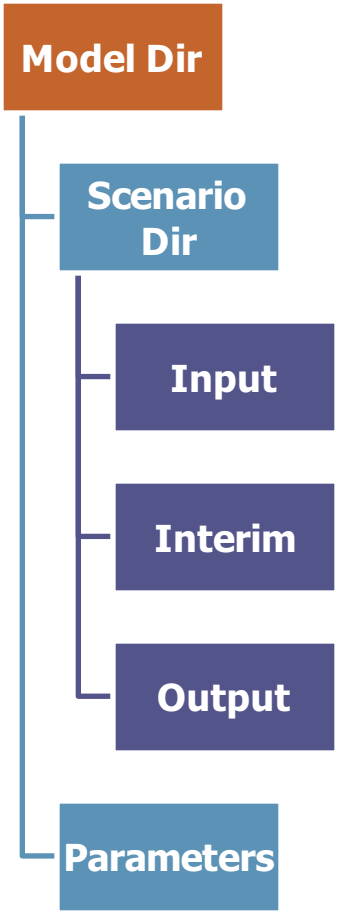
- Action Items:
  - Review traffic counts for two-lane highways – verify the accuracy of the data
  - Review the centroid connectors in relation to how they assign to the two-lane highways
  - Overall low assignment indicates that we are not getting enough trips systemwide.
  - **FIRST STEP:** Recall that the intrazonal percentages were much too high. Adjust for the intrazonal percentages (K-factors) and rerun the model to see if the VMT statistics improve.
  - **TIP:** When making model adjustments it is wise to make only ONE adjustment at a time and then test the results of that adjustment before making another adjustment.
  - **SECOND STEP:** Recall that we had an imbalance in the HBW productions and HBW attractions, where the productions were lower than the attractions. It was also noted that the %HBW trips was lower than what is typically expected. Since we balance to productions we may need to adjust the trip production rates for the HBW trip purpose.

Problem	Possible Solutions
Systemwide volumes are higher than ground counts	a.Raise auto occupancy rates b.Lower trip production rates c.Are number of households to high d.Is auto ownership to high e.Lower average trip length f.Increase intrazonal trips g.Check counts
Systemwide volumes are lower than ground counts	a.Lower auto occupancy rates b.Raise trip production rates c.Are number of households to low d.Is auto ownership to low e.Raise average trip length f.Decrease intrazonal trips g.Check counts
Total systemwide volumes match ground counts but specific links do not	a.Verify speed and capacity of roadway section b.Modify local network c.Add or delete nearby centroid connectors d.Check nearby special generators e.Check socioeconomic data of nearby zones

Graphical User Interface



Required Directory Structure



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File Names and Descriptions – Parameters Folder

File Name	Description
CAPACITY.BIN	BIN file with capacities for study area – MUST BE UPDATED BY USER
ALPHA.BIN	BIN file with standard values for alpha coefficient
HHSIZE.BIN	Default household size curve coefficients
AUTOS.BIN	Default auto ownership curve coefficients
JOINTDIST.BIN	Joint household size/auto ownership seed matrix
NCPRODRATES.BIN	Default trip production rates
NCATTRRATES.BIN	Default trip attraction rates
CVPRODRATES.BIN	Default commercial vehicle trip production rates
CVATTRRATES.BIN	Default commercial vehicle trip attraction rates
IXATTRRATES.BIN	Default IX trip attraction rates
GAMMACOEFFICIENTS_*.BIN	Default Gamma Coefficients
KFACTORS.MTX	User defined matrix of K-factors (if needed)
MODESHARES_*.BIN	Auto mode shares
VEHOCCUPANCYFACTORS_*.BIN	Vehicle occupancy factors
NC_HOURLY_*.BIN	PA to OD TOD conversions
PEAKFACTORS_*.BIN	Peak hour factors used to convert hourly capacity to time period capacity

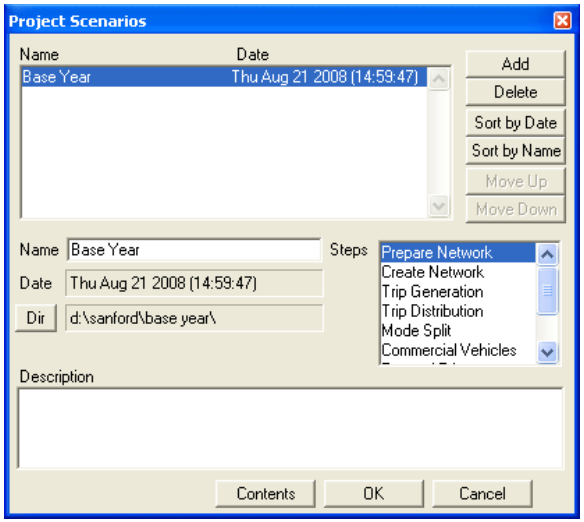
Scenario Input Files

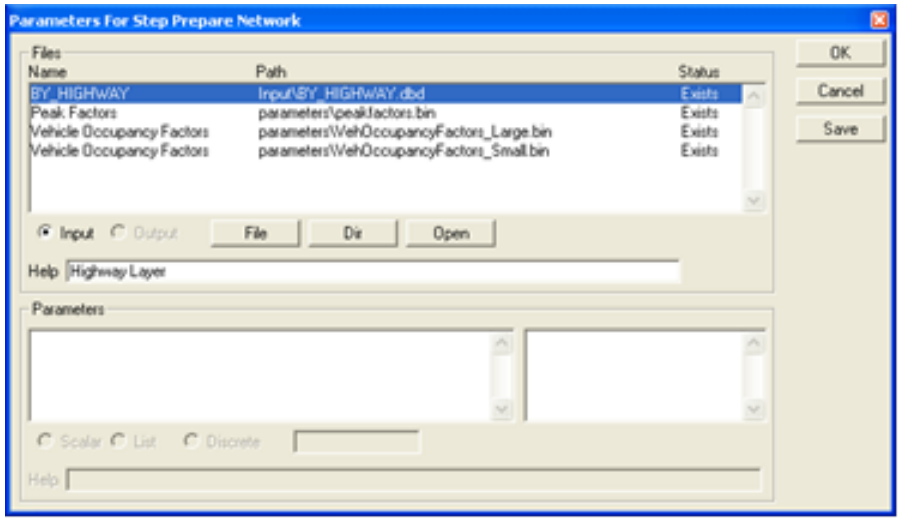
File Name	Model Step(s)	Description
*_SEDATA.BIN	Trip Generation, Commercial Vehicles, External Trips	Zonal data inputs and external station inputs
BY_HIGHWAY.DBD	Prepare Network, Create Network, Traffic Assignment	Base year highway line layer
*_HIGHWAY.DBD		Any future scenario line layer
*EE_TRIPS.MTX	Time of Day	Through trip table for given year or scenario

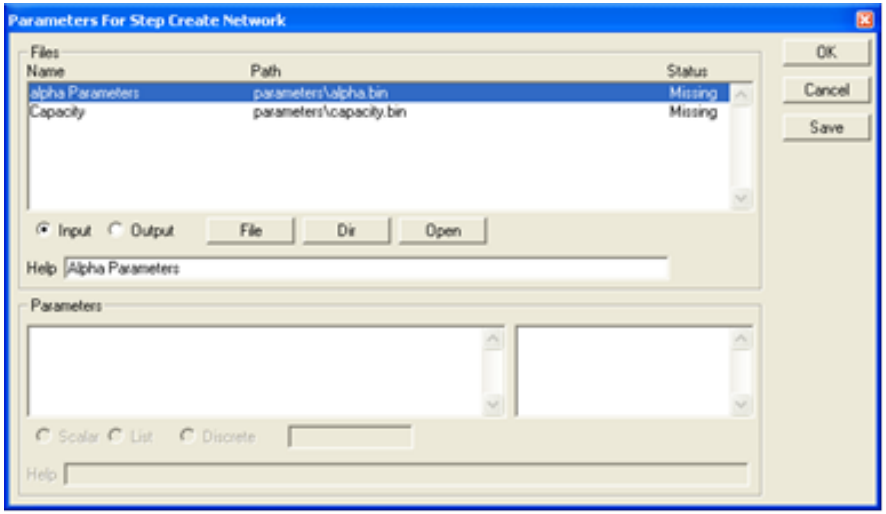
Scenario Output Files

File Name	Model Step	Description
NETWORK.NET	Create Network	Network file for path building and assignment
SHORTESTPATH.MTX		Skim matrix with zone to zone minimum travel time and associated distances.
GENCOST.MTX		Combined generalized cost matrix used in person trip distribution
BALANCE_PA2.BIN	Trip Generation	Balanced productions and attractions for internal person trips (NHBW and NHBO_NR trips included), CV trips, and IX trips.
BALANCE_CV.BIN		
BALANCE_IX.BIN		
AMTOT_TRIPS.MTX	Time of Day	Total vehicle trip tables by time of day
MDTOT_TRIPS.MTX		
PMTOT_TRIPS.MTX		
OPTOT_TRIPS.MTX		
AM_LINKFLOW.BIN	Traffic Assignment	Total vehicle link flow by time of day
MD_LINKFLOW.BIN		
PM_LINKFLOW.BIN		
OP_LINKFLOW.BIN		
TOTAL_LINKFLOW.BIN		Daily total link flow

Scenario Management







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Overall benefits

- Streamlines and standardizes model development
- Moves NCDOT towards current best practice
- Provides basis for training
- Adaptable to future enhancements
- Rates and parameters based on North Carolina data

NCDOT – that was then, this is now

- Great tool for education and standardization
- Good for the basic modeler
- Agency buy-in at all levels is critical to success
- Formal hands-on training is essential and should be repeated periodically
- Need to implement a process to maintain and update
- Standardization does not equate to all models being the same!

North Carolina Metropolitan Planning Organizations and Rural Planning Organizations

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