CALIBRATION REPORT: DURHAM-UNH TRANSPORTATION MODEL

TABLE OF CONTENTS

INTRODUCTION 1

DATA SOURCES OF THE MODEL 1

TRANSPORTATION ANALYSIS ZONES AND LAND USES 2

LAND USE DATA 4

CORRESPONDENCE WITH SEACOAST REGION TRAVEL DEMAND MODEL 6

TRANSPORTATION NETWORK 8

MODEL CALIBRATION 11

TIME PERIOD FOR CALIBRATION: AM PEAK HOUR 12

DEVELOPMENT OF AM PEAK HOUR TRIP TABLE 13

TRIP ASSIGNMENT 14

CALIBRATION PERFORMANCE 14

LIST OF TABLES

Table 1: External Transportation Analysis Zones and Associated Highway 3

Table 2: Paramics Road Types (Sample) 10

Table 3: Transit Routes Coded into the Durham-UNH Model 11

Table 4: Model Calibration Relative to Recommended Calibration Thresholds for Regional Travel Demand Models 15

Table 5: Model Performance Relative to Calibration Standards for Microsimulation Models 15

LIST OF FIGURES

Figure 1: Map of Durham Area Showing Transportation Analysis Zone (TAZ) Boundaries 3
Figure 2: Model TAZs Color-Coded According to Trip Generation Type 5
Figure 3: Region Covered by the Seacoast Region Travel Demand Model 7
Figure 4: Correspondence Between the Seacoast Region Travel Demand Model(blue) and the Durham-UNH Model (orange) 8
Figure 5: Durham Road Network 9
Figure 6: Road Network Speed Classifications 10
Figure 7: Paramics "Estimator" Interface Showing Locations of Calibration Count Set in Model 12
Figure 8: Distribution of Traffic Counts vs. Model Output 14

INTRODUCTION

An important analytical tool for evaluating future land uses and transportation improvements is the Town of Durham/University of New Hampshire Transportation Model. The Town of Durham and the University of New Hampshire initiated this project in October 2007 and have established a Memorandum of Understanding (MOU) for using the model for planning purposes. The model can be used to investigate a variety of important planning issues, including evaluating the traffic impacts of development proposals and understanding how proposed transportation improvements will affect local traffic patterns.

The development of the model has occurred under the direction of a Steering Committee jointly staffed by representatives of the Town of Durham and UNH. Members of the Steering Committee are:

- Richard Kelley, PE, Durham Planning Board
- Jim Campbell, Durham Town Planner
- Doug Benckes, UNH Architect
- Steve Pesci, UNH Special Projects Manager

Resource Systems Group met with the Steering Committee on 4 separate occasions, including 2 by videoconference, over the course of model development to review progress and receive input and feedback. Model development progressed according to a scope of services established jointly by RSG, Durham, and UNH. The Town and UNH were integrally involved in the data collection and verification aspects of the project, being responsible for the development of land use data and the acquisition of over 200 traffic counts.

This integrated modeling tool incorporates a wealth of information on land use and travel behavior and processes this information to provide estimates of travel patterns associated with land use and/or transportation changes. In addition, the model has an attractive interface that enables users to “see” how traffic travels through the local roadway network in response to land use or transportation improvement changes.

This memorandum describes the data sources of the model and the process and results of calibrating the model to measured traffic conditions.

DATA SOURCES OF THE MODEL

The Town of Durham/University of New Hampshire Transportation Model combines several sources of information into an analytical tool that estimates the AM peak hour of travel within the town of Durham. These data include:

1. Transportation Analysis Zones (TAZs);

2. Land use data
3. Transportation network data;
4. Data/information from the Seacoast Regional Transportation Model

Transportation Analysis Zones and Land Uses

All land use data are enumerated within a geographic unit called a Transportation Analysis Zone (TAZ). Within the geographic boundary of the Town of Durham, 67 separate TAZs have been defined, which allow a high level of demographic detail to be incorporated into the model. Linking the model externally are 12 external TAZs that represent the major roadways entering and exiting Durham (Table 1). In addition, the model has been coded with 12 "dummy" zones that are not used in the current version but that can be used for modeling a variety of land use scenarios. For example, an unused TAZ can be inserted into the model to provide a higher level of geographic detail for modeling a new proposed land use.

Internal TAZs were created in consultation with the project Steering Committee, and were developed to be consistent with the following other geographies:

- Year 2000 U.S. Census tracts and block groups
- Durham zoning
- Durham parcel data
- Seacoast Region Travel Demand model geography (see below)

Figure 1 shows the TAZ boundaries for the entire model area. Table 1 lists the 12 external TAZs and the highway associated with each TAZ.

Figure 1: Map of Durham Area Showing Transportation Analysis Zone (TAZ) Boundaries

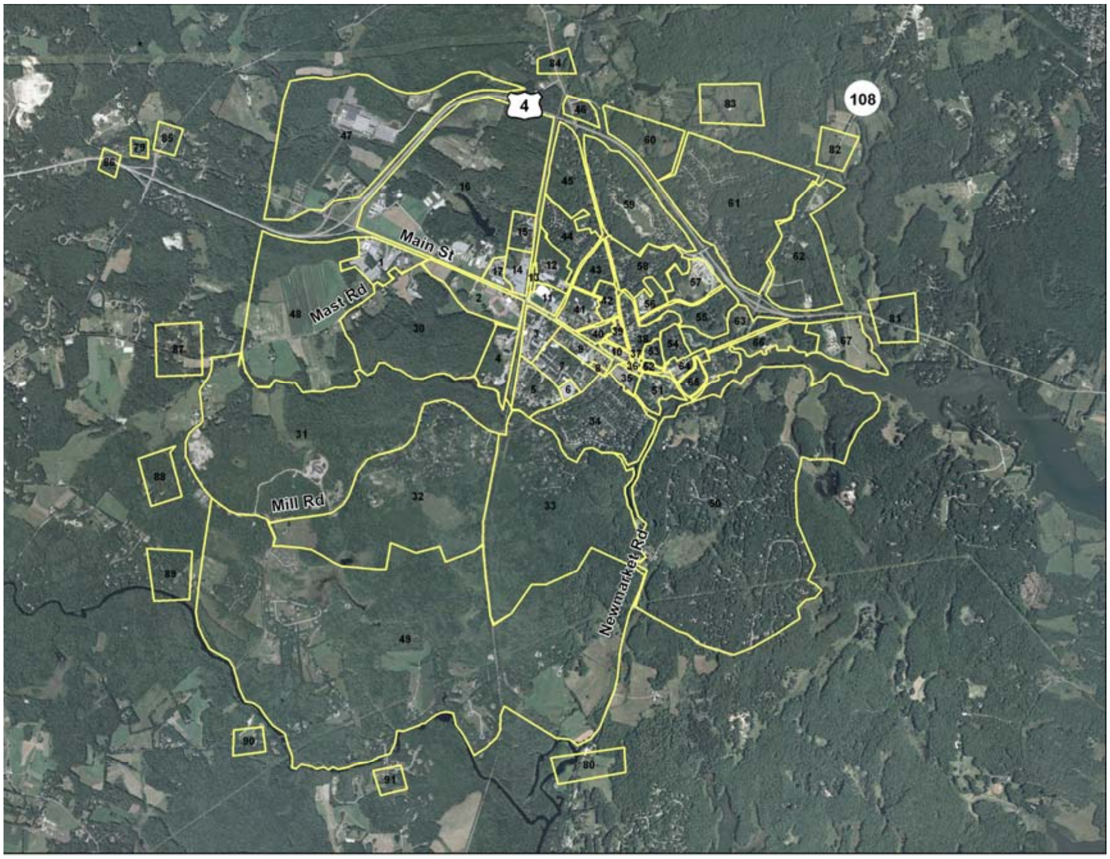


Table 1: External Transportation Analysis Zones and Associated Highway

TAZ	Highway
79	Old Concord Turnpike
80	NH 108 South
81	US 4 East
82	NH 108 North
84	Madbury Road
85	NH 155
86	US 4 West
87	NH 155/155A
88	Jenkins Road
89	Wednesday Hill Road
90	Wiswall Road
91	Packers Falls Road

The transportation model is "land use based", which means that land uses generate and attract vehicular traffic. TAZs represent a collection of land uses. The model was designed with this foundation so that it can be easily applied for investigating scenarios involving future land use changes. For example, the model can be used to investigate the traffic impacts associated with a development proposal. To do this, the development program (e.g. the number of residential units or the projected number of jobs) is inserted into the appropriate TAZ. A number of trips associated with those land uses is "generated" automatically and distributed to the local roadway network within the simulation model.

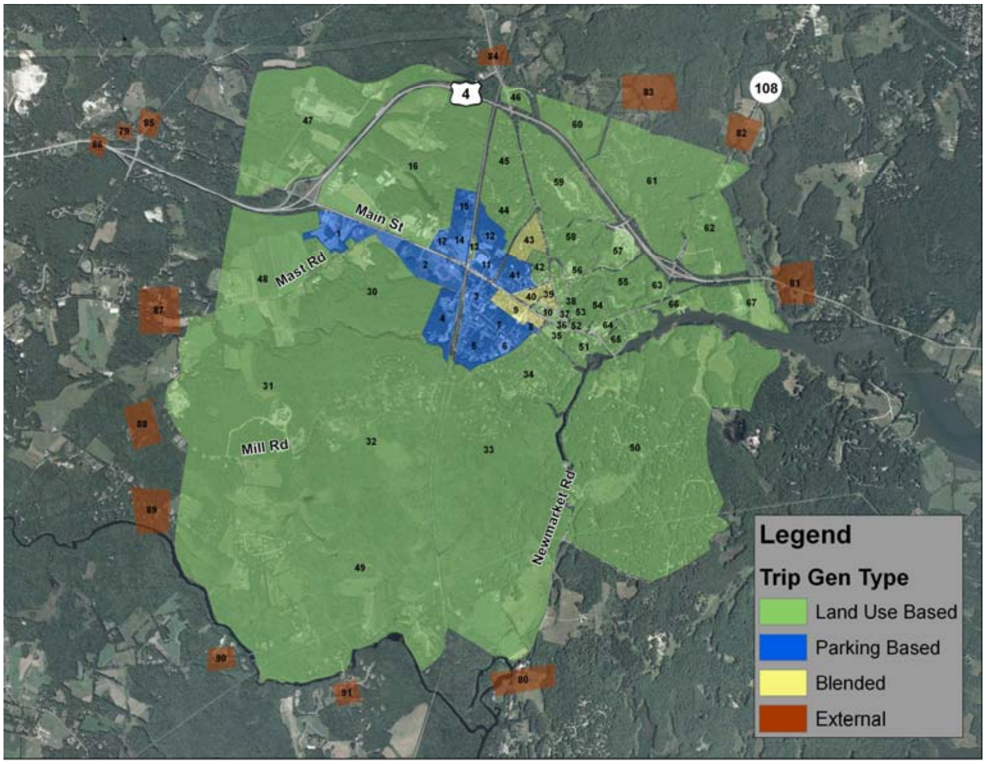
Land Use Data

All land use data have been assigned to the 67 TAZs internal to the Durham-UNH model by UNH and Town of Durham staff. In the Durham-UNH model, the land uses that have been enumerated within TAZs are:

- Residential Units – single family, multi-family, group unit
- Employment – retail, non-retail
- Parking spaces – low, medium, and high turnover

Figure 2 shows how the model's TAZs have been classified for land use purposes. There are 3 general approaches to enumerating land use in the model. First, for 14 UNH zones (shaded blue), the number of parking spaces has been enumerated for each zone. Parking spaces are classified according to their trip generation characteristics – low, medium, or high turnover. Low turnover parking represents long term parking, similar to sections of the West End lot designated for cars of residential students. High turnover parking represents short-term parking of typically less than 30 minutes duration. Medium term parking covers the duration between these two extremes.

Figure 2: Model TAZs Color-Coded According to Trip Generation Type



For UNH TAZs, the following process was used to estimate land use (parking) at the TAZ level:

- Determine the buildings and lots in each TAZ using aerial maps with overlaid TAZ outlines. Compose and review list for each TAZ.
- Using the 2008 Master Building List, fill in function description for each building (eg. Academic, student housing, etc).
- Using the 2008 Master Building List, fill in bed counts for each dormitory. Discuss and evaluate special cases, such as Forest Park, the Gables, and the Woodsides.
- Using the 2008 Parking Lot List, fill in number of parking spaces for each zone. Major lots are listed as individual entries, while building adjacent parking is listed under the same entry as the building (eg: James Hall has nine affiliated parking places listed with its entry).
- Total and cross-check for each zone and for all UNH zones and UNH entries for shared zones.

There are 31 TAZs that are fully within the Town of Durham and do not contain significant amounts of university-owned land use. For these TAZs, land use has been classified by the number and type of residential units, and by the number of jobs by type – retail or non-retail.

For Durham TAZs, the following process was used to estimate land use at the TAZ level:

- Determine the lots and addresses in each TAZ using tax maps with overlaid TAZ outlines.
- Using Census data fill in residential counts for each residential TAZ.
- For commercial zones, determine which businesses are in each TAZ using addresses. Request employee information via mail. For those businesses that do not reply, visit on foot and ask for employee (retail and non-retail) count.
- For sororities and fraternities, access database to determine capacity for bed counts.
- Consult 2008 parking lot data for parking space counts in commercial zones. For large business and church parking lots, count spaces on foot.
- Total each Durham zone and each Durham entry in shared zones. Discuss and evaluate special cases such as high school parking, bars and restaurants only open at night, and church parking.

There are also 10 TAZs that have blended land use – some of the land use is University-related and other land use is privately owned. For these TAZs traffic is generated based on all types of land use – parking, employment, and residences.

Correspondence with Seacoast Region Travel Demand Model

The Seacoast region is served by 2 Metropolitan Planning Organizations (MPOs) who are charged with planning for transportation improvements in Rockingham and Strafford Counties. Both MPOs have sponsored the development of a regional travel demand model, which estimates peak hour and daily travel patterns across the region. Figure 3 shows a map of the regional model and depicts the Durham-UNH model as a blue area within the larger boundary.

Figure 3: Region Covered by the Seacoast Region Travel Demand Model

Figure 4 shows the correspondence between the TAZ geographies used in the Seacoast Region Travel Demand Model and the TAZs in the Durham-UNH model. The Seacoast model has 15 TAZs representing the Town of Durham, which correspond to the 67 TAZs in the Durham-UNH model. The Seacoast model has been used to obtain 3 types of information on external traffic (within the AM peak hour) that is critical for developing a calibrated model:

- External-to-external traffic – traffic that originates outside the Durham-UNH model boundary, enters the model area, and exits the model across a separate boundary;
- External-to-internal traffic – traffic that originates outside the Durham-UNH model boundary and completes its trip with a destination within the Durham-UNH model;
- Internal-to-external traffic – traffic that originates within the Durham-UNH model and completes its trip with a destination external to the model boundary.

Figure 4: Correspondence Between the Seacoast Region Travel Demand Model(blue) and the Durham-UNH Model (orange)

Transportation Network

The Durham road network is represented using Paramics, a microscopic traffic simulation software package. Figure 5 shows a representation of the Durham road network.

Figure 5: Durham Road Network

Road links are coded in to represent road types differentiated by functional class (e.g. arterial, collector, local), incorporating information on road capacity and operating speed. Table 2 lists several of the road types used in this model.

Figure 6: Road Network Speed Classifications

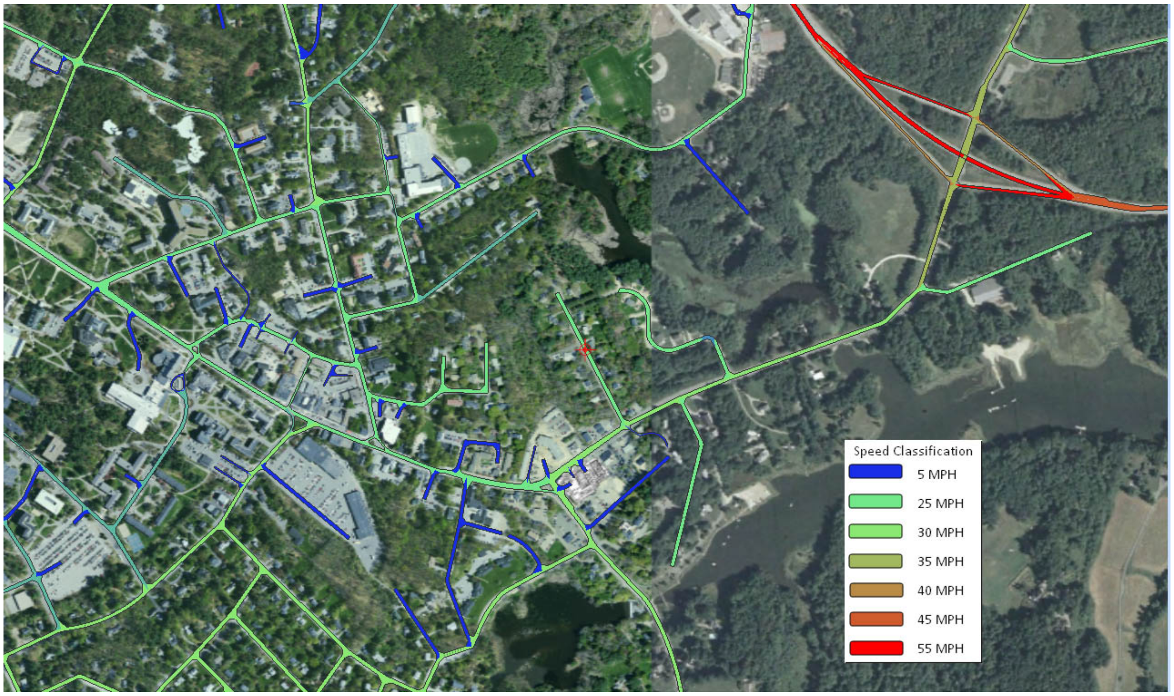


Table 2: Paramics Road Types (Sample)

Speed	# Lanes	Lane Width	Functional Classification
55 mph	1	13	Major Arterial
45 mph	1	13	Major Arterial
35 mph	1	12	Minor/Major Arterial
30 mph	1	12	Minor/Major Arterial
30 mph	1	12	local/collector
25 mph	2	11	Minor/Major Arterial
25 mph	1	11	Minor/Major Arterial
25 mph	1	11	Local/Collector
20 mph	1	11	Local/Collector

The model includes intersection controls (i.e. stops, signals, roundabouts), lane designations, circulation restrictions, and turn restrictions. The model incorporates detailed information on traffic signal timing, phasing, and sequencing.

Wildcat Transit and Campus Connector bus services are modeled in the network, reflecting route, stop, and frequency of the existing services. The microsimulation model is a vehicle-based model and does not include a mode split module that would estimate bus ridership separately from automobile usage. To estimate bus ridership in the existing model, it would need to be person-trip based instead of vehicle-trip based. While it is possible to modify the existing model to be a person-based model, this level of effort was not scoped as part of the original development effort.

Table 3: Transit Routes Coded into the Durham-UNH Model

Wildcat Transit	Campus Connector
Route 3A	Gables Connector
Route 3B	West Edge Express
Route 4A	IOL Connector
Route 4B	Woodside Connector
Route 5	Mast Road Connector

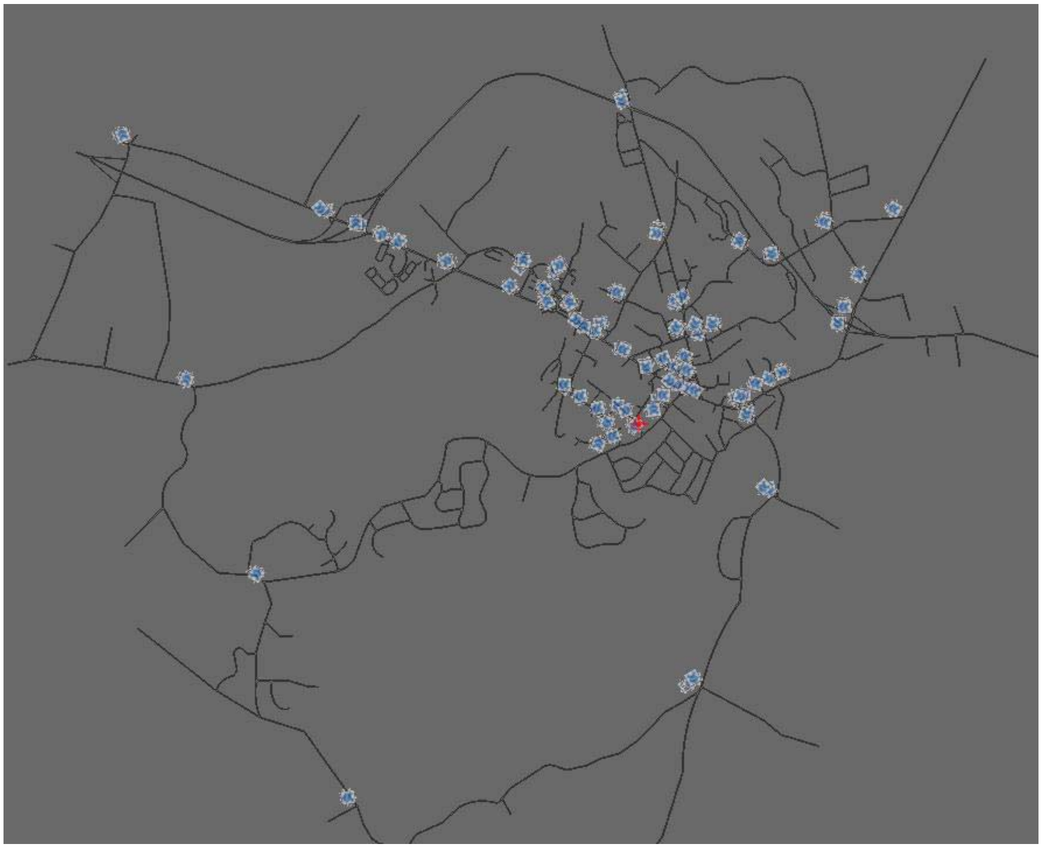
Traffic operations in Durham, particularly in the University area, are strongly affected by pedestrian movements crossing streets. The Paramics model does not include pedestrian movements; however, at crosswalks where periodic delay to traffic from pedestrian crossings is anticipated (e.g. along Main Street at Garrison) external delays have been coded in the model as traffic signals which stop both directions of traffic. This has the impact of delaying vehicle movement similar to the effect a platoon of pedestrians would have.

MODEL CALIBRATION

The model is calibrated to 401 traffic counts conducted over the AM peak period (7AM-9AM) between February and April 2008. A total of 64 individual intersections were counted[1]. Raw traffic counts have been adjusted from 4-11% to reflect peak month traffic conditions. In addition roadway counts were obtained for specific roadways, such as US 4 and NH 108, which are typically used for estimating external traffic. Figure 7 shows the Paramics model network with the count locations highlighted.

[1] Each intersection turning movement count generates multiple calibration counts. For example, a count at the intersection of 2 roadways where all turns are permitted from all approaches generates a total of 12 individual counts to be used in calibration (4 approaches X 3 turns (left, through, right) per approach).

Figure 7: Paramics "Estimator" Interface Showing Locations of Calibration Count Set in Model



Time Period for Calibration: AM Peak Hour

Common time periods for evaluation include AM peak hour, PM peak hour, or a specialized alternative peak hour. Alternative time periods could represent special event traffic flows or mid-day traffic flows in areas characterized by a high concentration of retail land uses. The traffic model can be used to assess special event traffic and related management plans, but this is considered a specialized use of the model.

The decision between AM and PM peak period models most often relates to the traffic patterns of the area or future planned developments. Communities in which the local school system is a significant contributor to local traffic – as in Hanover, New Hampshire – usually leads to modeling the AM peak hour. During the AM peak hour local school traffic overlaps with general commuting traffic, creating more acute periods of congestion. In some communities, such as Burlington, Vermont, the PM peak hour is the most congested time period due to the overlap of commuting traffic with shopping trips generated by a strong retail presence.

For Durham, the AM peak hour has slightly more traffic congestion and is more likely to reflect traffic influences from UNH. University faculty and staff arrive in a relatively concentrated time period before 8:30 but depart over a several hour period in the afternoon. In general, with no major center, the PM peak hour does not experience strong retail-generated traffic. This may change in the future in Durham as more retail develops.

The AM peak hour better captures current travel patterns. A PM model could easily be developed using the same zone structure, land use enumeration, and travel network as that developed for the AM model.

Development of AM Peak Hour Trip Table

The critical process in model calibration is the estimation of an origin-destination matrix ("O-D matrix") that represents the zone-to-zone vehicle trips during the AM peak hour. Including external TAZs, the model has a total of 79 TAZs, leading to a 79 X 79 matrix of vehicle trips. A matrix estimation process was used to develop the calibrated AM peak hour trip table.

The estimation process involves assigning an estimated O-D matrix to the roadway network and comparing the accumulated vehicle travel paths against the calibration count set. Thus, every left turn, through movement, and right turn estimated in the model is compared against the actual number of left turns, through movements, and right turns within the calibrated count set.

Calibration involves the iterative process of estimating the OD matrix. Mathematically, the process used is referred to as an "under-specified multivariable optimization", which means that, without specific information on origin-destination flow from other sources, there is no unique solution to the O-D Matrix. For the Durham-UNH model there are several other sources of information that are used to constrain the O-D estimation process, including:

- Data on external trip making obtained from the Seacoast Travel Demand Model (described above);
- Information on the origins of faculty, staff, and students from the UNH Master Plan;
- Zone-specific traffic counts (e.g. A Lot, Mill Brook Plaza) that allow the estimation process to constrain the vehicle origins and destinations from and each specific TAZs.
- Generalized trip generation rates (e.g. AM peak hour vehicle trip generation for single family residences) that allow estimates of TAZ-specific origins and destinations that can, in turn, be used to constrain zonal OD values.

As the process evolves, confidence in the values of specific origin-destination pairs increases, allowing those values to be constrained. This, in turn, focuses the O-D estimation process on those O-D pairs for which less information is available. After each iteration, the estimated O-D pair is assigned to the roadway network and compared with the count set. There are statistical measures of fit (described below) that provide the analyst with a quantification of the calibration. When those calibration thresholds are met, the calibration process is considered complete and the resulting model is considered valid for planning purposes.

Trip Assignment

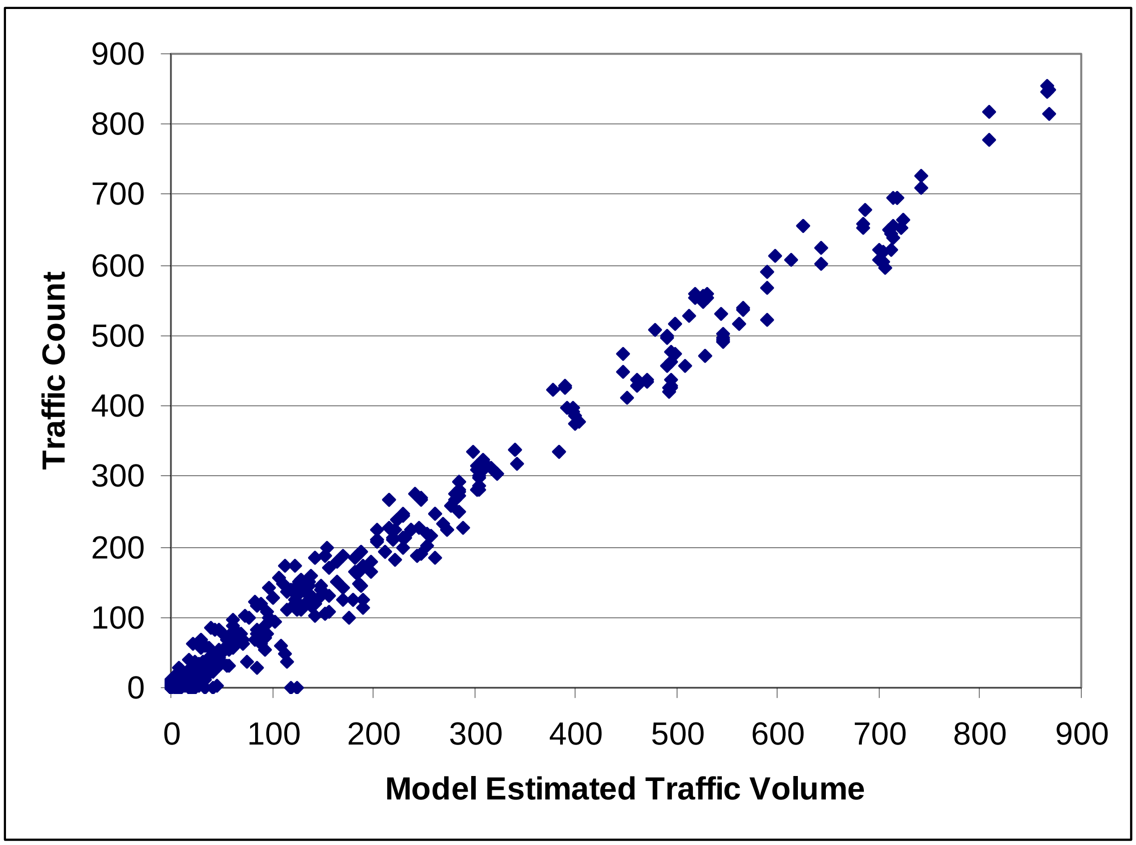
Trip assignment is performed within Paramics. Trip assignment, "assigns" each vehicle trip to a specific route along links and through intersections in the Durham network. The vehicle trips from the origin/destination matrix (described above), are "assigned" to the network based on a dynamic assignment algorithm which enables vehicles to route based on knowledge of congestion along what would otherwise be the shortest path to the destination TAZ.

The outputs of the assignment module include vehicle volumes, operating speeds, and travel times on each link.

Calibration Performance

Figure 8 shows the distribution of model output compared to actual traffic counts. A 45-degree line represents a perfect correlation of model output against the traffic count.

Figure 8: Distribution of Traffic Counts vs. Model Output



There are two levels of calibration standards that the model has been compared to. The first level relates to the standards that are conventionally applied to travel demand models. These standards have been developed by the Federal Highway Administration (FHWA) to provide a threshold of quality for transportation models used for regional transportation planning. Table 4 shows the model performance relative to the recommended FHWA standards for traffic volumes assigned to functional classes.

Table 4: Model Calibration Relative to Recommended Calibration Thresholds for Regional Travel Demand Models

	Recommended	Current Model
RMSE	<40%	13%
Coefficient of Correlation (r)	>= 0.88	0.99
Percent Error (Region)	+/- 5%	-5%
Percent Error (Principal Arterials)	+/- 10%	-3%
Percent Error (Minor Arterials)	+/- 15%	-5%
Percent Error (Collectors)	+/- 25%	-7%

Additional standards have been developed specifically for microsimulation travel models. These standards were first published in 2004 by the Transportation Research Board (TRB), a branch of the National Science Foundation[1]. The TRB standards rely upon the GEH statistic, which is an empirical measure of fit used to compare errors across roadways with largely different traffic flows. The GEH statistic is computed as follows:

$$GEH = \sqrt{\frac{(ModelVolume - CountVolume)^2}{0.5 * (ModelVolume + CountVolume)}}$$

Table 5 shows the performance of the Durham-UNH model relative to standard for the GEH statistic.

Table 5: Model Performance Relative to Calibration Standards for Microsimulation Models

	GEH by Movement		
	<5	5-->10	>10
Recommended	>85%	<=15%	0%
Durham-UNH Model	94%	6%	0%

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[1] "Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Software". FHWA-HRT-04-040. June 2004.

The Durham-UNH model is considered well-calibrated according to published standards of the traffic engineering profession. It is ready to use for planning studies as directed by the Town of Durham and the University of New Hampshire.