MODEL DEVELOPMENT

While traffic volume counts on existing streets are useful in evaluating the ability of the current system to meet travel demands, they reveal little as to the actual travel desires (origins and destinations) of the travelling public. For thoroughfare planning purposes, a comprehensive look at the origins and destinations of existing and future travel is essential.

The method used to predict future travel involves the development of mathematical models relating population and employment to travel. These models are developed 1) to estimate trips produced (origins) and trips attracted (destinations) by traffic analysis zones (TAZ) and 2) to estimate travel patterns between zones. The models were developed using the TRANPLAN modeling software.

There are three basic types of trips: internal, external, and through. ***Internal trips*** are defined as those trips that have both an origin and destination inside the planning area. ***External trips*** are those trips that have one trip end inside the planning area and the other trip end outside the planning area. ***Through trips*** are those which have origins and destinations outside the planning area but come through the planning area in the process.

The planning area was enlarged from the 1985 Greenville thoroughfare planning area to reflect and include the growth that is happening beyond the city limits of Greenville. New zones for the planning area were established. There are now 229 traffic analysis zones (TAZ's) and twenty-six external stations. Figure 1 shows the planning area, external stations, screenlines and zones. New socioeconomic and housing data was collected on a zonal basis. Traffic counts were done for the Greenville urban area and external stations. An origin-destination (O & D) survey for internal trips and an origin-destination survey for external trips were also done for this update. The information from the internal O & D survey was used to determine the trip generation distribution by trip purpose (home based work, non-home based work, and home based other) for the internal trips. For more information concerning the internal O & D survey, please refer to **Final Report: Greenville Urban Area MPO Household Travel Survey** prepared for Greenville Urban Area MPO by URS Greiner in March 1999. The external O & D survey information, collected by NCDOT, was used to calculate through trips for the base year.

The socioeconomic data is the foundation on which the model is built. The type, intensity, and location of the population and employment within an area largely determine the travel patterns. The validity of the model was tested by comparing the traffic volumes computed by the model to traffic counts taken on the existing street system. (This procedure is referred to as "model calibration").

After the synthesized travel forecast model was calibrated for 1996 so that it adequately duplicated travel, design year traffic estimates were produced through the input of design year data on population, employment and trip generation.

Figure 1

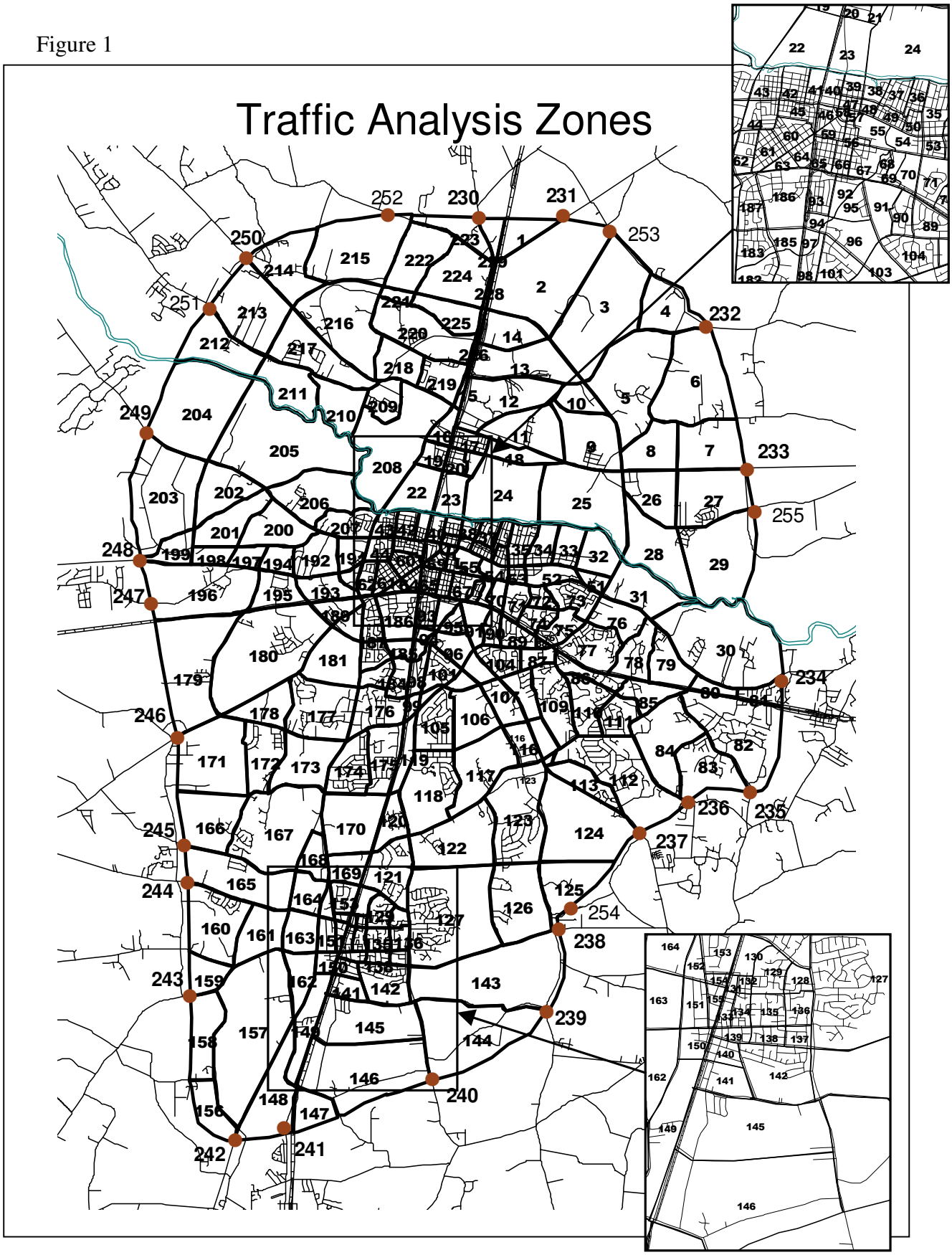

Table 1 displays a general summary of daily trips used in this study.

Table 1
Daily Trip Summary

Trip Type	*1996*	*2025*
Trips per DU*	7.83	7.95
Internal Trips	**253,339**	**548,387**
Home Based Work (HBW)	53,201	97,887
Home Based Other (HBO)	129,203	237,726
Non-Home Based (NHB)	70,935	130,516
NHB Secondary	**47,086**	**105,492**
External Trips	**141,258**	**316,475**
Commercial Vehicles	**27,901**	**60,553**
Through Trips	**11,442**	**24,794**
Total Daily Trips	**481,026**	**1,055,701**

*Includes campus dormitories for East Carolina University which had a lower trip rate

1996 Travel Patterns

A synthetic method was used to estimate 1996 internal trip patterns. A model was developed using the TRANPLAN modeling software. Figure 2 shows the Greenville/Winterville Base Network. This method consisted of the following general steps:

1. Determination of trip productions per zone based on trip generation rates per dwelling unit.

2. Determination of trip attraction factors per zone based on a multiple regression equation procedure that uses type of employment and dwelling units as variables.

3. Trip distribution by a three-purpose gravity model (home-based work, home-based other, and non-home based) using trip length frequency curves.

4. Traffic assignments to the existing network using an ***all-or-nothing loading***, and accuracy checks of the procedures and results.

Internal Trip Productions

Average daily trip productions were estimated on a zonal basis in four categories: 1) trips produced by dwelling units, 2) trips produced by trucks, 3) trips produced by commercial passenger vehicles, and 4) trips produced by taxis.

1) Trips produced by dwelling units were computed by multiplying the appropriate trip generation rate by the number of dwelling units in each zone. For each category of dwelling unit (excellent, above average, average, below average, poor, or ECU students in dormitories), a different generation rate was applied. These rates are a composite from other studies and the rates used in the previous Greenville study. They are validated in the model calibration process. These trip generation rates are summarized in Table 2. Zonal totals in these categories based on these rates can be found in Appendix A, Base Year IDS Input.

2) and 3) Trip generation rates for trucks and commercial vehicles have also been taken from the 1985 Greenville study and many other studies that reveal a statewide urban average of 6.5 trips per day. Appendix B also shows commercial vehicles/zone.

4) A standard rate for taxis is also used throughout the State. Taxis produce an average of 40 trips per day. Appendix B shows the number of taxis/zone.

Since the total trips generated by these rates contained both internal-to-external and internal-to-internal trips, the total trip productions were reduced so as not to double count the internal-external trips originating within the planning area. These trips are counted as part of the external trips at the planning area boundary (PAB). Due to a very favorable employment-to-population ratio*, the total internal trip table was reduced by 15 percent.*

Internal-internal (zonal) trip productions were then divided into the three trip purposes: home-based work trips (HBW), home-based other trips (HBO), and non-home based trips (NHB). The percentages used were: HBW = 21%, HBO = 51%, and NHB = 28%.

The remaining component of internal trips are “secondary” trips; the NHB trips produced by vehicles garaged outside the planning area but having both trip ends within the planning area. *It was assumed that one third (1/3) of these externally garaged vehicles made a secondary trip* while in the planning area. This count, 47,086 trips in 1996, was added to the previously calculated NHB internal trips and distributed to the traffic zones based on the trip attraction factors for NHB trips.

The final generation rates used for internal trip productions are shown below in the following table.

Table 2

1996 and 2025 Trip Generation Rates (Trips/DU)

Housing Classification	1996 and 2025
Excellent	10.0
Above Average	9.5
Average	8.0
Below Average	6.5
Poor	4.6
Special (Students on Campus)	3.0
Commercial Vehicles	
Taxi's	40.0
Autos and Trucks	6.5
Year	**Persons/Dwelling Unit**
1996	2.4
2025	2.3

Trip Attractions

Attraction factors for the various zones in the study area are directly related to employment characteristics in these zones. HBW trip attraction factors were based on total employment. HBO and NHB trip attraction factors were based on employment groupings in each zone. These employment figures were used as the independent variable in a multiple regression analysis. The dependent variable consisted of the external-internal trip ends inside the planning area. The employment statistics are shown in Appendix A.

After review, it was determined that the regression equations for internal trips and external trips calculated for the 1985 study were still viable and were thus used for this update with the exception of added variables for certain zones with special characteristics (TAZ's 102, 103, 173, and 176, and 192).

Home Based Work (HBW) Regression Equation:

$$\mathbf{Y = 26 + 1.00_{X1} + 1.00_{X2} + 1.00_{X3} + 1.00_{X4} + 1.00_{X5} + 1.00_{X6} + 1.00_{X7} + 1.00_{X9} + 1.00_{X10} + 1.00_{X11}}$$

Home Based Other (HBO) Regression Equation:

$$\mathbf{Y = 26 + 3.96_{X1} + 5.21_{X2} + 1.34_{X3} + 1.09_{X4} + 1.65_{X5} + 3.17_{X6} + 0.50_{X7} + 0.9_{X9} + 2.00_{X10} + 2.50_{X11}}$$

Non-Home Based Work (NHB) Regression Equation:

$$\mathbf{Y = 26 + 3.96_{X1} + 5.21_{X2} + 1.34_{X3} + 1.09_{X4} + 1.65_{X5} + 3.17_{X6} + 0.50_{X7} + 0.9_{X9} + 2.00_{X10} + 2.50_{X11}}$$

External Trips

$$\mathbf{Y = 26 + 3.96_{X1} + 5.21_{X2} + 1.34_{X3} + 1.09_{X4} + 1.65_{X5} + 3.17_{X6} + 0.75_{X7} + 0.9_{X9} + 2.00_{X10} + 2.50_{X11}}$$

Where: Y = Attraction factor for each zone

X_1 = Retail employment (SIC 52-54, 56, 57, 59)

X_2 = Highway Retail (SIC 55, 58)

X_3 = Office/Institutional (SIC 60-67, 80-82, 91-96)

X_4 = Industrial (SIC 1-49)

X_5 = Wholesale (SIC 50, 51)

X_6 = Personal Services (SIC 70, 72, 88)

X_7 = Dwelling Units

X_9 = Special - Hospital

X_{10} = Special - Shopping Center

X_{11} = Special - Shopping Center

Notes: SIC = codes from the Standard Industrial Classification Manual, 1972.

As previously mentioned, because of special characteristics, a few variables were added to the equation for certain zones. These are listed below:

TAZ (Transportation Analysis Zone) **192** - (Hospital Area): 0.90_{X9} = Medical Services Employment

TAZ 173 and 176 (Shopping Center): 2.00_{X10} = Retail and Highway Retail Employment

TAZ's 102 and 103 (Shopping Centers): 2.50_{X11} = Retail Employment

TAZ's 49, 55, 69 and 70 had special housing (on-campus housing at ECU). These zones were handled differently than the other zones. As mentioned previously, the generation rate for the campus dormitories was 3.0. But the model programs did not take into account trip attractions for the special housing category. These special housing totals in zones 49, 55, 69 and 70 were multiplied by 10.0 because the travel patterns of this group seemed to follow those of dwelling units with an "excellent" housing classification.

The zonal attraction factors thus derived were adjusted so that the total attractions equaled the total productions (which are deemed the more accurate estimates). This adjustment was done by multiplying each zonal attraction factor by the ratio of total productions to total unadjusted attractions for each trip category. The resulting productions and attractions were then input into the gravity model for the trip distribution phase.

Trip Distributions

The gravity model trip distribution program was used to distribute internal trips. Input to this program included: 1) zone-to-zone travel times obtained from a "traffic paths" computer simulation using the existing 1996 street network, 2) individual zonal trip productions and attractions, and 3) trip length frequency curves obtained from studies of similar cities. Table 3 shows the friction factors used.

Table 3
Friction Factors

Time (minutes)	HBW	OHB	NHB	Ext-Int
1	11300	12500	10400	25000
2	20900	23000	25000	21000
3	25000	24800	19800	13500
4	24800	25000	14611	5600
5	24000	20800	9000	5300
6	22409	14300	6200	3400
7	22273	10500	4200	2700
8	17624	7600	2900	2600
9	12885	5300	1905	1400
10	11700	3700	1300	1200
11	9600	2500	921	700
12	8008	1700	600	500
13	6400	1100	400	300
14	4808	700	300	250
15	4000	500	200	150
16	3206	300	100	120
17	2406	200	100	100
18	1900	100	100	100
19	1400	100	100	100
20	1100	100	100	100
21	910	100	100	100
22	300	100	100	100
23	100	100	100	100
24	100	100	100	100
25	100	100	100	100

1996 External and Through Trips

Traffic counts were taken at 26 locations (external stations) around the planning area boundary (PAB). These stations are shown in Figure 1. An origin and destination survey was also conducted for this study by NCDOT. The resulting trip data is shown in Table 4.

Table 4
1996 and 2025 External Travel Analysis

External Station	1996 Station Count	1996 Thru	2025 Projected Station Count	2025 Projected Thru*
230	9,900	474	21,805	605
231	5,300	602	11,501	1,001
232	1,000	278	4136	486
233	12,100	2,078	27,153	4,953
234	10,200	566	21,002	952
235	1,400	70	3,600	96
236	3,600	46	8,500	100
237	10,700	664	26,621	1,521
238	3,900	0	8,700	0
239	3,000	58	6,201	101
240	1,800	128	8,499	279
241	5,400	133	10,001	251
242	17,100	1,288	45,116	2,716
243	3,100	0	6,400	0
244	1,800	56	4,601	101
245	2,900	140	7,197	285
246	13,400	618	18,704	1,104
247	4,500	464	8,212	1,372
248	14,600	2,391	29,069	5,269
249	6,500	422	15,911	887
250	7,400	616	17,001	1,251
251	2,400	350	5,800	464
252	750	0	1,800	0
253	2,700	0	6,500	0
254	800	0	1,100	0
255	640	0	1,500	0

*% Thru at each station same for base year 1996 and design year 2025.

Accuracy Checks

The model's ability to simulate travel patterns in the area was checked by a comparison of assigned traffic to actual counts taken by the North Carolina Department of Transportation.

Two screen lines were used for calibrating the Greenville/Winterville travel demand model. The first screen line, Screen Line A runs north to south following the railroad (see Figure 1). Screen Line B runs east to west following the Tar River. The results of the screen line calibration are shown below in Table 5. Figure 3 shows actual counts vs loads on the modeled base network.

Table 5
Screenlines Check

	Total Count	Total Load	% Accuracy
Screenline A	142,900	135,300	95%
Screenline B	74,400	82,400	110%

Statistics were also compiled for the entire network for all links where counts were available. The results of this analysis are shown below:

- Total sum of links with counts = 6,412,092
- Total sum of link assigned loads = 6,417,525
- Total count minus total assigned load = -5,433
- Percent error in modeled load = -0.1%

Table 6
Network Load/Count Statistics

Two Way Vol. Group	Number of Sections	Average Count	Average Model Vol.	Average Difference	% of Total	RMS	% Load/Count
1-2000	144	1,034	1,486	-452	2.3	1,604	143.7
2001-4000	94	3,192	3,218	-26	4.7	1,920	100.8
4001-6000	72	5,178	4,574	604	5.8	2,978	88.3
6001-10000	105	7,958	7,876	82	13.0	3,428	99.0
10001-14000	105	12,144	11,380	766	20.0	4,572	93.7
14001-20000	96	17,170	18,584	-1,412	25.7	5,436	108.2
20001-30000	58	24,784	23,924	860	22.6	6,136	96.5
30001-40000	12	32,652	31,356	1,296	5.9	7,484	96.0
Total (Weighted Average)	686	9340	9348	-8	100.0	3906	100.1

*RMS - Root Mean Square

The results of these two accuracy checks were considered within the acceptable limits for uses concerning transportation planning.

2025 DESIGN YEAR TRAVEL PATTERNS

2025 Internal Trips

These travel patterns were estimated by projecting the socioeconomic data to the year 2025, and then using the 1996 internal travel development procedures to estimate the 2025 travel. The City of Greenville provided the projections of housing and employment by zone for the design year.

Dwelling unit trip generation rates per classification were kept the same as in 1996. The average dwelling unit generation rate went from 7.83 trips/dwelling unit in 1996 to 7.95 trips/du. The increase comes from an increase in housing growth in the area with the greatest increases in average housing (571%) and above average housing (341%) classifications over the planning period. The 2025 trip generation rates for trucks and commercially owned passenger cars were assumed to remain at 6.5 trips per vehicle. It was assumed that the ratio of these vehicles to employment would remain constant in each zone throughout the planning period. Based on projected employment in the area, the commercial vehicles will grow from 4090 in 1996 to 9122 by the 2025 design year.

The percentage breakdown of internal trips by purpose was assumed to remain constant over the planning period.

Trip attraction factors for HBW trips were taken as the total projected 2025 employment by zone. Trip attraction factors for HBO and NHB purposes were determined by using the 1996 regression equations with projected 2025 zonal employment and dwelling unit data. The distribution of 2025 employment and housing was based on land development plans, zoning, topography, vacant land and city staff's knowledge of the area. A complete listing of socioeconomic data for 2025 is shown in the future year IDS data found in Appendix B.

Design year internal trips were distributed by the "gravity model" trip distribution algorithm. The resulting trip tables are based on vehicle trips.

2025 External and Through Trips

External and through traffic volumes for the year 2025 were determined by trendline analysis and land use forecast near the planning area boundary. The through trip ends were balanced using the FRATAR method of successive approximations. The gravity model distributed these trips. The base year and design year travel at all stations is shown in Appendix C.

A complete daily trip summary is shown in Table 1. The "Total Daily Trips" represent the combined internal, external, and through trips.

Computer Files used in Greenville/Winterville Model

Base Year (1996) Files:

G96base.net – (modified 11-29-00) – 1996 ***unloaded*** base network
Gload96.bas – (modified 11-29-00) – 1996 ***loaded*** base network
Gbasids.txt – (modified 11-27-00) – 1996 Internal Data Summary Program input
pas.bas – (modified) – Output P's and A's for 1996 used in Gravity Model
G255th – (modified 11-2-00) – 1996 thru trip table (255 zones = zones + external stations)
Gturn1.txt – (modified 10-25-00) – Turn prohibitor file
Greenb.bas – (modified 11-29-00) – 1996 loaded base network in plot format

Future Year (2025):

Gload25.fbn - (modified 12-1-00) – 2025 traffic ***loaded*** base year network
Newgtp.net – (modified 11-28-00) – 2025 ***unloaded thoroughfare plan*** network
Gload25.tpn - (modified 11-28-00) – 2025 ***loaded thoroughfare plan*** network
Gfutids.txt – (modified 11-28-00) – 2025 Internal Data Summary Program input
pas.fut – (modified) – Output P's and A's for 2025 used in Gravity Model
Gth25.tbl – (modified 11-17-00) – 2025 thru trip table
Green25.tpn – (modified 11-28-00) – 2025 loaded throughfare plan network in plot format

*For general purposes a scale factor of **442** was used for the network in HNIS.

**All-or-nothing loading was used.

Acronyms

Ext-Int – external-internal trips
HBO – home-based other
HBW - home-based work
MPO - Metropolitan Planning Area
NCDOT – North Carolina Department of Transportation
NHB – non-home based
NHBS – non-home based secondary
O & D – origin and destination
PAB – Planning Area Boundary
RMS – Root Mean Square
SIC – Standard Industrial Classification
TAZ – Traffic Analysis Zone
Trips/DU – Trips per Dwelling Unit