# Chapter 13

## 1. TRAFFIC FORECASTING PROCESS

### Introduction

During the course of the design process, the designer will be requesting traffic data to be used for capacity analysis of the arterial to ensure that the functional requirements of the route are met. In addition the traffic volumes are used to determine the pavement structure of the arterial road. For Georgia DOT projects designed by in-house, traffic volumes are supplied by the Office of Environmental and Location Design (OEL).

For consultant designed projects, the traffic volumes may be provided by the Department if available or by the consultant as part of the scope of services in the consultant's design contract.

### Data Collection

#### Site Visit

A site visit should be conducted to gather current information that is not readily available from other sources. MUTCD should be followed when collecting new data. The presence and needs of children, elderly persons, disabled, transportation disadvantaged, pedestrians, and bicyclists should be included in a typical site visit.

Data to be collected during the site visit frequently includes the following:

- Number of lanes, lane usage, and presence and type of medians;
- Curves and grades (if significant enough to affect capacity or traffic operations);
- Lane, median, and shoulder widths;
- Traffic control devices;
- Traffic signal phasing;
- Traffic signs (particularly regulatory signs and posted speed limits;
- Regulatory pavement markings;
- Pavement conditions;
- Sidewalks, bicycle lanes, and multi-use paths;
- Marked and unmarked crosswalk locations;
- Presence and type of on-street parking and parking regulations;
- Street lighting;
- Driveways of major generators or truck generators (collect the same information as would be collected for side streets);
- Transit stop locations and amenities, transit schedules, and types of transit vehicles in service;
- Adjacent land use, density, and occupancy;
- Roadway functional classification;

- Route governmental jurisdiction; and
- Travel times.

Other data that may be needed include:

- Sight distances;
- Vertical and lateral clearances;
- Safety hazards;
- Utility information (pole, storm drain, and valve cover locations); and
- Right-of-way location.

The State Roadway Classification Map and RCInfo file (contact GDOT Office of Transportation Data) contain speed limits, lane widths, shoulder widths, and information on many other roadway characteristics. These resources should be reviewed prior to a site visit. GDOT should be contacted immediately if a site visit returns information that differs from that in existing data sources.

**Existing Traffic Data**

Existing traffic data needed for the analysis should be gathered. Before collecting existing traffic data, a memorandum and map should be sent to the Section Head of GDOT's Traffic Analysis Section to summarize the site visit, confirm the locations and types of counts to be collected, and request current information.

Typical traffic data requests include 24-hour volume counts (summarized by hourly or 15-minute intervals) and peak-hour (or peak period) turning movement counts. The highest traffic volumes are usually during the weekday morning (7 - 9 a.m.) and evening (4 - 6 p.m.) peak periods. However, in some areas, such as near major shopping centers or recreational areas, the highest traffic volumes may be in the evenings or on weekends. The peak hours may also change over time, especially in developing areas. The time and duration of peak periods can be verified by careful review of 24-hour volume counts.

The local jurisdiction should be consulted to determine if there are hazardous or high-accident locations are within the study area. Law enforcement agencies collect this data in many communities; traffic engineering agencies may also collect collision data.

Existing traffic data should generally be no more than one year old. Existing traffic data needed for the analysis frequently include the following:

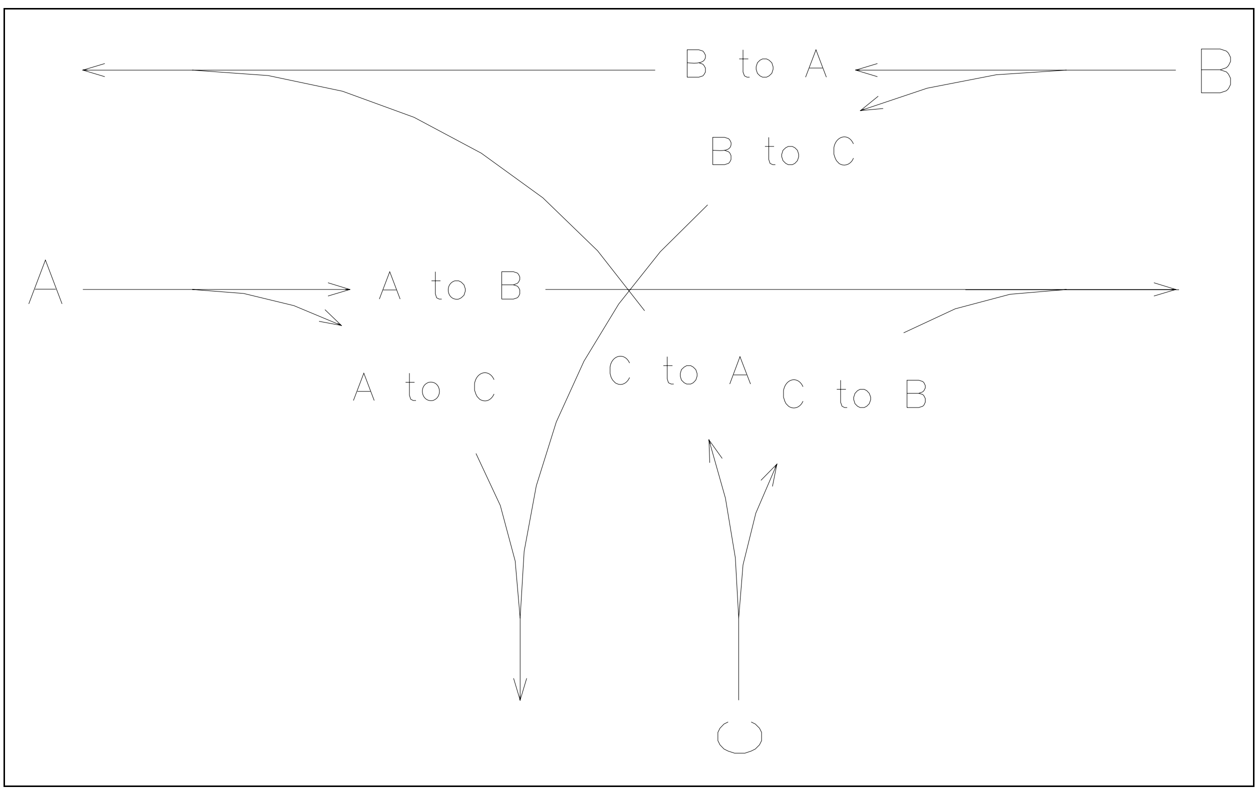
- Peak period turning movement counts (including cars, single-unit trucks and buses, combination trucks, bicycles, and pedestrians);
- At least 1-day directional volume, speed, and, in some locations, vehicle classification machine counts (7-day counts in recreational areas);
- Historic daily volume counts for the most recent fifteen years available (contact the Office of Transportation Data); and

- Accident history for the most current three years at locations identified by the local jurisdiction (contact the Office of Traffic Safety and Design).

Daily machine counts should be adjusted by seasonal and axle factors. GDOT's Office of Transportation Data can furnish factors from previous years, but data from nearby count locations should be used to determine the seasonal factors. Nearby tube counts can be used to determine vehicle classification and thus the axle factor. Any adjustments to raw traffic counts should be explained and agreed to by the person preparing the study and the person responsible for review and approval.

**Establish Existing Traffic Patterns**
Directional roadway volumes, and turning movements for AM peak hour and PM peak hour turning movements at the study intersections need to be established. This can be accomplished by collecting new counts where data is needed. However, counting all locations may not be practical.

Where counting all locations is impractical, GDOT has established the following procedure for estimating the existing turning movement counts from directional counts at three-leg intersections.




A, B, and C are the approach volumes on each leg.
X = (A + B + C) / 2.
X - C = *A to B* and *B to A*; X - B = *A to C* and *C to A*; and X - A = *B to C* and *C to B*.

For four-leg intersections, assumptions are first made about the traffic on the minor leg. Then the three-leg procedure is followed for the other three legs. As further guidance, GDOT assumes that at the intersection of two major routes, 55% to 70% of the trips on each approach are going straight.

## Establish Existing Year Average Daily Traffic (ADT)

### Daily Volumes and Their Uses

Traffic volume data is commonly reported as a daily value. Daily Volumes are typically used for highway planning, general observations of trends as well as the design of pavement structures for the roadway. The following four daily volumes are typical or widely used:

- Average Annual Daily traffic (AADT) - Defined as the average 24-hour traffic volume at a given location over a full 365 day year. This means the total of vehicles passing the site in a year divided by 365.

- Average Daily Traffic (ADT) is the average 24-hour traffic volume at a given location for some period of time less than a year. While AADT is a full year, an ADT may be measured for six months, a season, a month, and a week or as little as two days. Therefore an ADT is valid only for the period for which it was measured.

- Average Annual Weekday Traffic is (AAWT) is the average 24-hour traffic volume occurring on weekdays over a full year. This volume is of considerable interest when weekend traffic is light, so that averaging weekday volumes over 365 days would mask the impact of weekday traffic. AAWT is computed by dividing the total weekday traffic for the year by 260.

- Average Weekday Traffic (AWT) is the average 24-hour traffic volume occurring on weekdays for some period of time less than one year

The unit by which all of these volumes are measured is vehicles per day (vpd). Daily volumes are typically not differentiated by direction or lane, but are the totals for the entire facility at a given location.

### Base Year and Design Year Traffic

For all Georgia DOT projects, the designer should request for traffic volumes for the base year and design year.

The base year is the year the project is anticipated to be open for traffic use. The designer should not confuse this year with the construction programmed date or the project let date. For example if a project is scheduled for a let date some time in 2006 and it is estimated the construction of the project will take two years to complete, then the volumes for the base year 2008 should be requested.

The design year is the anticipated future life of the project and for all GDOT projects the future traffic volumes will be 20 years from the base year. For the example above, the design year traffic volumes to be requested by the designer will be year 2028.

For some projects the design year may be shorter than 20 years, i.e., two (2) years or five (5) years such as in the case of minor safety and intersection improvement projects or interim projects that may be programmed to address a short term operational problem at a location along the facility. The Design Engineer is advised to confirm the base and design years early the concept development stage of the project.

**Urban Area Transportation Models**

Georgia presently includes fifteen different Metropolitan Planning Organizations (MPOs) with a population of more than 50,000 people.  The fifteen areas range from an area of one county to several counties.  GDOT develops a long-range traffic forecasting model for each MPO, except for Atlanta and Chattanooga.  GDOT updates each model every five years.

The fifteen Georgia MPOs are presented in Exhibit 1 below.

**Exhibit 1**
**Urbanized Areas with Associated Counties**

| Urbanized Area | County |
|---|---|
| Albany | Dougherty |
| | Lee |
| Athens | Clarke |
| | Oconee |
| | Madison |
| Atlanta | Barrow |
| | Bartow |
| | Cherokee |
| | Clayton |
| | Cobb |
| | Coweta |
| | DeKalb |
| | Douglas |
| | Fayette |
| | Forsyth |
| | Fulton |
| | Gwinnett |
| | Henry |
| | Newton |
| | Paulding |
| | Rockdale |
| | Spalding |
| | Walton |

| Urbanized Area | County |
|---|---|
| Augusta | Columbia |
| | Richmond |
| | Aiken, SC |
| | Edgefield, SC |
| Brunswick | Glynn |
| Chattanooga | Catoosa |
| | Walker |
| | Hamilton, TN |
| Columbus | Muscogee |
| | Lee, AL |
| | Russell, AL |
| Dalton | Whitfield |
| Gainesville | Hall |
| Hinesville | Liberty |
| | Long |
| Macon | Bibb |
| | Jones |
| Rome | Floyd |
| Savannah | Chatham |
| | Lanier |
| Valdosta | Lowndes |
| | Berrien |
| Warner Robins | Houston |
| | Peach |

The forecasting model is a transportation tool for determining long range traffic volumes on the functionally classified road network (collector or above). There are eight recommended model networks that may be developed for each of the different MPO's. These models may not include all of the counties within the Urbanized Area since the MPO is required to only include 75% of the Urbanized Areas. The counties that are in the long range transportation models are determined by the MPO's. The MPO's are responsible for collecting the socio economic data for the base model and future year model. The socio economic data include population, employment, school enrollment, etc. The MPO is also responsible for disseminating information from the models to the public. The eight recommended models developed by GDOT are:

1. Base Year (1st Network) - This Network should include all functionally classified roads in the study area open to traffic in the Base Year (for example, 2003 Base Year). Functional classification is based on GDOT's RCInfo file. Functionally classified roads include all roadways not coded as urban local = 19 or rural local = 9. Local roadways may appear in the Base Year Network but are not required

to be there. Once calibrated, this Network should replicate the travel patterns that existed in the Base Year.

2. Do-Nothing System Projects (2nd Network) - This Network is intended to show what would happen in the plan year 2030 model if no new projects were built. The Do-Nothing Network would be built on the Base Year Network and would consist of the Base Year Network + any projects under construction, opened to traffic since the Base Year, or whose funds have been authorized but construction has not yet begun. Network 2 examples: projects under construction in 2003; projects opened to traffic since the Base Year; projects authorized for construction at the time of preparing this Network. Network 2 basically reflects “now” roadways with resulting capacity deficiencies from future traffic conditions.

3. Existing + Committed (E+C) System Projects (3rd Network) - This Network is built on the previous Network (Do-Nothing = 2nd Network) and is intended to address deficiencies in it. This Network is intended to show what would happen in the future if only Existing and presently Committed projects were built. Committed projects are defined as those projects in the current STIP/TIP having either ROW or CONST dollars shown. Projects with only PE monies in the STIP/TIP are not considered “committed” when building such a model system. No long range plan projects would appear in this Network. Network 3 example: projects with ROW or CONST in the FY05-07 STIP/TIP. Network 3 basically reflects “committed” short range improvements.

4. Remainder of TIP (PE and TIER 2 Projects and CWP) Projects (4th Network) - This Network is built on the previous Network (E+C = 3rd Network) and is intended to address deficiencies in it. This Network includes programmed projects from TIER 2, the second phase of the TIP document (last three years). Programmed projects in TIER 2 should coincide with the last three years of the Construction Work Program (CWP). Projects with PE monies would be included in this Network. MPO’s sometimes place “desired” projects in the TIER 2 section of the TIP document without an identified dedicated funding source. If a project has not been programmed (does not have a GDOT PI#) or does not have locally dedicated funds allocated, it should not be included in this Network. Network 4 example: projects with any phase programmed for FY08-10 in the FY05-10 TIP/TIER2/CWP. Network 4 basically reflects previously programmed mid range improvements.

   TIER 2 refers to the last three years of projects typically included in the MPO’s TIP document, but not considered part of the official TIP recognized by FHWA, e.g., FY05-07 TIP; FY08-10 TIER 2. The CWP is a GDOT document listing State and Federally funded projects approved by the Transportation Board for Preliminary Engineering (PE), Right of Way Acquisition (ROW) and/or

Construction (CONST), scheduled in the current and next five fiscal years (total six years), e.g., FY05-10 CWP.

5. Remainder of Programmed LRTP Projects (5th Network) - This Network is built on the previous Network (Remainder of TIP = 4th Network) and is intended to address deficiencies in it. This Network includes current Long Range Transportation Plan (LRTP) projects that are programmed by GDOT as Long Range (LR). If local jurisdictions have a method of documenting programmed local projects already included in the current LRTP, those projects could be included in this Network. Network 5 example: projects with PE, ROW or CONST programmed by GDOT for LR = beyond the CWP's last year of 2010. Network 5 basically reflects programmed long range projects from the current LRTP. Current LRTP projects not yet programmed are not to be included in Network 5.

   NOTE: If time is of the essence, Networks 5 and 6 may be combined.

6. Remainder of LRTP Projects (6th Network) - This Network is built on the previous Network (Remainder of Programmed LRTP Projects = 5th Network) and is intended to address deficiencies in it. Network 6 includes projects in the current Long Range Transportation Plan (LRTP) that have not been captured in any of the previous Networks. Network 6 example: projects listed in the current LRTP, that have not advanced from their status as LRTP "recommendations".

7. New Projects – Recommended Plan for Public Comment (7th Network) - This Network is built on the previous Network (Remainder of LRTP = 6th Network) and is intended to address deficiencies in it. Network 7 includes any new project that does not appear in the current LRTP, including LR projects programmed by GDOT but not included in the current LRTP. This Network provides the opportunity to test various improvement scenarios and could actually consist of several Networks, possibly deleting projects included in previous Networks. This series of analyses could produce two Networks for public comment: 1) an aspirations plan; and 2) the financially constrained recommended plan. The latter is required to receive public review and comment.

8. Financial Constraint: The LRTP must demonstrate that anticipated revenues meet or exceed anticipated costs for the LRTP's recommendations. This requires that the cost of all projects be summed together and that this total cost be compared to anticipated monies available. It must be shown that there are enough monies available to pay for the projects. If it is calculated that monies available are less than the sum of project costs, then projects must be removed. All plan projects including roads, bridges, bike/ped, transit, passenger rail, and maintenance should be accounted for in the project costing / revenues available analysis in order to show a financially constrained plan.

Recommended Financially Constrained Plan – Post Public Comment (8th Network) - This Network may or may not be needed. Upon reviewing and responding to public comments received on the draft LRTP, the MPO's staff or committees may request Network revisions or additional scenarios. If significant changes are made, for example new projects not previously presented to the public, additional public comment may be needed. If the public had the opportunity to comment on the projects proposed for revision, additional public comment may not be needed. These decisions are for the MPO staff or are handled through the committee process. Whatever action is decided must be consistent with the MPO's adopted Public Involvement Process (PIP). The final Network must be consistent with the financially constrained LRTP adopted by the Policy Committee.

### Traffic Projections from the Urban Area Transportation Model

For a roadway improvement project on an existing roadway, the Existing + Committed (E+C) model should be used to determine the route's estimated traffic volumes. For a roadway improvement project on a new roadway, or a roadway not included in the E+C model, the volumes from the first model where it is included should be used. To determine design year traffic for a project using an Urban Area Transportation Model, the volumes can be prorated or extrapolated based on the growth in traffic between the base model year and the year of the E+C Model. However, if there is a discrepancy between the existing model and existing counts, it is better to determine that difference and add this to the existing traffic.

A more general approach for using the model would be to obtain an average percent growth of all the roads in the project area from the travel demand model between the base year and the future year and apply this percent growth to the proposed roadway improvement.

In most cases, volumes from the model should not be used as design traffic. The model traffic can be used to determine the absolute growth (i.e. future volume minus base year volume) for each modeled roadway, then that absolute growth can be added to the traffic count for the roadway segment. This method removes any error that was present in the base year model. An example of this is shown in Exhibit 1.2.

Socio-economic data is also available within the model, including population, households, employment, and school enrollment for each Traffic Analysis Zone (TAZ).

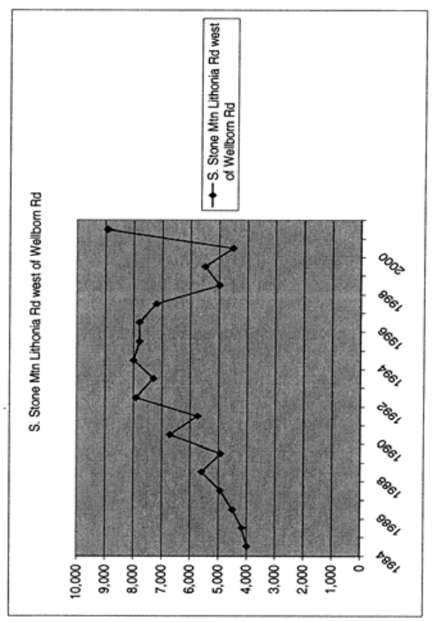
### Traffic for New Roadway Corridors

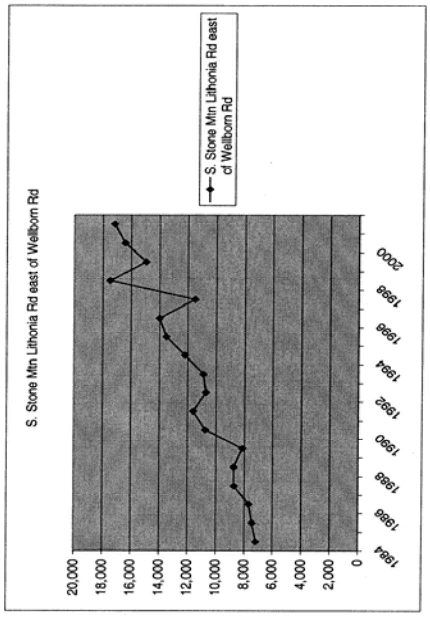
Traffic projections for a new roadway or bypass route can be determined based on traffic counts, an origin-destination study, or from the local MPO transportation model. The percentage of traffic that will be relocated to the new route can be determined in several ways.

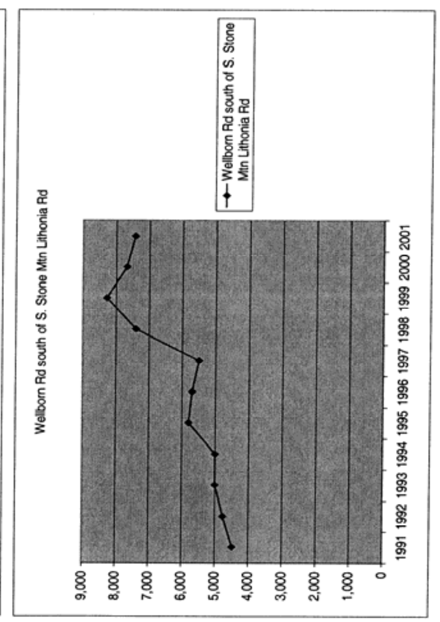
**Wellborn Road at S. Stone Mountain Lithonia Road**

**GDOT Historical Counts**

| Location | Count Station | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Forecast 2014 | 01 to 14 Annual Growth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S. Stone Mtn Lithonia Rd west of Wellborn Rd | 463 | 3,988 | 4,175 | 4,511 | 4,943 | 5,595 | 4,927 | 6,714 | 5,736 | 7,912 | 7,300 | 8,000 | 7,800 | 7,800 | 7,200 | 5,000 | 5,499 | 4,520 | 8,930 | 9,444 | 0.43 |
| S. Stone Mtn Lithonia Rd east of Wellborn Rd | 516 | 7,186 | 7,457 | 7,697 | 8,732 | 8,754 | 8,158 | 10,767 | 11,597 | 10,716 | 10,900 | 12,200 | 13,500 | 14,000 | 11,500 | 17,500 | 14,945 | 16,443 | 17,179 | 24,418 | 2.74 |
| Wellborn Rd south of S. Stone Mtn Lithonia Rd | 479 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,485 | 4,756 | 5,000 | 5,000 | 5,800 | 5,700 | 5,500 | 7,400 | 8,281 | 7,680 | 7,431 | 12,765 | 4.25 |




**Considerations:**
The traffic counts and ARC model due not concur, except slightly for Wellborn Road.
Neither the GDOT counts or ARC model can be used directly since the counts and assignments are not located right at the intersection itself.
Use percents that are a compromise between the estimated GDOT count growth and estimated ARC growth.

**Conclusions:**
Use 2% growth per year for all roads.

**ARC Model Daily Assignments**

| Location | Count Station | GDOT 2000 | ARC 2000 | ARC 2025 | ARC Growth (00-25) | GDOT 2000 + ARC Growth | 00-25 Annual Growth |
|---|---|---|---|---|---|---|---|
| S. Stone Mtn Lithonia Rd west of Wellborn Rd | 463 | 4,520 | 5,520 | 12,380 | 6,860 | 11,380 | 3.8% |
| S. Stone Mtn Lithonia Rd east of Wellborn Rd | 516 | 16,443 | 18,840 | 22,300 | 3,460 | 19,903 | 0.8% |
| Wellborn Rd south of S. Stone Mtn Lithonia Rd | 479 | 7,680 | 11,940 | 16,120 | 4,180 | 11,860 | 1.8% |

**Exhibit 3.1**
**Example for Determining Growth Rates Using Urban Area Transportation Models**

For a minor bypass route, existing traffic counts obtained on nearby roadways will generally show a trend that can be used to determine how much of the traffic would continue along the bypass and how much would be distributed to the local network of the community being bypassed.

A more accurate determination of the percentage of traffic that would use a bypass route within a non-urbanized area is to conduct an origin-destination study. Procedures for conducting an origin-destination study can be found in the ITE Manual of Uniform Traffic Studies. The questions to be asked during the interview should be included in the Traffic Data Memorandum submitted to the Office of Environment and Location for their approval.

Another method for an origin-destination study is to conduct a license plate study either manually or electronically.

Within an urbanized area, the Transportation Model should be used to determine the amount of traffic on a new bypass route. Typically, new roadways are already included in the Transportation Model. Their design traffic volumes can be read directly from the loaded model network. If this is not the case, the new route should be added to the Future Year Model to determine the design year traffic.

**Establish Base Year and Design Year ADT and DHV**

For all Georgia DOT projects, the designer should request traffic volumes for the base year and design year.

The base year is the year the project is anticipated to be open for traffic use. The designer should not confuse this year with the project let (bid award) date or the construction programmed date. For example if a project is scheduled for a let date some time in 2006 and it is estimated the construction of the project will take two years to complete, then the volumes for the base year 2008 should be requested.

The design year is the anticipated life of the project. For all GDOT projects the design year is twenty years from the base year. For our example, the design year will be year 2028.

For some projects the design year may be shorter than twenty years, i.e., two years or five years for minor safety and intersection improvement projects, or for some interim projects that may be programmed to address a short term operational problem. The Design Engineer is advised to confirm the base and design years early the concept development stage of the project.

The base year Average Daily Traffic (ADT) for an existing roadway should be calculated from real traffic counts, adjusted to reflect appropriate axle factors and seasonal factors. For accuracy, the axle factors should be obtained from a vehicle classification count conducted at the same time as the traffic counts. (Many count machines can collect both types of data simultaneously.) Truck percentages and seasonal adjustment factors can also be obtained from the GDOT Road Characteristic Data Base available from the

Office of Transportation Data. Base year and design year ADTs should be determined for each link of the roadway between major intersections, and for each side street.

**Establish Traffic Growth Rate Trends**

The traditional traffic forecasting method relies greatly on historical trends. Historical counts for the past fifteen years should be used if available. The counts should be smoothed to eliminate any bad counts and to show the general trend. Using the least squares method (Excel program), calculate base year and design year volumes based on the last fifteen, ten, and five years, giving the most weight to the ten year trend. This calculation is performed for each coverage count location along the project and for the cross streets. The base year volume is divided by the existing year volume to get the base year factor, and the design year volume is divided by the base year volume to get the design year growth factor.

Historical trend analysis is only part of the traffic forecasting process. Other factors to consider are population growth data, land use plans, planned development, and anything else that might affect future traffic. This information should be available from city/county officials, planners, and other roadway designers. Trips from major real estate development or other major traffic generator should be added based on techniques described in the latest edition of ITE's *Trip Generation*.

Using all available information, the forecaster must use his/her judgment to decide the future growth rates for the project.

When an existing route is paralleled by a much more attractive new route or improved facility, the total traffic on the two roads will be greater than that on the old road before the new one was opened. The additional traffic above that which can be accounted for by diversion and normal growth is defined as "generated traffic." This generated traffic is made up of the following classes of trips:

1. Trips which would not have been made at all, or made less frequently, if the improvement was not available.

2. Trips which would have been made to other destinations or from other origins. For example, shopping or business trips might be changed because of a shift in relative ease of travel.

3. Trips diverted from other forms of transportation. This mostly applies to new interstate routes.

4. Trips resulting from new developments along the road that are developed simultaneously with the construction of the new road.

Generated traffic is greatest for new interstate routes and other freeways. A little generated traffic can be expected for widening projects. Judgment is used to decide how much to modify the normal growth factor. Generally the normal growth factor should be multiplied by a range of 1.00 (no adjustment) to about 1.60 (for new interstates) to account for generated traffic.

**Develop Preliminary Traffic Projection and Check for Reasonableness**
Using traffic growth rates developed in accordance with the preceding, calculate future traffic for several sections along the project and compare this with traffic projections from the Urban Are Transportation Model where available. The two projections should be within 10% of each other. It is important to consider whether or not the future roadway can handle the expected volume. If not, adjustments may need to be made because of limited capacity.

**Adjustments To Design Year ADT Volumes**
For some roadway design projects, adjustments may be required to the volumes projected by OEL. These adjustments will be required in anticipation of major land developments or significant changes in nearby street/ highway networks that will affect future traffic volumes expected on the roadway under design. Adjustments in traffic volumes for major land developments should follow any procedures established by OEL and the impacts should be approved by OEL before the adjusted volumes are used in design by the Design Engineer. The designer should document any assumptions made and the procedures utilized in the adjustment of the traffic volumes.

**Develop Traffic Forecast in Detail (ADT)**
Using the established growth rates, base year and future year turning movements are calculated for each intersection along the project limits. The existing year turning movements should be used as a pattern. The forecaster must decide if the same pattern will hold in the future as exists now. Also, each intersection should be examined for reasonableness of the growth rate, and adjustments made as needed. For example, a built out subdivision will have little, if any, growth, while other roads in the same general vicinity might grow at a higher rate. The forecaster must use his/her judgment. Turns might need adjustment based on future land use and/or development. In most cases, the volumes in each direction should be the same. There should be a reasonable explanation if there is a difference.

**Design Hourly Volumes And Their Uses**

While daily volumes are very useful in planning, hourly volumes are also needed for the design process. Because volumes vary significantly during the course of a 24-hour day, usually with periods of maximum volume occurring during the morning or afternoon rush hours.

The single hour of the day that has the highest hourly volume is called the “peak hour”. Capacity and other traffic analyses typically focus on the peak hour of traffic volumes, because it represents the most critical period for operations and has the highest capacity requirement. This peak-hour volume is not a constant value from day to day or from season to season.

The relationship between the hourly volume and the maximum rate of flow within an hour is defined as the peak-hour factor (PHF). For design and traffic analysis, peak volumes are usually measured for a period of time less than an hour usually 15-minute period. The 15-minute period shall be used for all capacity analysis by the designer.

The Design Hour Volume (DHV) is the traffic volume used to determine the number of traffic lanes on the roadway. The following formula expresses the relationship between the design hour volume and the average daily traffic volume:

**DHV = AADT x K**

where:

DHV = design hour volume of traffic (total, 2-way)
AADT = average 24-hour weekday, 2-way volume of traffic
K = ratio of design hour volume to AADT

At major intersections and at driveways leading to major activity centers, the design hour turning volumes are important in determining the intersection capacity, resulting number of lanes, and the storage length for exclusive turning lanes required for each approach. For intersections being reconstructed and that are in fully developed areas, existing turning movement percentages will be collected in the field and assumed to be the same for the future design year. For new intersections or for those significantly impacted by new land developments or major changes in nearby street/highway networks, existing and projected traffic data along with engineering judgment will be used to reassign vehicle trips on nearby street networks to derive the turning movements at project intersections.

Future traffic volumes shall be used to ensure that the road has enough traffic carrying capacity. The traffic volume during a period of time shorter than a day shall be used for design purposes, reflecting peak hour periods. For roads with unusual or highly seasonal fluctuation in traffic volumes, the 30th highest hour of the design year should be used. This can be computed using seasonal adjustment factors discussed in the previous section. Locations where this technique may be necessary include beach or mountain resorts, and roadways serving major sporting arenas or performance halls.

The directional design hour volume is the traffic volume for the rush hour period in the peak direction of flow. Use directional distribution factors based on existing traffic counts. If this information is not available it should be assumed that 60% of the traffic is going in one direction. For a more detailed analysis of intersection and road capacity, procedures as described in the intersection portion of this manual and the latest version of the HCM should be used.

Using short-term counts along project, peak hour and directional factors are calculated and compared to any ATR locations along the route. If there are no ATR locations along the route, ATR locations along nearby routes with the same functional class can be used. Appropriate K and D factors must be discussed and approved with appropriate GDOT staff. The K and D factors are applied to the ADT derived above to calculate the AM and PM design hour volumes. Since the DHV is the 30th highest hour, the PM movement is usually the return movement from the AM movement. In some cases, separate AM and PM volumes may need to be calculated. Also, sometimes the base year peak hour volumes (PHV) are needed. They are calculated the same way using the base year ADT.

**Determine Truck Factors**

Appropriate data sources must be used to determine 24-hour and peak hour truck percentages. As described above, serious consideration must be given to new traffic counts taken specifically for this purpose. The 24-hour percentage should be given as SU (single unit: Classes 4 through 7) and Comb. (Combination: Classes 8 through 15). Note that single unit trucks include buses.

**Finalize Traffic Forecast**

The traffic projections and design factors are finalized and submitted as MicroStation design files to GDOT, Head of Traffic Analysis Section for approval. The submittal should meet section standards as to size of drawing and lettering.

## 2. TRAFFIC ANALYSIS AND DESIGN

### Introduction

The purpose of this section is to provide some guidance to designers on some of the factors and design elements to consider in the operational and capacity analysis using the traffic data available to them. This information is intended as a supplement to Department adopted standards and to procedures outlined in the Highway Capacity Manual (HCM), published by the Transportation Research Board.

### Urban Arterial Classification

*The Green Book* describes urban areas as those places within the boundaries set by the responsible State and local officials having a population of 5,000 or more. Urban areas are further subdivided into urbanized areas (population of 50,000 and over) and small urban areas (population between 5000 and 50,000). For design purposes, the designer is encouraged to use the population forecast for the design year.

The four functional systems for urbanized areas are urban principal arterials, minor arterial streets, collector streets, and local streets. The differences in the nature and intensity of development between rural and urban areas cause these systems to have characteristics that are somewhat different from the correspondingly named rural systems.

In every urban environment there exists a system of streets and highways which can be identified as unusually significant to the area in which it lies in terms of the nature and composition of travel it serves. In smaller urban areas (under 50,000) these facilities may be very limited in number and extent and their importance may be primarily derived from the service provided to travel passing through the area. In larger urban areas their importance also derives from service to rural oriented traffic, but equally or even more important, from service for major movements within these urbanized areas.

Because of the nature of the travel served by the principal arterial system, almost all fully and partially controlled access facilities will be part of this functional system. However, this system is not restricted to controlled access routes. In order to preserve the identification of controlled access facilities, the principal arterial system is stratified as follows: (1) Interstate, (2) other freeways and expressways, and (3) other principal arterials (with no control of access).

The minor arterial street system should interconnect with and augment the urban principal arterial system and provide service to trips of moderate length at a somewhat lower level of travel mobility than principal arterials. This system also distributes travel to geographic areas smaller than those identified with the higher system.

The minor arterial street system includes all arterials not classified as a principal and contains facilities that place more emphasis on land access than the higher system, and offer a lower level of traffic mobility. Such facilities may carry local bus routes and provide intra-community continuity, but ideally should not penetrate identifiable neighborhoods. This system should include urban connections to rural collector roads where such connections have not been classified as urban principal arterials.

The collector street system provides land access service and traffic circulation within residential neighborhoods, commercial and industrial areas. It differs from the arterial system in that facilities on the collector system may penetrate residential neighborhoods, distributing trips from the arterials through the area to the ultimate destination. Conversely, the collector street also collects traffic from local streets in residential neighborhoods and channels it into the arterial system. In the central business district, and in other areas of like development and traffic density, the collector system may include the street grid which forms a logical entity for traffic circulation.

The local street system comprises all facilities not on one of the higher systems. It serves primarily to provide direct access to abutting land and access to the higher order systems. It offers the lowest level of mobility and usually contains no bus routes. Service to through traffic movement usually is deliberately discouraged.

### Rural Arterial Classification

Rural Principal Arterials consists of a network of routes with the following service characteristics:

- Traffic movements with trip length and density suitable for substantial statewide travel or interstate travel
- Traffic movements between urban areas with populations over 25,000.
- Traffic movements at high speeds.
- Divided four-lane roads.
- Desired LOS B

The Policy on Geometric Design of Highways and Streets 2001 commonly known as the GREEN BOOK) describes urban areas as those places within the boundaries set by the responsible State and local officials having a population of 5,000 or more. Urban areas are further subdivided into urbanized areas (population of 50,000 and over) and small urban areas (population between 5000 and 50,000). The Green book further states that for design purposes, the population forecast for the design year should be used.

Rural Minor Arterials are roads with the following service characteristics:
- Traffic movements with trip length and density suitable for integrated interstate or inter-county service.

- Traffic movements between urban areas or other traffic generators with populations less than 25,000.
- Traffic movements, at high speeds.
- Undivided lane roads.
- Striped for one or two lanes in each direction with auxiliary lanes at intersections as required by traffic volumes.
- Desired LOS C

## FREEWAY TRAFFIC ANALYSIS AND DESIGN

### General

Freeways can be distinguished from all other highway systems based on the categorization of providing non-interrupted flow. As opposed to interrupted flow which have at-grade intersections, the traffic flow conditions along uninterrupted-flow facilities result from the interactions among vehicles in the traffic stream and between vehicles and the geometric and environmental components of the roadway.

It should be recognized that categorization into uninterrupted and interrupted flow relates to the type of facility, not the quality of the traffic flow at any given time. A freeway experiencing extreme congestion differs greatly from a non-freeway facility experiencing extreme congestion, in that the conditions creating the congestion are internal to the facility, not external to the facility.

Freeways and their components operate under the purest form of uninterrupted flow. There are no fixed interruptions and access to the freeway facility is controlled and limited to ramp locations.

The analyst should realize that freeway facilities may have interactions with other freeway facilities in the area as well as other classes of roads in the vicinity. The performance of the freeway may be affected when demand exceeds capacity on these nearby road systems. For example, if the street system can not accommodate the demand exiting the freeway, the oversaturation of the street system may result in queues backing onto the freeway, which adversely affects freeway performance.

The traffic analysis and design process must also recognize that the freeway system has several interacting components, including ramps, and weaving sections. The performance of each component must be evaluated separately and their interactions considered to achieve an effective overall design. For example, the presence of ramp metering affects freeway demand and must be taken into consideration in analyzing a freeway facility.

High occupancy vehicle (HOV) lanes are common in many urban areas and require special analysis. HOV lanes are adjacent to general freeway lanes and are designated for use by buses and vehicles with two or more persons. If an HOV facility has two or more lanes in each direction all or part of the day and if access to the HOV facility is limited from adjacent freeway lanes (i.e. 1 mile or greater access point spacing), these procedures may be used. Otherwise, HOV lane(s) will have lower lane capacities.

**Technology**

Emerging transportation technologies, also known as intelligent transportation systems (ITS), enhance the safety and efficiencies of vehicles and roadway systems. ITS strategies aim to increase the safety and performance of roadway facilities. For freeway and other uninterrupted-flow highways, ITS may achieve some decrease in headways, which would increase the capacity of these facilities. In addition, even with no decrease in headways, level of service might improve if vehicle guidance systems offered drivers a greater level of comfort than they currently experience in conditions with close spacing between vehicles. Many of the ITS improvements, such as incident response and driver information systems, occur at the system level. Although ITS features will benefit the overall roadway system, they will not have an impact on the methods to calculate capacity and level of service for individual roadways.

**Capacity Analysis and Level of Service**

Capacity is defined as the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a given period under prevailing roadway, traffic, and control conditions. Service flow rates are similar because they define the flow rates that be accommodated while still maintaining a given level of service.

Most design or planning efforts typically use service flow rates at LOS C (for rural areas) and D (for urban areas), to ensure an acceptable operating service for facility users.

**Base Conditions**

Capacity analysis begins with defining the capacity analysis of a base condition for the component and then adjusting accordingly when the prevailing conditions deviate from the base condition. The base conditions assumes good weather, good pavement conditions, users familiar with the facility, and no impediments to traffic flow. Base conditions for uninterrupted-flow facilities include the following:

- Lane widths of 12 feet,
- Clearance of 6 feet between the edge of the travel lanes and the nearest obstructions or objects at the roadside and in the median,
- Free-flow speed of 60 mph,
- Only passenger cars in the traffic stream (no heavy vehicles),
- Level Terrain,

The prevailing conditions are broken into the roadway and traffic categories and a section is provided with a brief discussion of each.

**Prevailing Roadway Conditions**

Roadway conditions include geometric and other elements. In some cases, these influence the capacity of a road; in others, they can affect a performance measure such as speed, but not the capacity or maximum flow rate of the facility. Roadway factors include the following:

- Number of lanes,
- Lane widths,
- Shoulder widths and lateral clearances,
- Design speed,
- Horizontal and vertical alignments, and

The horizontal and vertical alignment of a highway depend on the design speed and the topography of the land on which it is constructed.

**Prevailing Traffic Conditions**

Traffic conditions that influence capacity and level of service include vehicle type and lane or directional distribution.

<u>Vehicle type</u> - the entry of heavy vehicles into the traffic stream affects the number of vehicles that can be served. Heavy vehicles (i.e. trucks, busses, and recreational vehicles) adversely affect traffic in two ways:

- They are larger than passenger cars and occupy more roadway space; and
- They have poorer operating capabilities, particularly with respect to acceleration, deceleration, and the ability to maintain speed on upgrades.

The inability of heavy vehicles to keep pace with passenger cars in many situations creates large gaps in the traffic stream. The resulting inefficiencies in the use of roadway space can not be completely overcome. This effect is particularly harmful on sustained, steep upgrades, where the difference in operating capabilities is most pronounced. Heavy vehicles also affect downgrade operations, particularly when downgrades are steep enough to require operation in a low gear.

Trucks cover a wide range of vehicles, from lightly loaded vans and single-unit trucks to the most heavily-loaded combination unit, tractor-trailer trucks. An individual truck's operational characteristics vary based on the weight-to-engine performance ratio.

Intercity buses are relatively uniform in performance. Urban transit buses generally are not a powerful as intercity buses; their most severe impact on traffic results from the discharge and collection of passengers.

Recreational vehicles include a broad range of vehicles: self-propelled and towed campers, motor homes, and passenger vehicles towing variety of recreational equipment. Although these vehicles might operate considerably better than trucks, the drivers are not professionals, accentuating the negative impact of RVs on the traffic stream.

<u>Directional and Lane Distribution</u> - in addition to the distribution of vehicle types, two other traffic characteristics affect capacity, service flow rates, and level of service:

directional distribution and lane distribution. Directional distribution achieves optimal conditions when the amount of traffic is about the same in each direction. Capacity analysis for multilane highways and freeways focuses on a single direction of flow. Lane distribution, in general terms, relates lower volume, slower moving vehicles in the outside shoulder lanes and higher volume, faster moving vehicles in the inside shoulder lanes.

### Basic Freeway Segments

Basic freeway segments are outside of the influence area of ramps or weaving areas. An illustration of a basic freeway segment can be found in Exhibit 13-1. of the Capacity Manual.

### Freeway Capacity Terms

See chapter 1 for definition of terms. Capacity analysis is based on freeway segments with uniform traffic and roadway conditions. If any of the prevailing conditions change significantly, the capacity of the segment and its operating conditions change as well. Therefore, each uniform segment should be analyzed separately.

### Flow Characteristics

Traffic flow within basic freeway segments can be highly varied depending on the conditions constructing flow at upstream and downstream bottleneck locations. Bottlenecks can be created by ramp merge and weaving segments, lane drops, maintenance and construction activities, accidents, and objects in the roadway. An incident does not have to block a travel lane to create a bottleneck. For example, disabled vehicles in the median or on the shoulder can influence traffic flow within the freeway lanes.

Freeway research has resulted in a better understanding of the characteristics of freeway flow relative to the influence of upstream and downstream bottlenecks. Traffic flow within a basic freeway segment can be categorized into three flow types: (1) undersaturated, (2) queue discharge, and (3) oversaturated. Each flow type is defined within general speed-flow-density ranges, and each represents different conditions on the freeway.

Undersaturated flow represents traffic flow that is unaffected by upstream or downstream conditions. This regime is generally defined within a speed range of 55 to 75 mph at low to moderate flow rates and a range of 40 to 60 mph at high flow rates.

Queue discharge flow represents traffic flow that has just passed through a bottleneck and is accelerating back to the free-flow speed of the freeway. Queue discharge flow is characterized by relatively stable flow as long as the effects of another bottleneck downstream are not present. This flow type is generally defined within a narrow range of 2,000 to 2,300 passenger cars, per hour, per lane (pcphpl), with speeds typically ranging from 35 mph up to the free-flow speed of the freeway segment. Lower speeds are typically observed just downstream of the bottleneck. Depending on horizontal and vertical alignments, queue discharge flow usually accelerates back to the free-flow speed of the facility within 0.5 to 1 mile downstream from the bottleneck. Studies suggest that the queue discharge flow rate from the bottleneck is lower than the maximum flows observed before breakdown. A typical value for this drop in flow rate is approximately 5 percent.

Oversaturated flow represents traffic flow that is influenced by the effects of a downstream bottleneck. Traffic flow in the congested regime can vary over a broad range of flows and speeds depending on the severity of the bottleneck. Queues may extend several thousand feet upstream of the bottleneck. Freeway queues differ from queues at intersections in that they are not static or 'standing.' On freeways, vehicles move slowly through a queue, with periods of stopping and movement.

### Speed-Flow and Density-Flow Relationships

The free-flow speed of passenger cars (mph) on freeways is relatively insensitive to flow rate of passenger cars per hour per lane (pcphpl) in the low to moderate range (0 pcphpl to 1,200 pcphpl). Studies have shown that passenger cars operating at a free-flow speed of 70 mph maintain the operating speed for flows up to 1,300 pcphpl For lower free-flow speed, the region over which speed is insensitive to flow extends to higher flow rates. In general terms, the lower the flow rate, the higher free-flow speed of the vehicle. Similarly, the higher the flow rate, the higher the density, which is measured in pc/mi/ln. Exhibits 13-2 and 13-3 listed on pages 13-3 and 13-4 of the *Capacity Manual*, provide an illustration of Speed-Flow and Density-Flow Relationships.

Research leading to the curves illustrated in Exhibits 13-2 and 13-3 has discovered that a number of factors affect free-flow speed. The factors include the number of lanes, lane width, lateral clearance, and interchange density or spacing. Other factors believed to influence free-flow speed include horizontal and vertical alignment, speed limit, level of enforcement, lighting conditions, and weather.

Under base traffic and geometric conditions, freeways will operate with capacities as high as 2,400 pcphpl. This capacity is typically achieved on freeways with free-flow speed of 70 mph or greater. As the free-flow speed decreases, there is a slight decrease in capacity.

## FACTORS AFFECTING FREE-FLOW SPEED

### Lane Widths and Lateral Clearances

When lane widths are less than 12 feet, drivers are forced to travel closer to one another laterally than they would normally desire. Drivers tend to compensate for this by reducing their travel speed.

The effect of restricted lateral clearance is similar. When objects are located too close to the edge of the travel lane, drivers in the outside lanes will shy away from them, positioning themselves further away from the lane edge. However, studies have shown that restriction of lateral clearance has a greater affect on motorists in the rightmost travel lanes than on those in the median lane.

Drivers in the median lane appear to be unaffected by lateral clearance when minimum clearance is two feet, where as drivers in the outside lane are affected when lateral clearance is less than six feet.

**Number of Lanes**
As the number of lanes increases on a freeway facility, so does the opportunity for drivers to position themselves to avoid slower-moving traffic. In typical freeway driving, traffic tends to be distributed across lanes according to speed. Traffic in the median lane typically moves faster than in the lane adjacent to the outside shoulder. Typically, the free-flow speed of a freeway facility increases proportionally with the number of lanes (i.e. decreased maneuverability tends to reduce the average speed of vehicles).

**Interchange Density**
Freeway segments with closely spaced interchanges, such as those in heavily developed urban areas, operate at lower free-flow speed than suburban or rural freeways where interchanges are spaced further apart. The merging and weaving associated with interchanges affect the speed of traffic. The ideal average interchange spacing over a reasonably long section of freeway (five to six miles) is two miles or greater. The minimum average interchange spacing considered possible over a substantial length of freeway is ½ mile.

**Other Factors**
The design speed of the primary physical elements of a freeway can affect travel speed. In particular, the horizontal and vertical alignments may contribute to the free-flow speed of a given freeway segment.

**Passenger-car Equivalents**
The concept of vehicle equivalents is based on observations of freeway conditions in which the presence of heavy vehicles, including trucks, buses, and recreational vehicles, creates less than base conditions. The lesser conditions include longer and more frequent gaps of excessive length both in front of and behind heavy vehicles, the speed of vehicles in adjacent lanes, and the physical space taken up by a large vehicle (typically two to three times greater than a passenger car). To allow for these lesser conditions and ensure the method for freeway capacity is based on a consistent measure of flow, each heavy vehicle is converted to a passenger-car equivalent. The conversion results in a single value for flow rate in terms of passenger cars per hour per lane (pcphpl). The conversion factor depends on the proportion of heavy vehicles in the traffic stream and the length as well as the severity of the roadway grade.

**Driver Population**

Studies have shown that non-commuter driver populations display different, less aggressive characteristics than regular commuters. For recreational traffic, capacities have been observed to be as much as 10 to 15 percent lower than for commuter traffic traveling on the same segment.

**Level of Service (LOS)**

Although speed is a major concern of drivers as related to service quality, freedom to maneuver within the traffic stream and proximity to other vehicles are equally noticeable concerns. These qualities are related to the density of the traffic stream. Unlike speed, density increases as flow increases up to capacity, resulting in a measure of effectiveness that is sensitive to a broad range of flows.

Operating characteristics are represented by a specified Level of Service (LOS) ranging from LOS ‘A’ describing free-flow operations to LOS ‘F’ describing breakdowns in vehicular flow. Vehicular flow breakdowns occur for a number of reasons:

- Traffic incidents can cause a temporary reduction in the capacity of a short freeway segment, so that the number of vehicles arriving at the point is greater than the number of vehicles that can move through it.
- Points of recurring congestion, such as merge or weaving segments and lane drops, experience very high demand in which the number of vehicles arriving is greater than the number of vehicles discharged.
- In forecasting situations, the projected peak-hour (or other) flow rate can exceed the estimated capacity of the location.

Note in all cases, breakdown occurs when the ratio of existing demand to actual capacity or of forecast demand to estimated capacity exceeds 1.00.

**Freeway Weaving**

Weaving is defined as the crossing of two or more traffic streams traveling in the same general direction along a significant length of highway without the aid of traffic control devices (with the exception of guide signs). Weaving segments are formed when a merge area is closely followed by a diverge area, or when an entrance ramp is closely followed by an exit ramp and the two are joined by an auxiliary lane. Note that if a one-lane entrance ramp is closely followed by an one-lane exit ramp and the two are not connected by an auxiliary lane, the merge and diverge movements are considered separately using procedures for the analysis of ramp terminals.

Weaving segments require intense lane-changing maneuvers as drivers must access lanes appropriate to their desired exit points. Thus, traffic in a weaving segment is subject to turbulence in excess of that normally present on basic freeway segments. The turbulence presents special operational problems and design requirements that are addressed by Freeway Weaving (*Capacity Manual*, Chapter 24 - Freeway Weaving). Weaving segments may exist on any type of facility: freeways, multilane highways, two-lane highways, interchange areas, urban streets, or collector-distributor roadways.

**Weaving Configurations**
Three geometric variables influence weaving segment operations: configuration, length, and width. The most critical aspect of operations within a weaving segment is lane changing. Weaving vehicles, which must cross a roadway to enter on the right and leave on the left, or vice-versa, accomplish these maneuvers by making the appropriate lane changes. The configuration of the weaving segment (i.e. the relative placement of entry and exit lanes) has a major effect on the number of lane changes required of weaving vehicles to successfully complete their maneuver. There is also a distinction between lane changes that must be made to weave successfully and additional lane changes that are discretionary (i.e. are not necessary to complete the weaving maneuver). The former must take place within the confined length of the weaving segment, whereas the latter are not restricted to the weaving segment itself.

<u>Type A Weaving Configuration</u> - the identifying characteristic of a Type A weaving segment is that all weaving vehicles must make one lane change to complete their maneuver successfully. All of these lane changes occur across a lane line that connects from the entrance gore area directly to the exit gore area (i.e. the crown line). Type A weaving segments are the only such segments that have a crown line.

The most common form of a Type A weaving segment is formed by a one-lane entrance ramp followed by a one-lane exit ramp, with the two connected by a continuous auxiliary lane. All entrance-ramp vehicles entering the freeway must make a lane change from the auxiliary lane to the shoulder lane of the freeway. All freeway vehicles exiting at the exit ramp must make a lane change from the shoulder lane of the freeway to the auxiliary lane. This type of configuration is also referred to as a ramp weave.

A Type A weaving configuration, commonly referred to as a ramp weave, becomes a major weave if three or four of the entry and exit legs have multiple lanes (refer to Exhibit 13-8, page 13-15 of the *Capacity Manual*).

<u>Type B Weaving Configuration</u> - the identifying characteristic of a Type B weaving segment is that such weaving segments always have at least three entry and exit legs with multiple lanes (i.e. a major weave). One of the weaving movements can be made without making a lane change, and the other weaving movement requires at most one lane change.

Three scenarios, Exhibits 13-9(a), 13-9(b), and 13-9(c) are illustrated on page 13-16 of the *Capacity Manual*. Furthermore, Exhibits 13-9(a) and 13-9(c) provide for lane balance - the number of lanes leaving the diverge is one more than the number of lanes approaching it - at the exit point of the weave section; Exhibit 13--9(b) illustrates a major weave that does not have lane balance - traffic is forced to merge together at the entry point of the weave section.

Type B weaving sections are extremely efficient in carrying large weaving flows. Primarily because of the provision of a through lane for at least one of the weaving movements. Weaving movements can also be made with a single lane change from wither of the lanes adjacent to the through lane. Thus, weaving vehicles can occupy a substantial number of lanes in the weaving segment and are not as restricted in Type A segments.

Type C Weaving Configuration - the identifying characteristic of a Type C weaving segment is that one of the weaving movements may be made without making a lane change and the other weaving movement requires two or more lane changes.

Two scenarios, Exhibits 13-10(a) and 13-10(b) are illustrated on page 13-17 of the *Capacity Manual*. Exhibit 13-10(a) illustrates a major weave section where lane balance is not present at either the entry gore or exit gore points. Although such a segment is relatively efficient for weaving movements in the direction of freeway flow, it can not handle large weaving flows in the other direction.

Exhibit 13-10(b) illustrates a two-sided weaving segment. Two-sided weaving segments are characterized by a right-hand entrance ramp followed by a left-hand exit ramp, or vice-versa. Ramp to ramp vehicles must cross all lanes of the freeway to execute their desired maneuver. It is extremely difficult to analyze a two-sided weaving segment from a planning perspective, due to the variations in the freeway and ramp traffic composition, driver characteristics, and the length of the weaving segment.

**Effects of Weaving Configurations**
The configuration of the weaving segment has a marked effect on operations because of its influence on lane-changing behavior. Configuration has a further effect on the proportional use of lanes by weaving and non-weaving vehicles. Since weaving vehicles must occupy specific lanes to efficiently complete their maneuvers, the configuration can limit the ability of weaving vehicles to use outer lanes of the segment. This effect is most pronounced in Type A weaving segments, because weaving vehicles must primarily occupy the two lanes adjacent to the crown line, and least pronounced in Type B weaving segments, because this segment requires weaving vehicles to make the fewest lane changes.

**Weaving Length**
Because weaving vehicles must execute all the required lane changes for their maneuver within the weaving segment boundary from the entry gore to the exit gore, the parameter of weaving length is important. The length of the weaving segment constrains the time and space in which the driver must make all required lane changes. When the length of the weaving segment decreases, the resulting turbulence in traffic flow increases.

The length of a weaving segment is measured from a point on the entry gore where the outside lane of the freeway and the left lane of the merging lanes are two feet apart to a point on the exit gore where the two diverging lanes are 12 feet apart. In theory, the maximum length of a weaving segment is 2,500 feet. However, weaving segments may exist in longer segments, but merging and diverging movements are often separated, with lane changing tending to concentrate near merge and diverge gore areas. Weaving turbulence may exist to some degree throughout longer segments, but operations are approximately the same as those for a basic freeway segment, except for the ramp influence areas near the entry and exit gore areas.

**Weaving Width**

The third geometric variable influencing the operation of the weaving segment is its width, which is defined as the total number of lanes between the entry and exit gore areas, including the auxiliary lane, if present. It is important to note that as the number of lanes increases, the throughput capacity increases, however, the opportunity for lane changes also increases for discretionary lane changes that may take place within the weaving section.

**Type of Operation**

Whereas the total number of lanes in the weaving segment is important, the proportional use of those lanes by weaving and non-weaving vehicles is even more important. Under normal circumstances, weaving and non-weaving vehicles compete for space, and operations across all lanes tend to reach an equilibrium in which all drivers experience similar conditions. In a weaving segment, there is some segregation of weaving and non-weaving flows as non-weaving vehicles tend to say in outside lanes and weaving vehicles tend to occupy the lanes involved in crossing the roadway. Nevertheless, there is substantial sharing of lanes by weaving and non-weaving vehicles.

Under normal circumstances, weaving and non-weaving vehicles will reach equilibrium operation in which weaving vehicles effectively occupy a number of lanes and the non-weaving vehicles occupy the remainder of lanes in the weaving segment. However, the lane configuration of the weave segment limits the total number of lanes that can be used by weaving vehicles because of the lane changes that must be made. The guidelines on lane usage generally possess the following characteristics:

- Weaving vehicles may occupy all of a lane in which weaving is accomplished without a lane change.
- Weaving vehicles may occupy most of a lane from which a weaving maneuver can be accomplished with a single lane change.
- Weaving vehicles may occupy a small portion of a lane from which a weaving maneuver can be completed by making two lane changes.
- Weaving vehicles can not occupy a measurable portion of any lane from which a weaving maneuver would require three or more lane changes.

Exhibit 13-12 on page 13-19 of the *Capacity Manual*, illustrates the maximum use of lanes by weaving vehicles for Type A, B, and C weaving segments.

When the number of lanes weaving vehicles must occupy to achieve equilibrium operation with non-weaving vehicles is less than the number of lanes that can be occupied by weaving vehicles based on the geometric configuration of the weave segment, equilibrium operation will be established (i.e. unconstrained operation). When the number of lanes weaving vehicles must occupy to achieve equilibrium operation with non-weaving vehicles is equal to or greater than the number of lanes that can be occupied by weaving vehicles based on the geometric configuration of the weave segment, equilibrium operation can not be established (i.e. constrained operation). Under unconstrained operation, weaving and non-weaving vehicles usually experience similar operational characteristics. In constrained operation, however, weaving vehicles often experience operating conditions that are markedly worse than those of non-weaving vehicles.

**Ramps And Ramp Junctions**

A ramp is a length of roadway providing an exclusive connection between two highway facilities. On freeways, all entering and exiting maneuvers take place on ramps that are designed to facilitate smooth merging of on-ramp vehicles into the freeway traffic stream and smooth diverging of off-ramp vehicles from the freeway traffic stream onto the ramp.

**Ramp Components**

A ramp may consist of three geometric elements: the ramp-freeway junction, the ramp roadway, and the ramp-street junction. A ramp-freeway junction is typically designed to permit high-speed merging or diverging with minimum disruption to the adjacent freeway traffic. The geometric characteristics of ramp-freeway junctions vary. The length and type (taper, parallel) of acceleration or deceleration lanes, free-flow speed of the ramp in the immediate vicinity of the junction, sight distances, and other elements all influence ramp operations.

Geometric characteristics of ramp roadways vary from location to location. Ramps may vary in terms of number of lanes (usually one or two), design speed, grades, and horizontal curvature. The design of ramp roadways is seldom a source of operational difficulty unless a traffic crash causes disruption along their length. Ramp-street terminal problems can cause queuing along the length of a ramp, but this is generally not related to the design of the ramp roadway.

Freeway-to-freeway ramps have two ramp-freeway terminals and do not have a ramp-street terminal. However, many ramps connect limited-access facilities to local arterials and collectors. For such ramps, the ramp-street terminal is often a critical element in the overall design. Ramp-street junctions can permit uncontrolled merging and diverging movements, or they can take the form of an at-grade intersection. Queues forming at the ramp-street junction can, under extreme conditions, back up into the ramp-freeway junction and indeed onto the freeway mainline itself.

Operational Characteristics

A ramp-freeway junction is an area of competing traffic demands for space. Upstream freeway traffic competes for space with entering on-ramp vehicles in merge areas. On-ramp demand is usually generated locally, although urban streets may bring some drivers to the ramp form more distant origins.

In a merge area, individual on-ramp vehicles attempt to find gaps in the adjacent freeway lane traffic stream. Because most ramps are on the right side of the freeway, the freeway lane in which on-ramp vehicles seek gaps is designated as Lane 1. By convention, freeway lanes are numbered from 1 to N, from the right shoulder to the median.

The action of individual merging vehicles entering the Lane 1 traffic stream creates turbulence in the vicinity of the ramp. Approaching freeway vehicles move toward the left to avoid this turbulence. Field observations (i.e. Traffic studies) have shown that the operational effect of merging vehicles is heaviest in Lanes 1 and 2 and the acceleration lane for a distance extending from the physical merge point to 1,500 feet downstream. Exhibit 13-14 listed on page 13-21 of the *Capacity Manual*, illustrates on-and off-ramp influence areas.

Interactions are dynamic in ramp influence areas. Approaching freeway vehicles will move left as long as there is capacity to do so. Whereas the intensity of ramp flow influences the behavior of freeway vehicles, general freeway congestion can also act to limit ramp flow, causing diversion to other interchanges or routes.

At off-ramps, the basic maneuver is a diverge, that is, a single traffic stream separating into two streams. Exiting vehicles must occupy the lane adjacent to the off-ramp (Lane 1 for a right-hand off-ramp). Thus, as the off-ramp is approached, diverge vehicles move right. This effects a redistribution of other freeway vehicles, as they move left to avoid the turbulence of the immediate diverge area.

**Important Parameters**

A number of variables influence the operation of ramp-freeway junctions. They include all of the variables affecting basic freeway segment operation: Lane widths, lateral clearances, terrain, driver population, and the presence of heavy vehicles. There are additional parameters of particular importance to the operation of ramp-freeway junctions, including length of acceleration/deceleration lane, ramp free-flow speed, and lane distribution of upstream traffic.

The length of the acceleration or deceleration lane has a significant effect on merging and diverging operations. Short lanes provide on-ramp vehicles with restricted opportunity to accelerate before merging and off-ramp vehicles to decelerate off-line. The result is that most acceleration and deceleration must take place on the mainline, which disrupts through vehicles. Short acceleration lanes also force many vehicles to slow significantly and even stop while seeking an appropriate gap in the Lane 1 traffic stream.

Many characteristics influence the free-flow speed of the ramp, including degree of curvature, number of lanes, grades, and sight distances, among others. free-flow speed is an influential factor, since it determines the speed at which merging vehicles enter the acceleration lane and the speed at which diverging vehicles must enter the ramp. This, in turn, determines the amount of acceleration or deceleration that must take place. Ramp free-flow speeds generally vary between 20 and 50 mph. Although free-flow speed is best determined in the field, a default value of 25 mph may be used where specific measurement or predictions are unavailable.

Several factors influence the lane distribution of traffic immediately upstream of an on- or off-ramp; number of lanes on the facility, proximity of adjacent upstream and downstream ramps, and the activity on those ramps. As conditions force more approaching freeway flow into Lanes 1 and 2, merging and diverging maneuvers become more difficult. Therefore, estimation of the upstream freeway flow approaching in Lanes 1 and 2 of the freeway (which are the freeway lanes included in the merge and diverge influence areas) is important.

**Capacity of Merge and Diverge Areas**

There is no evidence that merging or diverging maneuvers restrict the total capacity of the upstream or downstream basic freeway segments. Their influence is primarily to add or subtract demand at the ramp-freeway junction. Thus, the capacity of a downstream basic freeway segment is not influenced by turbulence in a merge area. The capacity will be the same as if the segment were a basic freeway segment. As on-ramp vehicles enter the freeway at a merge area, the total number of ramp and approaching freeway vehicles that can be accommodated is the capacity of the downstream basic freeway segment. Exhibit 13-15 listed on page 13-23 of the *Capacity Manual*, illustrates the capacity of merge areas.

Similarly, the capacity of an upstream basic freeway segment is not influenced by the turbulence in a diverge area. The total capacity that may be handled by the diverge junction is limited either by the capacity of the approaching (upstream) basic freeway segment or by the capacity of the downstream basic freeway segment and the ramp itself. Exhibit 13-16 listed on page 13-23 of the *Capacity Manual*, illustrates the capacity of diverge areas. Most breakdowns at diverge areas occur because the capacity of the exiting ramp is insufficient to handle the ramp demand flow. This results in queuing that backs up into the freeway mainline.

Another capacity value that affects ramp-freeway junction operation is an effective maximum number of freeway vehicles that can enter the ramp junction influence area without causing local congestion and local queuing. For on-ramps, the total entering flow in Lanes 1 and 2 of the freeway plus the on-ramp flow can not exceed 4,600 pc/h. For off-ramps, the total entering flow in Lanes 1 and 2 can not exceed 4,400 pc/h. Demands exceeding these values will cause local congestion and queuing. However, as long as demand does not exceed the capacity of the upstream or downstream freeway sections or the off-ramp, breakdown will normally not occur. Thus, this condition is not labeled as LOS F, but rather at an appropriate LOS based on density in the section.

If local congestion occurs because too many vehicles try to enter the merge or diverge influence area, the capacity of the merge or diverge area is unaffected. In such cases, more vehicles move to outer lanes (if available), and the lane distribution is approximated.

**LOS**
Levels of service in merge and diverge influence areas are defined in terms of density for all cases of stable operation, LOS A through E. LOS F exists when the demand exceeds the capacity of upstream or downstream freeway sections or the capacity of an off-ramp.

**Required Input Data and Estimated Values**
Exhibit 13-17, listed on page 13-24 of the *Capacity Manual*, provides default values for input parameters in the absence of local data (Number of Ramp Lanes, Length of Acceleration/Deceleration Lane, Ramp free-flow speed, Length of Analysis Period, PHF, Percentage of Heavy Vehicles, and Driver Population). The analysis should note that taking field measurements for use as inputs to an analysis is the most reliable means of generating parameter values. Only when this is not feasible should default values be considered. Exhibits 13-18 and 13-19, listed on page 13-25, provide direction in the determination of acceleration and deceleration lane lengths.

**Service Volumes**
Service volumes for ramps are difficult to describe because of the number of variables that affect operations. Exhibit 13-20, listed on page 13-26 of the *Capacity Manual*, provides approximate values (for illustrative purposes only) associated with LOS for single on- and off-ramps.

**Traffic Management Strategies**
Freeway traffic management is the implementation of strategies to improve freeway performance, especially when the number of vehicles desiring to use a portion of the freeway at a particular time exceeds its capacity. There are two approaches to improving system operation. Supply management strategies work on improving the efficiency and effectiveness of the existing freeway or adding additional freeway capacity. Demand management strategies work on controlling, reducing, eliminating, or changing the time of travel of vehicle trips on the freeway while providing a wider variety of mobility options to those who wish to travel. However, in actual application, some strategies may address both sides of the supply/demand equation. The important point is that there are two basic ways to improve system performance.

Supply management strategies are intended to increase capacity. Capacity may be increased by building new pavement or by managing existing pavement. Supply management has been the traditional form of freeway system management for many years. Increasingly, the focus is turning to demand management as a tool to address freeway problems. Demand management programs include alternatives to reduce freeway vehicle demand by increasing the number of persons in a vehicle, diverting traffic to alternate routes, influencing the time of travel, or reducing the need to travel. Demand management programs must rely on incentives or disincentives to make these shifts in behavior attractive.

Freeway traffic demand management strategies include the use of priority for high-occupancy vehicles, congestion pricing, and traveler information systems. Some alternative strategies such as ramp metering may restrict demand and possibly increase the existing capacity. In some cases, spot capacity improvements such as the addition of auxiliary lanes or minor geometric improvements may be implemented to better utilize overall freeway system capacity.

**Freeway Traffic Management Process**

Freeway traffic management is the application of strategies that are intended to reduce the traffic using the facility or increase the capacity of the facility. Person demand can be shifted in time or space, vehicle demand can be reduced by a shift in mode, or total demand can be reduced by a variety of factors. Factors affecting total demand include changes in land use and elimination of trips due to telecommuting, reduced workweek, or a decision to forgo travel. By shifts of demand in time (i.e. leaving earlier), shifts of demand in space (i.e. taking an alternative route), shifts in mode, or changes in total demand, traffic on a freeway segment can be reduced. Likewise, if freeway capacity has been reduced (i.e. as the result of a vehicle crash that has closed a lane or adverse weather conditions), improved traffic management can return the freeway to normal capacity sooner, reducing the total delay to travelers.

The basic approach used to evaluate traffic management is to compare alternative strategies. The base case would be operation of the facility without any freeway traffic management. The alternative case would be operation of the facility with the freeway traffic management strategy or strategies being evaluated. The alternative case could have different demands and capacities based on the conditions being evaluated. The evaluations could also be made for existing or future traffic demands. Combinations of strategies are also possible, but some combinations may be difficult to evaluate because of limited quantifiable data.

Freeway traffic management strategies are implemented to make the most effective and efficient use of the freeway system. Activities that reduce capacity include incidents (including vehicle crashes, disabled or stalled vehicles, spilled cargo, emergency or unscheduled maintenance, traffic diversions, or adverse weather), construction activities, scheduled maintenance activities, and major emergencies. Activities that increase demand include special events. Freeway traffic management strategies that mitigate capacity reductions include incident management; traffic control plans for construction, maintenance activities, special events, and emergencies; and minor design improvements (i.e. auxiliary lanes, emergency pullouts, and accident investigation sites). Freeway traffic management strategies to reduce demand include plans for incidents, special events, construction, and maintenance activities; entry control/ramp metering; on-freeway HOV lanes; HOV bypass lanes on ramps; traveler information systems; and road pricing.

Capacity Management Strategies - Incident management is the most significant freeway strategy generally used by operating agencies. Incidents can cause significant delays even on facilities that do not routinely experience congestion. It is generally believed that more than 50 percent of freeway congestion is the result of vehicle crashes. Strategies to mitigate the effects of vehicle crashes include early detection and quick response with the appropriate resources. During a vehicle crash, effective deployment of management resources can result in a significant reduction in the effects of the incident. Proper application of traffic control devices, including signage and channelization, is part of effective incident management. Quick removal of crashed vehicles and debris is another part. Incident management may also include the use of accident investigation sites on conventional streets near freeways for follow-up activities.

Demand Management Strategies - The number of vehicles entering the freeway system is the primary determinant of freeway system performance. Entry control is the most straightforward way to limit freeway demand. Entry control can take the form of temporary or permanent ramp closure. Ramp metering, which can limit demand on the basis of a variety of factors that can be either preprogrammed or implemented in response to a measured freeway conditions, is a more dynamic form of entry control. Freeway demand can be delayed (changed in time), diverted (changed in space to an alternative route), changed in mode (such as HOV), or eliminated (the trip avoided). The difficult issue in assessing ramp metering strategies is estimating how demand will shift as a result of metering.

HOV alternatives such as mainline HOV lanes or ramp meter by pass lanes are intended to reduce the vehicle demand on the facility without changing the total number of person trips. Assessing these types of alternatives also requires the ability to estimate the number of persons who make a change of mode to HOV. In addition, it is necessary to know the origin and destination of the HOV travelers to determine what portions of the HOV facility they can use, since many HOV facilities have some form of restricted access.

Special events result in traffic demands that are based on the particular event. These occasional activities are amenable to the same types of freeway traffic management used for more routine activities such as daily commuting. In the case of special events, more planning and promotion are required than are typically needed for more routine activities.

Road pricing is a complex and evolving freeway traffic management alternative. Initially, road pricing involved a user fee to provide a means to finance highways. More recently, toll roads have been built as alternatives to congestion. Now, congestion-pricing schemes are being implemented to manage demand on various facilities or in some cases to sell excess capacity on HOV facilities. The congestion-pricing approach to demand management is to price the facility such that demand at critical points in time and space along the freeway is kept below capacity by encouraging some users during peak traffic periods to consider alternatives. Nontraditional road pricing schemes are still in their infancy, so little information is currently available on their effects compared with more traditional toll roads, which view tolls only as a means to recover facility costs.

## ARTERIAL TRAFFIC ANALYSIS AND DESIGN

### General

Arterials are a functional classification of street transportation facilities that are intended to provide for through trips that are generally longer than trips on collector facilities and local streets. While the need to provide access to abutting land is not the primary function, the design of arterials must also balance this important need. To further highlight the often competing demands of urban arterials, it should be recognized that other modes of travel such as pedestrians and public transit are also present and must be accommodated.

To assure that arterials can safely provide acceptable levels of service for the design conditions, a number of design elements must be addressed. Since each design element is essentially determined based on separate analyses, the designer should then evaluate the entire arterial system and be prepared to refine certain elements to obtain an effective and efficient overall design.

### Capacity Analysis and Level of Service

Capacity analysis is the key method to establish the number of travel lanes that will be needed to accommodate the design conditions. The design principles of this document are intended to be consistent with the methodology as outlined in the latest edition of the Highway Capacity Manual (HCM) published by the Transportation Research Board.

Capacity analysis software is essential to allow the designer to evaluate design alternatives in a timely manner. Several capacity analysis programs are acceptable, including The Highway Capacity Software (HCS), Synchro, and CORSIM. Other analysis packages should be discussed with the GDOT project manager prior to submitting as project documentation.

When conducting capacity analysis, the analyst will use reasonable timing parameters. When the arterial has a number of signalized intersections that are spaced less 1500 feet, then system operation is likely. In such cases, the capacity analysis will use the cycle length requirements from the critical intersection for all intersections.

The traffic analysis will also consider pedestrian requirements. When significant pedestrian crossing volumes are expected, the capacity analysis will include minimum pedestrian intervals.

The arterial Level of Service (LOS) in the current HCM is based on the average travel speed for the segment, section or entire arterial under consideration. This is the basic measure of effectiveness (MOE). The designer should refer to the current HCM for detail discussion and description of LOS.

The following briefly summarizes the levels of service:

- **LOS A** - free flow, with low volumes and high speeds (about 90% of free-flow speed). Control delay at signalized intersection is minimal.

- **LOS B** - reasonably free flow, speeds (70% of free-flow speed) beginning to be restricted by traffic conditions. Control delay at signalized intersection is not significant.

- **LOS C** - stable flow zone, most drivers restricted in freedom to select their own speed (50% free-flow speed).

- **LOS D** - approaching unstable flow, drivers have little freedom to maneuver (40% free-flow speed).

- **LOS E** - unstable flow may be short stoppages. High volumes, lower speeds (33% free-flow speed).

- **LOS F** - forced or breakdown flow. Intersection congestion is likely at critical signalized locations with high delays and high volumes and extensive queues.

The analysis method in the current HCM uses the AASHTO distinction between principal and minor arterials, but uses a second classification step to determine the design category for the arterial. The design criteria depend on factors such as:

- Posted Speed limit
- Signal density
- Driveway/access- point density, and other design features

The third step in the capacity analysis process is to determine the appropriate urban arterial class on the basis of a combination of functional category and design category

Refer to chapter 10 of the HCM 2000 for a detail descriptions for functional and design categories.

**Traffic Analysis Procedures**
The traffic analysis and design generally includes the following elements:

- Determination of Typical Section
- Access Management
- Intersection Design

The following sections will address each of these areas.

**Typical Section**
To begin the conceptual design of an arterial, the number of travel lanes that are needed on the mid-block segments can be estimated based on ideal capacities. The ideal capacity of a two lane roadway is 1,700 vehicles per hour (vph) in each direction. The ideal capacity of a multi-lane roadway is 2,000 vph per lane. Capacity analysis should be used to check that acceptable levels of service can be achieved with the selected typical section and the design traffic data.

The following general guidelines are provided to assist in the process of establishing typical sections:

- Two-lane roadways are generally acceptable only if the DHV are less than 800 vph in either direction.

- Undivided multi-lane roadways are typically limited to areas where the posted speed limit is no greater than 40 mph and the DHV does not exceed 3,000 vph in either direction.

- Continuous two-way left turn lanes may be considered for roadways with typical sections having a number of closely spaced intersections with low-volume streets when the main roadway has no more than four lanes.

**Access Management**
The Department has the responsibility of providing safe and efficient transportation while providing reasonable access to adjacent property through access management. The safety benefits of access management have been clearly documented by more than four decades of research that has consistently shown that access management increases roadway safety. These safety benefits are attributable to improved access design, fewer traffic conflict locations, and increased driver response time to potential conflicts. Studies of the effects of access management on roadway operations have addressed effects of access spacing on travel time and have demonstrated that access management helps to maintain desired speeds and reduce delays.

Poorly designed vehicular access not only affects roadway safety and efficiency, but it could also reduce the economic vitality of the corridor. Research supports the negative effects on Market Area and property Values in corridors that have closely spaced and poorly designed access connections. This is exemplified by the growing number of older commercial strips across the country that are experiencing economic decline. Although a variety of factors can contribute to this problem, such as excess zoning of arterial frontage for commercial strip development, key among them is inadequate access management. Access management is applied to all DOT road projects and in all cases where property owners request access to state highways.

Access management includes a range techniques beginning with zoning and subdivision regulations, and then with highway design aspects, and ending with driveway access controls. This document will focus on the design elements of highways used to manage access.

**Limited Access Facilities**

The Georgia Department of Transportation has the authority to acquire access rights when acquiring right of way. (See TOPPS policy for when limits of access are acquired.) This is how freeways, expressways, parkways, bypasses, and, in some cases, arterial roadways are protected. Roadways that serve higher volumes of regional through traffic need more access control to preserve their traffic function. The acquisition of access rights is still the best method available to the Department for preserving the functional intent of these roadways.

On roadways of regional significance with limits of access, there may be exceptional circumstances where the Department will consider allowing a property owner to break the limited access to construct an access point (or driveway). This will only be considered where a supporting street system is constructed to avoid forcing the use of the arterial for local trips. No approval will be granted for a single parcel of property where the only means of ingress and egress is via the limited access highway.

The following conditions must be met for consideration to be given a request for break in limited access.

1) A supporting street system, composed of some combination of side streets, parallel roads, and interparcel circulation systems must be provided. Interconnectivity between individual parcels of property is expected to be achieved for a distance of one half mile either side of the requested access break. See Figure 2 for an example of a supporting street system.

2) All proposed roads included in the supporting street system plan shall have a minimum 80’ right of way, which shall be deeded to the local government by the property owners.

3) The applicant's supporting street system plan shall be submitted to the local planning and zoning authority for review and favorable recommendation to the local elected governing authority. The local government's written approval of the plan shall be furnished to the Department.

4) If a break in limits of access is granted by the Department, all proposed roads that are included in the applicant's supporting street system plan must be constructed by the applicant prior to the conveyance of access by the Department.

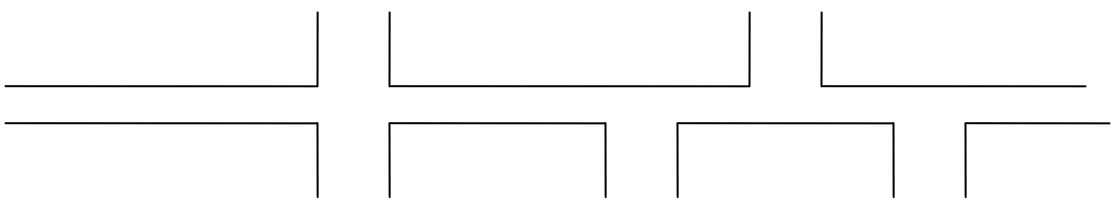
5) All roads constructed by the applicant shall meet the local government's minimum design standards for local public roads.

6) All work performed within the right of way of the State Highway shall be performed in accordance with the permit issued separately by the Department.

It is intended to provide a minimum of one mile spacing between new intersections of local roads with the limited access roadway. When a new access break is established as described herein, any future request for a break along the opposite side of the limited access roadway must align at the same point along the roadway, to create a four way intersection. The same conditions listed above will apply.

All breaks in limits of access must be approved by the Chief Engineer.

**Figure 1**



**Unacceptable Development Pattern**

**Selection of Median Opening Locations**
The location of median breaks along a divided roadway should be determined so that access to the facility is controlled in a manner that will maintain the operational integrity of the facility. During the traffic analysis and design, consideration should first be given

to locating median openings at locations that will serve the highest levels of existing and projected access requirements. In this process it will be necessary to consider the connectivity of the secondary street system.

It may become necessary to locate median openings at some streets with lower current turning volumes when such streets are connected to other streets with higher turning volumes and when this location maintains better overall median opening spacing. After the median opening locations are established, it is important to conduct a reassessment of the design traffic projections. During the development of the traffic data, the location of median openings may not have been known. If assumptions were made concerning these locations, they may have changed during the analysis stage. In any event, the occurrence of U-turn volumes must be accounted for in the analysis and traffic design.

**Urban Areas**
Access management is critical in urban areas since development is often intense. The minimum spacing between adjacent median openings should be no less than 660 feet (measured from center to center).

It is desirable to have median opening spacing greater than minimum distances, particularly when operating speeds are higher than 40 mph. Desirable median opening spacing is 1000 feet.

**Rural Areas**
Rural arterials are a functional classification of highways that are intended to connect cities and towns, as well as interstate corridors. Their primary purpose is to provide high speed travel between destinations, while their secondary purpose is to provide parcel access.

Median openings can be spaced further in rural areas due to the less intense nature of access requirements. The minimum spacing between adjacent median openings should be no less than 1320 feet (measured from center to center).

**Intersection Traffic Control and Design**
After the typical section is determined and the location of median breaks are determined (if the facility is divided), the traffic analysis should then focus on the intersections. It will be necessary to determine the type of traffic or right of way control and the need for turning lanes.

Since the type of traffic control affects the intersection design, it is first necessary to determine if traffic signal control will be needed. An example of this influence on intersection design is that designers will typically limit the number of lanes on stop controlled approaches to avoid vehicles stopping abreast of each other and blocking sight distance from the other vehicle. When multiple lanes are needed on stop controlled approaches, the design will include islands and/or increased turning radii to separate through and turning vehicles.

The need for traffic signal control is obvious at many intersections that are currently signalized. However, at other intersections traffic signal warrant analysis may be needed to establish the need for traffic signal control. At some intersections, where traffic signals are not currently needed, future traffic increases may warrant signal control. For such intersections, a warrant analysis should be conducted for both the construction year volumes as well as for the design year volumes. Warrant analyses should be conducted using the guidelines of the *Manual on Uniform Traffic Control Devices*, latest edition.

Signal warrants are typically conducted using hourly volumes throughout the normal day (not just peak hour volumes). Since the design volumes are limited to peak hour and daily volumes, it will be necessary to derive estimates of the volumes that occur during the remaining hours of the day.

An important signal warrant is Warrant 1, Eight-Hour Vehicular Volume. Therefore, the traffic analysis should estimate the eighth-highest volume of the day. The eighth-highest volume can be compared to the requirement of Warrant 1 to estimate if this important warrant will be satisfied with the projected volumes.

The eighth-highest volume can be estimated as representing 6.25 percent of the daily volume. If the eighth-highest volume exceeds the minimum volumes for Warrant 1 using the construction year volumes, then signal control should be considered for installation during the construction project.

If Warrant 1 is only met using the design year conditions, then signalization may not be included with construction, but the design may reflect the need for future signal control. For example, turn lanes may be constructed and striped out until signals are installed.

**Traffic Signal Permitting Process**

There are three distinct roadway systems in Georgia. These are the county roads, the city streets and the state routes. The Georgia Department of Transportation has authority over the state route system. Georgia Law empowers the Department with the authority to set standards for all public roads in Georgia. Because traffic signals are used at many intersections where state routes cross city streets or county roads, and because traffic signals are most often installed to meet a Local community need, a permit process to allow local governments to erect, operate and maintain traffic signals on state routes has been established. This formal process has been ongoing since the early 1950's. The authority to create uniform regulations and to place or cause to place traffic control devices on state routes is described in section 32-6-50 of the Official Code of Georgia.

Requests for traffic signals come to the Department from a wide variety of sources. State, city and county elected officials responding to their constituents will often request the Department to evaluate an intersection for a traffic signal. Requests may also be received directly into the Department from concerned citizens. All inquiries are considered a request for assistance and should be investigated to determine if a signal or some less restrictive improvement should be implemented.

Requests for signals are evaluated using the warranting values found in the *Manual on Uniform Traffic Control Devices (MUTCD)*. These warrants will be the minimum criteria for further study. Intersection evaluations indicating a signal will not meet any warrant may be denied by a letter of response from the District Traffic Operations Office. Intersections that will meet one or more of the MUTCD warrants will be studied further for justification.

All traffic signal devices erected on the State Route System must have a permit application from the local government to the Department of Transportation and a Traffic Signal Authorization issued by the Department prior to their installation. These permit documents serve as the agreement between the Department and the local government for the signal. Even in communities where signals are maintained by GDOT, a formal document of agreement is needed. The permit application is used to allow local government to formally request the use of a traffic signal. This application indicates the approval of the local government for the use of the signal. It also commits local government to provide electrical power and telephone service for the intersection.

The Traffic Signal Authorization is the permit indicating the formal approval of the Department for the use of the traffic signal at the intersection. Design drawings are a part of the authorization form showing the intersection details, the signal head arrangement, the signal phasing and the detector placement. Regardless of the method of funding and installation, a signal authorization is needed. The original of this authorization is kept in the Office of Traffic Safety and Design with copies sent to the District Office and from the District Office to the local government for their records.

Once a request is received, the District Traffic Engineer using the methods described in the Manual on Uniform Traffic Control Devices should initiate an engineering study. The study should first consider less restrictive measures such as improved signing, marking, sight distance, operational improvements, etc. If less restrictive measures can not be effectively implemented, a traffic signal should be considered if the conditions at the intersection satisfy one or more of the warrants in the MUTCD.

The completed Traffic Engineering study shall have a signature page that includes the conclusions of the study and the recommendations of the District Traffic Engineer. Approval blocks should be included for the, District Engineer (optional), State Traffic Safety and Design Engineer, and Division Director of Operations.

Once completed, the Traffic Engineering study will be sent to the Office of the State Traffic Safety and Design Engineer for review and approval. If the signal is found to be justified by the Traffic Engineering study, a Traffic Signal Authorization will be recommended for approval by the State Traffic Safety and Design Engineer. A permit approval form will be prepared and the entire package sent for signatures by the Division Director of Operations and final approval by the Chief Engineer of the Department. A copy of the approved permit and the design will be returned to the District Traffic Operations Office for transmittal to the local government for their records.

Signal permit revisions will be required for all changes made to the signal operation or design. Any addition of vehicle or pedestrian phases, modifications in phase sequences, modifications to signal head arrangements or other similar operational changes will require a permit revision. A request from the District outlining the changes needed and justifying the changes will be submitted in writing. A permit revision authorization will be issued with the appropriate design drawings similar to those required for a new signal.

It is appropriate for new signals to be included in roadway projects if a need has been identified. Even in these circumstances the permit application, the signal authorization and Traffic Engineering study is necessary for new signals to be installed in roadway projects. Existing signals requiring upgrading to meet the needs of the reconstructed roadway may be included in the construction project. A permit revision should be requested as outlined above.

The Traffic Engineering study prepared for the intersection proposed for signalization must adequately document two things. First, is there a need for this degree of control, and secondly, can it be demonstrated that the signal operation will be beneficial to the State Highway System. When these conditions are met, the State Traffic Safety and Design Engineer will recommend approval of the permit to the Division Director and Chief Engineer. The District Traffic Engineer should be the primary initiator for new signals on construction projects. This is to be accomplished as early in the project life as is possible, preferably at the design concept stage, and certainly should be accomplished by the preliminary PS&E inspection since the use of signals will usually affect the roadway design.

Due to the detrimental effect of traffic signals on the flow of arterial traffic a traffic signal may not always be to the benefit of the State Highway System. Therefore, it is likely that signals which are justified by design year traffic volumes will be denied or deferred if initial traffic volumes do not warrant their inclusion in the project. The traffic engineering study is even more important in this case as it will document conditions at a point in time and will assist in the decision making process to determine the right time to approve signalization.

**Pedestrian Accommodations At Signalized Intersections**

Crosswalks and pedestrian signal heads, including ADA considerations, **shall** be installed on all approaches of new traffic signal installations or revised traffic signal permits unless an approach prohibits pedestrian traffic. Exceptions may be granted if the pedestrian pathway is **unsafe** for pedestrians or the traffic engineering study documents the absence of pedestrian activity. The District Traffic Engineer, Project Manager, Consultant, local government, or Permit Applicant must document the conditions and justification for eliminating pedestrian accommodations for each approach being requested. The documentation will be included in the permit file if accepted.

In the case of one or more pathways being determined unsafe to cross at a signalized intersection, appropriate MUTCD signing prohibiting pedestrian traffic **must** be erected. Use of MUTCD signing may also be appropriate when it is necessary to restrict access to one pedestrian pathway.

Prior to the traffic engineering study recommending that pedestrian accommodations be eliminated based on the absence of pedestrian activity, the entity preparing the report should consider the existing development near the intersection, expected development within the next five year period, and input from local government. If any of these indicators project potential pedestrian activity the report should recommend pedestrian accommodations be included.

**Turn Lanes at Stop Controlled Intersections**

At stop controlled intersections, the number of lanes on the stop controlled approaches will normally be minimized. However, it may be desirable to provide a separate, channelized lane for the right turning traffic.

It is desirable to provide separate lanes for vehicles that are preparing to turn off of the arterial roadway, when such turning volumes are significant. Good guidelines for determining when such volumes are significant can be found in NCHRP Report 457.

**Turn Lanes at Signal Controlled Intersections**

The need for turn lanes at signal controlled intersections can also be evaluated using the guidelines found in NCHRP 457. However, capacity analysis will also be the basis for establishing the need for turn lanes and determining when multiple turn lanes are needed.

Although capacity analysis is used to identify potential needs for installing multiple turn lane bays, judgment must be used. For example, when providing dual left turn lanes, turn phases are generally operated in an "exclusive-only" manner. If dual turn lanes provide only marginal improvement over single turn lanes operated with protected/permitted phasing, it should be recognized that single turn lanes actually operate better during the off-peak times.

After the need for turn lanes are established, it is then necessary to define the length of tapers and full width storage. Capacity analysis will result in estimated lengths of queues. In general, full width storage will be provided that is sufficient to store the estimated queue lengths of turning vehicles.

The traffic analysts will use judgment to evaluate the interaction of queues resulting from the different movements at the approach to an intersection. For example, left turn bays sometimes "starved" due to the presence of long queues of vehicles in the through lanes. When the estimated queue lengths of turning vehicles is less than but comparable to the queues for through vehicle, then the turn lane for the turn movement should be extended based on the queues in the through lanes. However, engineering judgment should be employed when making such decisions. As an example, if the through queues are estimated to be 800 feet and the volume of left turn traffic is only 10 vph, then the left turn lane should not be extended to 800 feet for such a small volume.

**Drop Lanes**

When multiple turn lane bays are found to be needed on the arterial, it is sometimes necessary to widen the intersecting roadway to accommodate an additional receiving lane. This widening should be extended to the next downstream intersection. However, as a minimum, the widening should be a sufficient distance from the intersection in order to make the multiple turn lanes operate effectively and provide an adequate merging area.

The traffic analysis will consider the distance that should exist on the receiving lanes prior to a lane drop. The length of this distance will affect the lane utilization and appropriate lane utilization factors will be included in the capacity analysis. The traffic analysis will provide a recommended length of widening based on the capacity analysis and the expected lane utilization.

**Highly Congested Urban Areas**
In many highly developed urban areas, it may be infeasible to meet the desirable level of service criteria. The following are examples:

- Capacity analysis indicates a high number of lanes ( >6) needed to accommodate the design volumes
- Capacity analysis indicates grade separation would be required at major intersections
- The required improvements would require the acquisition and demolition of significant existing structures

When the traffic analysis indicates that it will be infeasible to meet the LOS standard, these conditions will be documented in the traffic analysis. The traffic analyst will then prepare an incremental analysis.

An incremental analysis will typically address each five year period within the twenty (20) year design period. The traffic analyst will then request incremental traffic projections or assume linear increase throughout the design period.

The incremental analysis will identify feasible improvements and report the expected operating conditions with these improvements at each incremental time period.

## 3. Trip Generation and Assignment for Traffic Impact Studies

Trip Generation is the process used to estimate the amount of traffic associated with a specific land use or development. A manual estimate of trip generation from the development will be required for all analyses. Trip Assignment involves placing trips generated by the new development onto specific roadways and adding them to specific turning movements at each area intersection.

### Trip Generation Data

For the purposes of this document, a trip is a single vehicular movement with either the origin or destination within the study site and one origin or destination external to the land use. Trip generation is estimated through the use of “trip rates” or equations that are dependent on some measure of intensity of development of a particular land use. Gross leasable area (GLA) is the most common measure, but there are other measures such as number of employees, number of parking spaces, or number of pump islands (as at a gasoline station) that are included as well. ITE’s *Trip Generation* is the most comprehensive collection of trip generation data available. The rates and equations provided in ITE’s *Trip Generation* are based on nationwide data. Some rates or equations, especially newer land use categories, are supported with a limited number of studies. However, this manual is accepted as the industry standard. Therefore, the rates and equations from ITE’s *Trip Generation* will be applied, except in rare cases. Deviation from rates, equations, or applications described in *Trip Generation* must be discussed and approved by appropriate GDOT staff prior to use in any study.

### Land Uses Identified in the ITE *Trip Generation* Manual

The current edition of *Trip Generation* contains equations and rates for the most common land use types that are currently in use. Each successive edition improves the quality and quantity of data by adding to the existing data sets for existing land uses and by adding new land uses as the commercial and residential real estate markets evolve over time. For this reason, the latest edition of *Trip Generation* will be used as a basis for trip generation estimates.

Each land use type within *Trip Generation* is identified with a unique numeric code. Similar land use types have code numbers that are close together. Some of the more common ITE land uses are listed in the table below:

**Table 3.2**
**Common ITE Land Use Codes**

| ITE Land Use Code | Land Use Name |
|---|---|
| 210 | Single Family Detached Housing |

| | |
|---|---|
| 220 | Apartment |
| 310 | Hotel |
| 520 | Elementary School |
| 565 | Day Care Center |
| 710 | General Office Building |
| 770 | Business Park |
| 814 | Specialty Retail Center |
| 820 | Shopping Center |
| 832 | High Turnover (Sit-Down) Restaurant |
| 834 | Fast Food Restaurant with Drive-Through Window |
| 853 | Convenience Market with Gasoline Pumps |
| 912 | Drive-In Bank |

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**Primary Trips, Passer-By Trips, and Diverted Trips**

There are three basic types of trips generated by a development: primary, passer-by, and diverted. Usually, the total trip generation volumes are computed as described previously and the generated trips are divided into these three components.

Primary trips are made for the specific purpose of visiting the development. Primary trips are new trips on the roadway network. Trips generated by office and institutional land uses are usually all or nearly all primary. Retail land uses are partially made up of primary trips; the larger the retail development, the bigger percentage of total trips that are primary.

Passer-by trips are trips made as intermediate stops on the way from an origin to a primary destination. Passer-by trips are attracted from traffic already on adjacent roadways to the site. The percentage of trips that are classified as passer-by will vary by the type of land use, the time of day and the volume of traffic on the adjacent streets, as well as the size of the development. Passer-by trips are usually associated with various types of retail or service developments. Gas stations, convenience stores and fast food restaurants are usually located to predominately serve passer-by traffic. Other retail establishments also have varying percentages of their trips that are passer-by.

Diverted trips are similar to passer-by trips except that they are attracted to a development from a nearby street or roadway that is not directly adjacent to the development. Like passer-by trips, diverted trips are not new to the roadway system overall. However, unlike passer-by trips, diverted trips use new routes to get to and from the development compared to their original route and thus have more impacts to the nearby roadway network than passer-by trips. Diverted trips are usually significant for larger retail developments such as a major shopping center that attracts traffic from many nearby roadways. Diverted trips may also be a factor when a new development is located along a roadway that carries relatively little traffic, but is a type of land use that attracts a large percentage of passer-by trips. In this case, many of the trips that would otherwise be passer-by, are instead diverted from other nearby roadways that carry a larger amount of traffic.

**Traffic Assignment**

Traffic assignment is the process of placing site-generated trips onto the roadway network within the study area. Traffic assignment is done either manually or with modeling software. Traffic assignment for small to medium sized developments is more commonly handled with manual methods, while modeling software is often used for larger developments that have a regional impact. The site-generated trips (usually vehicles per peak hour) are added to the “background” traffic, which usually consists of the existing peak hour turning movement volumes at each intersection plus additional turning movements which account for compounded annual growth and sometimes traffic attributed to other nearby developments.

The combined site-generated and background traffic form the total assigned traffic (intersection turning movements) that are used to measure level of service and determine necessary roadway improvements to accommodate the new development.

**Study Network**

The study network consists of the roadways in the vicinity of the development that traffic must use to enter and leave the study area. The study network includes the site access intersections onto adjacent off-site roadways and the sections of these off-site roadways that are located within the study area. The study network is further identified as a series of key intersections, which are the critical points and potential bottlenecks in urban and suburban roadway networks. Roadways within the study area can be further subdivided as described below.

**Site Entrances and Access Points**

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**Existing Roadway Network**

At a minimum, these are the streets and roadways that immediately adjoin the development. For larger developments, the network of streets and roadways to be included in the study can extend a considerable distance away from the immediate vicinity of the site. The key intersections along the roadways within the study area are the source of most delay and are what should be evaluated. The number and location of intersections that are to be included in the traffic impact study will be determined in consultation with GDOT prior to preparation of the study.

**Roadway Improvements Proposed as Part of Development**

These include public streets and roadways that are proposed to be relocated, widened, or newly constructed as part of the proposed site development. The traffic assignment will take into account changes in traffic patterns caused by any proposed changes or additions to the roadway network.

**Committed Offsite Roadway Improvements**

These include proposed roadway and intersection improvement projects that will be constructed by others within the time period of the study. The "others" are usually GDOT or local governments, but they could also include projects that will be constructed by other developers within the study area. Changes/improvements to roadways and intersections caused by these projects will be included in the traffic impact study. If it is uncertain whether or not a particular project will be completed, then alternative scenarios must be evaluated.

**Traffic Assignment for Phased Developments**

Many large developments are constructed in several phases over a period of years. The traffic impact study can reflect this reality by analyzing one or more intermediate phases, plus the full build-out scenario. Each new phase will assign additional traffic onto the assumed roadway network for that year. Background traffic for each new phase must include traffic assigned from previously opened phases of development.

**Traffic Assignment of Three Major Trip Types**

The three major trips types are primary trips, passer-by trips, and diverted trips. Each trip type will be separated when assigning site-generated traffic throughout the study network. This makes it easier for the reviewer to follow the assignment process and identify errors.

Primary trips are made for the specific purpose of visiting the development. Primary trips are new trips on the roadway network. Traffic will be assigned for primary trips throughout the study network according to the trip distribution percentages to and from the study area.

Passer-by trips are trips made as intermediate stops on the way from an origin to a primary destination. Passer-by trips are attracted from traffic already on adjacent roadways to the site. Passer-by trips are, by definition, already on the adjacent roadways. These trips are separately assigned to the study network only at site-access intersections and on internal circulation roadways within the site development itself. Turning movement volumes will be added at these intersections for entering and exiting traffic, while the through movements will be reduced by an equal amount.

Diverted trips are similar to passer-by trips except they are attracted to a development from a nearby street or roadway that is not directly adjacent to the site development. Like passer-by trips, diverted trips are not new to the roadway system overall, but their route will include off-site roadways and intersections on the study network. Like passer-by trips, these volumes will be deducted from the through traffic on the original roadway that they were traveling on, and the diverted volumes will be added to the revised route to and from the new developments.

## 3. Trip Generation and Assignment for Traffic Impact Studies

Trip Generation is the process used to estimate the amount of traffic associated with a specific land use or development. A manual estimate of trip generation from the development will be required for all analyses. Trip Assignment involves placing trips generated by the new development onto specific roadways and adding them to specific turning movements at each area intersection.

### Trip Generation Data

For the purposes of this document, a trip is a single vehicular movement with either the origin or destination within the study site and one origin or destination external to the land use. Trip generation is estimated through the use of “trip rates” or equations that are dependent on some measure of intensity of development of a particular land use. Gross leasable area (GLA) is the most common measure, but there are other measures such as number of employees, number of parking spaces, or number of pump islands (as at a gasoline station) that are included as well. ITE’s *Trip Generation* is the most comprehensive collection of trip generation data available. The rates and equations provided in ITE’s *Trip Generation* are based on nationwide data. Some rates or equations, especially newer land use categories, are supported with a limited number of studies. However, this manual is accepted as the industry standard. Therefore, the rates and equations from ITE’s *Trip Generation* will be applied, except in rare cases. Deviation from rates, equations, or applications described in *Trip Generation* must be discussed and approved by appropriate GDOT staff prior to use in any study.

### Land Uses Identified in the ITE *Trip Generation* Manual

The current edition of *Trip Generation* contains equations and rates for the most common land use types that are currently in use. Each successive edition improves the quality and quantity of data by adding to the existing data sets for existing land uses and by adding new land uses as the commercial and residential real estate markets evolve over time. For this reason, the latest edition of *Trip Generation* will be used as a basis for trip generation estimates.

Each land use type within *Trip Generation* is identified with a unique numeric code. Similar land use types have code numbers that are close together. Some of the more common ITE land uses are listed in the table below:

**Table 3.2**
**Common ITE Land Use Codes**

| ITE Land Use Code | Land Use Name |
|---|---|
| 210 | Single Family Detached Housing |

| | |
|---|---|
| 220 | Apartment |
| 310 | Hotel |
| 520 | Elementary School |
| 565 | Day Care Center |
| 710 | General Office Building |
| 770 | Business Park |
| 814 | Specialty Retail Center |
| 820 | Shopping Center |
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