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GDOT Traffic Forecasting and Analysis

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Chapter 13 Contents

List of Figures

List of Tables

13. TRAFFIC FORECASTING AND ANALYSIS CONCEPTS

13.1. Traffic Forecasting Process

This chapter explains the traffic forecasting process including how traffic analysis relates to roadway design.

During the course of the design process, the design engineer shall request traffic data for roadway capacity analysis to ensure that the functional requirements of the roadway are met. In addition, the traffic volumes are used to determine the pavement structure of the road. For Georgia DOT projects designed in-house, traffic volumes are supplied by the GDOT Office of Environment and Location (OEL). For consultant designed projects, the traffic volumes may be provided by GDOT, if available, or by the consultant as part of the scope of services in the consultant's design contract.

13.1.1. Data Collection

Site Visit

The traffic engineer should conduct a site visit to gather current traffic information that is not readily available from other sources. The site visit should be conducted when preparing the scope of the project or when development of the project concept begins. The *Manual on Uniform Traffic Control Devices* (*MUTCD*)[1] 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 generally includes the following information:

- 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 for major vehicle 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

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[1] FHWA. *Manual on Uniform Traffic Control Device (MUTC*D).
The 2003 version of this publication is available online at: http://mutcd.fhwa.dot.gov/kno-2003r1.htm

- adjacent land use, density, and occupancy
- roadway functional classification
- route governmental jurisdiction
- travel times

Other data that may be needed includes sight distances, vertical and lateral clearances, any safety hazards, utility information (such as utility poles, storm drain, and valve cover locations), and road right-of-way locations.

The (Georgia) State Roadway Functional Classification Map[2] and Roadway Characteristics (RC), RCInfo file[3] contain speed limits, lane widths, shoulder widths, and information on many other roadway characteristics. These resources should be reviewed prior to a site visit. The designer should contact GDOT immediately if a site visit yields information that differs from that of existing GDOT data sources.

Existing Traffic Data

The traffic engineer should collect existing traffic data for the analysis. Before collecting existing traffic data, the traffic engineer should send a memorandum and map that summarizes the project and site visit to the GDOT Office of Traffic Safety and Design to confirm the locations and types of counts to be collected and to 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 (7:00 a.m. – 9:00 a.m.) and evening (4:00 p.m. – 6:00 p.m.) peak travel 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 should be verified by careful review of 24-hour volume counts.

The traffic engineer should contact local government or jurisdictions to determine if there are hazardous or high-accident locations 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 if available Existing traffic data needed for the analysis frequently include the following information:

- peak period turning movement counts (including cars, single-unit trucks and buses, and multi-unit or combination trucks)
- one-day directional volumes, 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 that are available (contact the GDOT Office of Transportation Data)

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[2] GDOT. Functional Classification Map. 2006
Available through the GDOT Office of Transportation Data website at: http://www.dot.state.ga.us/dot/plan-prog/transportation_data/function_class_maps/index.shtml

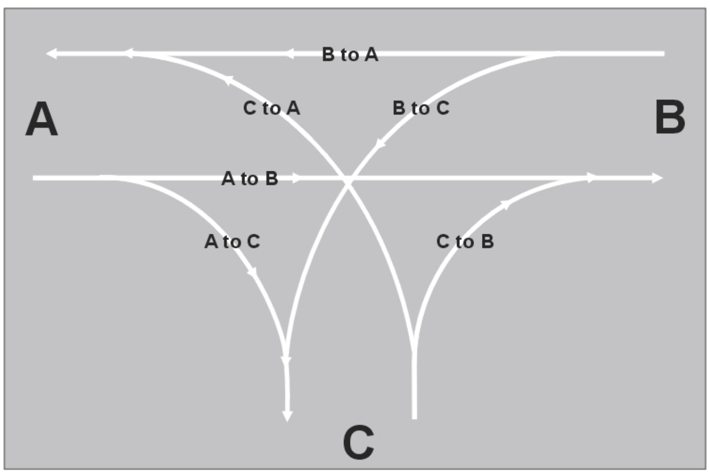
[3] RCInfo files are generated through the GDOT Network. Access to the network can be obtained through the GDOT Division of Information Technology.

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

Bicycle and pedestrian counts should not be requested as part of the traffic study unless the project is located where there are high concentrations of pedestrians and bicyclists, such as at a university campus, event center or a central business district. Daily machine traffic counts should be adjusted by seasonal and axle factors to estimate existing AADT volumes. The GDOT 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 discussed and mutually agreed upon between the traffic engineer and the person responsible for review and approval.

Establish Existing Traffic Patterns

Directional roadway volumes and turning movements for a.m. peak hour and p.m. peak hour at the study intersections need to be established. The traffic engineer can accomplish this by collecting new counts where data is needed. Since counting all traffic data locations may not always be practical, GDOT has established the a procedure for estimating the existing turning movement counts from directional counts at three-leg intersections, as illustrated in **Figure 13.1**.



Source: TRB. Highway Capacity Manual. 2003

A, B, and C are the approach volumes on each leg.

$$X = (A + B + C) / 2$$

Where: $X - C = A$ to B and B to A

$X - B =$ A to C and C to A

$X - A =$ B to C and C to B

Figure 13.1. Directional Counts at Three-Leg Intersections

For four-leg intersections, the traffic engineer should first make assumptions about the traffic on the minor leg, then follow the three-leg procedure for the other three legs. Furthermore, GDOT assumes that at the intersection of two major routes, 55% to 70% of the trips on each approach are going straight.

Daily Volumes and Their Uses

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

- **Average Annual Daily Traffic (AADT)** is 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. The GDOT Office of Transportation Data maintains Georgia's State

Traffic and Report Statistics (STARS) web site (http://www.dot.state.ga.us/dot/plan-prog/transportation_data/TrafficCD/index.shtml), which provides AADT counts collected from permanent and portable traffic collection devices throughout the state during the years 1999-2005 for every segment of Georgia's State Highway System.

- **Average Daily Traffic (ADT)** is defined as 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 (AAWT)** is defined as 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 24-hour 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 defined as 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 GDOT projects, the design engineer should request traffic volumes for the base year and design year. The base or opening 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 (bid award) date. For example, if a project is scheduled for a let date sometime in 2006 and it is estimated that the project will take two years to construct, then the volumes for the base year 2008 should be requested.

The design year is the anticipated future life of the project. For all GDOT projects, the future traffic volumes will be 20 years from the base year. For example, the design engineer would request 2028 design year traffic volumes for the base year 2008. For some projects the design year may be shorter than 20 years (i.e., two years or five years) such as for 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 roadway. The design engineer is advised to confirm the base and design years early in the concept development stage of the project.

The base year ADT for an existing roadway should be calculated from real traffic counts and 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 found in the GDOT RC database 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.

Design year traffic volumes can be developed by use of either an Urban Area Transportation Model or historical traffic growth trends. The historical growth calculations are also useful for checking the reasonableness of projections from the urban traffic model.

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 **Table 13.1.**

Table 13.1. Urbanized Areas with Associated Counties

Urbanized Area	County	State
Albany	Dougherty Lee	Georgia Georgia
Athens	Clarke Oconee Madison	Georgia Georgia Georgia
Atlanta	Barrow Bartow Cherokee Clayton Cobb Coweta DeKalb Douglas Fayette Forsyth Fulton Gwinnett Henry Newton Paulding Rockdale Spalding Walton	Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia Georgia
Augusta	Columbia Richmond Aiken	Georgia Georgia South Carolina
Brunswick	Edgefield Glynn	South Carolina Georgia
Chattanooga	Catoosa Walker Hamilton	Georgia Georgia Tennessee
Columbus	Muscogee Lee Russell	Georgia Alabama Alabama
Dalton	Whitfield	Georgia
Gainesville	Hall	Georgia
Hinesville	Liberty Long	Georgia Georgia
Macon	Bibb Jones	Georgia Georgia
Rome	Floyd	Georgia
Savannah	Chatham Lanier	Georgia Georgia
Valdosta	Lowndes Berrien	Georgia Georgia
Warner Robins	Houston Peach	Georgia Georgia

The forecasting model is a transportation tool for determining long range traffic volumes on the functionally classified road network (collector roads and 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 MPO's are 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 social and economic data for the base year model and future year model. The social and economic data includes population, employment, school enrollment, growth trends, and other demographic information. The MPO's are also responsible for disseminating information from the models to the public. The eight recommended models developed by GDOT are described below. Networks 2 through 7 build upon and address deficiencies of lower numbered networks.

- **Base Year (Network 1) -** 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 this network is calibrated, it should replicate the travel patterns that existed in the base year. The base year may not be the same as the project's base year.

- **Do-Nothing System Projects (Network 2) -** This network is intended to show what would happen in the plan year 2030 model if no new projects were built.

Network 2 basically reflects “now” roadways with resulting capacity deficiencies from future traffic conditions. Network 2 consists of the base year network plus any projects under construction, opened to traffic since the base year, or projects for which funds have been authorized but construction has not yet begun. Network 2 examples include: projects under construction in the base year; projects opened to traffic since the base year; projects authorized for construction at the time of preparing this network.

- **Existing + Committed (E+C) System Projects (Network 3) -** This network is intended to show what would happen in the future if only existing and presently committed projects were built. Network 3 basically reflects “committed” short range improvements. Committed projects are defined as those projects in the current State Transportation Implementation Plan/Transportation Improvement Program (STIP/TIP) having either right-of-way (ROW) or Construction dollars shown. Projects with only preliminary engineering (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. A Network 3 example is projects with ROW or construction in the FY05-07 STIP/TIP.

- **Remainder of TIP, PE, and TIER 2 Projects and Construction Work Program (CWP[4]) Projects (Network 4) -** Network 4 basically reflects previously programmed mid-range improvements. Network 4 includes programmed projects from TIER 2[5], the second phase of the TIP document (last three years). Programmed projects in TIER 2 should coincide with the last three years of the 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 Project Locator number) or does not have locally dedicated funds allocated, it should not be included in this network. A Network 4 example is projects with any phase programmed for FY08-10 in the FY05-2010 TIP/TIER2/CWP.

- **Remainder of Programmed LRTP Projects (Network 5) -** Network 5 basically reflects programmed long range projects from the current LRTP. This network includes current Long Range Transportation Plan (LRTP) projects that are programmed by GDOT as long range. Current LRTP projects not yet programmed are not to be included in Network 5. 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. A Network 5 example is projects with PE, ROW or construction programmed by GDOT for LR = beyond the CWP’s last year of 2010.

  NOTE: If time for completing the traffic forecasting is limited, Networks 5 and 6 may be combined.

- **Remainder of LRTP Projects (Network 6) -** This network includes projects in the current LRTP that have not been captured in any of the previous networks. A Network 6 example is projects listed in the current LRTP that have not advanced from their status as LRTP “recommendations”.

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[4] The CWP is a GDOT document listing state and federally funded projects approved by the Transportation Board for preliminary engineering, ROW acquisition, and/or construction scheduled in the current and next five fiscal years (total six years), e.g., FY05-10 CWP.

[5] 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.

- **New Projects – Recommended Plan for Public Comment (Network 7) -** This network 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 plan is required to receive public review and comment.

- **Recommended Financially Constrained Plan[6] – Post Public Comment (Network 8) -** 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 traffic engineer should use the E+C model 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 **Figure 13.2.** Socio-economic data is also available within the model, including a population, number of households, employment, and school enrollment for each Traffic Analysis Zone (TAZ).

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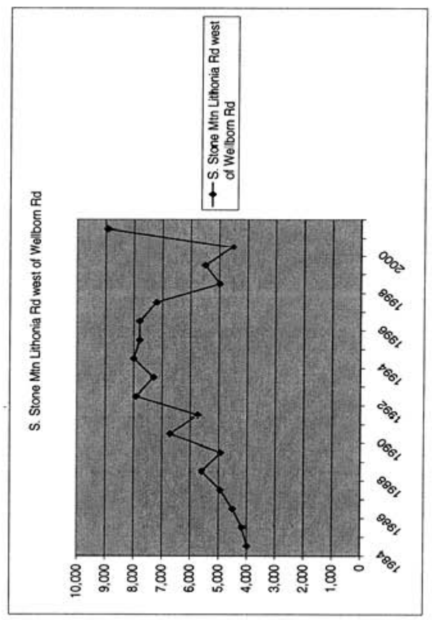
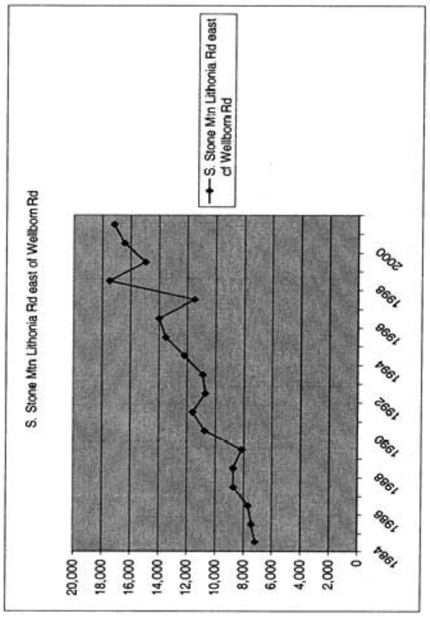
[6] Financial Constraint: The LRTP must demonstrate that anticipated revenues meet or exceed anticipated costs for the LRTP's recommendations. This requires that the cost of all projects be summed together and that this total cost be compared to anticipated monies available. It must be shown that there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

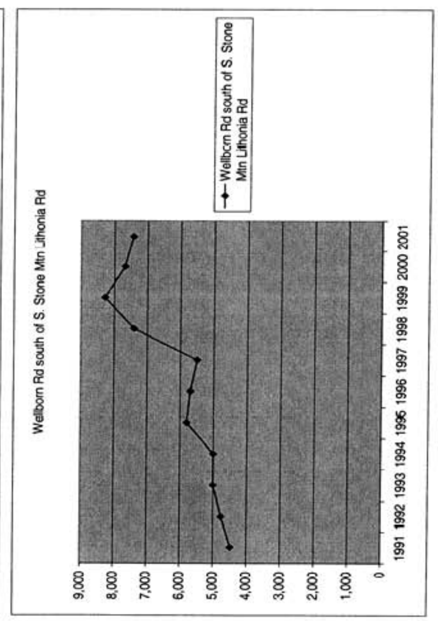
Wellborn Road at S. Stone Mountain Lithonia Road

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	7,330	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	10,930	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 AFC 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%

Figure 13.2. Example for Determining Growth Rates Using Urban Area Transportation Models

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 the ITE *Trip Generation Handbook*.

Using all available information, the traffic 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.

Traffic Projections for New Roadway Corridors

Traffic projections for a new roadway or bypass route can be determined based upon 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.

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 traffic 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 nonurbanized area is to conduct an origin-destination study. Refer to the current Institute of Transportation Engineers (ITE) *Manual on Uniform Transportation Engineering Studies* for procedures for conducting an origin-destination study. The questions to be asked during the origin-destination study interview should be included in the Traffic Data Memorandum and submitted to the Office of Environment and Location (OEL) for 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.

Preliminary Traffic Projections

Using traffic growth rates developed in accordance with the preceding methodology, calculate future traffic for several sections along the project and compare this with traffic projections from the urban area transportation model where available. The two projections should be within 10 percent of each other. It is important to consider whether or not the future roadway can handle the expected traffic volumes. If not, adjustments may need to be made because of limited road capacity.

Adjustments to Design Year ADT Volumes

For some roadway design projects, the traffic engineer may be required to adjust 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 design engineer should document any assumptions made and the procedures used in the adjustment of the traffic volumes.

Detailed Traffic Forecast

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 traffic engineer must decide if the same pattern will hold in the future as exists now. The traffic engineer should also examine each intersection for reasonableness of the growth rate, and make adjustments 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 traffic 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. If there is a difference, the traffic engineer should provide a reasonable explanation.

Design Hourly Volumes

While daily volumes are very useful in planning, hourly volumes are also needed for the design process. Volumes may vary significantly during the course of a 24-hour day 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 will vary 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 a 15-minute period. The design engineer should use the 15-minute period for all road capacity analysis.

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:

$$DHV = AADT \times K$$

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 the traffic engineer should assume that 60% of the traffic is going in one direction. For a more detailed analysis of intersection and road capacity, procedures should be used as described in the latest version of the TRB *Highway Capacity Manual.*

Using short-term counts along the project, peak hour and directional factors can be calculated and compared to any automatic traffic recorder (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 a.m. and p.m. design hour volumes. Since the DHV is the 30th highest hour, the p.m. movement is usually the return movement from the a.m. movement. In some cases, separate a.m. and p.m. 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 previously in this chapter, the traffic engineer must seriously consider the new traffic counts taken specifically for this purpose. The 24-hour percentage should be given as Single Unit (SU) trucks, Classes 4 through 7 and Multi-Unit or Combination (MU) trucks, Classes 8 through 15. 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 drawings and lettering.

13.1.2. Functional Roadway Classification

Refer to **Chapter 3. Design Controls, Section 3.1. Functional Classifications for Freeways, Arterials, Collectors and Local Roads**, for a detailed discussion relating to functional roadway classification.

13.2. Freeway Traffic Analysis and Design

Traffic Analysis and Design

The purpose of this section is to provide some traffic analysis guidance for design engineers on some of the factors and design elements to consider in operational and road capacity analysis. This information is intended as a supplement to GDOT adopted standards and procedures outlined in the Transportation Research Board (TRB) *Highway Capacity Manual*.

The TRB *Highway Capacity Manual* provides comprehensive guidelines related to freeway traffic analysis and design. Some considerations that must be made during the traffic analysis and design process include, but are not limited to:

- A freeway experiencing extreme traffic congestion differs greatly from a non-freeway facility experiencing extreme congestion since the travel conditions creating the congestion are internal to the facility, not external to the facility.
- Freeway facilities may have interactions with other freeway facilities in the area as well as other classes of nearby roads, and the performance of the freeway may be affected when travel demand exceeds road capacity on these nearby road systems. For example, if the street system can not accommodate the demand exiting the freeway, the over-saturation of the street system may result in queues backing onto the freeway, which adversely affects freeway travel.
- 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 require special analysis. 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.

13.2.1. ITS Technology

Intelligent transportation 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” (TRB, 2000 p. 2-6).

13.2.2. Capacity Analysis and Level of Service

TRB defines capacity 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; adding that “Capacity analysis is a set of procedures for estimating the traffic-carrying ability of facilities over a range of defined operational conditions (2000, p. 2-1)”.

Service flow rates are similar because they define the flow rates that be accommodated while still maintaining a given level of service.

There are numerous factors that affect capacity and LOS:

- base conditions
- prevailing roadway conditions (including geometric and other elements)
- prevailing traffic conditions, which also account for vehicle type (e.g. heavy vehicles) and distribution of vehicles

For design LOS for GDOT roadways, refer to **Chapter 6, Tables 6.1 through 6.4** of this Manual.

Traffic Flow Characteristics

Traffic flow on a freeway can be highly varied depending on the conditions constraining 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. Freeway traffic flow can be categorized into three flow types: (1) under-saturated, (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.

Under-saturated 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 immediately 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 passenger car per mile per lane (pc/mi/ln).

Refer to the current TRB *Highway Capacity Manual* Chapter 13, Freeway Concepts, for a detailed discussion and exhibits specific to Speed-Flow and Density-Flow Relationships and factors that affect free-flow speed.

Passenger-Car Equivalents

The concept of vehicle equivalents is based on freeway conditions in which the presence of heavy vehicles, including trucks, buses, and recreational vehicles, creates less than base operating conditions. These diminished operating 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 travel 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.

The following brief descriptions summarize the different 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.

Operating characteristics are represented by a specified LOS ranging from LOS A describing free-flow operations to LOS F describing breakdowns in vehicular flow. Breakdowns occur when the ratio of existing demand to actual capacity or of forecast demand to estimated capacity exceeds 1.00. 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.

Freeway Weaving

Weaving is defined as the crossing of two or more traffic streams traveling in the same 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. Weaving segments may exist on any type of facility: freeways, multilane highways, two-lane highways, interchange areas, urban streets, or collector-distributor roadways.

Refer to the current version of the TRB *Highway Capacity Manual*,Chapter 24, for guidance related to freeway weaving.

13.2.3. 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.

Refer to the current version of the TRB *Highway Capacity Manual* for guidance related to ramps and ramp junctions.

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.

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. 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.

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 TRB *Highway 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). Exhibits 13-18 and 13-19, listed on page 13-25, provide direction in the determination of acceleration and deceleration lane lengths. 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 TRB *Highway Capacity Manual*, provides approximate values (for illustrative purposes only) associated with LOS for single on- and off-ramps.

13.2.4. 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.

13.3. Arterial Traffic Analysis and Design

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.

13.3.1. Capacity Analysis and Level of Service (LOS)

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 TRB *Highway Capacity Manual*.(HCM).

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 1,500-ft., 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 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 design engineer should refer to the current HCM for detail discussion and description of LOS.

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 the *HCM* Chapter 10, for a detailed description of functional and design categories.

13.3.2. Traffic Analysis Procedures

The traffic analysis and design generally includes the following elements: the typical section, access management, and intersection design. The following sections will address each of these areas.

Determination of 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

Access management involves many techniques, ranging from zoning and subdivision regulations to highway design aspects and driveway access controls. For additional information related to Access Management, see **Section 3.5.** of this Manual.

For additional information relating to driveway and access controls, including permit procedures, access criteria, and geometric design criteria, refer to the most current version of the GDOT *Regulations for Driveway and Encroachment Control*[7].

13.3.3. 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 most current edition of the *MUTCD*.

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.

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[7] GDOT. (2006). *Regulations for Driveway and Encroachment Control.* Available online at:http://www.dot.state.ga.us/dot/preconstruction/r-o-a-d-s/DesignPolicies/index.shtml

The eighth-highest volume can be estimated as representing 6.25 % 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 GDOT 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 GDOT from a wide variety of sources. State, city and county elected officials responding to their constituents will often request GDOT to evaluate an intersection for a traffic signal. Requests may also be received directly into GDOT 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 *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 GDOT and a Traffic Signal Authorization issued by GDOT prior to their installation. These permit documents serve as the agreement between GDOT 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 the 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 GDOT 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 GDOT. 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 are 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, there is a need for this degree of control, and second, the analysis demonstrates 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 field inspection (PFPR) 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. Guidelines for determining when such volumes are significant can be found in National Cooperative Highway Research Program (NCHRP) *Evaluating Intersection Improvements: An Engineering Study Guide*[8], commonly referred to as 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 is established, it is then necessary to define the length of tapers and full 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 engineer 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 are sometimes “starved” due to the presence of long vehicle queues in the through lanes that block access to the left turn bay. 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-ft. and the volume of left turn traffic is only 10 vph, then the left turn lane should not be extended to 800-ft. for such a small volume.

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[8] NCHRP. *CHRP Report 457,* "Evaluating Intersection Improvements: An Engineering Study Guide." 2001

Drop Lanes

When multiple turn lane bays are found to be needed on the arterial, it may be 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 downstream from the intersection in order to make the multiple turn lanes operate effectively and provide an adequate merging area. The additional lane may need to be expanded to the next downstream intersection.

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 (more than 6 lanes) 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 engineer will then prepare an incremental analysis. An incremental analysis will typically address each five-year period within the twenty-year design period.

The traffic engineer must then request incremental traffic projections or assume linear increase throughout the design period. The incremental analysis will enable the traffic engineer to identify feasible improvements and report the expected operating conditions with these improvements at each incremental time period.

13.4. 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.

13.4.1. Trip Generation Data

For the purposes of this Design Policy Manual, 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.

Table 13.2. 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
Source: ITE. (2003).*Trip Generation Handbook,* 7th Ed.	

The current ITE *Trip Generation Handbook* contains the most comprehensive collection of trip generation data available. The rates and equations provided in this handbook 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 the most current edition of the ITE *Trip Generation Handbook* shall be applied. Deviation from rates, equations, or applications described in most current edition of the *Trip Generation Handbook* must be discussed and approved by appropriate GDOT staff prior to use in any study.

Trip generation data includes:

- **Land Uses -** Each land use type within *Trip Generation* is identified with a unique numeric land use 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 3.2.**
- **Primary Trips, Passer-By Trips, and Diverted Trips** The total trip generation volumes are typically 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.

  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.

  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.

- **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 Access Points -** These include key entrance roadways and driveways that serve the development and their intersections with the adjacent street and roadway network. These entrances/access points are usually newly constructed as part of the development.
- **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.

Land Uses Not Identified in the ITE Trip Generation Manual

The vast majority of real estate developments can be identified or approximated with land uses identified within *Trip Generation*. However, the commercial and residential real estate markets are constantly evolving, and new land use types, especially commercial and retail, are created all the time. Since *Trip Generation* is updated on a periodic basic, new land use categories are already in widespread use before being incorporated into *Trip Generation.*

New types of "big-box" retail establishments are constantly being created that do not neatly fit in any single land use category included in *Trip Generation*. There are even new land use types that combine aspects of offices and warehouses and even retail. Large entertainment land uses such as casinos or theme parks may generate large numbers of trips, but are so specific as to not be covered by the more general land use categories included in *Trip Generation.*

For land uses that are not found within Trip *Generation*, trip generation volumes can be estimated using other available information. However trip generation is estimated, each assumption must be clearly stated with backup information provided to the satisfaction of the reviewer. Permissible methods are listed below.

- Utilizing available marketing studies prepared by the client/developer
- Patronage estimates for rail/bus stations by transit agency
- Available parking spaces and assumptions on parking turnover per peak hour
- Using an existing ITE land use that most closely resembles the new land use, and modifying or adjusting generated trips, with all assumptions/calculations clearly stated

13.4.2. 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 is used to measure level of service and determine necessary roadway improvements to accommodate the new development.

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 trip 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 and they 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. 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. For more information on passer-by and diverted trips, please refer to the ITE Trip Generation Handbook, a companion to the ITE Trip Generation. The Handbook also includes helpful insight in preparing traffic impact studies, including studies for multi-use developments.

Chapter 13 Index