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CAPACITY AND LEVEL OF SERVICE FOR HIGHWAYS SEGMENTS IN NIGERIA

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Abstract - *Highway and traffic engineers are frequently engaged in evaluating the performance of different facilities of the highway system. These facilities include freeway segments, intersections, ramps, and other highway elements. The level of service is a measure of how well the facility is operating. It is both a qualitative measure of motorists' perceptions of the operational conditions existing on the facility, as well as a measure of the density of vehicular travel. A primary objective in highway and traffic engineering is to provide highway facilities that operate at levels of service acceptable to the users of those facilities. Regular evaluation of the level of service at the facilities will help the engineer to determine whether acceptable conditions exist and to identify those locations where improvements may be necessary. Levels of different operating conditions are assigned to varying levels of service, ranging from level of service A to level of service F for each facility. The different levels of operating conditions are also related to the volume of traffic that can be accommodated by the specific component. This amount of traffic is also related to the capacity of the facility. The write up we will focus on two-lane highways and freeways which are obtainable and used in different parts of Nigeria.*

Key Words: **Capacity, Segment, Freeways, Speed, Traffic.**

1. INTRODUCTION

Highway construction involves all aspects of the building process beginning with clearing of the native soil, preparation of the surface, placement of the pavement material, and preparation of the final roadway for use by traffic. Today, modern construction equipment is used for clearing the site, grading the surface, compaction of the pavement base courses, transporting materials, and placing the final highway pavement. Advances in construction equipment have made the rapid building of large highway sections possible. Advanced specialized equipment for handling concrete and bridge work are all innovations in the construction industry. Large, automatically controlled mix plants have been constructed and new techniques for improving durability some fundamental to note in relation to traffic flow is the relationship between flow and density. It is proven that traffic flows reasonably well when the flow rate is less than at capacity, but excessive delay and congestion can occur when the flow rate is at or near capacity. This phenomenon is a primary consideration in the planning and design of highway facilities, because a main objective is to design or plan facilities that will operate at flow rates below their optimum rates. This objective can be achieved when a good estimate of the optimum flow of a facility can be made.

Capacity analysis therefore involves the quantitative evaluation of the capability of a road section to carry traffic, and it uses a set of procedures to determine the maximum flow of traffic that a given section of highway will carry under prevailing roadway traffic and control conditions.

The maximum speed that can be achieved on a uniform section of highway is the mean-free speed, which depends solely on the physical characteristics of the highway. This speed can be achieved only when traffic demand volume approaches zero and there is little interaction between vehicles on the highway segment. Under these conditions, motorists are able to drive at a desired speed up to the mean-free speed and perceive a high level in the quality of traffic flow on the highway. As the demand volume increases, vehicle interaction and density increases, resulting in the gradual lowering of mean speeds and the quality of traffic flow.

As the interaction among vehicles increases, motorists are increasingly influenced by the actions of others. Individual drivers find it more difficult to achieve their desired speeds and perceive deterioration in the quality of flow as the density increases. The level of operating performance changes with traffic density. The measure of quality of flow is the "**level of service**" (LOS), a qualitative measure, ranging from **A to F** that characterizes both operational conditions within a traffic stream and highway users' perception. This chapter presents procedures for determining the level of service and other performance measures of uniform road segments on two-lane, multilane highways and freeways, which are obtainable in Nigeria.

1.1 Highway Capacity

The capacity of a facility defined as the maximum hourly flow rate at which the maximum number of vehicles, passengers, or the like, per unit time, which can be accommodated under prevailing roadway, traffic and control conditions with a reasonable expectation of occurrence. For most cases, to analyze the capacity we used the peak 15 minutes of the peak hour.

Capacity is independent of the demand. It speaks about the physical amount of vehicles and passengers that a road can afford. It does not depend on the total number of vehicles demanding service. Generally the highway capacity depends on certain conditions as listed below;

1.2 Road way characteristics:

This are associated with the geometric characteristics and design elements of the facility, which include type of facility, number of lanes, lane width, shoulder width, horizontal and vertical alignments, lateral clearance, design speed, and availability of queuing space at intersections. For example, a curved road has lesser capacity compared to a straight road.

1.3 Traffic conditions:

Capacity is expressed in terms of units of some specific thing (car, people, etc.), so it also does depend on the traffic conditions. The traffic conditions are associated with the characteristics of the traffic stream on the segment of the highway. These include the distribution of the different types of vehicles in the traffic stream or traffic composition such as the mix of cars, trucks, buses etc. and the directional and lane distribution of the traffic volume on the highway segment. Furthermore it includes peaking characteristics, proportions of turning movements at intersections etc.

1.3 Control conditions:

This primarily applies to surface facilities and includes the types of traffic control devices in operation, signal phasing, allocation of green time, cycle length, and the relationship with adjacent control measures.

2. Level of Service

The level-of-service concept was introduced in the 1965 HCM as a convenient way to describe the general quality of operations on a facility with defined traffic, roadway, and control conditions. Using a letter scale from A to F, a terminology for operational quality was created that has become an important tool in communicating complex issues to decision-makers and the general public. The HCM 2000 defines level of service as follows: "Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience."

A term level-of-service closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service or LOS tries to give a qualitative measure. Service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service.

Level of service (LOS) qualitatively measures both the operating conditions within a traffic system and how these conditions are perceived by drivers and passengers. It is related with the physical characteristics of the highway and the different operating characteristics that can occur when the highway carries different traffic volumes. Speed-flow-density relationships are the principal factor affecting the level of service of a highway segment under ideal conditions.

For a given road or facility, capacity could be constant. But actual flow will be different for different days and different times in a day itself. The intention of LOS is to relate the traffic service quality to a given flow rate of traffic. It is a term that designates a range of operating conditions on a particular type of facility. Highway capacity manual (HCM) provides some procedure to determine level of service. It divides the quality of traffic into six levels ranging from level A to level F. Level A represents the best quality of traffic where the driver has the freedom to drive with free flow speed and level F represents the worst quality of traffic.

Service A: This represents free-flow conditions where traffic flow is virtually zero. Only the geometric design features of the highway may limit the speed of the car. Comfort and convenience levels for road users are very high as vehicles have almost complete freedom to maneuver.

Service B: Represents reasonable free-flow conditions. Comfort and convenience levels for road users are still relatively high as vehicles have only slightly reduced freedom to maneuver. Minor accidents are accommodated with ease although local deterioration in traffic flow conditions would be more discernible than in service A.

Service C: Delivers stable flow conditions. Flows are at a level where small increases will cause a considerable reduction in the performance or 'service' of the highway. There are marked restrictions in the ability to maneuver and care is required when changing lane. Some minor incidents can still be absorbed while major incidents will result in the formation of queues. The speed chosen by the driver is substantially affected by that of the other vehicles. Driver comfort and convenience have decreased perceptibly at this level.

Service D: The highway is operating at high-density levels but stable flow still prevails. Small increases in flow levels will result in significant operational difficulties on the highway. There are severe restrictions on a driver's ability to maneuver, with poor levels of comfort and convenience.

Service E: Represents the level at which the capacity of the highway has been reached. Traffic flow conditions are best described as unstable with any traffic incident causing extensive queuing and even breakdown. Levels of Basic Elements of comfort and convenience are very poor and all speeds are low if relatively uniform.

Service F: Describes a state of breakdown or forced flow with flows exceeding capacity. The operating conditions are highly unstable with constant queuing and traffic moving on a 'stop-go' basis.

2.1 Factors affecting level of service

One can derive from a road under different operating characteristics and traffic volumes. The factors affecting level of service (LOS) can be listed as follows:

1. Speed and travel time
2. Traffic interruptions/restrictions
3. Freedom to travel with desired speed
4. Driver comfort and convenience
5. Operating cost.

Factors such as lane width, lateral obstruction, traffic composition, grade and driver population also affect the maximum flow on a given highway segment. The effect of each of these factors on flow is discussed.

3. TWO-LANE HIGHWAYS

The procedures developed for two-lane highway segments provide the basis to evaluate level of service and capacity. For highway segments, there are two levels of analysis:

(1) Operational and

(2) Planning applications.

Planning applications correspond directly to the procedures used for operational analysis but use estimates and default values in calculations. Two classes of two-lane highways are analyzed. They are defined according to their function in the following manner.

Class I. Two-lane highways that function as primary arterials, daily commuter routes, and links to other arterial highways. Motorists' expectations are that travel will be at relatively high speeds.

Class II. Two-lane highways where the expectation of motorists is that travel speeds will be lower than for Class I roads. These highways may serve as access to Class I two-lane highways; they may serve as scenic byways or may be used by motorists for sightseeing. They also may be located in rugged terrain. Average trip lengths on Class II highways are shorter than on Class I highways.

At an operational level of analysis, level of service is determined based on existing or future traffic conditions and specific roadway characteristics. The **Highway Capacity Manual** (HCM) procedure is designed to analyze two-lane highway segments for

(1) Two-way traffic,

(2) For a specific direction, or

(3) For a directional segment with a passing lane.

If the terrain is mountainous or if the segment length to be analyzed is greater than 0.6m and the grade is at least 3 percent, two-lane highways are analyzed as specific upgrades or downgrades. Figure below shows a two-lane, two way highway in a rural environment.

Typical Two-Lane, Two-Way Highway in a Rural Environment

At a planning level of analysis, operational procedures are followed but with estimates, HCM default values, and/or local default values. **Annual average traffic** (AAT) values are used to estimate **directional design hour volume** (DDHV).

There are two measures used to describe the service quality of a two-lane highway. These are

(1) Percent time following another vehicle and

(2) Average travel speed.

1. ***Percent time-spent-following another vehicle*** (PTSF) is the average percentage of time that vehicles are traveling behind slower vehicles. When the time between consecutive vehicles (called the "headway") is less than three seconds, the trailing vehicle is considered to be following the lead vehicle. PTSF is a measure of the quality of service provided by the highway.

2. ***Average travel speed*** (ATS) is the space mean speed of vehicles in the traffic stream. Space mean speed is the segment length divided by average time for all vehicles to traverse the segment in both directions during a designated interval. ATS is a measure of the degree in which the highway serves its function of providing efficient mobility.

Base conditions exist for the following characteristics:

- Level terrain
- Lane widths 12 ft or greater
- Clear shoulders 6 ft wide or greater
- Passing permitted with absence of no-passing zones
- No impediments to through traffic due to traffic control or turning vehicles
- Passenger cars only in the traffic stream
- Equal volume in both directions (for analysis of two-way flow)

Capacity of a two-lane highway is 1700 passenger cars per hour (pc/h) for each direction of travel and is nearly independent of the directional distribution of traffic. For extended segments, the capacity of a two-lane highway will not exceed a combined total of 3200 pc/h. Short sections of two-lane highway, such as a tunnel or bridge, may reach a capacity of 3200 to 3400 pc/h.

3.1 Level of Service (LOS)

Level of Service (LOS) expresses the performance of a highway at traffic volumes less than capacity. LOS for Class I

highways is based on two measures: PTSF and ATS. LOS for Class II highways is based on a single measure: PTSF.

Level-of-service criteria are applied to travel during the peak 15 minutes of travel and on highway segments of significant length. Level-of-service designations are from A (highest) to F (lowest). Definitions of LOS and appropriate ranges for PTSF and ATS values are as follows:

Level of Service A: This is the highest quality of service that can be achieved. Motorists are able to travel at their desired speed. The need for passing other vehicles is well below the capacity for passing and few (if any) platoons of three or more cars.

A two-lane road with overtaking lanes provides a level of service between that of two lanes and four lanes. The role of overtaking lanes is to provide an economical and practical method of breaking up traffic queues and improving traffic flow. Before traffic volumes demand an upgrade to dual carriage-ways, overtaking lanes maximize use of the road.

Overtaking occurs when drivers want to overtake another, slower moving vehicle. Overtaking lanes provide an opportunity to overtake safely. When planning overtaking opportunities, designers employ a number of different technical methods to determine where and when overtaking opportunities should exist.

Factors such as site distances, the nature of the traffic on the road, location of gradients, the geometry of the road, intersections and accesses, the length of road and spacing are all considered when overtaking lanes are designed.

The provision of overtaking lanes is one of the ways the department provides a positive, safer road user experience.

3.2 FREEWAYS

A freeway is a divided highway with full access control and two or more lanes in each direction for the exclusive use of moving traffic. Signalized or stop-controlled, at grade intersections or direct access to adjacent land use is not permitted in order to ensure the uninterrupted flow of vehicles. Opposing traffic is separated by a raised barrier, an at-grade median, or a raised traffic island. A freeway is composed of three elements: basic freeway sections, weaving areas, and ramp junctions.

Basic freeway sections are segments of the freeway that are outside of the influence area of ramps or weaving areas. Merging or diverging occurs where on- or off-ramps join the basic freeway section. Weaving occurs when vehicles cross each other's path while traveling on freeway lanes.

The exact point at which a basic freeway section begins or ends that is, where the influence of weaving areas and ramp junctions has dissipated depends on local conditions, particularly the level of service operating at the time. If traffic flow is light, the influence may be negligible, whereas under congested conditions, queues may be extensive.

Base free-flow conditions include the following freeway characteristics:

- Lanes are 12 ft wide
- Lateral clearance between the edge of a right lane and an obstacle is 6 ft or greater
- There are no trucks, buses, or RVs in the traffic stream
- Urban freeways are five lanes in each direction
- Interchanges are spaced at least 2 mi apart
- Grades do not exceed 2%
- Drivers are familiar with the freeway

The capacity of a freeway is the maximum sustained 15-minute rate of flow, expressed in passenger cars per hour per lane (pc/h/ln), which can be accommodated by a uniform freeway segment under prevailing traffic and roadway conditions in one direction. The roadway conditions are the geometric characteristics of the freeway segment under study, which include number and width of lanes, right-shoulder lateral clearance, interchange spacing, and grade. The traffic conditions are flow characteristics, including the percentage composition of vehicle types and the extent to which drivers are familiar with the freeway segment. Conditions of free-flow speed occur when flow rates are low to moderate (less than 1300 pc/h/ln at 70 mi/h). As flow rates increase beyond 1300, the mean speed of passenger cars in the traffic stream decreases.

3.3 Level of Service for Freeway Segments

Level of service (LOS) qualitatively measures both the operating conditions within a traffic system and how these conditions are perceived by drivers and passengers. It is related to the physical characteristics of the highway and the different operating characteristics that can occur when the highway carries different traffic volumes. Although speed-flow-density relationships are the principal factors affecting the level of service of a highway segment under ideal conditions, factors such as lane width, lateral obstruction, traffic composition, grade, speed, and driver population also affect the maximum flow on a given highway segment. The effects of each of these factors on flow are briefly discussed.

Lane Width: Traffic flow tends to be restricted when lane widths are narrower than 12 ft. This is because vehicles have to travel closer together in the lateral direction, and motorists tend to compensate for this by reducing their travel speed.

Lateral Clearance: When roadside or median objects are located too close to the edge of the pavement, motorists in lanes adjacent to the objects tend to shy away from them, resulting in reduced lateral distances between vehicles, a result similar to lane reduction. Drivers compensate by reducing speed. The effect of lateral clearance is more pronounced for the right shoulder than for the median.

Vehicle Equivalents: The presence of vehicles other than passenger cars such as trucks, buses, and recreational vehicles in a traffic stream reduces the maximum flow on the highway because of their size, operating characteristics, and interaction with other vehicles. Because freeway capacity is measured in terms of pc/h/ln, the number of heavy vehicles in the traffic stream must be converted into an equivalent

number of passenger cars. Figure Below illustrates the effect of trucks and other heavy vehicles on freeway traffic.

Effect of Trucks and Other Heavy Vehicles on Traffic Flow

Grade: The effect of a grade depends on both the length and slope of the grade. Traffic operations are significantly affected when grades of 3 percent or greater are longer than one-quarter meter and when grades are less than 3 percent and longer than one-half meter. The effect of heavy vehicles on such grades is much greater than that of passenger vehicles.

Speed: Space mean speed, is used in level of service analysis.

Driver Population: Under ideal conditions, the driver population consists primarily of commuters. However, it is known that other driver populations do not exhibit the same characteristics. For example, recreational traffic capacities can be as much as 20 percent lower than for commuter traffic.

4. CONCLUSIONS

Nigeria, possessing the world most populous black nation, has difficulties in managing and maintaining the free flow of human movement, goods and services all over the nation. Most of the roads are accessible while some are not accessible due to lack of maintenance or no road at all. To manage the congestion, the capacities of the highways are congested especially in most part of the country with large human habitation like Lagos and Kano, where movement can be frustrating because of traffic. According to Federal Road Safety Corps (FRSC), Nigeria, it classified road as:

- Private drive pathways
- Two-lane highways
- Dual carriageways
- Expressway (Nigeria Highway code)

The major highways that links Lagos state to the Federal Capital Territory, Abuja and the northern part of the nation are two-lane highways or dual carriageways, whose capacity compared to the activities on the highway is small, congested and an overload. The lack of maintenance of the highway has caused a lot of accident and makes movement frustrating and risky. The other highway that connects Lagos to the South-south and south-east are two-lanes or freeways but the major problem has been the lack of maintenance of the highways which makes it worse for movements.

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