

MS-07

TTS

0007

720.30(7)

DESIGN FOR LEVEL OF SERVICE

By
Phillip L. Wilson
Supervising Design Engineer
Texas Highway Department



Presented
at the
Fortieth Annual Texas Highway Short Course
College Station, Texas

Highway Design and Traffic Conference
Session D-4

December 15, 1966

DESIGN FOR LEVEL OF SERVICE

As some of you may already know, the first topic to be discussed this morning is "Level of Service" and how to design for it. I must confess that when I received my advance copy of the Short Course Program I was quite pleased to see this subject was included; however, my pleasure was short lived when I noted who had been selected to discuss this topic! I feel somewhat like a cracker-barrel philosopher holding forth in a supermarket. Nevertheless, I hope to live up to the best traditions of a technical speaker who, as you know, is a person who talks about something he doesn't understand and makes you believe that you are ignorant!

The phrase, "Level of Service", as defined in the Highway Capacity Manual, is a term which refers to an infinite number of different combinations of operating conditions that may occur on a given lane or roadway when it is accommodating various traffic volumes. In the layman's language, I would define it as the ability of the highway to serve traffic at various levels of efficiency.

Although the term "Level of Service" is somewhat new to the highway engineer, the concept it embodies has been with us for many years. In the design of our highway system, we have always evaluated certain characteristics to determine the safe design speed of each highway section. We have adjusted our design features for urban, sub-urban, rural, flat, rolling and mountainous conditions which have, in turn, affected the over-all operation of the particular facility. All of this has been done as a general approach to our problem of providing the traveling public with as good a facility as possible within the practical limits of available finance and based on the design criteria prevalent at the time.

As our society becomes more refined, we in the highway industry must periodically revise our tools in order that the facilities we build today will keep pace with the demands of the public. It is no news to anyone that more and more cars are being built. In fact, one motorist has admitted running over the same man twice.

Apparently the time has come when there aren't enough pedestrians to go around.

Be that as it may, we must provide the highways to handle the ever increasing number of cars. In order to do this, we must recognize the improved technology available to us. The level of service concept is one of our latest tools.

In 1950, the Bureau of Public Roads, through the U. S. Government Printing Office, published the "Highway Capacity Manual" (Slide No. 1) which has been widely used as a basic reference in designing highway facilities. This edition was a good practical guide to the designer; however, in the mid 1950's we entered the most rapid stage of highway development the world has ever known. As early as 1954, thought was being given to the revision of this Manual. As the wealth of new information concerning highway capacity and operation grew, it became obvious that new guidelines were necessary, particularly as regards freeway design and operation. Thus the new edition (Slide No. 2) of the Highway Capacity Manual was born.

I would not presume to discuss all of the information contained in this publication nor will time permit me to explain, in detail, the calculations necessary to determine the level of service for a highway. I do hope, however, to introduce you to this feature of design.

The Highway Capacity Manual establishes six levels of service which are designated "A" through "F", from best to worst, which are intended to cover the entire range of traffic

operation that may occur. The major factor in identifying a particular level of service is the travel speed. A second factor is also used which is known as the "v/c ratio". This is a ratio of demand volume to capacity or the ratio of service volume to capacity, depending on the particular problem situation. Travel speed may be either an operating speed or an average over-all travel speed, depending on the type of highway. From the rather blank looks on your face, I can see that I'm beginning to get to you!

Rather than confuse you further by trying to describe all the ramifications of the various levels of service, I believe the following slides would more eloquently describe what a certain level of service looks like on the ground.

28 Level of Service "A" (~~Slide No. 3~~) describes a condition of free flow, with low service volumes in the range of 1,400 passenger cars per hour total for two lanes in one direction under ideal conditions. Free flow may occur even on freeways with relatively poor alignment provided the volume is sufficiently low. There is little or no restriction in maneuverability due to the presence of other vehicles. Drivers can maintain their desired speeds with little or no delay. Where more than two lanes in each direction are provided (Slide No. 4), the influence of slower vehicles on the traffic stream is diminished since such vehicles are not so likely to obstruct the traffic stream. For Level "A", with three or more lanes in one direction, each additional lane above two will result in a one-way service volume increase of approximately 1,000 passenger cars per hour. I might mention that service volume is the maximum number of vehicles that can pass over a given section of lane or roadway during a specified time period. This volume must be adjusted downward to match the characteristics of the road such as curved alignment, grades, lateral clearances, per cent trucks, etc.

Level of Service "B" (~~Slide No. 5~~) is in the higher speed range of stable flow. For

25 freeways and expressways, it is defined by the requirement that operating speeds be at or greater than 55 miles per hour and that the service volume on two lanes in one direction not exceed 50% of capacity. This means a maximum service volume of 2,000 passenger cars per hour total for two lanes in one direction under ideal conditions.

Drivers still have reasonable freedom to select their speed and lane of operation.

Each additional lane above two (Slide No. 6) in one direction will result in an average one-way service volume increase of about 1,500 passenger cars per hour.

26 Level of Service "C" (~~Slide No. 7~~) ~~results when further inquiries in demand volume are accompanied by a resultant decrease in operating speeds.~~ Operation at this level ^{however} is

although still in the range of stable flow; is critical enough so that, unlike Levels "A" and "B", rates of flow within a period shorter than an hour must be considered. Most of the drivers are restricted in their freedom to select their own speed, change lanes or pass. For freeways, a 5-minute short period has been adopted as the standard. In general, the

requirements for Level of Service "C" are an operating speed of at least 50 miles per hour

and a service flow rate on two lanes in one direction not exceeding 75% of the capacity rate. For two lanes in one direction under ideal conditions, the peak 5-minute flow rate cannot exceed 3,000 passenger cars per hour total for one direction. Each additional lane (Slide No. 8) will provide a one-way peak flow rate increase of approximately 1,800 passenger cars per hour.

27 Level of Service "D" (~~Slide No. 9~~) is in the lower speed range of stable flow with volumes

higher than those found in Level "C", traffic operation approaches instability and becomes very susceptible to changing operating conditions. Operating speeds generally are in the

neighborhood of 40 miles per hour and service flow rates do not exceed 0.90 of capacity rates. Under ideal conditions on a four-lane freeway the peak 5-minute flow rate cannot exceed 3,600 passenger cars per hour, total for one direction. Potential conflict points begin to have a much greater effect on operations. These conflict points, or potential bottlenecks, begin to meter the flow throughout the entire roadway section. Drivers have little freedom to maneuver. Comfort and convenience are low, but conditions can be tolerated for short periods of time. New designs normally would not be based on this level. Additional lanes above two no longer improve average efficiency per lane. Traffic densities in all lanes are fairly uniform, regardless of the number of lanes, with the somewhat higher speeds in the inside lanes providing higher service volumes. Accordingly, each additional lane above two (Slide No. 10) in one direction will result in an average one-way service volume increase of about 1,800 passenger cars per lane per hour. For Level "D" the volume should not exceed 90% of capacity.

28
Level of Service "E" (Slide No. 11) is the area of unstable flow, involving over-all operating speeds of about 30-35 miles per hour and involving volumes approaching 100% of capacity, or about 2,000 passenger cars per lane per hour under ideal conditions. Service volume is regulated by the capacity at critical locations, with traffic being metered through each restriction (Slide No. 12). Demand does not greatly exceed capacity; therefore, long back-ups do not normally develop upstream. Traffic flow within the hour will show relatively little fluctuation. Although Level "E" operation is unstable, it is found on many freeways, under peak hour conditions, particularly where demand increases gradually. Level of Service "E" should not be used for design.

Level of Service "F" (~~Slide No. 13~~) describes a forced flow condition in which the

freeway acts as storage for vehicles backed up from a downstream bottleneck. Operating speeds range downward from those at capacity (at or near 30 miles per hour) to those during stop and go operations. Speeds can drop to zero in the extreme case of a complete jam (Slide No. 14). Volumes vary widely, depending principally on downstream capacity. This service is unacceptable. Very often, where a sudden demand surge occurs, operation may bypass Level "E" completely, passing directly from Level "D" into the forced flow associated with Level "F".

The characteristics which I have just described are for freeways. When determining levels of service for highways without access control, the characteristics are much the same although lower operating speeds generally prevail. These lower speeds thus result in slightly different volume-capacity ratios for certain levels.

In order to demonstrate how this level of service concept is interwoven into all phases of design, I might call your attention to the portion of the Highway Capacity Manual dealing with weaving. As you know, many of the traffic problems on our freeways result from insufficient weaving areas, generally on our older facilities. The turbulence caused by a short weaving area is generally reflected by a back-up on the freeway approaches. The new Capacity Manual has recognized this problem area and this feature is discussed in considerable detail in Chapter 7. To illustrate this particular feature, this slide (Slide No. 15) is an exact reproduction of Table 7.3 in the Manual.

You will note that the levels of service are indicated on the left hand side of the table and the types of highway are indicated across. You will further note that various qualities of flow on the weaving sections are designated by Roman Numerals "I" through "V". I should explain what these various designations are.

Case "I" describes the situation where operating conditions and speeds approach those normally found under free flow conditions without weaving. The effect of weaving on stream flow is slight, if any. Thus, with the appropriate number of lanes, speeds of 50 miles per hour or greater are feasible.

Under Case "II", operating conditions and speeds are only slightly more restricted than those generally found under free flow conditions without weaving. The effect of weaving on stream flow is slight to nominal. Some speed variations will occur, but with an appropriate number of lanes, operation at about 45-50 miles per hour can be achieved.

Case "III" describes the condition where weaving vehicles can maintain operating speeds of 40-45 miles per hour, although speed will vary considerably between individual vehicles. Non-weaving vehicles can maintain high speeds if sufficient capacity has been provided in the weaving lanes. Drivers are affected by other vehicles in the stream to a greater extent than normal under free flow conditions; however, the level of operation is not unreasonable for the condition where operating speeds on the approaches are 50 miles per hour. You will note that this is the worst case which may be used for design on the freeway proper.

In Case "IV", speeds will vary considerably between individual vehicles; however, weaving vehicles can maintain operating speeds of about 30-35 miles per hour. Non-weaving vehicles can maintain higher speeds if sufficient capacity has been provided in the through lanes. Occasional slowdowns and some maneuverability restrictions can be expected; nevertheless, operation is acceptable where approach speeds do not exceed 40 miles per hour. Case "IV" is the worst case which may be used for design on non-controlled access highways and on other than main lanes at interchanges.

Case "V" represents capacity for a given length of weaving section. The speed may be quite variable, normally below 30 miles per hour and frequently averaging 20 miles per hour or less. Slow operation and turbulence, including stopping of weaving vehicles, alternating of weaving movements between lanes and nosing into the parallel lane by drivers in one weaving lane are common occurrences. Minor accidents may be expected at a fairly high frequency. Back-up and loss of service are usually evident on at least one and possibly both approach legs during high-flow periods. This type of design is not acceptable for design purposes. Unfortunately, many of our weaving sections fall under Case IV.

Just for purposes of discussion, let us make a simple evaluation of the weaving requirements at one interchange which, I am sure, is familiar to most of you. This slide (Slide No. 16) shows the IH 20 - IH 35W - Toll Road Interchange in Fort Worth with IH 20 West running toward the top of your screen. The weaving area in question lies just below the railroad underpasses just west of the mixmaster. This slide (Slide No. 17) shows a view of this area looking east toward the directional interchange with the weaving area to the left. This particular location involves the merging of two direct connections and the main lane through roadway from the Dallas-Fort Worth Tollroad westbound.

The weaving area is created by two successive exit ramps, one serving Jones Street and the next serving Commerce Street. The Jones Street exit is the one visible to the left of the picture. A total weaving length of about 500 feet is provided from the mergence of the three lanes to the gore of the Jones Street exit. A secondary weaving length of 870 feet from the mergence of the roadways to the Commerce Street exit is provided. Admittedly, we cannot

truly consider either weaving area as a singular problem; however, if, for purposes of discussion, we look at only the Commerce Street weaving area, it will illustrate the point I am trying to make.

The existing traffic desiring to weave is approximately 2,000 vehicles per hour. Based on Figure 7.3 of the Manual, which we previously looked at, a Level of Service "C" with weaving restricted to Case III is the minimum which should be used for design. If we now refer to the weaving chart in the Manual (Slide No. 18), Table 7.3, we find that for Case III and 2,000 vehicles per hour, a minimum weaving length of 1,500 feet is indicated. The existing weaving area is, however, only 870 feet in length. If we again refer to the chart, we find that a weaving area serving 2,000 vehicles per hour of approximately 900 feet in length is a Case IV which results in a level of Service of either "D" or "E". Actually, at certain periods, Case V weaving results with what would appear to be Level of Service "F" on the approaches to the area.

I might point out that if we were designing the highway today, we should strive for Case II which would, in turn, require a weaving length of approximately 3,000 feet for today's traffic.

My purpose in showing this specific problem is not to embarrass anyone or criticize any individual design. This particular weaving area is only one of many such locations in the State which are, even now, entirely inadequate. It is expected that the application of the Level of Service concept to this feature of design will insure that our future facilities will operate at the greatest efficiency possible. It is not too far-fetched to also consider the possibility that in the not too distant future we will be rebuilding certain older facilities

which embody these substandard features. Thus, we will be in a position to take advantage of past experiences in planning for the future. We must learn from the experiences of others since none of us can possibly live long enough to make all the mistakes ourselves.

As I approach the end of my prepared remarks, I am reminded of the man who only one week after he started work announced to the foreman that he was quitting. "It isn't the pay", he explained, "It's just that I can't help having a guilty conscience". "What for?" asked the foreman. "Well, all the time I'm worrying about how I'm cheating some big, strong mule out of a job".

Our early freeways are today being asked to do a mule's job. If we apply all of our hard earned knowledge and technology, we may prevent tomorrow's traffic having to drive on yesterday's freeway. The Level of Service concept is one of our latest tools which can be used in meeting this objective.