50-443/444-OL
11/6/87
A-24

33

The effect of roadway and environmental factors on the capacity of a traffic-signal approach

The capacity of a traffic-signal controlled intersection is limited by the capacities of the individual approaches to the intersection.

There are two types of factor which affect the capacity of an approach: roadway and environmental factors, discussed in this chapter, and traffic and control factors discussed in chapter 34.

The roadway and environmental factors that control the capacity of an approach are the physical layout of the approach, in particular its width, the radii along which left- or right-turning vehicles have to travel, and the gradient of the approach and its exit from the intersection.

The capacity of an approach is measured independently of traffic and control factors and is expressed as the saturation flow.

Saturation flow is defined as the maximum flow, expressed as equivalent passenger cars, that can cross the stop line of the approach when there is a continuous green signal indication and a continuous queue of vehicles on the approach.

Observations of traffic flow made by the Road Research Laboratory at intersections in the London area and also in some of the larger cities, supplemented by controlled experiments at the Laboratory test track, have shown that the saturation flow(s) expressed in passenger car units per hour with no parked vehicles is given by

$$s = 550w \text{ p.c.u./h}$$

where w is the width of the approach in metres.

This formula is applicable to approach widths greater than 5·5 m: at widths less than 5·5 m the relationship is not linear and saturation flows may be estimated from table 33.1.

Applic Exh 24
Seabrook 11/6/87

TABLE 33.1

w (m)	3·00	3·40	3·65	4·00	4·50	5·20
s (p.c.u./h)	1850	1875	1900	1950	2250	2700

These saturation flows have to be amended for the effect of gradient. This modification has been reported as a decrease or increase of 3 per cent in the saturation flow for every 1 per cent of uphill or downhill gradient of the approach. The gradient of the approach was defined as the average slope between the stop line and a point on the approach 61 m before it. At the sites where these observations were made, the slope continued through the intersection.

Where vehicles crossing the stop line have then to travel immediately around a curve the rate of discharge across the stop line will be reduced. This occurs frequently when right-turning vehicles are able to discharge during a right-turning phase. Test-track experiments have shown that the saturation flow for right-turning streams may be obtained from

$$s = \frac{1800}{1 + 1{\cdot}52/r} \text{ p.c.u./h, for single-file streams}$$

or 1600 p.c.u./h

$$s = \frac{3000}{1 + 1{\cdot}52/r} \text{ p.c.u./h for double-file streams}$$

or 2700 p.c.u./h

where r = turning radius in metres.

The environment also has an effect on the saturation flow of an approach and while it is difficult to define this effect precisely, generalised modification factors are often applied.

Where a site is designed with a good environment, that is dual carriageway approaches, no noticeable pedestrian interference, no parked vehicles, no interferences to traffic flow from right-turning vehicles, good visibility and adequate turning radii then the saturation flow is taken as 120 per cent of the standard value.

If however a site is designed with poor environment, that is low average speeds, interference from standing vehicles and right-turning vehicles, poor visibility and poor alignment, then the saturation flow is taken as 85 per cent of the standard value.

Determination of the saturation flow of a traffic-signal approach

To determine the saturation flow of an approach select one in which there is a continuous queue even at the end of the green period. Avoid situations in which right-turning vehicles have an erratic effect on the traffic flow. For ease of observation it is preferable to select an approach that is restricted to straight ahead and left turning vehicles.

Using a stopwatch note the number, type and turning movement of each vehicle crossing the stop line during each successive 0·1 minute interval of the green and amber period. At the end of the amber period there will normally be an interval of less than 0·1 minute. Note the length of this interval and also the number and type of vehicles crossing the stop line in the interval. These intervals are subsequently referred to as last saturated intervals.

If at any time the flow on the approach is not saturated, then observations should be discontinued until the flow reaches saturation level again.

If it is not found possible to observe vehicle type then only the number and turning movement of vehicles should be noted. At the completion of observations a separate count is then necessary to determine the composition of the traffic flow.

The observations given in table 33.2 were obtained at a traffic-signal controlled intersection in the City of Bradford. In this instance observations were made of mixed vehicles travelling straight ahead.

TABLE 33.2 Observed discharge of vehicles across the stop line

Time (minute)	0	0·1	0·2	0·3	0·4	0·5
No. of vehicles crossing stopline	60	76	71	78	79	
No. of saturated intervals observed	32	32	32	32	32	
Discharge per 0·1 min	1·88	2·48	2·22	2·44	2·47	

Total duration of the last saturated intervals = 142 seconds
Total number of vehicles crossing stop line = 41.
Discharge per 0·1 minute during last saturated interval = (41·6)/142
= 1·74 vehicles/s

During the first and last saturated intervals there is a loss of capacity because of the effect of vehicles accelerating from the stationary position at the commencement of the green period and decelerating during the amber period.

The flow during the remainder of the observed periods represents the maximum discharge possible and their mean value gives the saturation flow for the approach

$$\text{saturation flow} = \frac{2{\cdot}48 + 2{\cdot}22 + 2{\cdot}44 + 2{\cdot}47}{4}$$

$$= 2{\cdot}40 \text{ vehicles per } 0{\cdot}1 \text{ minute}$$

$$= 1440 \text{ vehicles/h}$$

This value must now be converted to traffic-signal passenger car units and a subsidiary traffic count is required to determine the composition of the traffic.

Observe the composition and turning movements of the traffic flow for a period of 30 minutes and at similar time to when the original observations were made. The following composition of traffic was noted on the approach where the flow figures given in table 33.2 were observed (using the equivalent effects of various vehicle types given in chapter 34)

heavy vehicles	14 per cent
buses	5 per cent
motor cycles	6 per cent
private cars	75 per cent

all vehicles proceed straight ahead

The passenger car equivalent of the flow is then

$$0.14 \times 1.75 + 0.05 \times 2.25 + 0.06 \times 0.33 + 0.75 \times 1 = 1.16$$

Saturation flow = 1440 × 1·16
= 1670 p.c.u./h.

The design figure given in *Road Research Technical Paper* 56 is 1900 p.c.u./h for a 3·65 m lane width.

Problems

Four differing traffic signal approaches are described below. Place them in the order of their traffic capacity.

(a) An approach with good environmental conditions where all vehicles discharge straight across the intersection and where the approach width is 7·30 m.

(b) An approach with poor environmental conditions with a continuous uphill gradient of 3 per cent, where all vehicles discharge straight across the intersection and where the approach width is 10·50 m.

(c) An approach with normal environmental conditions from which all vehicles turn right in a double file stream on a path with a radius of 30 m.

(d) An approach with good environmental conditions and downhill gradient of 4 per cent, where all vehicles discharge straight across the intersection and where the approach width is 5·20 m.

Solutions

The traffic capacities of the approaches are:

(a) saturation flow = 550 × 7·30 = 4015 p.c.u./h
plus environmental factor of 20%

= 4015 × 1·2

= 4818 p.c.u./h

(b) saturation flow = 550 × 10·50 = 5775 p.c.u./h
minus environmental factor of 15%

= 5775 × 0·85

= 4909 p.c.u./h

minus gradient effect of 3 × 3%

= 4909 × 0·91

= 4467 p.c.u./h

(c) saturation flow = $\frac{3000}{1 + 1{\cdot}52/r}$ p.c.u./h

$$= \frac{3000}{1 + 1{\cdot}52/30}$$

= 2857 p.c.u./h

(d) saturation flow = 2700 p.c.u./h (table 33.1)
plus environmental factor of 20%

= 2700 × 1·2

= 3240 p.c.u./h

plus gradient effect of 4 × 3%

= 3240 × 1·12

= 3629 p.c.u./h

The order of capacity of the approaches is (a), (b), (d), (c).