(IV−23)

A New Discharge Capacity Formula for Priority Intersections with a Type-of-Control Parameter

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I. Introduction: Present capacity analysis methodologies for priority intersections do not adequately address the effect of the type of control. Operational characteristics at yield-controlled intersections are different from that at stop-controlled intersections. Thus, to overlook the effect of the type of control would result in faulty estimates.

II. Gap Acceptance Modeling of Priority Intersections: Gap acceptance models are used to formulate the capacity of a priority intersection. Gap acceptance models assume that an infinite queue of vehicles exist at a non-priority or minor road that intend to merge into a priority or major road with a given traffic flow characteristic (i.e. the headway distribution is known). The lead non-priority vehicle will merge into the major stream by waiting at the stop line for an acceptable gap between succeeding priority vehicles. Once the gap is greater than critical gap the lead minor road vehicle leaves the minor road and the next vehicle will move up the queue and reach stop line at the instant the lead vehicle fully discharges from the minor road. Thus, there will always be a minor road vehicle waiting at the head of the minor road queue. This assumption has been observed to be of reasonable accuracy in field conditions.

Plank[1] proposed a continuous analogue of the gap acceptance model in the priority intersection capacity problem called the fluid approximation approach. The formulation is intended for a capacity formula that is mathematically tractable for easy modification and extension to more complex assumptions.

In the fluid approximation approach, it is assumed that queued vehicles in the minor road behave like a fluid trying to merge into the priority stream. Headways (h) at the major road greater than an assumed constant critical gap (g) can then be thought of as a series of time intervals which the fluid traffic stream at the minor road can discharge. The fluid approximation of priority intersection discharge capacity (*cap*) can thus be expressed as the proportion of time that the major stream is non-blocking times the saturation discharge flow rate. Since the follow-up time, M, is the time required for the second queued vehicle to reach the stop line after the lead vehicle has discharged from the minor road, the saturation discharge flow rate can be expressed as the reciprocal of follow-up time assuming a constant follow up time. Thus, the capacity of a priority intersection be formulated as

$$cap = \Pr(h > g) \times 3600/M \qquad (1)$$

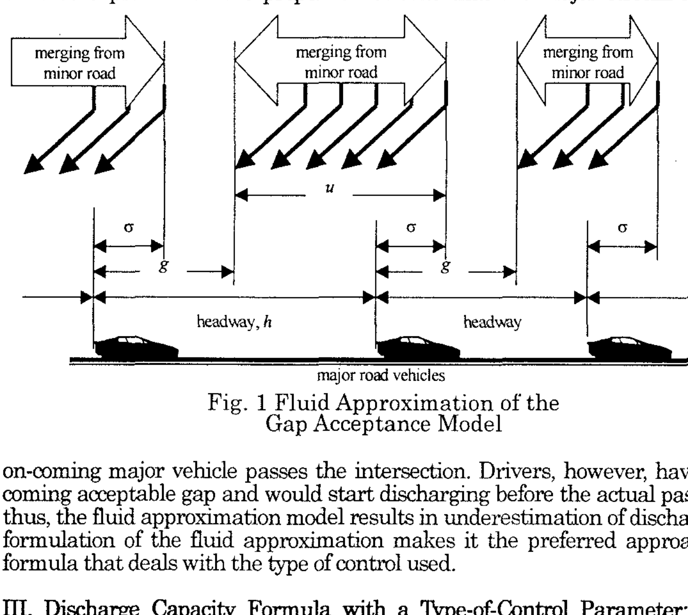

Fig. 1 Fluid Approximation of the Gap Acceptance Model

In the fluid approximation model, the drivers are assumed to start moving to merge into the major stream at the instant an on-coming major vehicle passes the intersection. Drivers, however, have the tendency to anticipate the on-coming acceptable gap and would start discharging before the actual passage of the on-coming major vehicle; thus, the fluid approximation model results in underestimation of discharge capacity. Nonetheless, the simple formulation of the fluid approximation makes it the preferred approach to the formulation of a capacity formula that deals with the type of control used.

III. Discharge Capacity Formula with a Type-of-Control Parameter: As an improvement of the fluid approximation of the gap acceptance model, a term is integrated into the formulation to describe the degree minor road drivers prematurely discharge from the stop line, assuming drivers try to enter the major stream as promptly as possibly allowed by the intersection control.

From the fluid approximation approach (Fig. 1), the minor vehicle is assumed to behave as a fluid entering the major stream when the gap at the major road allows for movement (i.e. gap > critical gap). Further assuming that drivers anticipate the next acceptable on-coming gap, the utilized time, u, used for discharging by the minor road vehicles can be formulated as $u = h - (g - \sigma)$. σ is the time difference between the actual passage of the on-coming priority vehicle and the time the lead non-priority vehicle starts to leave from the stop line.

In the original fluid approximation formula, σ is taken as zero. Here σ is taken as greater than zero and depends on the type of control of the particular priority intersection. Moreover, it is evident from Fig. 1 that σ is minimum at zero and maximum at follow-up time, M. Thus, σ can be replaced by κM, at which κ can vary from zero to one. Thus, the proportion of time utilized by the minor road stream for discharging is

$$u/h = \left(h - (g - \kappa M)\right) H / h \quad \text{where, } H = \begin{cases} 0 \text{ if } h - (g - \kappa M) < 0 \\ 1 \text{ if } h - (g - \kappa M) \geq 0 \end{cases} \tag{2}$$

Defining U as the mean proportion of time utilized by minor road vehicles for movement or discharging, the capacity of the intersection can be formulated as

$$cap = U \times \text{saturation discharge flow rate} = U \times 3600/M \quad \text{where, } U = E\left[\left(h - (g - \kappa M)\right)H\right]/E[h] \tag{3}$$

Assuming a negative exponential headway distribution and an average flow rate of λ at the major stream, Eq. 3 simplifies to,

$$cap = (3600/M) \times \exp\left(-\lambda(g - \kappa M)\right) \tag{4}$$

Table 1: Calibration Results

source	control	κ	mean
Bangkok	stop	0.37	0.37
Bangkok	stop	0.36	
Bangkok	yield	0.72	0.7
Jordan	yield	0.67	

IV. Calibration of the κ-parameter: It is theorized that the κ-parameter is dependent upon the type of control used. Thus, κ has a higher value if the control discipline is yield than if the control discipline is stop. To confirm this hypothesis, data was collected from two stop-controlled intersections and one yield control intersection in Bangkok by video recording. Also, an empirical curve of discharge capacity of yield-controlled intersections in Jordan[2] was used to augment the Bangkok data. From the data, capacity-versus-priority flow curves were derived. Then, the critical gap and saturation discharge flow rate were identified independently. The optimum κ-parameter was then determined for each case. The results, summarized in Table 1, indicate that the κ-parameter is non-zero and depends upon the type of control.

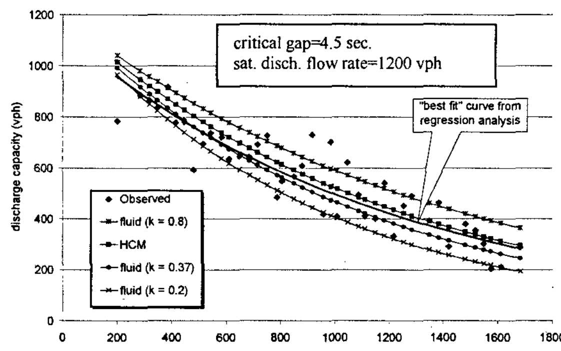

Fig 2. Comparison of the HCM formula and the Fluid Approximation Model with Different κ Values and Data from a Stop-Controlled Intersection in Bangkok

V. Comparison with the HCM Capacity Formula:

Fig 2 and Fig 3 shows a comparison of HCM model[3] and the fluid formula with different κ-parameter values. The comparisons illustrate that the HCM model overestimates discharge capacity for stop-controlled intersections and underestimates discharge capacity at yield intersections. On the other hand, the fluid model with the recommended κ-parameter value closely follows the "best fit" curve derived by regression analysis.

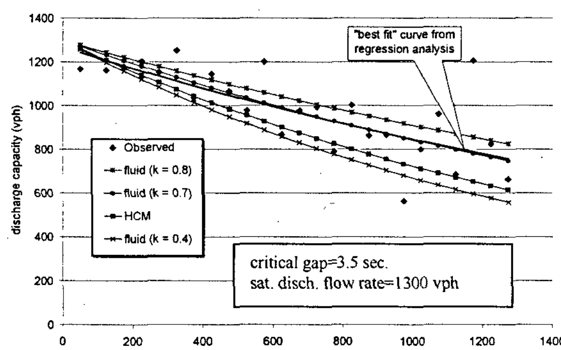

Fig 3. Comparison of the HCM formula and the Fluid Approximation Model with Different κ Values and Data from a Yield-Controlled Intersection in Bangkok

VI. Conclusion: This study has introduced a new capacity formula for priority intersections that is sensitive to the type of control used. Using the appropriate κ-parameter value and the new capacity formula, the effect of the type of control can be incorporated in capacity analysis of priority intersections resulting in more accurate prediction of delays and capacity and more informed traffic engineering decisions.

[1] Plank, 1982. The Capacity of a Priority Intersection-Two Approaches. *Traffic Engineering and Control* 23: 88-92.
[2] Hashem R. Al-Masaeid, 1995. Capacity of One-Way Yield Controlled Intersections. *Transp. Research Record* 1484: 9-15.
[3] *Highway Capacity Manual*, 1994. Transportation Research Board.