PICADY2 : A COMPUTER PROGRAM TO PREDICT CAPACITIES, QUEUES, AND DELAYS

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Abstract

PICADY2 is a computer program which predicts capacities, queues, and delays at major/minor priority junctions. This program has been developed by MVA Systems Inc. under contract to Road Research Laboratory, Department of Transport, United Kingdom.

The capacities were predicted using formulae developed by Kimber and Coombe (1980) which derived empirically the stream capacities as explicit functions of the controlling major road flows and the junction geometric features.

The associated queues and delays were predicted using an approximation method developed by Kimber and Hollis (1979).

1. Introduction

PICADY2 is useful as an aid for assessing options for either new junctions or modifications to existing ones.

The theoretical basis of PICADY2 and the program description will be set out in the sections below.

2. Theoretical Basis of PICADY2

2.1. Capacity

Capacity can be calculated from a knowledge of the minimum acceptable time gap in the major road streams which minor road drivers will accept. There are some difficulties, however, when it is used for determining practical estimates of capacity since the acceptable time gaps are not easy to measure. It is, therefore more straightforward to determine the traffic stream capacities and the factors affecting them empirically.

Tanner J.C. (1967) as quoted by Kimber and Coombe (1980) developed a relationship between capacity and controlling traffic flows as follows:

\[ q' = q_s - \Sigma \alpha \cdot q_i \]

where:

- \( q' \) : stream capacity (veh/s/unit time)
- \( q_s \) : saturation flow (veh/s/unit time)
- \( \alpha \) : a positive coefficient representing the degree of traffic interaction between stream i and the controlled stream
- \( q_i \) : controlling major road flows.

Both \( q_s \) and \( \alpha \) are dependent upon the layout of the junctions.

The main problem consists of determining the coefficient \( \alpha \) and the saturation flow \( q_s \) as functions of the junction geometry.

The determination of the stream using linear multivariate regression to establish the relationship between stream-capacity, controlling stream flows and geometric of a junction was developed by Kimber and Coombe (1980).

Their analysis can be divided into two parts. Firstly, the traffic flow affecting a given controlled stream and the specific relationship between them are determined. Secondly, the geometric layout which affects the relationship are taken into account.

From the research carried out, the best predictive equations for determining the capacity at non-priority traffic streams at 3-arm priority junction were found.
to be:

\[ q^2_{BA} = X_3 \cdot \left( \frac{627 + 14W_{BA} - Y(0.364 q_{BA} + 0.144 q_{CB}) + 9.520q_{BA}}{1} \right) \]

\[ q^2_{BC} = X_4 \cdot \left( \frac{725 - Y(0.364 q_{BA} + 0.144 q_{CB})}{1} \right) \]

\[ q^2_{CA} = q^2_{AC} \frac{q^2_{BA}}{(1-f)q_{BA} + f q_{AC}} \]

where:

\[ Y = (1 - 0.0345 W) \]

\[ X_3 = (1 + 0.094(W_{BA} - 3.65))(1 + 0.0009(V_{BA} - 120)) \]

\[ X_4 = (1 + 0.094(W_{BC} - 3.65))(1 + 0.0009(V_{BC} - 120)) \]

\[ f = \text{the proportion of minor road traffic flow} \]

\[ q_{BA}, q_{BC}, q_{CA}, q_{AC} \]: the capacity of right turning minor road stream (pcu's/unit time)

\[ q_{BA}^{2-CA} : \text{the capacity of combined single minor road traffic stream containing both left turning and right turning minor road streams (pcu's/unit time)} \]

\[ l : \text{lane width for non-priority stream (m)} \]

\[ W_{CA} : \text{width of central reserve (m)} \]

\[ V_{BA} : \text{visibility distances to the right.} \]

\[ V_{CA} : \text{visibility distances to the left.} \]

2.2. Queue Lengths and Delays

Steady state queueing theory is widely used for predicting queue lengths and delays. However, this method has a disadvantage because it gives infinite queue length and delays when the demand flows reach the capacity available to it.

Deterministic queueing theory gives unsatisfying predictions when demand flows are close to capacity because when demand flow only just reaches capacity zero delays are predicted (AD. Ma; and HEM Keller 1967).

Approximation methods are developed to smooth the steady state stochastic formula into the deterministic relationship by integrating the excess of demand over capacity.

Queues and delays are calculated according to the following rules which are derived by Marie C. Semmens (1985). Consider a short time interval t, during which the demand flow q and capacity μ may be regarded as approximately constant. There are several cases, depending on the ratio of flow to capacity \( D = q/μ \), and if \( D < 1 \), on the relative values of \( L_x \), the queue at the start of the time interval under consideration, and \( D = L_x/(1-D) \) the equilibrium queue length \( L_x \), the number of waiting vehicles at time \( t \).

If \( F \), is a queueing function defined for \( x \) (a time variable by):

Then the average queue length, \( L_x \), after a time \( t \), is given by the following expressions:

\[ L(0) = F(0) + L_x \]

where \( L_x = L_x(L_x + 1) / \mu \)

\[ \text{a) for } D < 1 : \]

\[ L(0) = F(0) + L_x \]

\[ \text{where } L_x = L_x(L_x + 1) / \mu \]

\[ b) L_x = J \]

\[ c) J < L_x < 2J - L(0) \]

\[ \text{where } L_x = (2J - L_x)(2J - L_x + 1) / \mu \]

\[ d) L_x > 2J \]

\[ L(0) = L_x + (J - L_x(L_x + 1)/\mu) \]

\[ \text{for } 0 < J < 1 \]

\[ L(0) = 2J - F(0) - \mu \text{for } J > 1 \]

These equations represent the growth or decay in queue length within a time segment of length \( t \). The total average delay during this time is obtained using and algorithm which is equivalent to integrating appropriate queue length equation over time segment.

3. Program Description

As set out in the PICADY2 User Manual the program description is as follows.
3.1. Operation

Firstly, PICADY2 divides the total time for which capacity and queue lengths or delays are calculated into a number of small, equal length time intervals, such as five minute or fifteen minute time intervals. The second step is, to process these time segments sequentially, based on the assumption that during each segment, demand flows and capacities are constant.

The procedure for calculating the capacities, queue lengths and delays is as follows:

1. The profile of demand flows in time is calculated where appropriate and values are derived for each time segment.
2. The traffic demand in each traffic stream is calculated for each time segment. By taking into account the flows in the conflicting traffic streams, and of the initial queue for the time segment, the junction entry capacity and final queue length are calculated for each stream.
3. For each traffic stream the calculated queue length of one time segment is taken as the initial queue length for the next segment.
4. The procedure is repeated, segment after segment, until the whole of the required period has been processed.

3.2. Data Input

Data input to the program consists of geometric features and traffic data. Geometric features needed are set out in table 1.

The traffic data consists of the demand flow (vehicles/minute) and the percentage of heavy vehicles for each traffic stream and for each time segment.

3.3. Output

The output of the program is queue length and delay information for each time segment. The information contains the ratio of demand flow to predicted capacity (RFC), delay (vehicle minutes/time segment), queue length. Moreover, it provides queuing delay information over the whole period. An example of the output is shown in appendix.

3.4. Batch and Interactive Modes

PICADY2 can be used either in batch mode or in interactive mode. The only difference between them is the way in which the data are input. In the batch mode data are read from a card reader or a card image. In the interactive mode, data are input by answering a series of questions asked by PICADY2. Furthermore, the user can choose whether data are read from an existing card-image file or are entered from the terminal keyboard.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>w</td>
<td>major road width in the proximity of arm B (m)</td>
</tr>
<tr>
<td>w1</td>
<td>width a central reserve in the proximity of arm B (m)</td>
</tr>
<tr>
<td>w2</td>
<td>lane width for right-turning (C—B) major road stream (m)</td>
</tr>
<tr>
<td>w3</td>
<td>lane width for left-turning (B—C) minor road stream (m)</td>
</tr>
<tr>
<td>w4</td>
<td>lane width for right-turning (B—A) minor road stream (m)</td>
</tr>
<tr>
<td>w5</td>
<td>lane width for right-turning (C—B) major road stream (m)</td>
</tr>
<tr>
<td>V1</td>
<td>visibility to the left for traffic on minor arm B (m)</td>
</tr>
<tr>
<td>V2</td>
<td>visibility to the right for traffic on minor arm B (m)</td>
</tr>
<tr>
<td>Vmax</td>
<td>visibility distance along arm A for right-turning (C—B) major road stream</td>
</tr>
</tbody>
</table>

4. Conclusion

The capacity of a minor traffic stream at priority junction can be predicted from a knowledge of the minimum acceptable time gap accepted by minor road drivers. However, because of difficulties in the use of this method for practical estimates an empirical method has been developed to predict the capacity of...
the controlled traffic streams by considering the effects of the controlling traffic flows and the geometric layout features.

Both steady state queueing theory and deterministic queueing theory cannot predict queue lengths appreciably when traffic intensity is between 0.9 and 1.1. Approximate methods are therefore developed to treat the whole range of traffic intensity.

References


Appendix

Output of PICADY2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Time step</td>
<td>Value</td>
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<tr>
<td>Duration</td>
<td>Value</td>
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<td>Location</td>
<td>Value</td>
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Additional data on PICADY2 output including specific parameters and values can be found in the table above.

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<thead>
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<th>TIME</th>
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<th>S (W/m²)</th>
<th>T (W/m²)</th>
<th>U (W/m²)</th>
<th>V (W/m²)</th>
<th>X (W/m²)</th>
<th>Y (W/m²)</th>
<th>Z (W/m²)</th>
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<th>B (W/m²)</th>
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