

MEASURES OF THE SENSITIVITY AND EFFECTIVENESS OF THE CORQ TRAFFIC MODEL

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The traffic simulation model on corridor queuing, CORQ, was tested and used to predict the effects of some alternative traffic control schemes designed to relieve a bottleneck on the Ottawa Queensway. For each control scheme, CORQ predicted the link flows and queues as well as the total travel time for the entire Queensway corridor. The corridor was modeled as a network of nodes and links. Demands were represented by a set of origin-destination matrices corresponding to a sequence of 15-min time sections, each of which had assumed time-stationary demand rates. The CORQ model assigned these demands to the network and was found to reproduce measured flows and queues reasonably well. It then was calibrated to measured values and used to predict the flows, queues, and total travel time for each of the various control schemes. The model was found to be sensitive to a variety of strategies including the metering or closure or both of freeway ramps, revised red-green splits at traffic signals, and re-striping or channelization. In this particular application, CORQ predicted that the closure of a certain off ramp would have the greatest single effect on total network travel time. CORQ does not account for the feedback effect on corridor origin-destination demands because of new operating conditions caused by traffic controls. The user is left to alter the origin-destination matrices to account for those demand changes that he or she feels are required.

•A TECHNIQUE has been developed to predict the effects of various alternative strategies that might be designed to improve the traffic operation of any given roadway corridor (1,2). The technique has been specialized to treat corridors with peak-directional flows rather than a completely generalized network. This specialization has simplified detailed treatment of important effects such as time-varying demands and capacities, transient queues, and the backing up of physical queues to block upstream interchanges. The name CORQ was derived from the emphasis of the technique on modeling queuing effects due to transient demands that are responsible for a large share of delays and inconvenience in traffic corridors. Unlike the FREQ model (3), which is further specialized to detailed analysis of freeway queues, CORQ treats all flows in a corridor network except for those in the nonpeak direction. The result is that all travel times are accounted for in evaluating control strategies. For example, the effects on parallel arterials due to a freeway-control strategy are included in the assessment of the strategy by the model. The CORQ computer program cumulates the cost of travel and queuing on all the links of the network. This aggregate cost can be used as a measure of performance for a particular traffic control scheme.

DESCRIPTION OF OPERATIONAL PROBLEM STUDIED BY USING CORQ

A queue has been observed to form at the Maitland interchange (Figure 1) of the east-

Figure 1. The Ottawa Queensway Corridor studied with the aid of CORQ.

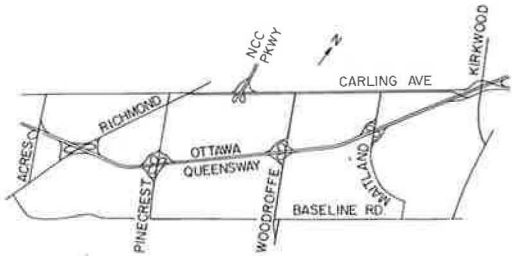
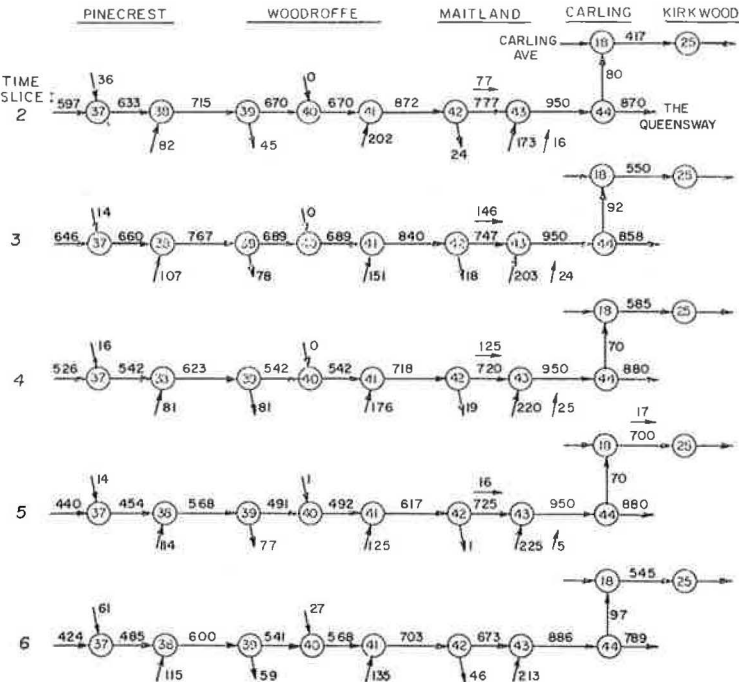


Table 1. Control schemes 1 though 4 tested by CORQ for estimated effects on total travel time at existing morning peak demand levels.

Control Scheme	Strategy Description*	Results Predicted by CORQ	Estimated Time Savings (vehicle h/day)
1	No alterations	See Figure 2	0
2	Ramps from the south at Maitland and Woodroffe interchanges metered (7:15 to 8:15 a.m.) Access denied to Queensway from the north at Maitland and Woodroffe Avenues (7:15 to 8:15 a.m.) 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 3	95
3	Carling interchange off ramp closed (7:15 to 8:15 a.m.) 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 4	123
4	Carling interchange off ramp closed (7:15 to 8:15 a.m.) Access denied to Queensway from the north at Maitland and Woodroffe Avenues (7:15 to 8:15 a.m.) Maitland interchange on ramp metered 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 5	127

*In terms of alterations to existing network.

Figure 2. Flows and queues predicted for control scheme 1 for existing level of demand.



bound Ottawa Queensway on typical weekday mornings. The queue begins just downstream of the Maitland on ramp and backs upstream, often extending through the Woodroffe interchange that is approximately 1 mile (1.6 km) upstream. On days with incidents, the queue has extended upstream through 3 or more interchanges.

The problem was attributed to short-term demands exceeding capacity immediately downstream of the Maitland interchange on ramp where the Queensway has 2 lanes in each direction. The accumulation of flows along the Queensway up to and including the Maitland interchange on ramp was more than the section could serve during a critical part of the morning peak period; therefore, the excess demand had to wait in queue until it could be served. In addition to the high demand in this section, an uphill grade immediately downstream of the Maitland interchange merge accentuated the deficiency in capacity. When breakdowns occurred in the section, the grade impeded acceleration and further slowed recovery.

SYNTHESIS OF STRATEGIES FOR IMPROVED OPERATION

Although the Queensway has 3 lanes in each direction east of the Carling interchange, it was not considered feasible to add an eastbound lane from the Maitland interchange to the Carling interchange, at least in the short to medium term. Parallel routes not shown in Figure 1 have either insufficient excess capacity or incompatible destinations to help relieve the Queensway and are not discussed in this paper. Because it was felt that the ultimate capacity of the bottleneck section on the Queensway could not be increased, strategies for improvement were synthesized from control techniques designed to decrease the demand at the bottleneck without unduly affecting other sections of the network shown in Figure 1.

The basic philosophy of the control strategies was to shift some of the Queensway flows to Carling Avenue, which had some excess capacity. In so doing, care had to be exercised not to transfer more demand than Carling Avenue was able to accept. The potential bottleneck on Carling Avenue was calculated to be at its intersection with Kirkwood Avenue.

A report by Walshaw, Upton, and Walker (4) outlined some proposals for on-ramp metering and closure.

Traffic engineering capacity analysis was employed mainly at signalized intersections to estimate required changes in traffic signal splits because of anticipated flow variations on the surface streets resulting from freeway controls.

Network flow capacity analysis showed the off ramp from the Queensway to Carling Avenue to be detrimental to the ultimate capacity of the corridor because it joins the critical sections of the parallel major routes in series. That is, any vehicle using this ramp will encounter the potential bottleneck section of Carling Avenue immediately after passing through the bottleneck on the Queensway. As a consequence, it takes up to 2 units of critical capacity, which decreases the ultimate capacity of the corridor by 1 unit. Therefore, vehicles should be discouraged from using this ramp during periods when capacity is critical. This should apply even more in the future as demands grow to where the flows approach the ultimate capacities on the critical sections of both the Queensway (between the Maitland and Carling interchanges) and Carling Avenue (at Kirkwood Avenue). When this happens, capacity will have to be increased or demand will have to be decreased. One way to accomplish this would be to close the Carling interchange off ramp.

Although it was felt that each of the above strategies would, by itself, improve the overall operation of the corridor, this was not certain. Furthermore, it was not possible to predict which strategy or combination of strategies would work best. CORQ therefore was applied in testing the various strategy packages not only to order them but also to quantify their respective effects on the network. Although a cost-benefit analysis was beyond the guidelines of the study, one could be employed easily to weigh the implementation costs of the various strategy packages against their relative travel time savings to adopt the best net package.

CALIBRATION OF CORQ TO THE QUEENSWAY CORRIDOR

Demand Estimation

The existing flows and queues on the links (roadway sections) of the network were measured for each of the 15-min time sections of the morning peak period. An origin-destination (O-D) survey of the corridor users was conducted by handing out postcard questionnaires at all of the eastbound on ramps shown in Figure 1 as well as at strategic locations on Carling Avenue and Base Line Road. The results of the returned postcards were factored up to represent the observed flows and queues, and "filler" origins and destinations were inserted for noncritical sections that were not represented in the O-D survey.

Network Characteristics

The relationships of link flow and travel time were obtained from floating vehicle studies that were conducted at the same time as the counts. Intersection capacities were estimated according to the Highway Capacity Manual (5) except where floating vehicle studies and observed counts indicated that the Highway Capacity Manual value was too low. In such cases the capacity had to be estimated by some other procedure. This was done for the critical intersection of Carling Avenue at Kirkwood Avenue where the Highway Capacity Manual value for capacity was exceeded by flows observed in the field. The main-line and on-ramp capacities for the critical Maitland interchange merge section were estimated from data obtained by time-lapse photography.

Calibration Runs

For testing control schemes, network characteristics were taken to be deterministic. The most critical of these was the Maitland interchange merge section, which was given a fixed capacity at an estimated reasonably stable value of 3,800 vehicles/h. The O-D demands were altered to preserve actual flows and queues, and the capacity was kept constant at the accepted value of 3,800 vehicles/h. The initial simulation run reproduced measured flows and queues reasonably well; therefore, the model was accepted. It then was calibrated to measured flows and queues by perturbations on the O-D matrices.

STRATEGIES TESTED AND PREDICTIONS BY CORQ

For efficiency of presentation, only a partial report of the strategies tested and the corresponding predictions by the CORQ model are presented in this paper. The strategies and test results have been selected to demonstrate the power of CORQ to emulate their effects. Other reports offer a more exhaustive treatment of the documentation and application of CORQ (6, 7).

Table 1 gives some selected control strategies that were tested with CORQ for current O-D demands. It also contains CORQ-predicted net effects (in vehicle hours) on the total network during the morning peak period. Figures 2 through 5 show the predicted flows and queues for the relevant 15-min time sections of the morning peak period that correspond to the strategies described in Table 1. (Flows are quoted in vehicles per 15-min time section, and queues are indicated by floating arrows in Figures 2 through 11. The peak period from 7:00 to 9:00 a.m. is represented by 8 time sections.) These flows and queues are shown only for the part of the network considered most relevant in the present context, which includes the Queensway as far east as the Carling interchange off ramp and Carling Avenue to Kirkwood Avenue. Figure 2 shows the locations of the respective interchanges. The total node-arc type of model used for

the network is shown elsewhere (6, 7). In each of Figures 2 through 11, only the time sections with relevant information are shown.

Because lead time often is required in the implementation of major controls and traffic demands tend to increase both before and after implementation, it was felt that the results shown soon would be outdated. All the O-D demands for each time section therefore were arbitrarily increased by 9 percent to reflect some medium-term growth, and some control strategies were derived and tested for this increased level of demand. It was realized that growth patterns would not necessarily reflect existing demand patterns, but it was considered adequate for current purposes to assume proportional growth (7). Table 2 gives some selected control schemes that were tested on the increased demands and the corresponding net results that CORQ predicted for them. Figures 6 through 11 show the predicted flows and queues for the relevant 15-min time sections of the morning peak period corresponding to the respective strategies described by the data given in Table 2.

DISCUSSION OF STRATEGIES IN LIGHT OF RESULTS PREDICTED BY CORQ

The purpose of this paper is to illustrate an application of the CORQ model and indicate some of the types of strategies that it could test. It is not intended to compare specifically the tested total control schemes or to promote any of them for the Ottawa Queensway corridor. The discussion and conclusions therefore will emphasize the sensitivity of the model to the various types of strategies and will deemphasize the control scheme selection aspect of the application. The results in Tables 1 and 2 and Figures 2 through 11 indicate types of tests and comparisons that can be made with the

Table 2. Control schemes 5 through 10 tested by CORQ for estimated effects on total travel time at existing morning peak demand levels increased by 9 percent.

Control Scheme	Strategy Description ^a	Results Predicted by CORQ	Estimated Time Savings (vehicle h/day)
5	No alterations	See Figure 6	0
6	Ramps from the south at Maitland and Woodroffe interchanges metered (7:15 to 8:15 a.m.) Access denied to Queensway from the north at Maitland and Woodroffe Avenues (7:15 to 8:45 a.m.) 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 7	115
7	Carling interchange off ramp closed (7:15 to 8:15 a.m.) 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 8	148
8	Carling interchange off ramp closed (7:15 to 8:45 a.m.) Access denied to Queensway from the north at Maitland and Woodroffe Avenues (7:15 to 8:45 a.m.) Pinecrest interchange on ramp from the north and Maitland interchange on ramp closed (7:15 to 8:15 a.m.) 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 9	175
9	Access denied to Queensway from the north at Maitland Avenue, Woodroffe Avenue, and Pinecrest Road (7:15 to 8:45 a.m.) Ramps from the south at Maitland and Woodroffe interchanges metered 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 10	222
10	Carling interchange off ramp closed (7:15 to 8:45 a.m.) Access denied to Queensway from the north at Maitland and Woodroffe Avenues (7:15 to 8:15 a.m.) Maitland interchange on ramp metered 2 right-turn lanes established from Maitland Avenue northbound onto Carling Avenue	See Figure 11	258

^aIn terms of alterations to existing network.

Figure 3. Flows and queues predicted for control scheme 2 for existing level of demand.

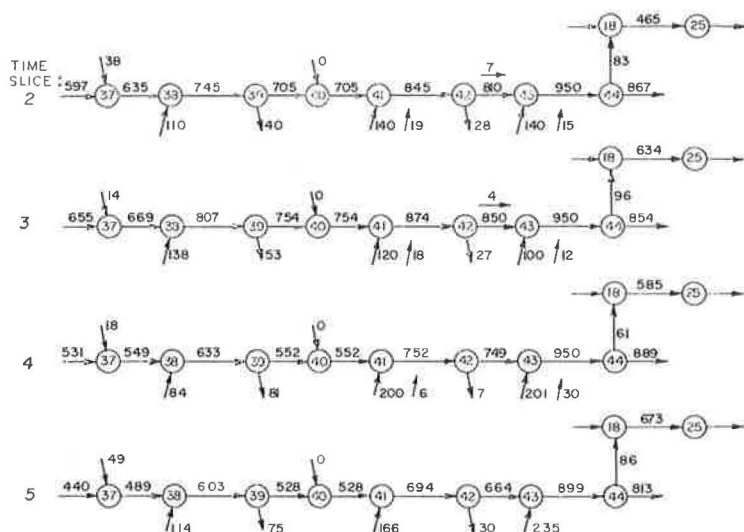


Figure 4. Flows and queues predicted for control scheme 3 for existing level of demand.

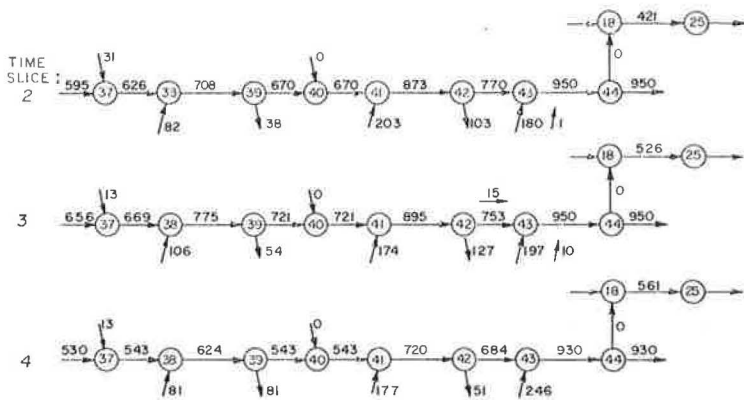


Figure 5. Flows and queues predicted for control scheme 4 for existing level of demand.

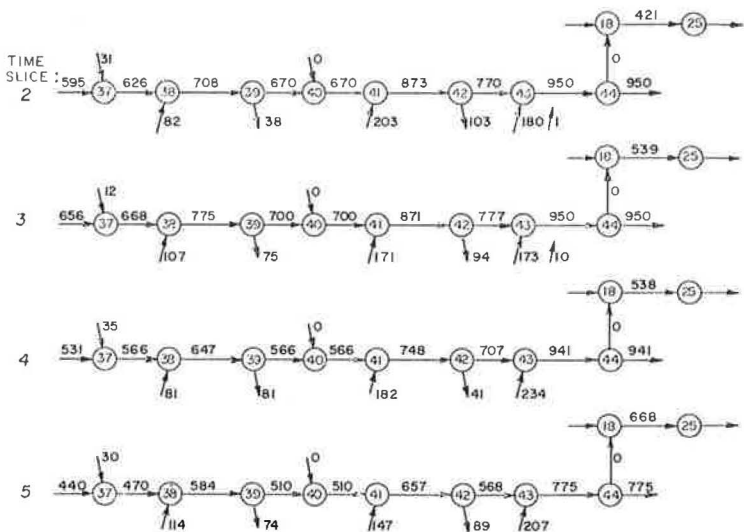


Figure 6. Flows and queues predicted for control scheme 5 with existing demands increased by 9 percent.

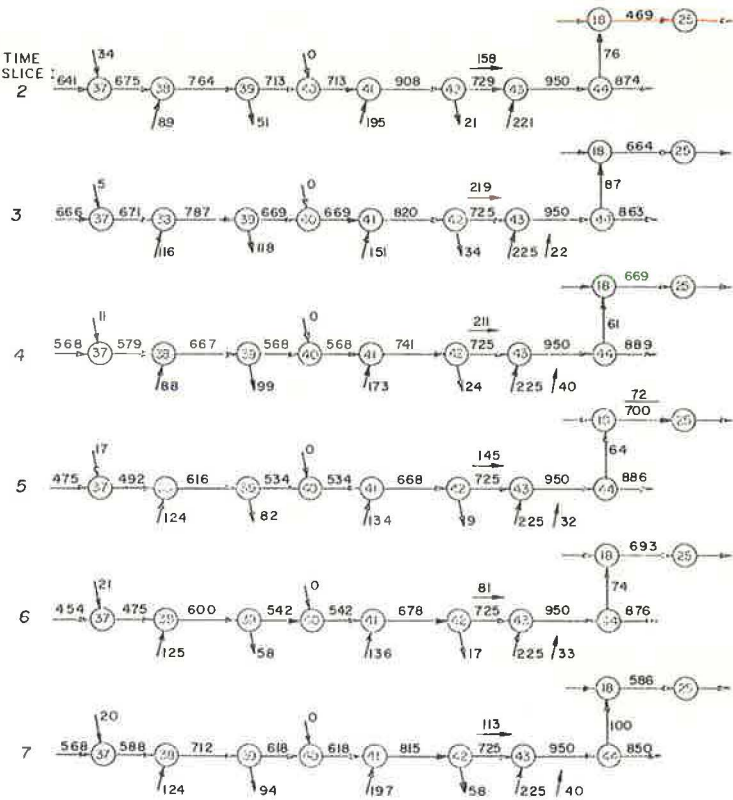


Figure 7. Flows and queues predicted for control scheme 6 with existing demands increased by 9 percent.

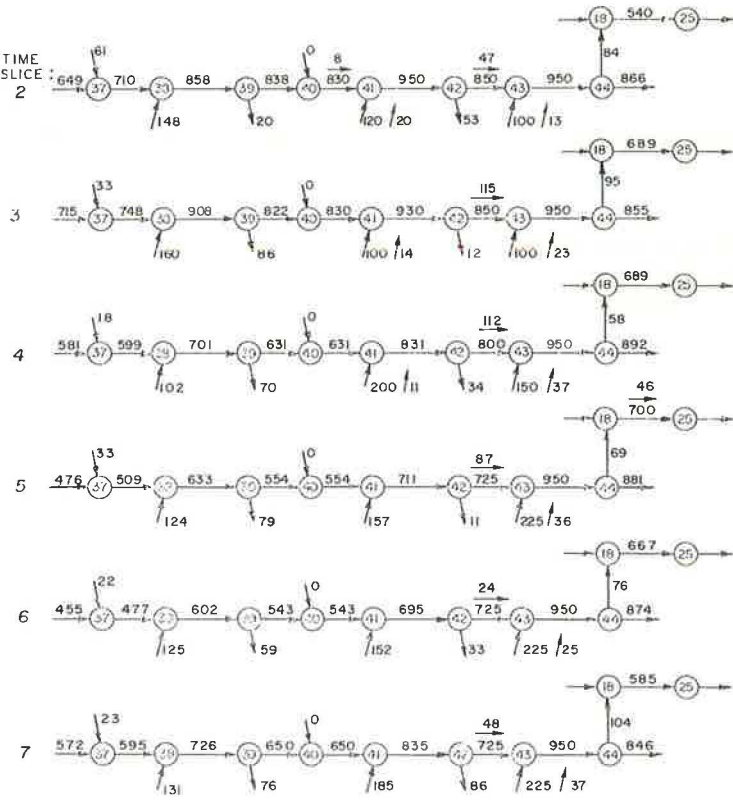


Figure 8. Flows and queues predicted for control scheme 7 with existing demands increased by 9 percent.

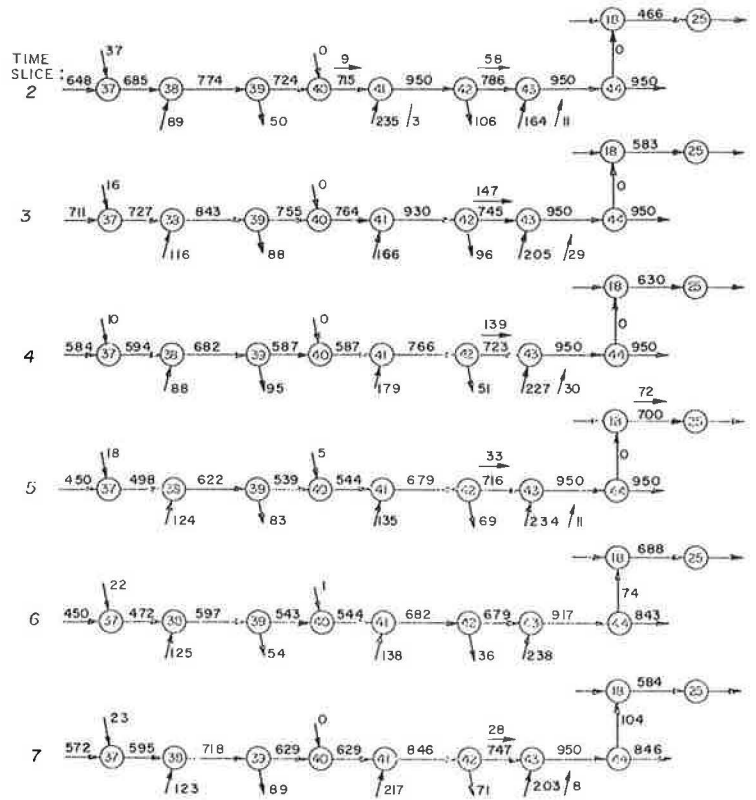


Figure 9. Flows and queues predicted for control scheme 8 with existing demands increased by 9 percent.

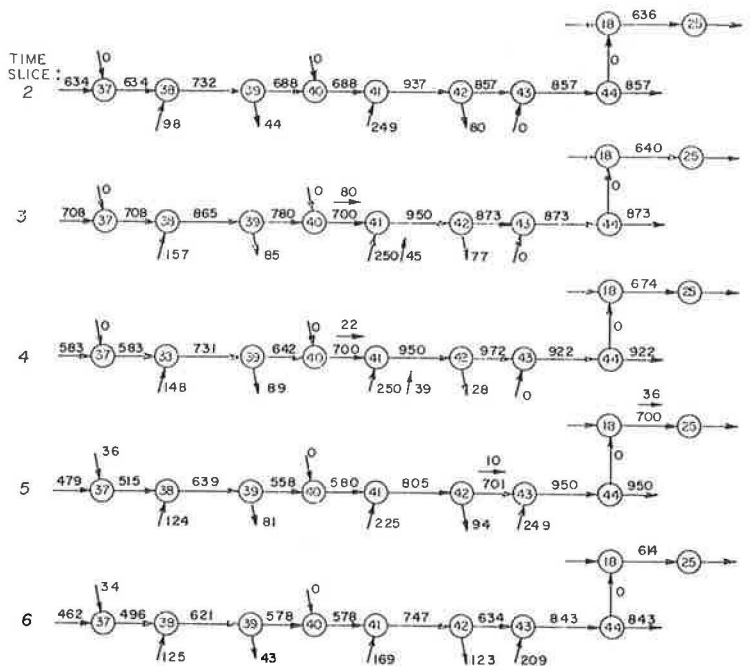


Figure 10. Flows and queues predicted for control scheme 9 with existing demands increased by 9 percent.

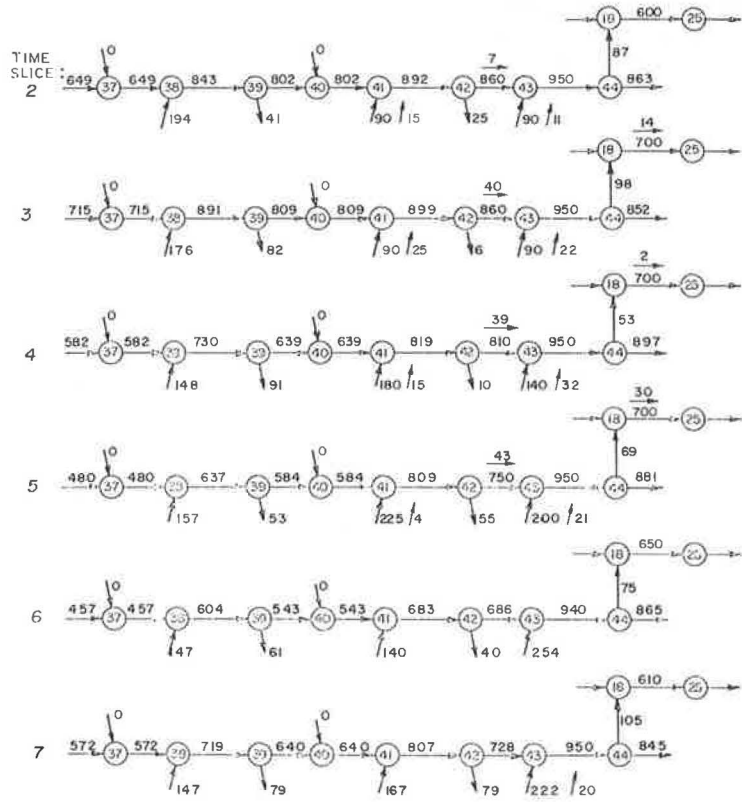
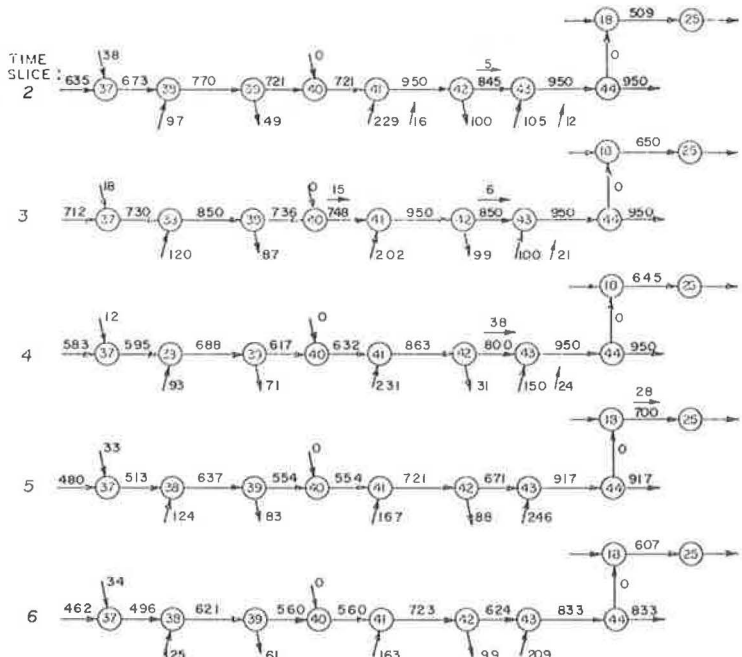


Figure 11. Flows and queues predicted for control scheme 10 with existing demands increased by 9 percent.



CORQ model before an expensive or irrevocable commitment is made to certain specific types of traffic controls.

Figures 2 through 11 attest to the sensitivity of the model to adjust its flow predictions to conform rationally to the various controls. Some examples of this are identified. By comparing Figure 2 (no controls) and Figure 3 (metering at nodes 41 and 43), one can see that metering downstream on ramps increases upstream use of the Queensway and decreases the critical downstream Queensway demand as expected. The result of this metering is less queuing on the Queensway and a predicted potential gain of 95 vehicle h/peak period. Figure 5 shows that the additional closure of the Carling interchange off ramp (link 44-18) results in less congestion than that shown in Figure 3 at both the Queensway and Carling Avenue bottlenecks. As discussed previously, the total flow at the corridor bottlenecks is decreased because of the Carling interchange off-ramp closure. The predicted net gain for this total scheme is 127 vehicle h/peak period. Figure 4 shows a prediction of the effects of closing only the Carling interchange off ramp. Again there is less demand at both the Queensway and Carling Avenue bottlenecks than in Figure 2.

Figures 6, 7, 8, and 11 are analogous to Figures 2, 3, 4, and 5 respectively but correspond to 9 percent higher demands and therefore greater queuing. The time savings made available by using traffic controls are consequently greater. The model predicts the same relative order of performance for these 4 strategies in both cases, further attesting to its credibility. As before, upstream use of the Queensway is higher in Figure 7 than in Figure 6. As in Figure 5, Figure 11 again indicates decreased congestion on both the Queensway and Carling Avenue relative to Figure 7 because of the closure of the Carling interchange off ramp. Again, the model reacts to closing only the Carling interchange off ramp by assigning less demand to both the Queensway and Carling Avenue bottlenecks, as indicated by Figure 11 versus Figure 6. Figure 10 shows the severe effects on Carling Avenue due to very stringent metering at Woodroffe and Maitland Avenues. The prediction for control scheme 8, in which the Maitland interchange on ramp is closed, is shown in Figure 9. A great overload is predicted at the Woodroffe interchange on ramp, which would cause an overload at the Woodroffe interchange merge area. The model has been sensitive enough to reroute many of the drivers who normally would use the Maitland interchange on ramp to Woodroffe Avenue. The validity of this action by the model was verified by a study of the O-D postcards returned by current users of the Maitland interchange on ramp.

Although between 15 and 30 vehicles were observed to use the on ramp from the north to the eastbound Queensway at Woodroffe Avenue in time sections 2 through 5 (7), the model did not see it this way, as can be seen in Figure 2. A careful study of these ramp users showed that they had approximately equal paths (in terms of travel time) via Carling Avenue and the Queensway and that the Carling Avenue option generally was better. The model therefore has been as rational as the drivers. In fact, it has guided the analyst toward the conclusion that this ramp is not necessary and could be closed during the peak period and have little adverse effect on the rerouted individuals.

The results consistently indicate that, in terms of total network travel time, closure of the Carling interchange off ramp is the best single strategy among those tested. If this is not feasible, then metering of the Maitland interchange on ramp and closure of certain access points to the Queensway from the north are a promising alternative.

CONCLUSIONS

The CORQ model has been found to be sensitive to a variety of traffic control schemes. In spite of the considerable human factors involved in the emulation of traffic assignments, the model has illustrated an ability to predict flows and queues with reasonable accuracy. The level of detail used in the modeling processes allows it to give quite accurate relative appraisals of various traffic networks and control schemes. However, careful attention must be paid to all critical flows in calibrating the model.

The application to the Queensway corridor indicates some potential large savings in travel time through the types of traffic control strategies that are amenable to testing

by CORQ. The strategies include ramp closure, ramp metering, lane restriping, and traffic signal green split alteration. In the application described in this paper, CORQ predicted that closing the Carling interchange off ramp would have the greatest single impact on total travel time.

When the model has been calibrated to a specific corridor, a large variety of control schemes can be tested with relatively little effort. A cost-benefit analysis then can be applied to select 1 scheme out of those that show the most promise. The cost-benefit analysis should consider operational feasibility of strategies such as closure of off ramps.

An indication of the power of the CORQ model is in its not emulating the patterns observed for some users, who generally are as well or better off (in terms of travel time) by using the path predicted by CORQ. This can lead the analyst toward control strategies in which the controlled drivers are not adversely affected.

The predicted effects of the tested control schemes do not consider added demands due to users attracted to the corridor from the NCC Parkway or other routes. The effects of such route changes could be beneficial to the total system provided that reroutings be considered in the control of the corridor subsystem. However, this was not done. Although such reroutings can be beneficial to a total system if they are accounted for properly, any new demands generated by improved operation generally negate some of the gains.

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