Abridgment

Airborne Traffic Advisories: Their Impact and Value

JON D. FRICKER and HUEL-SHENG TSAY

ABSTRACT

Airborne traffic advisories provided by radio stations have long been considered primarily a promotional activity, but at least part of the expense of this service might be justified in terms of improved traffic flow. An assessment of airborne traffic advisories in a major U.S. city is described along with a technique for quantifying and comparing the response of drivers to a sudden incident that blocks traffic flow--with and without traffic surveillance. The study is presented in the context of an Interstate highway corridor leading into a downtown area during the morning peak period. A graphical queueing analysis technique is used to calculate the delay on the link where the incident takes place. An equilibrium traffic assignment model is adapted to determine the changes in travel times elsewhere in the corridor as traffic avoids the partially blocked link. Preliminary results indicate a surprising magnitude of benefits to justify the traffic advisory service in terms of the extra delay that can be avoided. In the case study, the queue on the Interstate highway cleared 21 percent sooner, and 33 percent of the delay in the queue was prevented when just 20 percent of the approaching drivers heard (and heeded) the traffic advisory.

Almost every U.S. city with any degree of traffic congestion has one or more radio stations that offer some form of traffic advisory service. Of particular interest to this study is the sudden incident that blocks one or more lanes of traffic (traffic accident, vehicle breakdown, traffic signal malfunction, emergency equipment in use, etc.) and that could lead to severe deterioration of network service, if untreated. Private radio stations that provide a response to this condition usually do so as a public service that also serves as a promotional tool. It would be of interest to determine just how much impact their traffic advisory service has on alleviating congestion and reducing travel times. A preliminary analysis is demonstrated of the role of airborne traffic advisories in helping traffic adjust to a sudden loss of capacity in one part of a road network.

CASE STUDY: INDIANAPOLIS

Indiana's capital city has several commuter corridors that are vulnerable to disruption by the lane-blocking incidents described earlier. One of these corridors lies along I-70 East, and is shown as running through nodes 17, 19, 21, 33, 35, and 40 in Figure 1. Between 7 and 9 a.m., westbound volumes on this Interstate highway segment approximate saturation flow. This segment leads to the infamous Spaghetti Bowl (node 40), named for the impression given an airborne observer by the many ramps at the

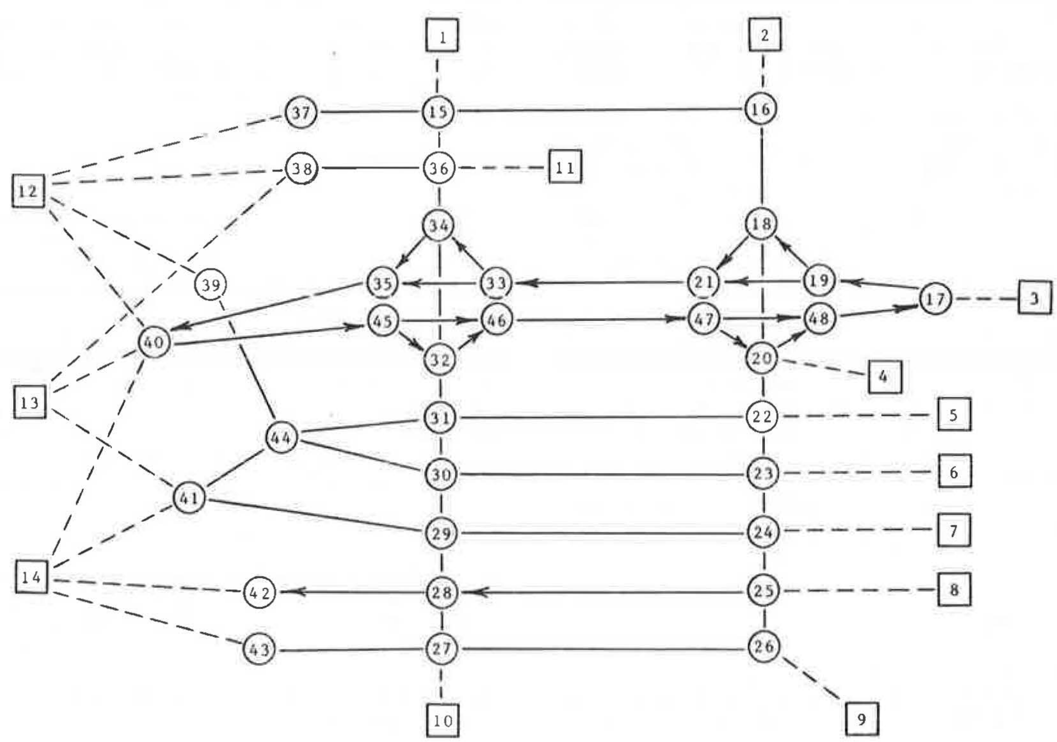


FIGURE 1 Link-node diagram of the I-70 corridor.

I-70 interchange with I-65. There are several major arterials that either parallel I-70 or cross this corridor. They connect with I-70 via ramps at Keystone Avenue-Rural Street (nodes 32 through 35) and Emerson Avenue (nodes 18 through 21). In the event that an incident occurs in, or on the approach to, the Spaghetti Bowl, these ramps and arterial routes can become vitally important. These facts, together with the availability of useful data, make this corridor a good one for a sample analysis.

STEPS IN ANALYSIS

1. Calibrate a traffic assignment (T/A) model to duplicate existing link volumes.
2. Run the T/A model to determine driver and network response to a lane blockage without a traffic advisory service.
3. Repeat step 2, but allow for some form of traffic advisory service.
4. Examine differences in driver route choices and network response for the cases tested.
5. Compare travel time saved (if any) with the cost of providing the traffic advisory service.

NORMAL CONDITIONS (Case 0)

In the link-node diagram of Figure 1, nodes 1 through 14 are actually centroids representing the origins and destinations (O-D) of trips through the corridor. It was necessary to develop an O-D trip interchange table for these centroids that, when loaded onto the corridor's links, led to link volumes similar to the counts provided by the Indianapolis Department of Transportation (DOT). Using the city DOT data on speed limits, lane counts, travel times, and volumes by time of day for each link (ℓ) in the corridor, reasonable initial values for a and b in the FHWA link congestion function (1)

$$T = T_0\ [a + b(V/C)^4] \qquad (1)$$

were derived. In Equation 1, T = travel time on link, T_0 = free-flow link travel time, V = link volume, and C = link capacity. Because the focus is on driver behavior, especially with respect to route choice, the equilibrium T/A model was selected (2-4). After a few applications of the equilibrium T/A model--followed each time by adjustments of values for a_ℓ, b_ℓ, and the trip interchanges--the observed link volumes were reproduced within reasonable limits.

AN INCIDENT WITHOUT INFORMATION (Case 1)

A vehicle breakdown or accident on the approach to the Spaghetti Bowl (node 40 in Figure 1) is fairly common. Weaving maneuvers and limited sight distances not only increase the frequency of such incidents there, but also add to the problems of succeeding drivers who must decide how to respond to the suddenly blocked lanes.

For this case study, the assumption is that an incident occurs just east of node 40 (about 1.1 miles west of node 35) at 7:20 a.m. such that one westbound lane of I-70 is blocked. Given normal traffic volumes for this time of day, the question becomes: How will drivers respond to this incident if no information about it is provided to them before they seek to enter link (35,40)? The problem must be addressed in two parts. First, the geometry of link (35,40) is such that a traffic backup is not visible to drivers approaching on link (21,33) until the tail end of the backup is close to the Keystone-Rural interchange, represented by nodes 32 through 35. This means that, in the absence of outside information, approaching drivers have no warning until the queue of vehicles on (35,40) nearly reaches node 35. Second, when the approaching drivers observe this situation, what is their response and how does the street network perform?

Queueing on Link (35,40)

Under normal conditions, the capacity of each freeway lane is 1,600 vehicles per hour (vph) (5). If one of three lanes on a freeway is closed to traffic, the combined capacity of the remaining two lanes is approximately 3,000 vph (6). The westbound traffic flow passing node 35 at 7:20 a.m. is about 4,375 vph and increasing. To measure the increase of the vehicular queue where the arrival rate (traffic volume) exceeds the service rate (road capacity) and is nonuniform, the analysis period is divided into 5-minute intervals. The data in Table 1 indicate the increase in the arrival rate and the queue during a one-half-hour period beginning at 7:20 a.m., if no drivers change route choice and if the lane obstruction is not removed.

TABLE 1 I-70 Queue With One Westbound Lane Blocked

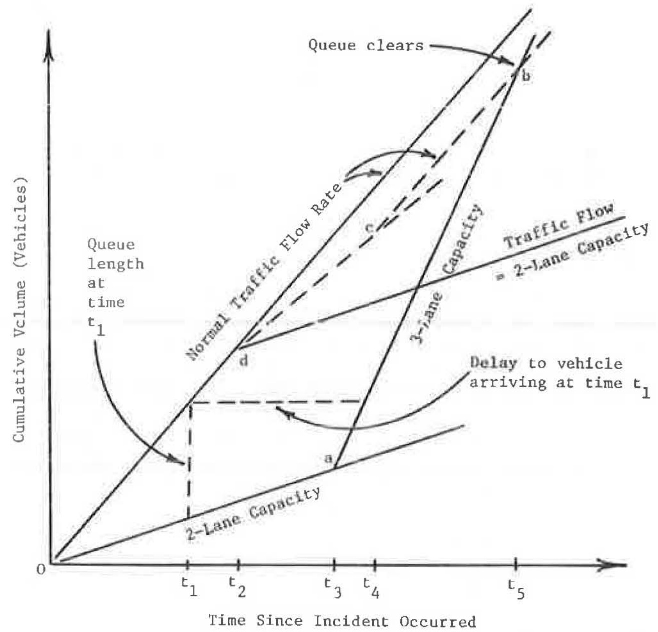
Time Period (Peak a.m.)	Three-Lane Volume (No. of Vehicles)	Two-Lane Capacity (No. of Vehicles)	End-of-Period (No. of Vehicles)	Queue Length (Miles)
7:21-7:25	368	250	118	0.34
7:26-7:30	374	250	242	0.69
7:31-7:35	375	250	367	1.04
7:36-7:40	378	250	495	1.41
7:41-7:45	382	250	627	1.78
7:46-7:50	384	250	761	2.16

The far right column in Table 1 indicates that by 7.35 a.m., the queue has nearly reached the 1.1 miles to node 35 and is visible to approaching motorists. An easy graphical technique to verify the entries in Table 1 and to calculate delay in the queue is shown in Figure 2. The broken line (d,c) indicates the reduced traffic flow into link (35, 40), as some of the traffic volume in excess of 3,000 vph diverts from I-70 at the Keystone-Rural ramps. Diversion can take the form of choosing not to enter I-70, as well as exiting from I-70. This diversion rate will be estimated in the next section. Line (c,b) in Figure 2 represents a return to normal flow rates after the queue is no longer visible. The area of the polygon 0, a, b, c, d represents the total delay in the queue.

Delays to Diverted Traffic

When approaching drivers become aware of a queue ahead, each must make a new decision as to the best route to follow. To portray driver reactions using a T/A model that gives only final equilibrium link loadings requires some care. The following steps were devised to calculate delays for Case 1.

1. Establish Case 0 equilibrium link loadings for the entire corridor.
2. At t = 0, the incident on link (35,40) occurs. The area of triangle 0, e, d in Figure 2 is the queueing delay on link (35,40) through time...



t_1 = time at which a vehicle enters the queue
t_2 = time at which the queue becomes visible to approaching traffic
t_3 = time at which the lane blockage is removed
t_4 = time at which the queue becomes invisible again
t_5 = time at which the queue clears (becomes empty).

FIGURE 2 Graphical analysis of a transient queue.

3. At t_2 = 15 minutes, the queue has backed up within sight of the Keystone-Rural interchange. Modify the travel times in Step 1 by running a separate T/A loading for Corridor West with capacity of links (33,35) and (35,40) at 3,000 vph. Corridor West is that part of the network in Figure 1 that is affected by westbound traffic avoiding link (35,40). It consists of all links on Keystone Avenue and Rural Street (between nodes 1 and 10) and those west of this line. Apply the graphical queueing analysis to link (35,40) for this time period, until...

4. At t_3 = 25 minutes, the blockage is removed. Case 0 travel times will once again apply throughout the corridor except on link (35,40). On this link use Figure 2 to monitor the clearing of the queue, until...

5. At t_4 = 35 minutes, the traffic backup becomes invisible to approaching traffic as queue-clearing proceeds; diversion from I-70 ceases.

6. The queue clears (point b in Figure 2) at t_5 = 212 minutes.

The seemingly long time until the queue clears is due to the strict definition of a queue that is inherent in using Figure 2: as long as any entering vehicle is delayed (a horizontal line can be drawn from left to right between the traffic and service lines), a queue exists. The later stages of queue clearing are actually periods of congestion delay, much like the saturated flow conditions on link (35, 40) just before the incident, rather than a prolonged series of starts and stops. Ending the study period at t = 60 minutes provides a reasonable common basis for comparing Cases 0, 1, and 2.

The sequence of the preceding steps recognizes the changing observations of drivers in the corridor during the study period. It neglects detailed calculations of travel times during transition periods between the equilibria generated by the T/A model as being insignificant. The contributions of each step to the total travel time values in Case 1 are weighted by the duration of each step. Delay in the queue is calculated as the difference between the saturated flow travel time in Case 0 and the values calculated using Figure 2. The results in Case 1 were: 355 vehicle-hours of queueing delay on link (35,40) and 13 extra vehicle-hours in the rest of the network for a total of 368 extra vehicle-hours of travel time caused by the lane blockage. Flow entering link (35,40) was reduced by 757 vph (16 percent) while the queue was visible, according to the T/A output for Corridor West. This reduction is 55 percent of the volume in excess of that link's 3,000 vph capacity during the partial blockage.

AN INCIDENT WITH TRAFFIC ADVISORIES (Case 2)

This is the same lane-blocking incident as in Case 1. The only difference is that an airborne traffic advisory service is now in operation. Often, the Indianapolis traffic observer hears about incidents from ground observers before they are seen from the air. The region is too large to allow constant air surveillance of every trouble spot. Therefore, the Case 2 analysis is begun by assuming that 5 minutes will elapse between the time of the incident and the time it is reported on the radio.

As in Case 1, when a driver becomes aware of severely reduced capacity on a link ahead in the intended path, his or her route selection process must start anew. In this case, however, listeners to traffic advisories can plan ahead to avoid link (35,40). For example, westbound drivers, who have not reached node 19 have the additional option of exiting at Emerson. Again, the responses to these options were analyzed in two parts.

Delay in the Queue on Link (35,40)

Figure 2 can be applied again to calculate total delay, with the traffic flow line undergoing modifications as traffic conditions change. For Case 2, t_2 = 5 minutes, but it is defined here as the time at which the traffic advisory is broadcast on the radio. The time at which the removal of the blockage is announced--the Case 2 definition of t_4--is assumed to be 5 minutes after t_3, or at t_4 = 30 minutes. After the diversion rate is estimated using the T/A model, t_5 and the area of the delay polygon can be calculated.

Delays Due to Diverted Traffic

In Case 1 the new route selection process was initiated on the basis of a driver's direct observation of the queue. In Case 2 this direct observation is replaced in large part by a perception conveyed by the traffic observer's broadcast. What complicates the problem is that only A percent of the drivers have heard the advisory. The other 1-A percent will operate unaware, as in Case 1. A reduction in volume between nodes 19 and 33 of something less than A percent would be expected, to allow for those drivers who choose to postpone their diversion until node 33. An upper bound for this diversion rate can be found by setting the capacity of links (19, 21) and (21, 33) to 3,000 vph, as if all drivers perceived these approach links to link (35,40) being as congested as (35,40) itself. The T/A model produces a diversion rate of 22 percent for this situation. If 75 percent of the approach links' capacity is restored to recognize that only about 25 percent of the drivers may be listening to the traffic advisories, the T/A model result is a 10 percent diversion rate at the Emerson ramps (nodes 18 through 21).

With this early diversion possible, the total drop in traffic entering link (35,40) becomes 20 percent. Among listeners, the diversion rate is estimated to be 40 percent at Emerson and 79 percent at or before Keystone-Rural.

In calculating total delay, the lower actual travel times between nodes 19 and 33 in the T/A output were restored, because capacity there would not actually be reduced. Table 2 summarizes the calculations for all three cases. The obvious reason for reduced delay in Case 2 is that the traffic advisory prevented the queue from filling too rapidly and, therefore, also had less of a queue to clear. The strict definition of a queue (Figure 2) was maintained until t = 166 minutes, but the Table 2 entries are only for the 60-minute study period. There was a 33 percent reduction (239 vehicle-hours versus 355) in queueing delay on link (35, 40). An examination of the link loadings elsewhere indicates a more subtle, but wider spread result of the traffic advisory. By allowing some drivers to divert away from an invisible queue, an increase of 7 vehicle-hours of travel time in the network exclusive of link (35,40) occurs. However, this diversion makes possible the 116 vehicle-hour saving in queueing delay on link (35,40) during the study period.

TABLE 2 Travel Time and Delay in the I-70 Corridor

	Total Travel Time (Vehicle-Hours)	Delay Due to Incident (Vehicle-Hours)	Δ Delay Case 2, Case 1 (Vehicle-Hours)
Case 0	1,125	–	–
Case 1	1,493	368	–
(In 35, 40 queue)	–	355	–
(In rest of network)	–	13	–
Case 2	1,384	259	109
(In 35, 40 queue)	–	239	116
(In rest of network)	–	20	-7

EVALUATION OF BENEFITS

Cities experience capacity-reducing incidents that will differ in frequency and severity. However, every conceivable incident need not be modeled in detail at every possible location to provide a reasonable basis for evaluating the impact of traffic advisory services. It should be sufficient to model the typical incidents that frequently plague a system during rush hour, then categorize each actual incident occurring over an evaluation period in terms of these standard incidents.

In the I-70 example, 109 hours of delay time were saved by the traffic advisory service. If an incident of this severity occurs within the observation area about four times a week, if delay time saved has the average value of $3.50 per hour per person, and if average vehicle occupancy is 1.5 persons, then $120,000 in travel time is saved each year by this service (see Figure 3). This annual value can be based on a series of analyses for typical incidents of different severity (fraction of lanes blocked, sight distance) and venue (expressway, arterial). The results can be combined by means of a weighted sum:

$$D = \sum_i f_i \cdot E[d_i] \qquad (2)$$

where

D = total travel time saved,
f_i = frequency of incident type i, and
$E[d_i]$ = expected value of delay saved after incident i.

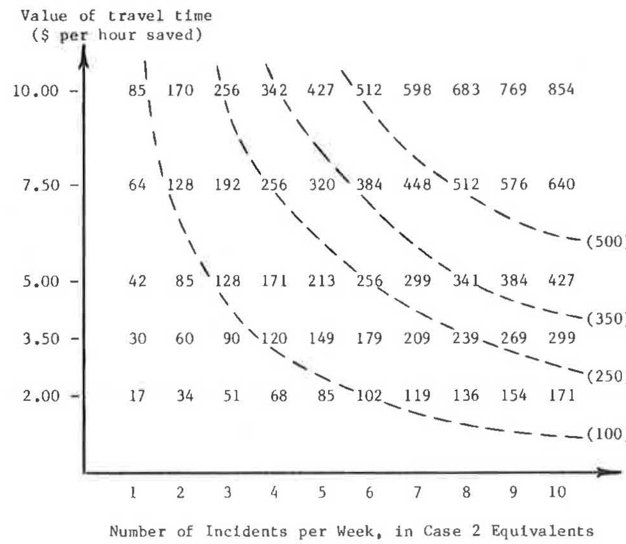


FIGURE 3 Annual benefits of travel delay saved by traffic advisory service (Case 2) for various combinations of incident frequency and value of time. An average of 1.5 occupants per vehicle. Dollar value entries are in thousands.

Using Figure 3, a current or potential provider of a traffic advisory service can compare the annual benefits and annual costs of the service. Figure 3 is drawn for the incident described in this paper. If the equivalent of only three such incidents occur in the Indianapolis surveillance area each week, if the value of travel time saved is $5.00, and if the annual cost to provide the service is $350,000, then 37 percent ($128,000) of that cost can be justified by the annual benefits of reduced delay.

CONCLUSIONS

A framework is introduced for analyzing the role of airborne traffic advisories in alleviating congestion caused by incidents that cause sudden reductions in roadway capacity. Although refinements in the procedures presented are possible, the techniques used produce believable results without excessive efforts.

The results of Case 2--an incident with informed drivers--revealed a large improvement in traffic flow over the uninformed drives in Case 1. Graphical queueing analysis estimated a 33 percent reduction in delay on link (35,40) when only 10 percent of the traffic headed for the trouble spot was able to leave I-70 just one exit ramp earlier, having heard the traffic advisory. Another 10 percent will exit at Keystone-Rural, responding to the radio report.

A means of combining a variety of incidents for evaluating economic benefits was suggested. The isoquant display of Figure 3 allows the analyst flexibility in dealing with such hard-to-specify values. The sample calculations demonstrated sizable economic benefits (saved travel time) that the advisory service provider could cite to justify its costs. Such findings could be used by a radio station to quantitatively support the public service element of the advisory's mission. This part of the station's programming may therefore become more attractive to both listeners and advertisers. The benefits accruing to the traveling public are, of course, otherwise unrecoverable. In the absence of airborne advisories provided by radio stations, local governments could use the methods described in this paper to evaluate the idea of providing or subsidizing such a service. It should be pointed out that surface-based advisories are nearly as effective as airborne services, are much less expensive, and can be analyzed with the methods described in this paper.

ACKNOWLEDGMENTS

The analysis in this paper is based on data supplied by Ron Greiwe of the Indianapolis Department of Transportation and Kirk Mangold of the Indiana Department of Highways. The authors also thank traffic observer "Big John" Gillis and Program Director Jed Duvall of Radio Station WIBC in Indianapolis for explaining the details of their airborne traffic advisory operation. Finally, the helpful comments of several anonymous reviewers and the word processing skills of Bonnie Misner are gratefully acknowledged.

REFERENCES

1. Traffic Assignment Manual. Report 5001-00060. FHWA, U.S. Department of Transportation, 1973.
2. R.W. Eash, B.N. Janson, and D.E. Boyce. Equilibrium Trip Assignment: Advantages and Implications for Practice. In Transportation Research Record 728, TRB, National Research Council, Washington, D.C., 1979, pp. 1-8.
3. J.G. Wardrop. Some Theoretical Aspects of Road Traffic Research. Proc., Institution of Civil Engineers, Part II, No. 1, 1952, pp. 325-378.
4. Y. Sheffi. Traffic Assignment and Network Equilibrium--A Short Review of the State of the Art. Presented at the 62nd Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 1983.
5. Institute of Transportation Engineers. Transportation and Traffic Engineering Handbook. W.S. Homburger, ed., Prentice-Hall, Inc., Englewood Cliffs, N.J., 1982.
6. C.L. Dudek and S.H. Richards. Traffic Capacity Through Urban Freeway Zones in Texas. In Transportation Research Record 869, TRB, National Research Council, Washington, D.C., 1982, pp. 14-18.

Publication of this paper sponsored by Committee on Motorist Services.

Road Surface Reflectance Measurements in Ontario

W. JUNG, A. KAZAKOV, and A. I. TITISHOV

ABSTRACT

A photometer for measuring surface reflectance matrices of dry pavements was developed at the University of Toronto and has been used to measure the light reflectance properties of many pavements in Ontario. The laboratory measurements were carried out on 6-in. diameter samples, and statistical deviations were carefully studied to determine the feasibility of classifying the pavements in accordance with Committee International de l'Eclairage (CIE) and (more recent) Illumination Engineering Society (IES) practice and to establish a reliable sampling procedure. The measured pavement types were classified on the basis of their reflectance parameters (Q0, S1, S2) established as average values from reflectance matrices of at least three samples. These parameters were found to be dependent on aggregate polishing and stone brightness, and on accumulated traffic load. The influence on the light reflectance of the viewing angle α being different from the standard 1 degree was also studied, and it was found that all parameters tend to decrease with increasing angle α. The findings indicate that reflection properties can be measured with fair accuracy and confidence, but that significant fluctuations of the reflectance properties can occur on a given pavement. The IES or CIE proposal for four specularity classifications under dry conditions can be recommended; however, the brightness parameter, Q0, was found to be of greater significance in lighting than originally anticipated and more accurate values should be established as discussed in this paper.

The Illumination Engineering Society (IES) has recommended the luminance method of lighting design for expressways and freeways (1), and there are some efforts to introduce even more advanced design methods based on luminance contrast or visibility index. All of these computer-based design methods require information on light reflectance properties of pavement surfaces for computational input of data.

Sponsored by the governments of Ontario and Canada, the University of Toronto has built a photometer for the measurement of road surface reflectance matrices based on the concepts originally developed by the Committee International de l'Eclairage (CIE) (2). The Ontario system features an automated control of positioning, reading and recording, and a conveniently small sample size [6 to 8 in., (150 to 200 mm)] obtained from normal pavement cores, although at least three samples are needed to classify a pavement type (3).