Traffic Management During Road Closure

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The overall objective of this research was to provide potential users, particularly small municipalities, with a basis for selecting the travel demand analysis package best suited for evaluating traffic management alternatives during road closures. Four travel demand analysis packages (QRS II, System II, TRANPLAN, and MINUTP) were studied and rated with respect to 14 characteristics. Of the four software packages, the two top-rated packages were used to estimate traffic in a network. The performance of the two packages was evaluated on the basis of predictive accuracy, modeling deficiency, comprehensiveness, and compatibility with other software. It was found that both packages could be used to evaluate the impact of changes in network and zonal characteristics on travel demand. However, both packages are not developed to the extent that is needed to generate all the information needed to determine the alternative traffic management strategies. Thus, it is suggested that potential users specify the primary functions for which it is to be used before investing in a software package.

The decentralization of local government functions in most large cities has led smaller entities to become more responsible for planning, designing, and managing the transportation systems. In addition to the routine tasks, such as evaluation of proposals for land development, road closures for infrastructure maintenance, changes to parking facilities or regulations, and numerous others that may affect traffic conditions, these entities are now responsible for formulating local area land-use and transportation plans. Thus, if each small municipality had its own data base and microcomputer-based analytical package, the impact on the network due to an extension of the city or a major development could be analyzed in more detail and at a comparatively smaller cost than if it were done manually.

A user survey recently conducted by the Transport Association of Canada (*1*) revealed the general consensus that the right combination of software and hardware can easily overcome many of the existing time and staff constraints faced by agencies. The survey data also show that planning models are being used for a multitude of purposes, including the examination of different scenarios, policies, and assumptions. However, the selection of the appropriate software package from several similarly priced and marketed products is not an easy task. Brochures and demo disks are often inadequate to assess the full array of underlying analytical tools or the input data, equipment, and training/educational requirements. Thus, one needs to establish certain criteria for evaluating the characteristics of each package in relation to the needs.

This article is based on a study undertaken to examine the impact of a proposed road closure on travel demand and the level of service of the road network in the city of Verdun, Montreal, Quebec. The primary objective of the study was to identify traffic management options during the period when the road would be closed for pavement reconstruction and utility upgrading. This situation, where a principal artery (Wellington Street) was closed for 4 months, was an ideal case study to better understand the pros and cons of using transportation planning software for evaluating traffic management alternatives when data and computer skills are limited.

Four travel demand analysis software (TDAS) packages—TRANPLAN (*2*), MINUTP (*3*), System II, (*4*) and QRS II (*5*)—were examined and rated with respect to 14 characteristics. From these four, the two top-rated TDAS packages (System II and QRS II) were applied to determine the optimal work-zone traffic diversion plan.

TDAS EVALUATION

The principal features of the four TDAS packages examined are summarized in Table 1. These four were evaluated on the basis of 14 criteria, some of which have been used previously by Khisty and Rahi (*6*) and the Transportation Association of Canada (TAC) (*1*). They were then ranked (10, indicating best and 0 indicating worst) with respect to each of the 14 criteria according to the degree to which they satisfied the needs. All four packages could be used in this area; however, according to the total points shown in Table 2, System II and QRS II were selected for further analysis.

STUDY AREA AND DATA COLLECTION

Verdun is a mature residential community with limited commercial and industrial activities. As shown in Figure 1, the city is bounded by the St. Lawrence River to the east and the Lachine Canal to the west and by the two cities Montreal and LaSalle to the north and south, respectively. Thus, points of access to the city are restricted to the bridges across Lachine Canal and one point to the north leading to Montreal. The two border arteries to the east and west are the main links to the southern city of LaSalle. There is also a dense central business district, which accounts for approximately 10 percent of the total land area of Verdun and contains mostly retail activity. Verdun was divided into 20 traffic zones corresponding to the census tracts, and all the external trips were considered as 10 external zones.

With the exception of traffic count data for the major arteries from May 1990, Verdun possessed no other traffic data. Therefore, the basic input data were collected from the following sources:

- Network data such as capacities, intersection types, control measures, etc., were compiled through site visits, and a 1-hr cordon count was made during one weekday afternoon peak period.
- Land use types in each zone were obtained from the city's master plan.
- The population and information on dwelling units were obtained from Statistics Canada's 1988 Census records.

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TABLE 1 Basic Features of QRS II, System II, TRANPLAN, and MINUTP

FEATURE	QRS II	SYSTEM II
Trip End Estimates	default parameters	user input trip rates
Trip Distribution	default parameters	user input friction factors
Mode Choice	need to build transit network	incomplete
Assignment	all-or-nothing in default mode	multi-path based on chosen delay/flow model
Graphics	only print screen option	presents information in many forms and CAD options
Network Performance	travel time and volume tables	travel time, volume, node/link, LOS.
Sensitivity Analysis	node and link codes change every time a change is made, thus difficult to keep track.	facilitates comparison of performance under different conditions.

FEATURE	TRANPLAN	MINUTP
Trip End Estimates	user input trip rates	user input trip rates
Trip Distribution	user input friction factors	user input friction factors
Mode Choice	splits trips between two modes.	splits trips between two modes.
Assignment	all-or-nothing, stochastic	all-or-nothing, stochastic
Graphics	presents information in many forms.	presents information in many forms.
Network Performance	many options including travel time, volume, LOS	total volume, directional volume, volume capacity ratio, congested speed
Sensitivity Analysis	accepts surveyed O-D table, and link volumes for calibration.	facilitates comparison of performance under different conditions.

- The number of retail and nonretail employees were estimated in proportion to the gross floor area of the respective activities in each zone.
- The zonal trip-generation rates were obtained from the Institute of Transportation Engineers manual on trip generation (*7*).
- Since the transit ridership figures were not available, a fixed share of 10% was used.

TRIP ASSIGNMENT

In each of its four modules (generation, distribution, mode choice, and assignment), QRS II contains default parameters based on the NCHRP Report 187 (*7*). Users have the option of using either these default parameters or other values. In the present case, all the available default values were used. For instance, it was assumed that observed volumes were unavailable, and the default function based on area size was chosen without calibrating the gravity model to the existing conditions. Likewise, the default assignment procedure was used with no adjustments to link capacities or travel time factors. Moreover, because QRS II is not geared for treating zones with land use other than residential or commercial, the zones that contained an arena and a large municipality parking facility were treated as external zones. The final results are given as observed to estimated p.m. peak volume ratio (R_k) for several selected links in Table 3.

The same zonal and network configuration used in QRS II was adopted for System II. To minimize the iterations and to determine the extent to which the distribution model parameters are transferable, the travel-time-based default friction factors from QRS II were used as the starting values for the calibration. The input parameters for trip-generation analysis were taken from the ITE manual on trip generation (*8*). The assignment was based on an exponential delay/volume function. A summary of R_k for System II is also given in Table 3.

TABLE 2 Applicability Scores of the Models—0 (Worst) to 10 (Best)

		Models			
	Criteria	TRANPLAN	MINUTP	SystemII	QRS II
1	Data required	6	6	6	10
2	Cost	4	6	10	10
3	Run time	8	8	8	10
4	Flexibility	10	8	10	4
5	Input parameters	6	6	6	10
6	User friendliness	4	4	8	10
7	Comprehensiveness of output	8	8	10	6
8	Graphics display	8	6	10	4
9	On-screen help menu	6	6	8	6
10	Reference manual	7	7	9	6
11	Hardware needs	10	10	10	10
12	Knowledge on modeling	6	6	8	10
13	Preparation time	6	4	6	10
14	Subarea analysis option	10	10	10	0
	Total	99	95	119	106

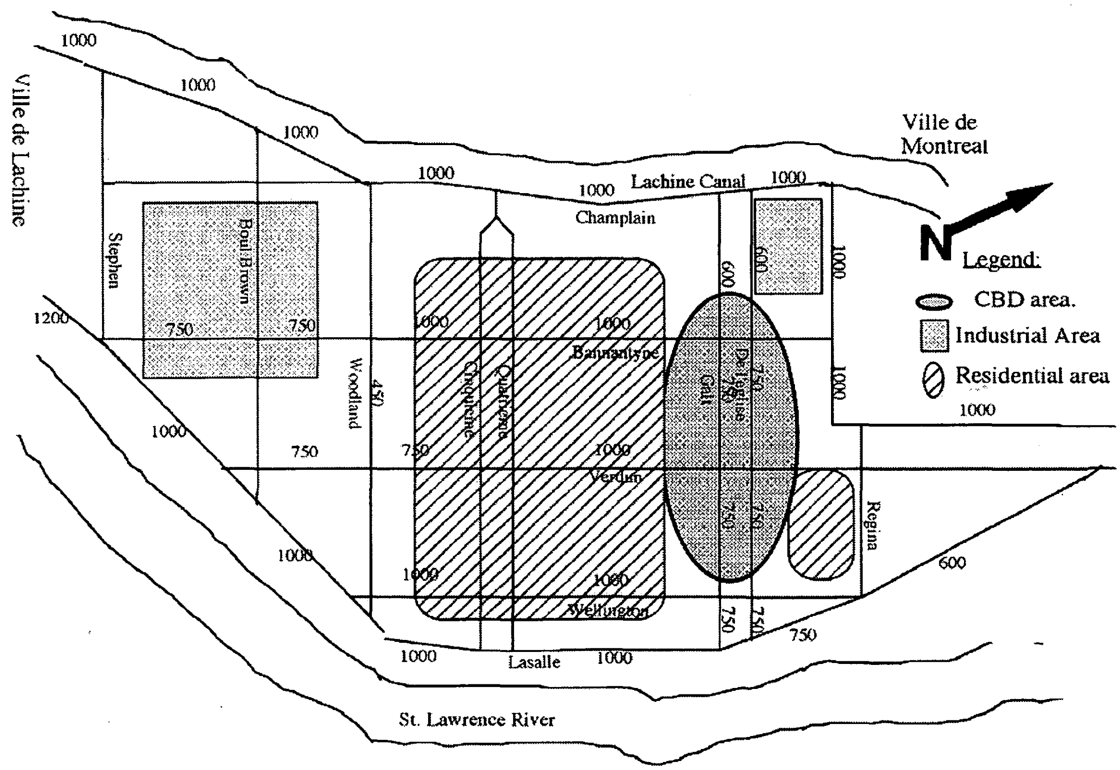

FIGURE 1 Observed p.m. peak link volumes.

TABLE 3 Ratio of Observed to Estimated Volumes (R_k) on Selected Links

LINK NAME	QRS II	SYSTEM II
Lasalle	0.90	1.56
Wellington	0.88	0.80
Verdun	0.87	1.04
Bannantyne	0.97	0.88
Champlain	0.95	0.97
Woodland	0.78	0.64
Galt	6.99	1.23
De l'eglise	2.45	1.44
Mean of R_k (MR)	1.85	1.07
Std. dev. of R_k (SD)	2.15	0.31

$R_k = O_k/E_k$

where: O_k = Observed Volume on link k,
E_k = Expected Volume on link k.

$$MR = \sum_{\text{all } k} \frac{R_k}{N}$$

$$SD = \sum \frac{(R_k - MR)^2}{(N-1)}$$

ALTERNATIVE TRAFFIC MANAGEMENT STRATEGIES

Because the objective of this exercise was to identify the traffic diversion options, it was decided to determine the various means of ensuring that traffic is reassigned according to the modeled form during the closure of Wellington Street. A discussion of the procedure adopted for each TDAS follows.

System II

There are two ways to identify the traffic diversion options. First, one could search for all origin-destination (O-D) pairs in each of the links that would experience a change in flow after the closure. Accordingly, signs could be placed at the appropriate nodes (intersections) to divert the traffic to the alternate links with the hope of achieving the modeled state. However, because System II does not have such a search procedure (select link analysis), it would have taken a considerable amount of time to perform a manual search from the trip tables. Thus, it was decided to use the second approach, which is to simply work backward from the existing conditions, that is, determine the O-D matrix for trips along the entire length of Wellington Street before closure, and reroute these trips during closure to achieve the modeled assignment without Wellington Street.

As expected, three groups of trip ends were identified as the primary users of Wellington Street: (*a*) trip ends terminating in zones bordering on Wellington Street, (*b*) trip ends originating in zones bordering on Wellington Street, and (*c*) through trips connecting to and from Boulevard LaSalle at the southern end of Wellington Street.

It was also found that most of these p.m. peak trips had origins or destinations in zones to the northwest, the north, and, to a lesser extent, the south. Thus, the system's shortest path algorithm was used to determine the optimal routes for rerouting trips between the zones identified above and five external zones: one in the north (Montreal), two in the northwest, and two in the south.

These paths (shown in Figure 2) enabled the identification of the nodes at which the detour signs should be placed. Also, because the shortest paths are the paths from the skim tree based on the appropriate delay/flow function, the detours would ideally result in the expected assignment pattern.

As mentioned earlier, the links that would experience significant changes in level of service due to these detours could be easily addressed through simple traffic management measures involving parking. For instance, field surveys of the affected links, such as Boulevard LaSalle, indicated that capacity could be increased to minimize the impact by simply changing parking regulations in the vicinity, that is, removing parking restrictions on the cross streets to permit those presently parked on Boulevard LaSalle to park on these cross streets during the peak periods.

QRS II

As for identifying points of diversion, this system also lacks an algorithm for searching the O-D matrix for a given link. Moreover, the shortest path algorithm is not geared for identifying the path between a specific O-D pair; instead, the algorithm identifies all shortest paths between a specific node and all other nodes in the network. Thus, the procedure used in conjunction with System II for selecting the detour points will involve much more tedious manual work than that of QRS II. Under the circumstances, one will be required to make educated guesses on the basis of the expected assignment given in Figure 2 about where to place the detour signs.

TDAS PERFORMANCE

Estimation Errors

The performance or accuracy of the selected models can be evaluated on the basis of either parametric or nonparametric tests as suggested by James (*9*). In the present case, three parametric tests—observed to expected volume ratio on link *k* (O_kE_k), mean ratio (MR), and percent RMSE—were used.

According to the O/E ratios in Table 3, QRS II estimation error is approximately 20 percent on most links, except the Galt and de l'eglise Streets. In terms of the mean ratio (MR), QRS II overestimates link volumes by an average of 95 percent with a standard deviation of 215 percent. The QRS II percent RMSE, on the other hand, is 39 percent.

In comparison, assignment errors of System II seem much smaller. The largest error according to O_kE_k, as shown in Table 3, is 56 percent. MR is 1.07 with a standard deviation of 0.31, and the percent RMSE value is 28. However, there are more links than with QRS II where the assigned volumes are greater than plus or minus 20 percent of the observed volumes. Most of these links carry volumes in the range of 400 to 800 vph (vehicles per hour), as shown in Figure 3.

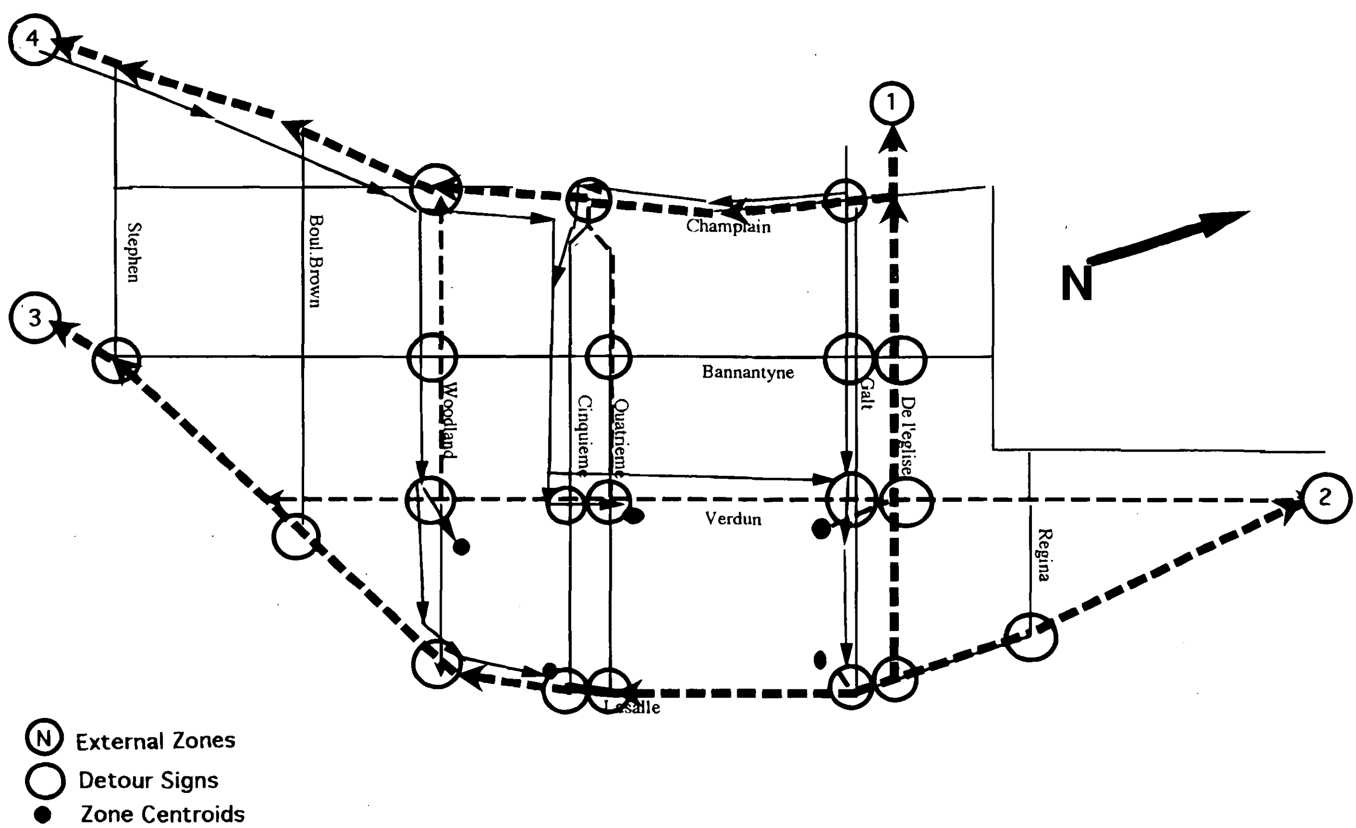

FIGURE 2 System II estimated shortest paths from selected zones.

Both packages considered here were indeed sufficient to model the travel patterns in Verdun with reasonable accuracy. From the frequency distribution in Figure 4, it is evident that differences between estimated and observed link volumes are relatively small.

Significance of Errors

A series of statistical tests was performed as shown in Table 4 to verify the significance of the differences between estimates of the two TDAS packages. It is seen from Table 4 that, with QRS II, volumes on 15 links are underestimated on the average (μ_u) by 291 vph, and the volumes are overestimated in 15 links by an average (μ_o) of 401 vph. The average μ_u and μ_o of System II were 205 and 269 vph, respectively. The t-values indicate that in both cases (QRS II and System II), the differences between μ_u and μ_o are significant. But, the mean differences (MDs) were not significantly different from one another at the 5 percent level.

The two packages were also compared in relation to the reassigned volumes after eliminating Wellington Street from the network. The frequency distribution of the changes in link volumes without Wellington Street is shown in Figure 5. Statistical tests were performed on two hypotheses about overall system performance. The first hypothesis was that the mean increase in traffic volume on certain links is not significantly different from the mean decrease in others after the closure. If everything else were the same, this means that the deterioration of the level of service (LOS) in some links would be offset by an improvement in the LOS in others. The second hypothesis was that the mean deviation (increases and decreases) after the reassignment with QRS II equals the mean deviation with System II reassignment. This hypothesis means that even without calibration, QRS II can produce an assignment similar to a calibrated model. It can be seen from Table 4 that both hypotheses are acceptable at the 5 percent level of significance.

COMPARISON OF PACKAGES

Despite ignoring the transit ridership and parking facilities, the ratio of observed and estimated volumes shown in Table 2 are in reasonable accordance with the observed volumes. Although the estimation errors on the two links, Galt and de l'eglise, seem unusually high, according to both Robbins (*10*) and Easa (*11*) they can be regarded as insignificant. Robbins (*10*) notes that it is common to see large discrepancies between observed and synthesized volumes, regardless of the sample size. Such errors are said to result mainly from deficiencies in modeling practices, and, until they are resolved, existing tools will have to suffice.

Each package was also found to have certain other merits and demerits. Neither system can generate all the information needed for decision making simply through pull-down menus. For instance, as in the case of finding the trips likely to be affected during road closure, the user must use trip tables to identify them.

QRS II's inability to treat all different types of land use in zones with mixed land use is a serious limitation. Despite the closeness of the observed and modeled volumes as compared with System II, this limitation makes it unsuitable for users who may need to perform site impact analyses.

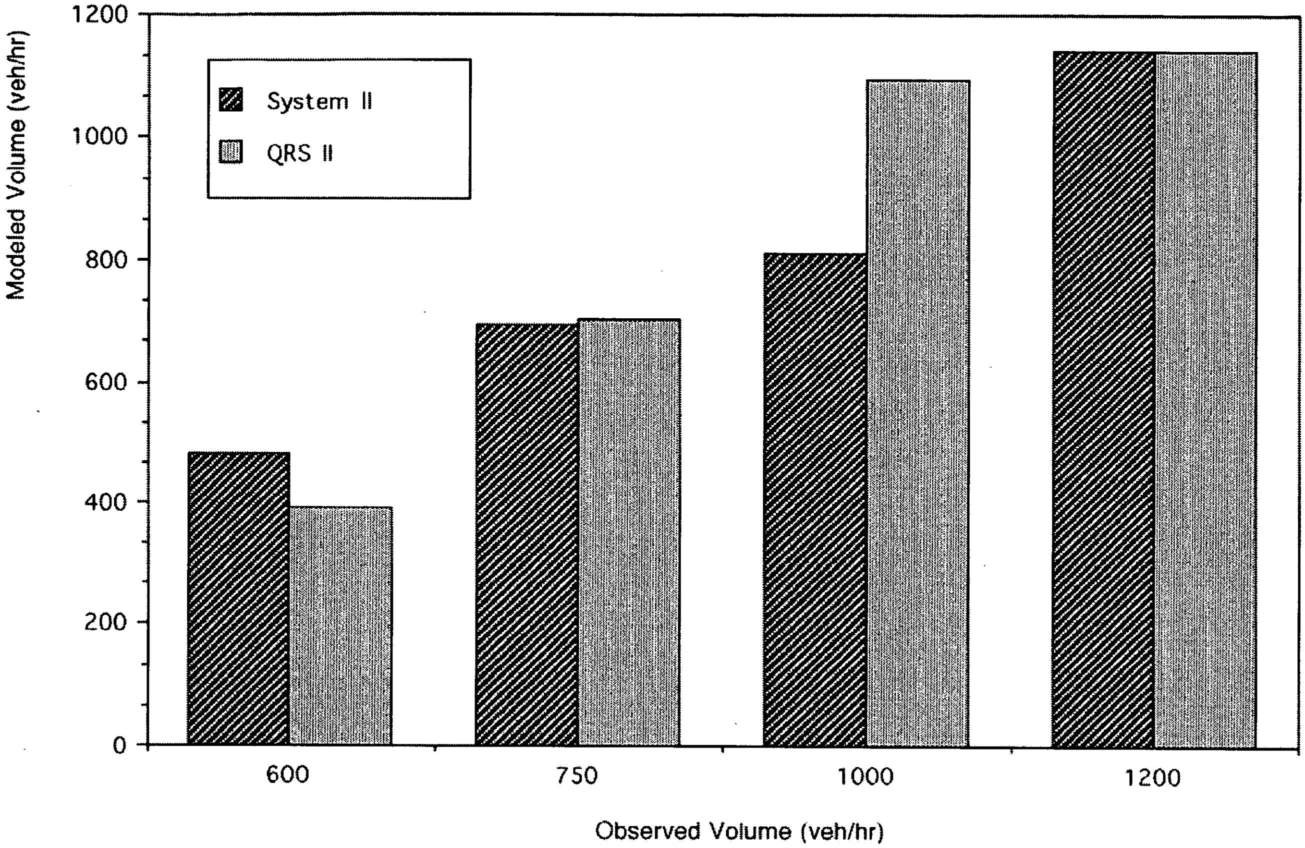

FIGURE 3 Comparison of observed and modeled link volumes.

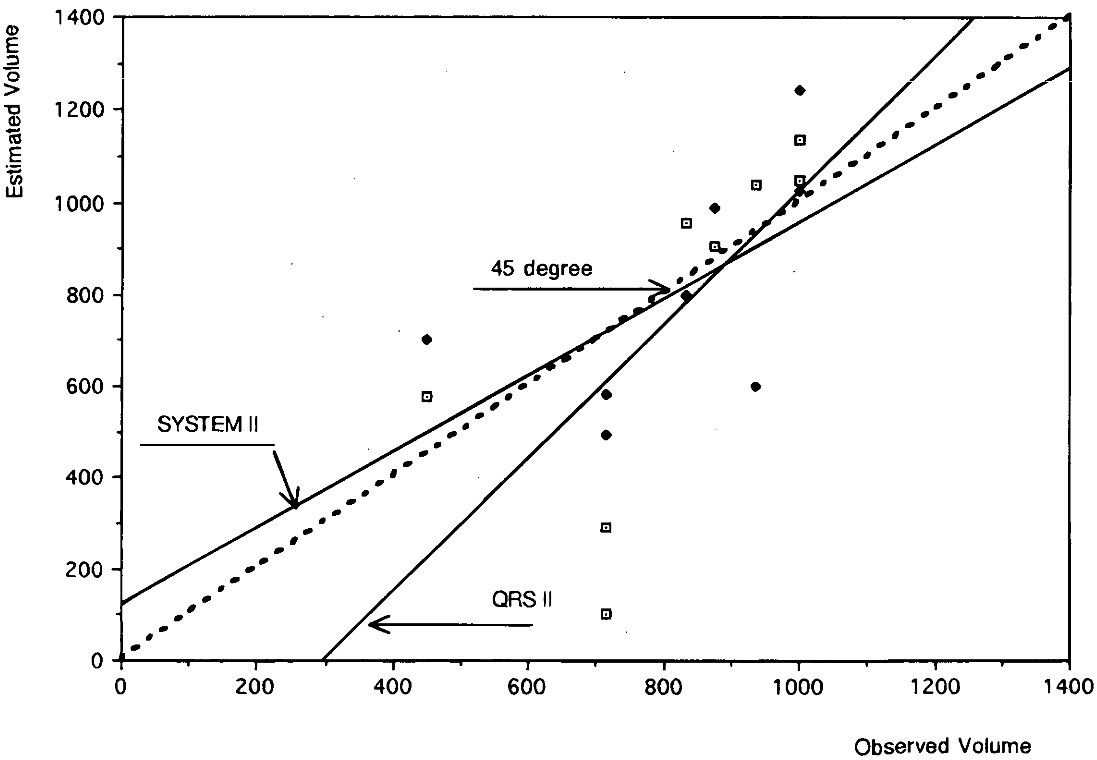

FIGURE 4 Estimation accuracy of QRS II and System II.

TABLE 4 Statistical Tests

	# of Links	MD	St. Dev.	Significance	% RMSE**
(1) QRS II					
(a) Links with $O_k<E_k$	15	-291	274		
(b) Links with $O_k>E_k$	15	401	201		
*(c) All links	30	346	339		39.28
(d) Test of MD in 1(a) and 1(b)				t =1.21	
(2) SYSTEM II					
(a) Links with $O_k<E_k$	15	-205	124		
(b) Links with $O_k>E_k$	14	269	236		
*(c) All links	30	237	267		28.15
(d) Test of MD in 2(a) and 2(b)				t = 0.80	
(3) Test of MD in 1(c) and 2(c)				z = 1.39	
(4) SYSTEM II VS. QRS II Estimated change in volume (from before to after closure)					
(a) SYSTEM II					
(i) Links with $O_k<E_k$	25	-232	335		
(ii) Links with $O_k>E_k$	16	63	78		
*(iii) All Links	49	148	344		
(iv) Test of MD in 4.a(i) and 4.a(ii)				t = 1.91	
(b) QRS II					
(i) Links with $O_k<E_k$.	34	129	173		
(ii) Links with $O_k>E_k$	13	73	75		
*(iii) All links	49	101	188		
(iv) Test of MD in 4.b(i) and 4.b(ii)				t =1.08	
(5) Test of MD in 4.a(iii) and 4.b(iii)				z = 0.02	

$$\text{Mean Difference} = \text{MD} = \sum_{\text{all k}} \frac{(O_k - E_k)}{N}$$

$$^{*}\ \text{Mean Absolute Difference} = \text{MAD} = \sum_{\text{all k}} \frac{|(O_k - E_k)|}{N}$$

** Root Mean Square Error (RMSE) - observed vs. expected

Both packages are compatible with the hardware associated with IBM AT or PS–2 systems. Both QRS II and System II can process a network of the size of Verdun (49 links) on a PS–2/Z70 in approximately 20 min. However, the user needs to interact more with System II because each of the subprograms representing the four-stages of the conventional travel demand modeler modeling technique requires independent processing (i.e., needs to be run in batch mode).

QRS II's data input is via software specific templates, and output files are not transferable to other systems. Hence, additional processing, such as for calculating noise indices, will need to be performed using specially created data files. On the contrary, System II files ware directly transferable to a geographic information system (GIS) containing land use data, and the computations can be performed within the GIS. Another criticism of QRS II's output format is that the link and node identification numbers change every time the program is executed. This makes it difficult to track changes in link volumes from one run to the next.

ENVIRONMENTAL IMPACT

The impact of traffic management schemes during construction on many areas other than delays and LOS are rapidly becoming critical. Concerns about the changes in traffic-generated noise levels, air quality, and safety appear to be some of the issues that have been brought to the attention of the responsible agencies.

In this context, a limited analysis was performed of the expected changes in traffic noise using a noise prediction model by Blair and Lutwak (*12*). From this simple model, the L_{eq} at 7.5 m from the centerline of the nearest lane was computed for each link in the network using the following equations:

$$L_{eq}(\text{cars}) = 10.5 \log N + 23 + 10 \log 24/T$$

$$L_{eq}(\text{single events}) = L_{\max} + 10 \log N - 47 + 10 \log 24/T$$

$$L_{eq}(\text{composite}) = 10 \log \sum_{i=1}^{n} 10^{[L_{eq}^{(i)}/10]}$$

where

N= automobile flow during observation time,
T= observation time,
$L_{\max}$= peak noise level, and
n= different noise component.

The link noise levels before and after the closure of Wellington Street were computed to identify the links that would experience a

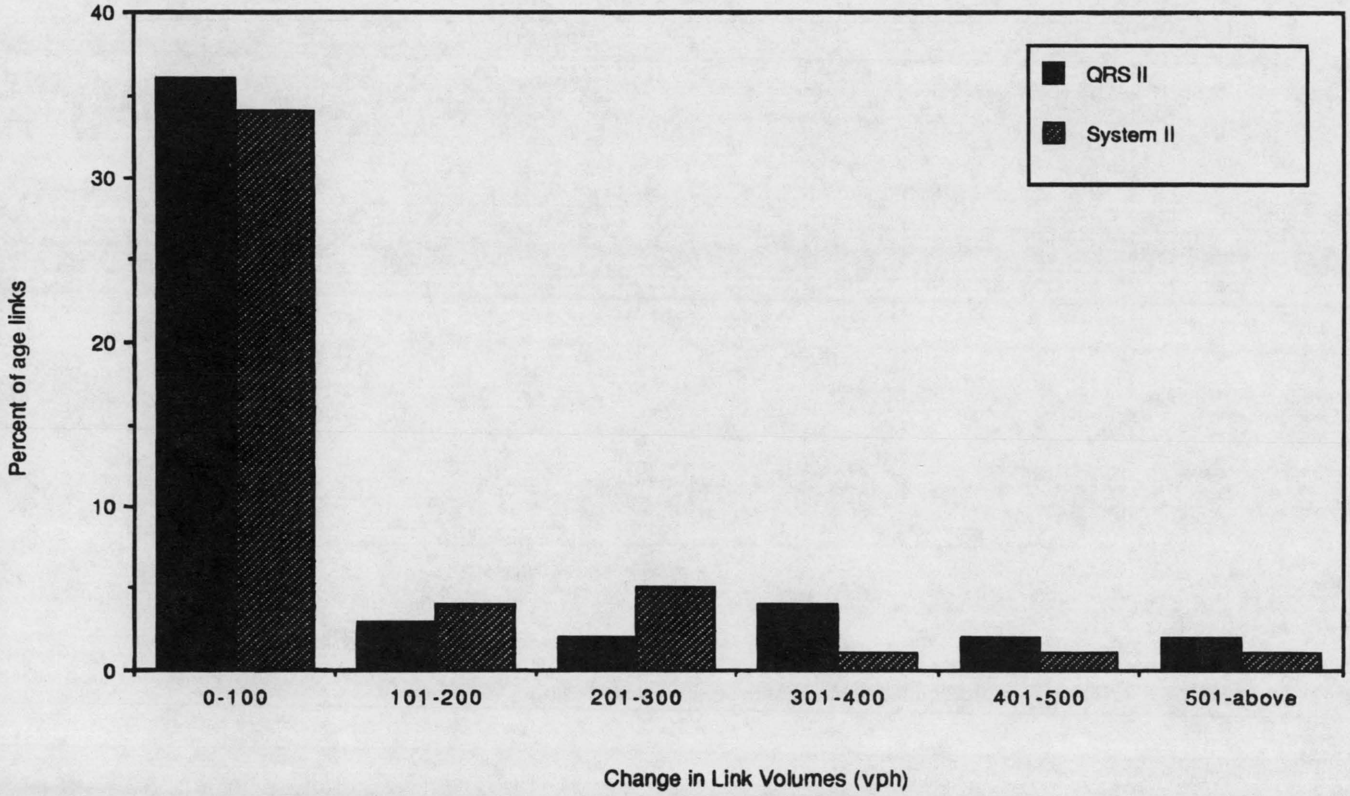

FIGURE 5 Frequency distribution of changes in expected volumes without Wellington.

change. The distribution in Figure 6 suggests that 75 percent of the links would experience less than a 5 dB increase, although, in terms of intensity, this corresponds to an increase of between 100 and 200 percent, the noise level if no link reached the 55 dBA suggested for residential zones. Thus, the detour plan shown in Figure 2 was retained as the preferred alternative.

For the purpose of examining the efficiency of the reassignment in relation to noise, a noise index (*NI*) was defined as:

$$N_{ij} = \frac{\text{change in } L_{eq} \text{ on link } (i,j)}{[\text{linear density of population on link } (i,j)]}$$

where linear density equals the average building occupancy (persons/m^2) multiplied by the total building area along link *ij* divided by twice the linear length (km) of link *ij*.

In the analysis, the noise index after closure (NI_{ija}) was computed manually for each link *ij*, and average noise index (NI_a) was estimated. Then, using NI_a as the threshold value, all links with $NI_{ija} > NI_a$ were identified and deleted from the network, and the traffic was reassigned. However, it was found that the new mean (NI'_a) was significantly larger than mean NI_a at the 5 percent level of significance. Therefore, the first detour plan given in Figure 4 was taken to be the most environmentally favorable.

CONCLUSIONS AND SUMMARY

The rate of arrival of new transportation planning software in the market indicates the growing demand for such tools. The declining price of hardware and the need to make the maximum use of limited personnel should soon entice many local authorities to adopt these tools, which are many times easier to understand and use than the preceding generation of mainframe-based packages. However, given that every software package is not necessarily designed to perform all tasks, it could mean more work than before, unless the selection is preceded by a complete review of the needs.

QRS II and System II were chosen from a sample of four popular TDAS packages. Their application to a basic traffic management problem demonstrated the need to know the systems limitations before selection. For instance, it was found that several tasks, such as finding O-D pairs of trips on a particular link, had to be performed manually. Moreover, the effects of transit services and intersection delays on trip distribution or assignment were difficult to assess. Thus, the trade-off between cost and versatility needs to be carefully considered before selecting a package.

Finally, regardless of the limitations, it became evident that these tools help users examine many detour alternatives under different scenarios. Moreover, once the area has been coded and entered, and the system models have been calibrated, updating and maintaining the data bases are minor tasks. Thus, when small local authorities assume broader roles than simply responding to the routine requests for road closures, development permits, or Transportation Systems Management (TSM) proposals from numerous sources, a fully calibrated software package will undoubtedly be a tremendous asset, particularly for testing alternatives. It is a tool that nontechnical persons can use to develop reports and other data for the analysts and decision makers.

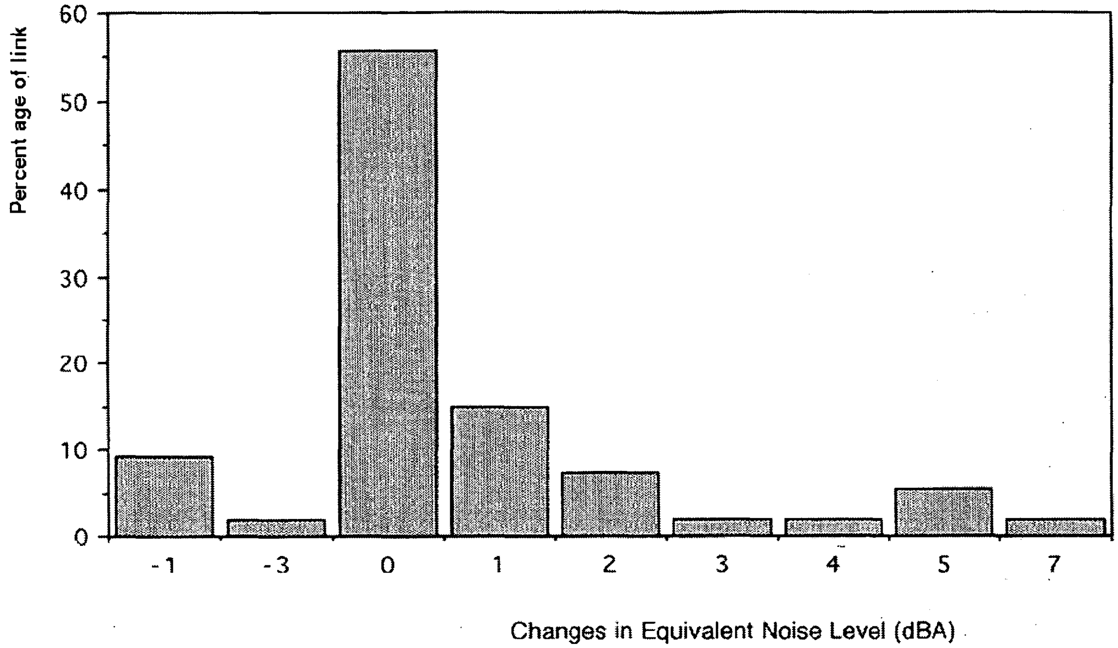

FIGURE 6 Frequency distribution of changes in noise level after closing Wellington.

ACKNOWLEDGMENTS

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REFERENCES

1. *Transportation Planning Models in Canada, Volume 1: Future Directions.* Transportation Association of Canada, Ottawa, Ontario, 1990.
2. TRANPLAN (Version 7.0) and NIS (Version 3.0) User Manual. The Urban Analysis Group, Calif., 1990.
3. MINUTP Technical Reference Manual. COMSIS Corporation, 1989.
4. System II User's Guide. JHK & Associates, Alexandria, Va., 1990.
5. Horowitz, A. J. Quick Response System II Reference Manual (Version 2.1). Center for Urban Transportation Studies, University of Wisconsin, Milwaukee, Wis., 1988.
6. Khisty, C. J., and M. Y. Rahi. Evaluation of Three Inexpensive Travel Demand Models for Small Urban Areas. In *Transportation Research Record 1283*, TRB, National Research Council, Washington, D.C., 1990.
7. *Trip Generation*, 4th edition. Institute of Transportation Engineers, Washington, D.C., 1987.
8. Transportation Research Board, *NCHRP Report 187: Quick-Response Urban Travel Estimation Techniques and Transferable Parameters User's Guide.* HRB, National Research Council, Washington, D.C., 1978.
9. James, M. L. Accuracy Evaluation Tests for Assignment Models of Large Traffic Networks. *ITE Journal*, Jan. 1987, pp. 36–40.
10. Robbins, J. Mathematical Modelling—The Error of Our Ways. *Traffic Engineering and Control*, Vol. 19, No. 1, Jan. 1978, pp. 32–35.
11. Easa, S. M. Traffic Assignment in Practice: Overview and Guidelines for Users. *ASCE Journal of Transportation Engineering*, Vol. 117, No. 6, 1991, pp. 602–623.
12. Blair, C. N., and S. D. Lutwak. Simplified Traffic-Noise-Prediction Model for Transportation and Land Use Planning. In *Transportation Research Record 789*, TRB, National Research Council, Washington, D.C., 1981.

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