ECONOMIC EVALUATION OF THE CHRISTCHURCH SOUTHERN ARTERIAL

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ABSTRACT: *The Christchurch Southern Arterial project has been the subject of four economic evaluation studies. The first was undertaken about half-way through the construction phase and gave a benefit/cost (B/C) ratio of 0.78 for completing the project. The second study entailed observing traffic flow patterns before and after opening of the arterial and gave a B/C ratio of 1.88 for the whole project. The third study involved using the strategic planning model for metropolitan Christchurch and gave an estimate of -0.26 for the whole project. The fourth and most recent study (described in detail in this paper) involved the use of the SATURN programme to modern traffic flow in the area around the new arterial, giving an estimated overall B/C ratio of 0.17. This paper discusses the sources of the wide variation in the estimates. Three major sources of inaccuracy are identified; the scaling of estimates of benefits for a small part of a weekday to give estimates of annual benefits, the consideration of only a sub-set of all trips through or within the area, and the scaling of benefits for a "basic section" by the traffic flow at a point on the basic section. It is concluded that procedures for the economic evaluation of road network improvements need considerable improvement, in order to obtain reliable estimates of the B/C ratios for such projects.*

ECONOMIC EVALUATION OF THE
CHRISTCHURCH SOUTHERN ARTERIAL

1. INTRODUCTION

The Christchurch Southern Arterial was initially conceived by the Canterbury Regional Planning Authority as a motorway, with the following objectives (C.R.P.A., 1967):

(a) to give relief to the network of arterial roads serving traffic in the area to the south and west of Christchurch (that is, Lincoln, Blenheim and Riccarton Roads).

(b) to provide free and convenient access to the central business district and beyond, for traffic from the region to the south and west of Christchurch.

The locations of the Southern Arterial and the other arterial roads, are shown in Figures 1 and 2.

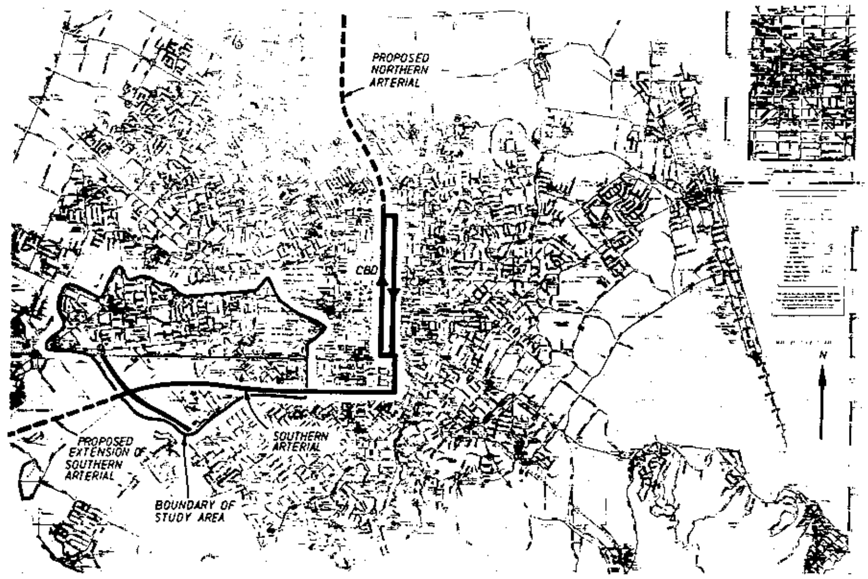

Fig. 1 - Location of Southern Arterial and Study Area

Construction of a Southern Motorway commenced in 1971, but work was halted in 1977 after expenditure of (1980) $4.85 million, pending an economic evaluation of the project. As a consequence of the economic evaluation, the project was scaled down from a four-lane motorway to a two-lane arterial. That economic evaluation indicated a benefit/cost ratio of 0.78 (Cox, 1977) for the extra expenditure to complete the arterial, the final cost of which turned out to be (1980) $10 million. The Southern Arterial was opened in May 1981.

In 1979, a before-and-after study of traffic patterns and flow characteristics in the vicinity of the Southern Arterial was commissioned. That study (Hasell and Scott, 1981, 1983a and 1983b) indicated that the project had been very worthwhile, giving an overall benefit/cost ratio of 1.88.

The considerable discrepancy between the above two estimates of the benefit/cost ratio lead to a third study, the aim of which was to provide an authoritative, reliable estimate of the B/C ratio. That study (by the Canterbury United Council) encountered some methodological problems, and was considered inconclusive. It gave an estimate of -0.26 for the B/C ratio (C.U.C., 1985).

The study reported here was undertaken as part of a study of uncertainty in the economic evaluation of transportation projects (Tai, 1987). There was clearly considerable uncertainty regarding the B/C ratio for the Southern Arterial, and the primary goal was to identify the sources of error and uncertainty in the estimation of the B/C ratio.

2. REVIEW OF PREVIOUS STUDIES

2.1 1977 Study

This study (Cox, 1977) was undertaken during a period of rapidly increasing awareness of the importance of economic evaluations of roading projects, and the method used reflected the lack of knowledge as to how such studies should be done. Since then, there have been three documents produced (M.W.D., 1980 and 1984, and Bone 1986), for the purpose of instructing practising engineers in the appropriate procedures for the economic evaluation of roading projects.

This study was commenced when work on the proposed Southern Motorway was well advanced, and there was a very real time constraint, which precluded a major study over an extended period.

It was estimated that even after a substantial scaling down of the project (from a four lane motorway to a two lane arterial), the discounted benefits would be substantially less than the discounted costs of completing the project to the reduced standard. Despite the result (a B/C ratio of 0.78), the project was completed.

The study involved:

(1) measuring travel times (using a test vehicle) for selected trips;

(2) measuring traffic volumes for selected links and intersections;

(3) manually reassigning traffic to the Southern Arterial, on the basis of the observed travel times on the existing network and the expected travel times on the network with the Southern Arterial;

(4) estimating the changes in vehicle operation and time costs, on the basis of the observed and expected travel times and speeds;

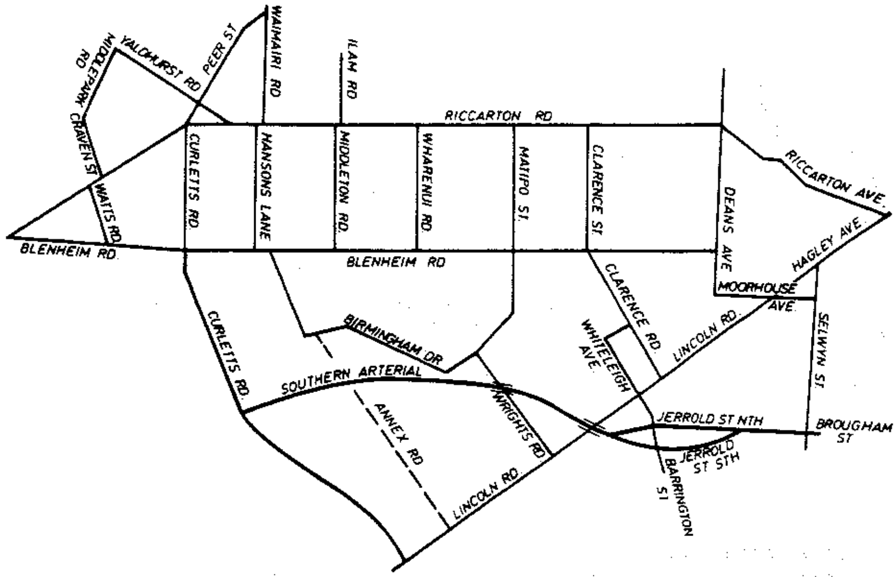

Fig. 2 - Road Network in Study Area

(5) estimating the B/C ratio, assuming an analysis period of 15 years, a discount rate of 15%, and a residual value amounting to about 4% of the total capital cost.

In doing this study, Cox followed the procedures which were subsequently embodied in Memo 98 (M.W.D., 1980).

There were a number of shortcomings, including;

(1) the omission of maintenance and accident costs; Cox expected these to increase rather than decrease, so the B/C ratio was considered an upper bound value;

(2) the omission of user cost changes for trips not expected to divert to the Southern Arterial;

(3) the traffic assignment was for a typical 24-hour period (weekday), with the 24-hour flows being obtained from scaling observed weekday peak and off-peak flows;

(4) the analysis period was only 15 years, which covered only 11 years of use of the road since it took four years to complete construction;

(5) the discount rate was 15% (a 10% discount rate is now used).

Simply changing the analysis period from 15 to 25 years and the discount rate from 15% to 10%, omitting a residual value, and using Cox's estimates of extra capital investment and user benefits, gives a substantial increase in B/C ratio (from 0.78 to 1.3). In view of this, the decision to complete the project seems a wise one. Had the total capital investment been used (this would have been appropriate if the economic evaluation was done before work commenced), the B/C ratio would have been reduced to about 0.55.

2.2 1980 - 1982 Study

The objectives of this study were (Hasell and Scott, 1981, 1983a and 1983b)

(a) to measure and record certain physical, performance and cost variables pertaining to the network of streets in the area influenced by the Southern Arterial, both before and after opening of the arterial;

(b) to assess the accuracy of previous predictions of traffic movements against those measured after the arterial was opened;

(c) to assess the accuracy of previous predictions of the benefits likely to be gained from constructing the arterial;

(d) to identify those areas where existing techniques of prediction and assessment are deficient and comment on their relative importance.

This study involved a major number plate survey, both before and after opening of the arterial, to obtain:

(a) travel times between external stations (these were set up at each of 12 major roads crossing the external cordon);

(b) vehicle routing (survey stations were set up on each of 3 major routes within the study area);

(c) traffic composition information.

The study area is shown in Figure 1.

In addition, roadside interviews were conducted at two of the internal stations (one before and one after), in order to obtain information on vehicle occupancy, the location of trip origin and destination, and trip purpose. In the after study, users of the Southern Arterial were asked which route they used before the arterial was opened. Traffic counting and spot-speed surveys were done at selected locations, and travel speeds were measured using a test-vehicle procedure.

Using the information about travel times and speeds, along with unit cost data (e.g. value of time for occupants and freight, vehicle operating cost versus vehicle speed relationships) in Memo. 98

relationship used during traffic assignment to bear little relationship to the true volume-delay relationship.

This study was considered inconclusive, and it was concluded that while the strategic model "is an effective tool for general transportation planning purposes, especially for the proper consideration of the scale of changes needed to cater for future demands on a corridor or sector basis", "more detailed evaluation (both operational and economic) would be better served by a more detailed model, such as SATURN".

3. STUDY METHOD

3.1 Traffic Modelling

The study area and network for the most recent study (Iai, 1987) was virtually identical to that used by Hasell and Scott (Figure 1), while Cox excluded the area north of Blenheim Road and East of Hansons Lane (Figure 2). The 1985 study covered the whole metropoliton network, but excluded some of the links shown in Figure 2 (namely, Middlepark Road, Craven Street, Watts Road, Ilam Road, Middleton Road, and the portion of Clarence Street alongside Whiteleigh Avenue).

The Southern Arterial project entailed more than just the construction of a new arterial road; it also involved changing the form of control at eight intersections and the closure of two roads (shown as dashed lines in Figure 3). It was decided to use the SATURN (Simulation and Assignment of Traffic to Urban Road Networks) suite of programs, for the analysis of traffic flows in the network, before and after opening of the arterial. The SATURN model is essentially a traffic assignment model, combined with a simulation model, so that one obtains a traffic assignment consistent with simulated travel costs (Van Vliet, 1982).

It was decided to model six time periods, as follows:

(a)	weekday morning peak	(0700-0900)
(b)	weekday evening peak	(1600-1800)
(c)	weekday off peak	(0900-1600)
(d)	weekday night	(1800-0700)
(e)	weekend day	(0800-1800)
(f)	weekend night	(1800-0800)

In order to do this, it was necessary to derive origin-destination matrices for each of the time periods, and the ME2 (Matrix Estimation using Maximum Entropy) model was used for the task. A three-step procedure was adopted:

(a) firstly, a "prior" all-day trip matrix was estimated, using standard transportation planning models firstly to estimate productions and attractions for each zone (Figure 4), and then to estimate the number of trips between each pair of zones;

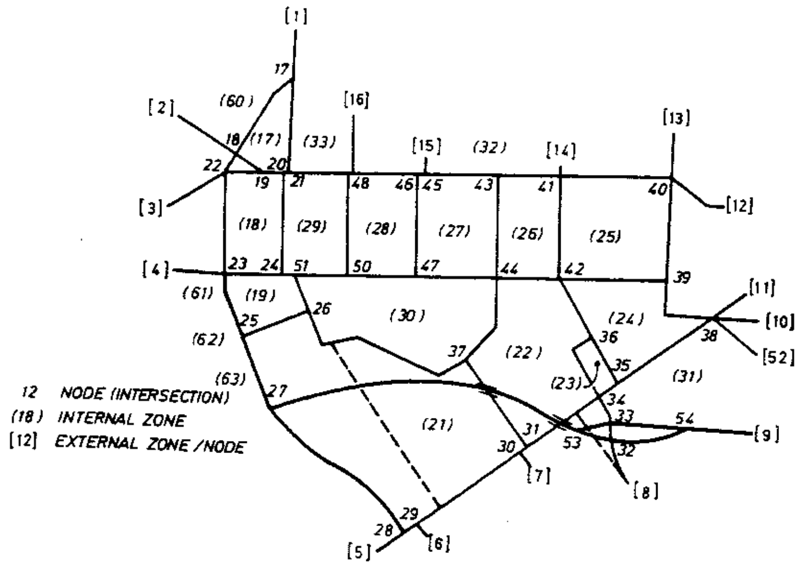

Fig. 3 - Analysis Network

(b) the "prior" all-day trip matrix was sub-divided and scaled, to give a "prior" trip matrix for each of the six periods;

(c) the "prior" matrix for each time period was updated, using traffic counts for selected links and intersections for the appropriate period, and the ME2 model.

It was known, from traffic data collected before and after opening of the arterial (including data collected by Hasell and Scott) that there had been substantial changes in travel patterns in the vicinity of the arterial. Whereas a study of the whole metropolitan area may have shown no change in trip distribution but merely a changed assignment, in this study there appeared to have been a substantial change in trip distribution. This is simply due to the fact that only a portion of the metropolitan area was studied, and trips which were re-routed through the area gave increased flows across the external cordon and increased trips between external zones (Figure 3). Hence, the before-arterial trip matrix derived for each of the time periods was different to the after-change trip matrix for the corresponding time period.

The SATURN model as run 12 times, once for each of the six time periods, for both the before-and after-arterial situations. The standard SATURN output (including link flows, turning flows at intersections, travel times, etc) was obtained and analysed in detail.

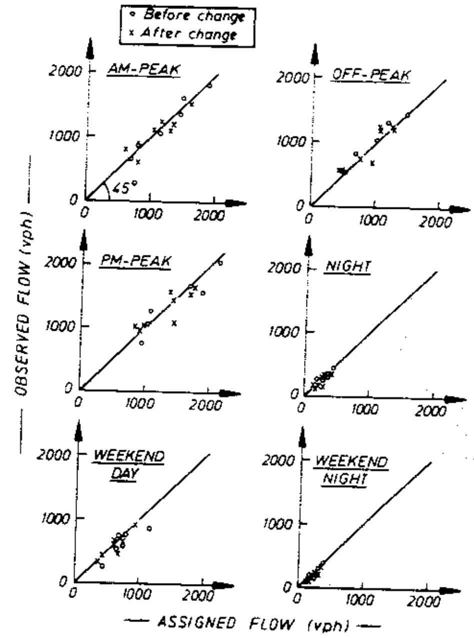

Fig. 4 - Observed Versus Assigned Flows

Taking advantage of the "ex post" nature of his study, Tai checked the reliability of the SATURN model, by comparing the flows predicted by SATURN with observed flows for nine selected locations in the network. The traffic count data for those locations, which were spread around the network, were excluded from the traffic count data input into ME2 during the matrix updating stage. Good agreement between the assigned and observed flows was found for each of the six time periods (Figure 4).

To further check the output from SATURN, the journey times predicted by SATURN for the weekday morning peak period, for trips between eight zone pairs before opening of the Southern Arterial, were compared with those measured by Hasell and Scott (1981), as part of their study of the before-arterial situation. Their travel time estimates, obtained via a test vehicle method, involved a minimum of ten measurements of travel time for each trip. Not surprisingly, Hasell and Scott found considerable variation in the measured times for particular trips. It was found by Tai (1987) that the journey times predicted by SATURN were within the lower half of the observed ranges (Hasell and Scott, 1981) for seven of the eight zone pairs. The predicted travel time for the eighth zone pair was just 4% less than the lowest observed travel time

Given the uncertainty associated with the traffic counts and the travel time measurements, it was felt that SATURN was performing well enough to proceed with confidence.

It was then necessary to establish where the traffic on the Southern Arterial had come from. An analysis of traffic flows across screenlines (Figure 5 shows the screenline flows for the weekday morning peak period) enabled an assessment of the proportion of Southern Arterial traffic that had come from other roads in the study area; the remainder of the traffic was assumed to have been generated or diverted from other roads not in the study area.

The CBD, a major generator of traffic, lies to the north-east of the study area, and it is likely that much of the traffic using the Southern Arterial was moving to or from the CBD, having diverted from more direct routes (such as Riccarton or Blenheim Roads). For the case of travel between external zone 4 and the CBD (Figure 6), let the travel times after opening of the arterial be

(a) $T_b = T_{b1} + T_{b2}$ for the Blenheim Road route

(b) $T_a = T_{a1} + T_{a2}$ for the Southern Arterial route

where T_{b1} and T_{a1} represent the travel times within the study area, and T_{b2} and T_{a2} represent the travel times between the study area boundary and the CBD. Clearly, the Southern Arterial route would be chosen only if $T_a < T_b$. That is, it was not appropriate to consider only changes in travel times within the study area.

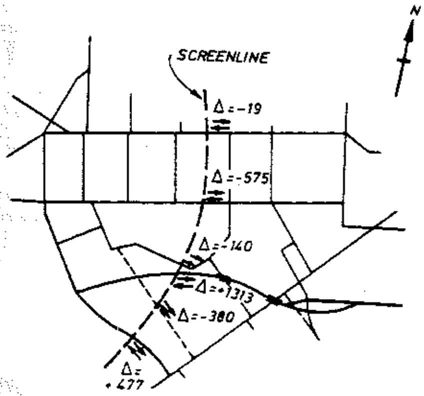

Fig. 5 - Screenline Flow Changes

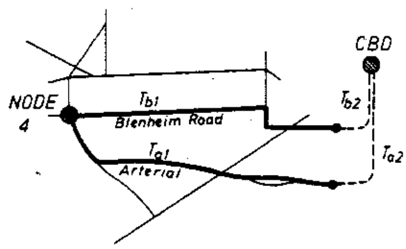

Fig. 6 - Alternative Routes to/from CBD

Whereas it was appropriate to consider only the after-arterial travel times when analysing route choice, the before-arterial travel times had to be considered when estimating the travel time savings. For instance, assuming no change in the travel times outside the study area, then the travel time saving for vehicles which diverted from Blenheim Road to the Southern Arterial equalled

$$(T_{b1} - T_{a1} - \Delta T_{b1}) - (T_{a2} - T_{b2})$$

where ΔT_{b1} represents the effect of the opening of the Southern Arterial on the travel time (within the study area) for Blenheim Road. The term $(T_{a2} - T_{b2})$ represents a correction for the extra travel outside the study area (estimated to be between 66 and 79 seconds for the trip from zone 4 to the CBD).

In order to apply the correction for extra travel outside the study area, it would have been necessary to know what proportion of Southern Arterial users were undertaking extra travel outside the study area. In fact, such extra travel is not confined to trips to or from the CBD. It was not possible to reliably estimate the amount of extra travel outside the study area, so the correction was not able to be applied. Hence, the estimate of user benefits obtained was essentially an upper-bound value.

An analysis of minimum time paths and travel times with and without the arterial was undertaken, for travel from each major external zone to all others. Analysis of the minimum time paths with the arterial and the changes in travel time led to the catchment shown in Figure 7, based on the assumption that the Southern Arterial would only be used for trips for which it offered a reduced travel time.

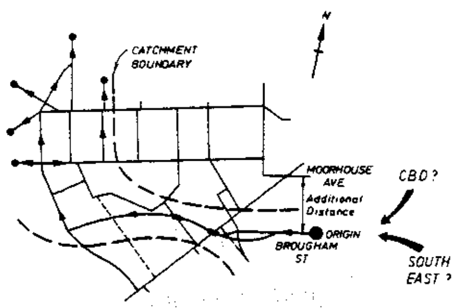

Fig. 7 - Catchment for Southern Arterial

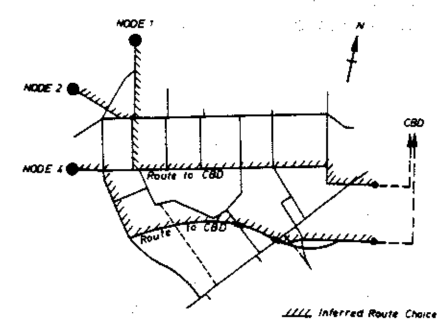

Fig. 8 - Inferred Route Choice to/from CBD

It is worth noting that for all the external zones to the west and north-west of the study area (apart form zone 4), trips to the CBD would not be expected to use the Southern Arterial, as the more direct routes had lower estimated travel times (Figure 8). This suggests that the number of diverted trips, to which the above-mentioned correction (for extra travel outside the study area) would apply, is not very large. That is, the over-estimation of user benefits was not large.

3.2 Accident Study

It was assumed by Hasell and Scott (1983a) that accident costs after the opening of the Southern Arterial would account for 5.6% of the total of user plus accident plus maintenance costs, as they had done for the before arterial situation. During 1986, a study was undertaken of accident data for the study area (Figure 1) for the four years both before and after opening (Jadaan and Nicholson, 1987). One of the aims of the study was to reassess the accident cost changes.

A total of 996 reported injury accidents occurred in the study area during the eight years, 515 in the four years before and 481 in the four years after opening. The corresponding numbers of injuries were 682 and 636, respectively. During the same periods, there were 5592 and 5418 reported injury accidents, respectively, for the whole of the Christchurch metropolitan area. Thus, there was a 6.6% and 3.3% decrease in accidents in the study area and metropolitan Christchurch, respectively, giving an effective accident reduction of 3.5% due to the Southern Arterial.

In addition to the reduction in injury accident numbers, there as a 38% decrease in the number of serious injuries and a 10% increase in minor injuries, for the study area. Clearly, the changed traffic pattern, together with the changes in traffic control, gave rise to a substantial shift in accident severity.

Using accident cost data, derived by Hasell and Scott (1981), for accidents of varying severity (fatal/serious, minor, property-damage-only), and assuming seven property-damage-only accidents for each reported injury accident, an estimate of the annual accident cost savings was obtained.

3.3 Economic Evaluation Procedure

For the calculation of user benefits, Tai (1987) used the following expression to estimate user benefits:

$$\text{user benefit} = \sum_i \sum_j \sum_k \frac{1}{2} (t^b_{ijh} + t^a_{ijh})(P^b_{ijh} - P^a_{ijh})$$

where t^b_{ijh} and t^a_{ijh} represent the trips from zone i to zone j with vehicle type h before and after the arterial, respectively

P^b_{ijh} and P^a_{ijh} represent the corresponding trip costs.

The expression is consistent with that proposed by Neuburger (1971).

Economic evaluation procedures in NZ (MWD, 1984, Bone, 1986) require the calculation of user benefits, as follows:

(a) vehicle operating cost savings;

(b) time savings for vehicles and occupants;

(c) accident savings.

The first two components are vehicle-dependent (hence the form of the above expression for user benefit). Basic unit values (e.g. values of time, and vehicle operating costs) were taken from Memo. 144 (MWD, 1984).

In order to calculate the user benefit as defined above, it was necessary to have interzonal trip and cost matrices. The former was obtained for each time period from the traffic modelling (in particular, the ME2 program) as described above. Cost matrices were not directly available from the traffic modelling phase and it was necessary to construct such matrices using:

(a) SATURN output (interzonal trip time and distance matrices, plus information on the number of stops) for each time period;

(b) vehicle operating cost relationships (MWD, 1984).

4. <u>STUDY RESULTS</u>

It was found that the introduction of the Southern Arterial and the associated traffic control changes gave small journey time increases, ranging from 10-20 seconds, approximately, for trips along Riccarton, Blenheim and Lincoln Roads between the external zones in the west of the study area and external zones in the north-east (nearest the CBD). An analysis of travel times for the various segments of the trips revealed that this increase in travel times on the traditional routes was due to increased delay at intersections where the form of control had been changed to signals. It is shown in Figure 9 that the effect on intersection delay of a change in the form of intersection control is volume dependent; it seems that for many of the intersections in the study area, the traffic volumes were too small for a reduction in delay from signalisation. Any benefit arising from a reduction of traffic flow on the three roads was apparently more than offset by the effect of the signalisations.

The annual user benefits for each time period were then estimated (see Table 1). A number of points should be noted:

(a) there were very large variations in the annual user benefits

(b) positive benefits applied only for the weekday daytime periods;

(c) negative benefits were associated with the other time periods;

(d) accident cost changes were not calculated for each time period.

Those benefits were then combined with the accident cost saving estimate and the capital cost, to produce an estimate of 0.17 for the B/C ratio (Table 2). Also shown in Table 2 are the benefit estimates obtained by Hasell and Scott (1983a, 1983b) and Cox (1977), and it can be seen that both previous studies involved substantial over-estimation of the benefits of the project.

In addition to the temporal distribution of benefits, the spatial variation was also investigated. The results are shown in Table 3; it should be noted that the changes in travel costs do not include the changes in vehicle time costs. It is clear that the

	Vehicle operating cost savings	Occupant and vehicle time savings	Total savings
Weekday pm-peak	23,600	96,400	120,000
Weekday am-peak	11,800	43,400	55,200
Weekday offpeak	26,500	19,600	46,100
Weekday night	-4,500	-20,300	-24,800
Weekend day	-6,300	-37,500	-43,700
Weekend night	-9,700	-14,800	-24,500
Total	41,400	86,800	128,200

Table 1 - Temporal Distribution of Benefits

	Thai	Hasell & Scott	Cox
Travel Cost Savings	128,200 (63%)	3,708,600 (94%) (2,778,000 at 1980 values)	890,900 (500,800 at 1977 values)
Accident Savings	75,100 (37%)	221,600 (6%) (166,000 at 1980 values)	-
Total User Benefits*	203,300 (100%)	3,930,200 (100%)	-
Present Value of Benefits**	2.40 m	46.38 m	-
Capital Cost	14.06 m	14.06 m	-
B/C Ratio	0.17	3.30	-

* Estimate does not include maintenance cost
** Based on an analysis period of 25 years, a discount rate of 10% and an annual arithmetic growth rate of 3% (recommended values; MWD, 1984).

Table 2 - Summary of Benefits, Costs and B/C Ratios

distribution of benefits over zones was just as uneven as was the distribution of benefits over time periods. It seems that

(a) travellers to or from zones at the east or west of the study area have generally received some benefit, while travellers to or from other zones have generally benefitted little or have been disadvantaged;

(b) travellers to or from zones 1, 2, 3, 4, 9, 18, 60 and 63 have received substantial benefit, while travellers to or from zones 5, 10, 11, 12, 13, 14, 21, 27 and 29 have disbenefitted substantially.

An analysis, to ascertain the benefit (or disbenefit) associated with travel between each zone pair, was also done.

The results of the screenline analysis revealed that there was considerable temporal variation in the proportion of Southern Arterial traffic that had diverted from parallel routes. For instance, during the weekday morning peak period, the proportion of diverted traffic was 61% for the east-west segment of the arterial and 80% for the southern leg. The corresponding proportions during the weekday off-peak period were 39% and 24%.

About 80% of the diverted traffic on the east-west segment of the arterial seems to have come from Blenheim Road, with only a few percent of the diverted traffic having come from Riccarton Road.

It was found that the annual accident cost saving, due to the 3.5% decrease in the number of accidents each year and the reduced severity of accidents, amounted to $75100, or about 37% of the total user benefits (Table 2).

5. DISCUSSION

The estimate of annual travel cost savings for this study is only about 3.5% of the estimate for the 1980-82 study and about 14.5% of the estimate for the 1977 study. The accident cost saving estimate is about 34% of the estimate for the 1980-82 study. Such discrepancies are of considerable concern, and the sources are discussed in the remainder of this section.

The first major source of error appears to be the practice of measuring or analysing traffic patterns for a portion of a weekday, and then factoring the benefits for that period (by the ratio of the total daily flow to the flow during that period) to obtain an estimate of the benefits for whole day. Hasell and Scott (1983) show calculations that indicate that daily benefits were estimated at about 10 times the measured benefits for the period 0800 to 1100 hours. The results of this study (Table 1) indicate that for the same three hour period, the annual benefit is about $14,800 (= 55,200/2 + 2 x 46100/7), which is about 32% of the annual benefit of $128,200. Hence, a scaling factor of 3 seems more appropriate then 10.

ZONE	BENEFITS FOR TRIPS ORIGINATING IN ZONE	BENEFITS FOR TRIPS DESTINED FOR ZONE
1	29495	36130
2	14346	42149
3	41495	25727
4	60386	65753
5	-54461	-62053
6	-8937	-12552
7	8117	1864
8	1073	677
9	119256	103466
10	-48632	-24740
11	-21447	-14084
12	-13122	-10653
13	-23184	-10204
14	-13346	-13719
15	3087	-8087
16	-1213	-2492
17	7174	17353
18	29686	42027
19	2158	1048
21	-11613	-35161
22	211	-1051
23	-1274	-1529
24	-1473	-2850
25	-6465	-7375
26	-1422	-6745
27	-2978	-13665
28	-2218	-4677
29	-3383	-17996
30	-1082	1569
31	-237	-610
32	-3981	-9328
33	-3633	-4919
52	-962	-78
60	8262	15576
61	4099	2349
62	2488	3207
63	14015	25958
Mean :	3251	3251
Std. Dev. :	28174	28223
Grand Totals :	120285	120285

* Distribution of benefits due to vehicle time savings, which constitute only a very small proportion of the total benefits, was not carried out. Hence, the total annual user benefits shown here are marginally less than that in Table 1.

Table 3 - Spatial Distribution of Benefits

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It should be noted that the need to consider short-term variations in travel demand was pointed out at least 20 years ago. Wohl and Martin (1967) suggested that changes in travel cost due to an improvement in transport supply can vary drastically over different demand periods. As shown in Figure 10, the change in average unit price of travel is much greater for a high-demand period (dP_1) than for a low-demand period (dP_{160}).

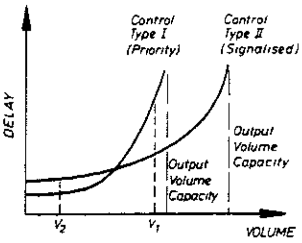

Fig. 9 - Delay versus Volume (Signal and Priority Control)

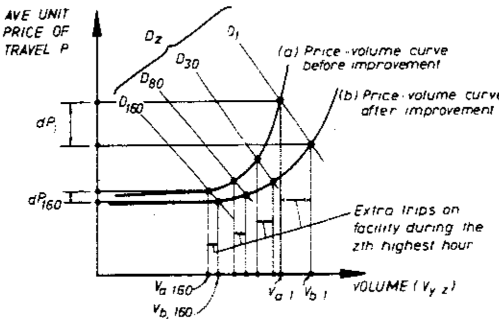

Fig. 10 - The Effect of Short-Term Variations in Demand (Wohl & Martin)

To better understand how short-run demand variations affect the Southern Arterial project, the relationship between journey time (as a surrogate for the journey cost) versus flow was investigated for selected trips. The relationship for journeys from zone 3 to zone 1 is shown in Figure 11. The curves in Figure 11 were plotted using the assignment and simulation results from the SATURN model, and it can be seen that there was a substantial shift in transport supply (corresponding to a more than 30 second reduction in journey time). The demand curves were assumed to be linear, and it can be seen that the reduction in the journey time was greatest for the weekday evening peak period and least for the weekday night period.

The second major source of error seems to be the use of an incomplete trip matrix. Analyses based on an incomplete trip matrix (or a sub-set of trips in the network) will inevitably result in benefits or disbenefits for some zones not being taken into account. The results for this study show that there are some zones for which there are large associated disbenefits, which off-set to a considerable extent the benefits associated with travel to or from other zones. Hence, the use of an incomplete trip matrix opens the way to inaccuracy in the estimation of user benefits. The extent of the potential inaccuracy is difficult to quantify, but in view of the fact that the mean zonal benefit (Table 3) is $3251, with a standard deviation of 8.7 times the mean, it is not difficult to imagine errors of a similar magnitude as for ignoring the temporal variation in user benefits (particularly if an unrepresentative sub-set of trips is chosen).

In the 1980-82 study, the survey omitted trips other than those to or from zones 1 to 6 and 8 to 13. Summation of the benefits (Table 3) for trips from and to those zones gives average benefits of 8002 and 11635, respectively. These values are 2.5 and 3.6 times the overall mean zonal benefit, indicating that the estimated user benefit was about 3 times too large due to the use of an incomplete trip matrix.

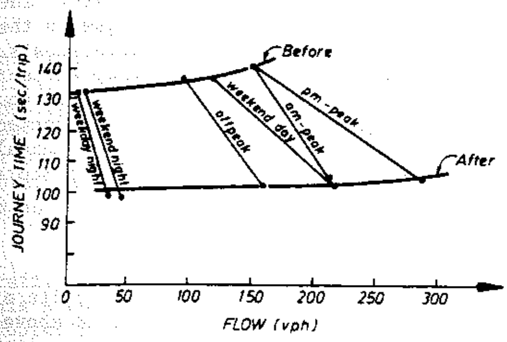

Fig. 11 - Journey Time Changes for Different Time Periods

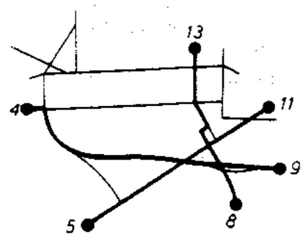

Fig. 12 - Basic Sections

The third major source of error in the earlier studies seems to stem from the use of the method of "basic sections". This procedure (AASHTO, 1977) involves choosing basic sections within the study area, identifying the changes in travel costs (per vehicle) associated with each basic section, scaling those changes by the traffic volume at some point within the basic section, and then summing over the basic sections to obtain an estimate of the change in total travel costs. This procedure was apparently used by in both the 1977 and 1980-82 studies. Some basic sections for the study area are shown in Figure 12. There are two types of error which can arise from use of the procedure. Firstly, not all trips are included (discussed above). Secondly, the scaling by traffic volumes is a source of error. For instance, the traffic volume on the basic section 5-11 (Figure 12) includes traffic making trips other than from zone 5 to zone 11. Depending upon where the traffic volume is measured, it may include traffic from zone 5 to zone 9. The study has shown that the annual disbenefit for travel from zone 5 to zone 11 was $5200, whilst for travel from zone 5 to zone 9, the annual disbenefit was $21,700. The average flow for the latter trip is only about 8% greater than for the former. Clearly, the average disbenefit per trip was much greater for travel from zone 5 to zone 9, than for zone 5 to zone 11. Hence, the lumping together of trips with different origins and/or destinations, but which use the same length of road, is inappropriate. It may possibly lead to errors of a similar magnitude to ignoring the temporal variation or using an incomplete trip matrix.

Assuming that the three error sources are separately responsible for benefits being overestimated by a factor of about 3, and that they compound together, then it is not difficult to imagine user benefits being overestimated by a factor of about 30; the estimate of user travel benefit for the 1980-82 study as about 30 times that obtained by Tai (1987), as shown in Table 2.

The discrepancy in the estimates of the accident cost savings (Table 2) arises from two sources. Firstly, Hasell and Scott assumed that accident costs would be 5.6% of the total of user plus accident plus maintenance costs. Since they estimated a 12% decrease in user costs, they obtained a 12% decrease in estimated accident costs. The study by Jadaan and Nicholson (1987) revealed a 6.6% decrease in the number of accidents per year and a 7.1% decrease in accident costs. For the purpose of this study, it was also necessary to take account of the 3.1% decrease in accident numbers in metropolitan Christchurch. Hence, the construction of the Southern Arterial was deemed responsible for a 3.8% decrease in accident costs, giving an annual accident cost reduction about 33% the size of the Hasell and Scott estimate.

6. CONCLUSIONS

There is considerable uncertainty regarding the benefits of the project, with widely varying estimates. The study reported above, the most recent of four studies, appears to have achieved the goal of identifying the sources of error and uncertainty. The three main sources, which are thought to have contributed fairly equally to the error in estimating the benefits of the project, are:

(a) the scaling of estimates of benefits for a small part of a weekday, to give an estimate of benefits over a full year;

(b) the consideration of only a sub-set of all trips through or within the area;

(c) the use of the method of "basic sections" (in particular, the scaling of benefits for a basic section by the traffic volume at a point on that basic section).

Economic evaluation procedures in NZ would benefit considerably from a greater allocation of resources for traffic modelling. Large gains in accuracy are available from making better use of models, to include:

(a) traffic modelling of several time periods, to take account of short-run demand variations;

(b) consideration of all trips through or within the area, using a matrix-based approach.

Wohl and Martin (1967) warned of the effect of ignoring short-run demand variations. Their discussion of the problem waas qualitative, and it is now possible to quantify the effect. For the Southern Arterial study, the effect was over-estimation of benefits by a factor of about 3.3.

In order to model several time periods, it is necessary to have a trip matrix for each period. The SATURN model (with the ME2 model) made the derivation of trip matrices much easier. In addition, the calculation of benefits for each trip interchange can be done using matrix manipulation programs within SATURN. That is, the traffic modelling and economic evaluation procedures can be integrated. This was done as part of this study.

The calculation of a matrix of benefits enables the identification of the differential impacts of a project; one can readily identify who wins or loses, and to what extent.

The method of basic sections seems generally inappropriate for urban studies, where there are frequent intersections where traffic can enter or leave the basic sections. The study method adopted by Hasell and Scott involved considerable resources. The results of this study suggest that the surveys would need to be extended considerably, both spatially and temporally, in order to obtain sufficient accuracy. It seems that this would make that study method rather unattractive.

Finally, there is a need for research to assist practising traffic engineers/planners to identify an appropriate study area. For this study, the external cordon was chosen to coincide with that adopted in two previous studies. In retrospect, it would have been useful to have considered a wider area, so that the extent of increased travel outside the study area, by travellers diverting to the Southern Arterial, could be assessed. The "buffer network" facility in SATURN could have been put to good use.

7. ACKNOWLEDGEMENT

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