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THE SIMULATION OF TRAM ROUTE SERVICE IMPROVEMENTS

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ABSTRACT: *Public transport faces many challenges in offering improved levels of service at reasonable cost. The interaction between physical system characteristics, operating characteristics and patronage forms a complex demand-supply system. Within a conceptual model of this system, this paper examines the effect of various physical system changes on the system operating characteristics of a tramway route by means of a newly-developed simulation model. In particular, the paper examines the effects of changes in vehicle performance, signal priority and stop spacing. It is demonstrated that a simulation research technique can be used in helping to improve the operations of a public transport system.*

INTRODUCTION

Public transport operators are being faced with increasingly complex problems in attempting to improve or maintain levels of service to patrons and potential patrons whilst, at the same time, attempting to contain rising deficit levels. In trying to reduce the level of deficit funding, two basic options are open to the operator. Firstly, services can be cut back in an attempt to reduce operating costs. Secondly, services can be improved in an attempt to increase patronage and hence revenue. In each of these strategies, however, it is necessary to make an assumption about the way in which travellers will react to the change in the level of service.

If, in the former case, the reduction in the level of service has the effect of turning away passengers from that part of the system which is left operating then the reduction in operating costs may be outweighed by a reduction in revenue with a consequent increase in the deficit. In the latter case, the increase in revenue from the increase in the level of service may not be enough to justify the increase in operating or capital costs and hence, once again, the deficit may increase.

In such a situation, it is obvious that there is a need for tools which will enable a comprehensive evaluation of the proposed strategy before implementation in the field. Such evaluation methods must consider three fundamental types of system model: supply model, demand model, and costing model. The inter-relationship between these three types of model is shown in Figure 1.

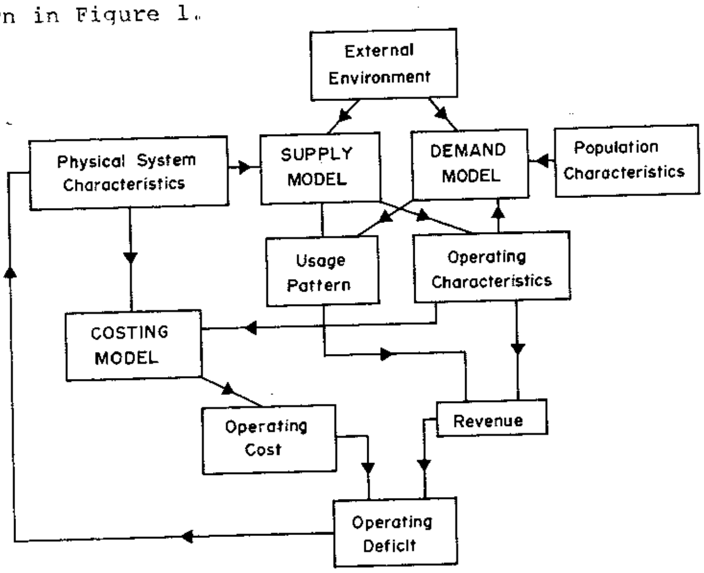

Figure 1. Structure of Public Transport System Model.

The supply model takes account of the physical system characteristics, the external environment (such as general traffic conditions) and the current pattern of usage of the system and generates a set of system operating characteristics, i.e., the supply model describes how the public transport system works. The demand model assesses the reaction of the population of current and potential travellers (within the prevailing external environment) to the set of system operating characteristics and generates a new pattern of usage (patronage) as a result of any changes in the system operating characteristics. Obviously this new pattern of usage may (through the supply model) result in a new set of operating characteristics. If this is the case, then the supply and demand models must be used in an iterative fashion until an equilibrium state is reached, wherein the pattern of usage and the operating characteristics are mutually compatible within the prevailing external environment.

Given equilibrium operating characteristics and usage patterns the revenue may be calculated by summing the fares charged over the total usage pattern. At the same time, other operating characteristics such as vehicle productivity and transit time may be used in a costing model, in conjunction with various physical system characteristics, to produce an estimate of the operating cost of the system. A comparison of operating cost and revenue provides a measure of operating deficit (or surplus). If this deficit is deemed to be unsatisfactory then some attempt can be made to change the physical system characteristics, as mentioned previously, in an attempt to reduce the deficit.

The aim of the project reported in this paper is to develop an integrated supply-demand modelling package which gives equal weight to each type of model. Whilst many equilibrium models have been developed previously (e.g. Gaudry, 1979; Wilson, 1979; Florian, Nguyen and Ferland, 1975) few, if any, have attempted to provide a comprehensive treatment of each type of model. Far greater attention has been paid to the development of mathematical techniques for the efficient determination of equilibrium states, and to the application of equilibrium modelling to road traffic assignment problems.

The basis of the modelling package developed in this study is a conceptual model of public transport system operation, first developed by Richardson and Ogden (1978) and shown in Figure 2. This diagram attempts to show the major interactions present in the operation of a public transport system. Whilst it may appear at first sight to be rather awesome it is in fact fairly straightforward, especially if relatively small sections of the diagram are examined at any one time. It should perhaps be realised that the diagram is, in fact, a substantial simplification of the multitude of complex interactions present in a real public transport system operation.

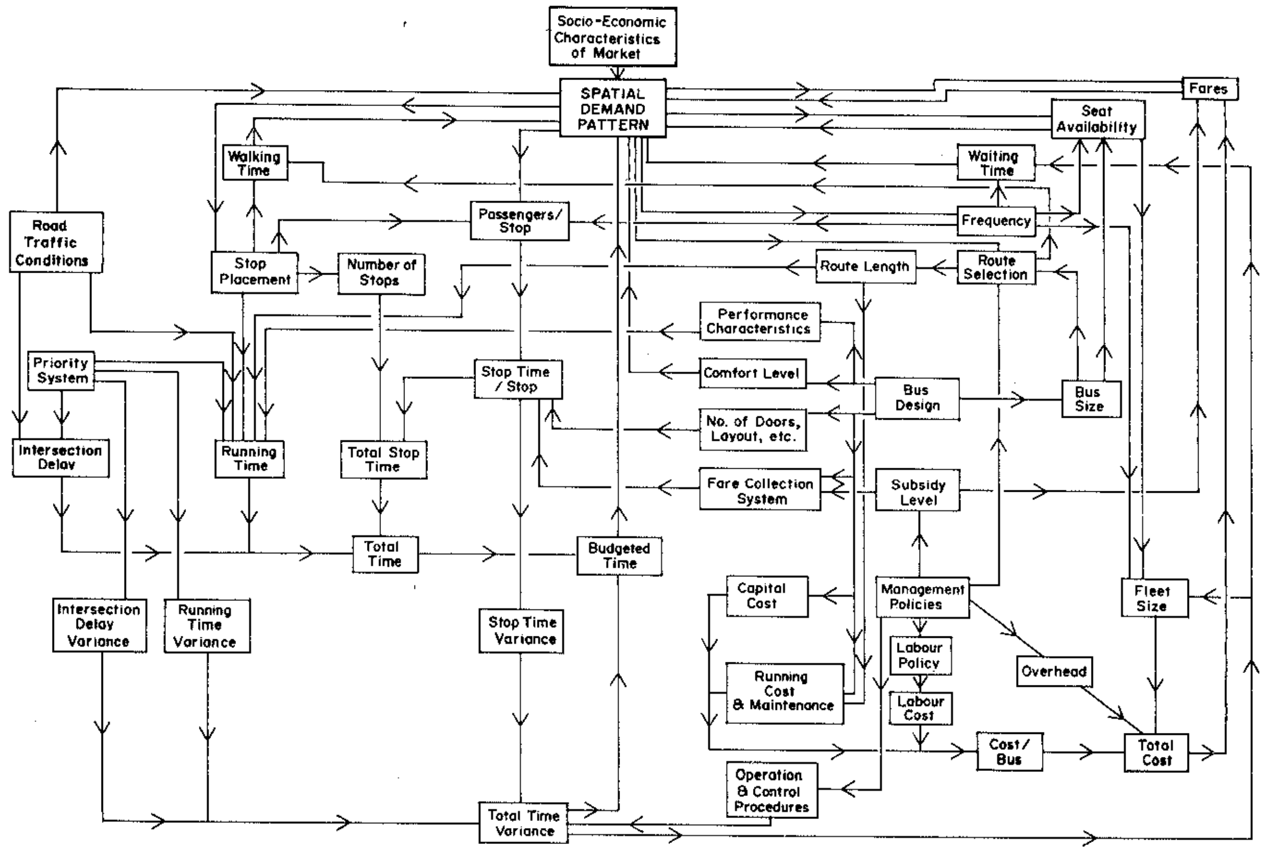

Figure 2. Conceptual Supply Model for Bus System Operations.

Figure 2, in fact, concentrates on the supply modelling aspects of the system, with the demand model and costing model being given relatively scant attention. This emphasis on supply modelling is appropriate in this paper, since most of the work on the package, so far, has concentrated on the development of a tram system supply model by means of a vehicle-by-vehicle route simulation model. It is the aim of this paper to describe this model and to provide some examples of the results which may be generated by the simulation model.

THE SIMULATION MODEL

The simulation model developed in this study simulates the movement of individual trams as they traverse the specified route. Because no overtaking is possible in the system, it is permissible to simulate on a vehicle-by-vehicle basis rather than on an event-update or time-update basis. In vehicle-by-vehicle simulation, each tram is followed from beginning to end of the route without reference to the movement of other trams, except where one tram catches up with another. When this happens, the second tram follows, but does not influence, the movement of the first tram.

A simplified flow-chart of the simulation model is shown in Figure 3. Thus for each tram, the time of leaving the beginning of each link is calculated and the time to reach the end of the link is determined. If the link ends at a tram stop it must be decided whether the tram will stop or not and, if so, for how long it will stop. If the link ends at a traffic signal then, depending on the prevailing aspect and the degree of priority in operation, it must be decided whether the tram will be stopped and, if so, for how long. The tram then proceeds onto the next link until the end of the route is reached. The simulation then proceeds to the next tram until all trams in the simulation period have been accounted for.

As shown in Figure 1, a supply model needs three basic types of input; physical system characteristics, external environment characteristics and the current pattern of usage. The physical system is described in terms of the route and the vehicles traversing the route. The route is described in terms of nodes and links where the nodes may be either a tram stop or a signalised intersection. Each link is assigned a cruise speed factor which accounts for the effects of the prevailing road traffic conditions on that link (an element of the external environment) and a gradient factor. (The traffic signals along the route operate in quasi-vehicle-actuated fashion whereby stochastic phase times are generated for each cycle. In addition, allowance is made for the effects of right-turning traffic at signalised intersections, as will be described later. The trams are described in terms of their passenger capacity (both seated and standing), acceleration and

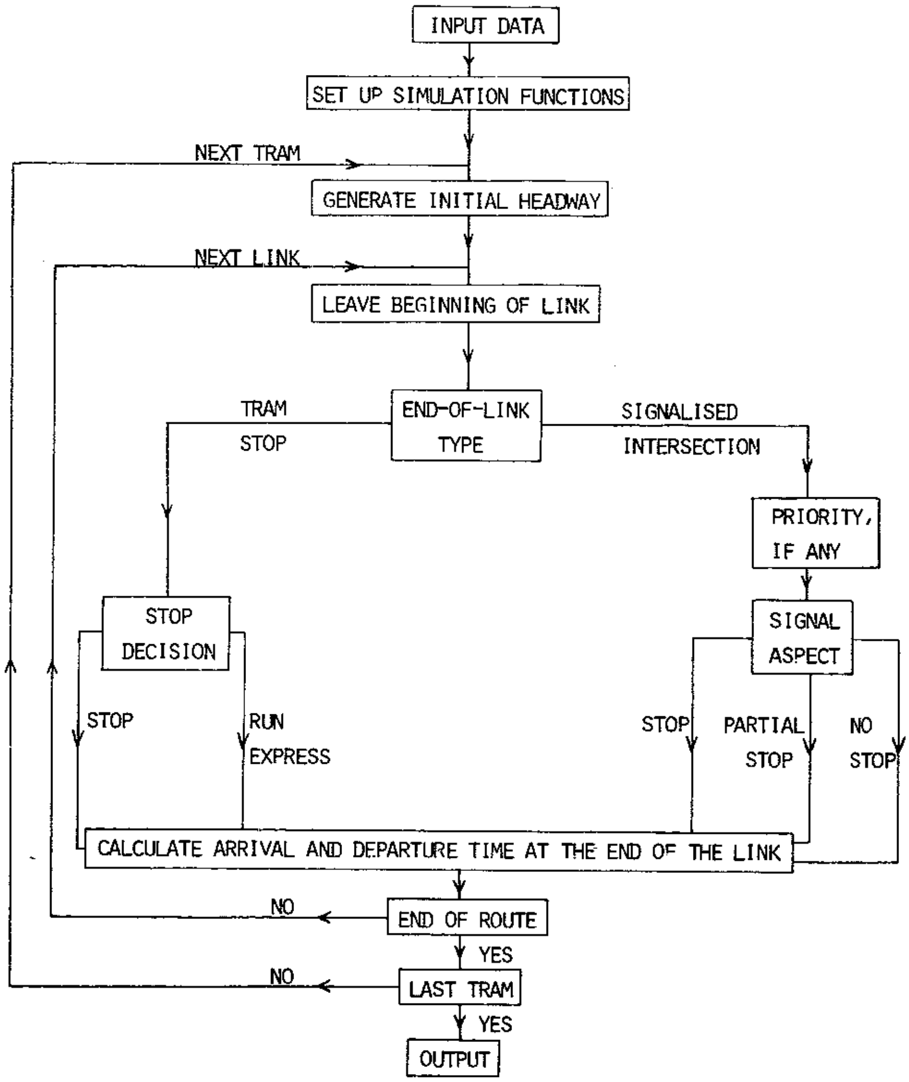

Figure 3. Outline of Tram Simulation Model Structure.

deceleration rates, cruise speed and passenger loading and unloading rates.

The current usage pattern is described in terms of two distributions. The first is the pattern of usage over time, which allows for varying passenger flows within the simulation period. The second is the distribution of passenger boardings and alightings over the length of the route.

The simulation model operates by reference to a series of submodels which generate stochastic outputs for further use in the model. The major submodels handle the generation of:

(i) Departure time from terminus
(ii) Vehicle characteristics
(iii) Link travel time
(iv) Passenger arrivals at tram stops
(v) Alighting passengers from trams
(vi) Tram stop service times
(vii) Traffic signal phasing
(viii) Right turning traffic arrivals and departures.

The details of many of these models have been described elsewhere (Vandebona and Richardson, 1981a). At this point, reference will be made to only three of these sub-models as they are relevant to analyses later in this paper.

The generation of vehicle characteristics involves the selection of a cruise speed and rates of acceleration and deceleration from triangular distributions around specified input values of the parameters. The variance of the triangular distributions may be specified by the user to reflect the variability of vehicle performance within a specific fleet. For each link, the tram cruise speed is modified by the link-specific cruise speed factor and the link speed, acceleration and deceleration are obtained for a tram by stochastic generation using a lognormal generator. These three values are then used to compute link travel time based on trajectory diagram calculations for the link in question.

At the end of the link the tram may negotiate either a tram stop or a signalised intersection. Passenger boardings and alightings at each stop are generated stochastically. Given the number of boardings and alightings for a particular tram, the tram stop service time is generated by means of an equation where:

$$T = fn\ (A, B, \alpha, \beta, \gamma) \qquad (1)$$

where

T = tram stop service time
A = number of alightings
B = number of boardings
α, β = service times for alighting and boarding passengers, respectively
γ = dead-time at stop.

The form of the function used will vary depending on door layout etc., whilst the service times may be varied by the user to reflect the performance of different types of tram.

At signalised intersections, it is assumed that while trams will not be delayed by through vehicles proceeding in the same direction, they may well be delayed by right-turning vehicles who block the tram track whilst waiting to make their turn. The delay experienced by right-turners will vary depending on whether they have an exclusive right-turn phase or whether they have to filter through opposing traffic. The exclusive right-turn phase may be either leading or lagging. In the general case of filtered right-turners, it is assumed that right-turners cannot proceed whilst the opposing queue is dispersing. After the opposing queue has dispersed, right-turners pick gaps in a random stream of traffic until the end of the green phase. In addition, it is assumed that two right-turners move off in the following amber period. For all right-turn signal strategies, the delay to right-turners (and hence to a following tram) is given by a general formula where:

$$D = fn\ (R, Q, L, C_1, C_2, S) \qquad (2)$$

where

D = delay due to right-turners
R = right-turning flowrate
Q = opposing flowrate
L = number of lanes in opposing flow
C_1, C_2 = gap acceptance parameters
S = flag to indicate the type of right-turn signal strategy in operation

DEMONSTRATION CASE STUDY

To illustrate the type of analysis which may be performed using the simulation model, a demonstration case study will be described wherein two variations in vehicle characteristics (cruise speed and number of doors) are tested, the usage pattern is changed and the external environment (in terms of number of right turners at signalised intersections) is changed. Rather than test these changes on a completely hypothetical route, the study was based on Melbourne and Metropolitan Tramways Board route No. 75 which runs between East Burwood and the City (see Figure 4). The route, of approximately 18km length, contains 73 regular stops of which 11 are timetabled (see circles on route in Figure 4). In addition, the route passes through 32 signalised intersections. Whilst the route used in this case study is not identical to the East Burwood route, the use of a real route as a basis ensures that there are realistic assumptions about stop spacing and the placement of tram stops relative to signalised intersections.

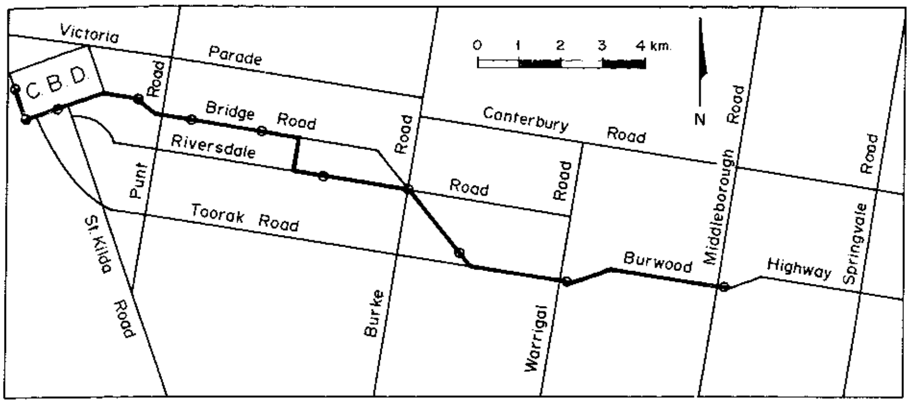

Figure 4. Demonstration Case Study Route.

Using this route description, the simulation model was used to test the effects of:

(i) Changes in tram cruise speed
(ii) Changes in number of doors on tram and hence loading and unloading rates
(iii) Changes in the number of right-turners at signalised intersections
(iv) Changes in the passenger demand for the tram service.

To provide a basis for comparison when testing each of these options, a base case simulation was performed wherein the following assumptions were made for each of the above parameters:

(i) Tram cruise speed equal to 50 kph
(ii) Trams equipped with one door only, whereby unloading and loading takes place sequentially
(iii) An average arrival rate of 120 right-turners per hour at each of the signalised intersections
(iv) A temporal distribution of passenger demand such that a total of 1000 passengers board in the first hour of the simulation, 1400 in the second hour and 700 in the third hour.

In addition a number of other input parameters were specified with respect to physical system characteristics and demand patterns.

Whilst the model provides a large array of output performance measures, only four of these measures will be described in this paper. These measures are the average unit travel time, the average passenger waiting time at tram stops, the average bunch size of tram platoons and the probability of a passenger not obtaining a seat in the tram. Examples of other performance measures which are generated by the model, but not used in this paper, include the standard deviations of travel time, waiting time and bunch size, the mean and standard deviation of schedule deviations and various measures of passenger crowding within the trams.

The variations in the selected performance measures along the route are shown in Figures 5 through 8. Thus in Figure 5, the average unit travel time over the previous timetabled section of the route is shown as a function of position along the route. To assist in identification, several well-known locations along the route are identified on the graph. It can be seen that as trams get nearer to the city centre, the unit travel time increases from 3 min/km (20 kph) to 6 min/km (10 kph). This increase in travel time is a result of closer stop spacing, more frequent signalised intersections and greater road traffic congestion.

As well as becoming slower it can be seen from Figure 6 that there is an increase in the tendency of trams to form bunches as they proceed along the route. Thus wheras trams are completely unbunched when they leave the East Burwood terminus at Middleborough Road, by the time they reach the city the average bunch size has increased to 1.35. This means that the effective frequency of trams has dropped by approximately 30%. This decrease in effective frequency, together with the effects of increases in travel time variability, can be represented most dramatically by observing the increase in average passenger waiting time along the route, as shown in Figure 7. Thus at the East Burwood terminus where trams depart at regular 5 minute headways, the average waiting time (assuming random passenger arrivals) is 2.5 minutes (i.e. half the tram headway). As one proceeds along the route, however, the average waiting time increases until near the city centre where the average waiting time is equal to five minutes (i.e. equal to the overall average headway).

The final performance measure of interest is the probability that a boarding passenger will have to stand in the tram (because all the seats have been taken already). This measure of passenger comfort is primarily a function of the spatial pattern of boardings and alightings, but is also directly affected by the variability in tram headways as reflected in the formation of

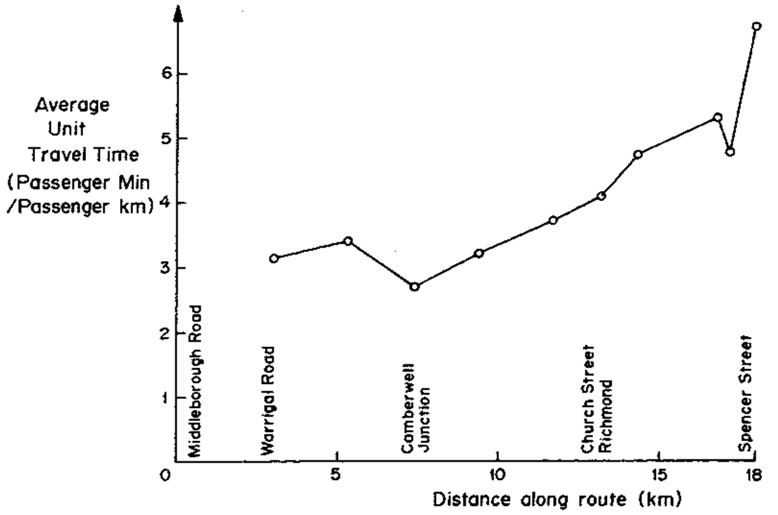

Figure 5. Variation in Average Travel Time along Route.

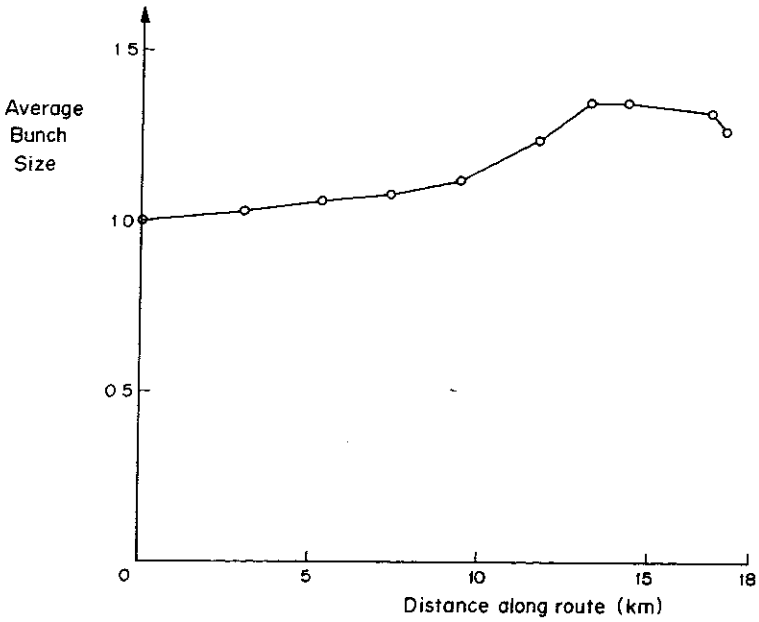

Figure 6. Variation in Average Bunch Size along Route.

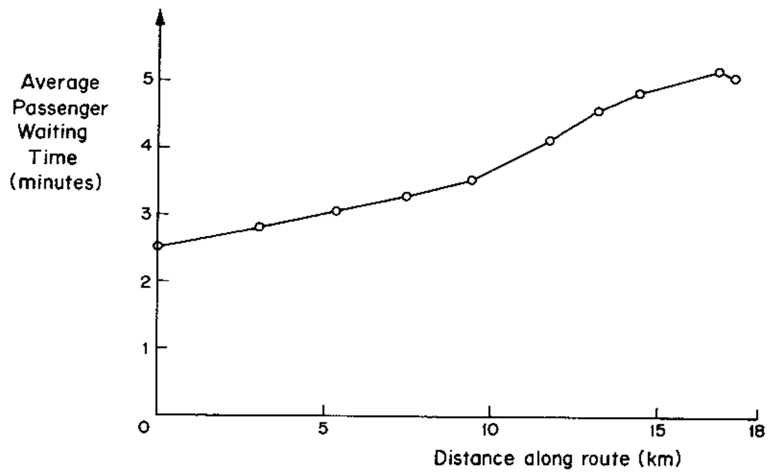

Figure 7. Variation in Average Waiting Time along Route.

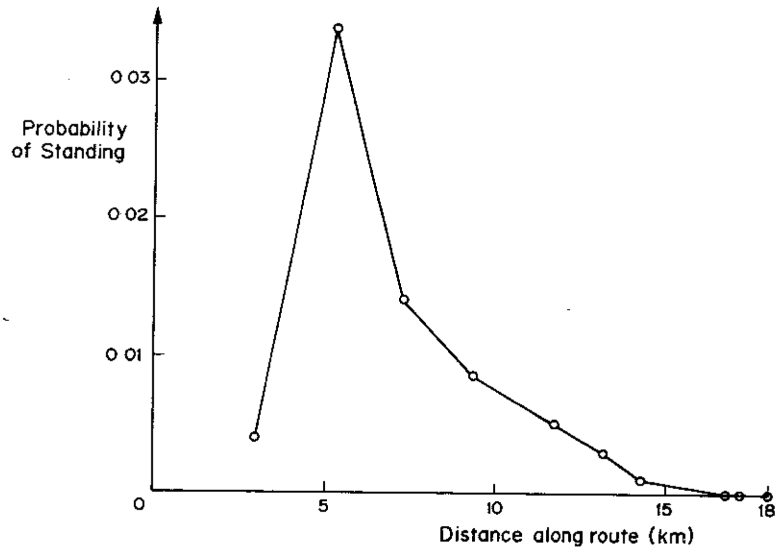

Figure 8. Variation in Probability of Standing along Route.

bunches. If a bunch does form then the leading tram will always have a higher passenger loading than the following tram, and whilst there may be vacant seats in the following tram there may also be standing passengers in the leading tram. The pattern of variation in the probability of standing passengers along the route, as depicted in Figure 8, is the result of the assumed distributions of boarding and alighting along the route, whereby boardings decrease with increased distance along the route whilst alightings increase with increased distance along the route. A point to note from this graph is that whilst travel time and waiting time have been shown to be worst closest to the city, passenger comfort may improve as one approaches the city.

Given a feeling for the way in which these performance measures vary along the route, attention is now turned to a consideration of the way in which these performance measures change given the changes in system characteristics outlined previously. Rather than examine the variations in performance measures along the route for each operating option, global measures of the performance measure have been derived to express the magnitude of the performance measure over the entire route. Each global measure is a weighted average of the performance measures obtained for each of the eleven timetabled sections of the route.

Changes in Tram Cruise Speed

The average tram cruise speed was varied from the base case cruise speed of 50kph to consider an increased speed of 60kph and a decreased speed of 40kph. The results of these changes are shown in Table 1. As expected, the change in cruise speed has been reflected in a change in the average unit travel time along the route. The lower cruise speed trams have substantially higher unit travel times while the higher cruise speed trams have more modest reductions in unit travel time. Over the length of the route the increase in total travel time for the slower trams would be slightly over four minutes whilst the fast trams would have a reduction in travel time of approximately one minute. The effects of trams with faster cruise speeds are substantially nullified by the close stop spacing on this, and other, tram routes. It would therefore appear that investment in trams with cruise speeds greater than 50-60kph would not be worthwhile, unless substantial changes were made to stop placement to enable the trams to cruise at top speed for longer periods of time during a journey.

The changes in tram cruise speed appear to have had no significant effects on any of the other three global performance measures, and hence this parameter appears to be rather specific in the way in which it affects tram route performance.

TABLE 1

EFFECTS OF CHANGES IN AVERAGE TRAM CRUISE SPEED

Performance Measure	Average Cruise Speed		
	40 kph	50 kph (Base Case)	60 kph
Average Unit Travel Time (min./km.)	3.73† (0.04)	3.50 (0.06)	3.44† (0.04)
Average Bunch Size	1.13 (0.03)	1.15 (0.05)	1.15 (0.06)
Average Waiting Time (Min./pass.)	3.30 (0.13)	3.42 (0.27)	3.42 (0.12)
Probability of Standing	0.003 (0.003)	0.004 (0.004)	0.006 (0.005)

Note: Figures in brackets are the standard errors of the estimates of the means.
† Significantly different from base case at 5% level.

Changes in Number of Tram Doors

In the base case simulation, it was assumed that each tram had only one door through which both boardings and alightings took place. Thus alighting passengers would need to get off before boarding passengers could begin to get on the tram. A second option was therefore tested in which it was assumed that the tram had two doors; one exclusively for boarding and one for alighting. In this way, boarding and alighting can proceed simultaneously and the tram stop service time will be determined by whichever process takes the longer time. This second option corresponds closely to the situation with Z-class trams which operate on the East Burwood line, whilst the base case is purely hypothetical and does not correspond to any tram operating in the Melbourne system.

The results of the simulations with different door layouts are shown in Table 2. The only global measure in which there has been a significant change is the average passenger waiting time at tram stops. This is perhaps to be expected since the objective of the extra door was to allow passengers to board as soon as the tram stopped and to allow the tram to leave the stop earlier. Whilst statistically significant, however, the reduction in waiting time is not substantial and amounts to only 15 seconds per passenger on any journey. The increased number of doors per tram appears to have had no significant effect on any of the other performance measures.

TABLE 2

EFFECTS OF CHANGES IN TRAM DOOR LAYOUT

Performance Measure	Number of Tram Doors: 1-Door (Base Case)	Number of Tram Doors: 2-Doors
Average Unit Travel Time (min./km.)	3.50 (0.06)	3.55 (0.05)
Average Bunch Size	1.15 (0.05)	1.10 (0.05)
Average Waiting Time (min./pass.)	3.42 (0.27)	3.16† (0.20)
Probability of Standing	0.004 (0.004)	0.002 (0.004)

Note: Figures in brackets are the standard errors of estimates of the means.
† Significantly different from base case at 5% level.

Changes in Right-Turning Traffic Volumes

To test the effect of right-turning traffic at signalised intersections on tram route performance, the average arrival rate of right-turners at each intersection was varied from the base case value of 120 right-turners per hour to values of zero, 60 and 240 right-turners per hour. To make the analysis feasible, it was necessary to assume that the right turn volume at each intersection was the same. Whilst this situation is highly unrealistic, it does serve to illustrate the general effects of right-turners on tram performance. If so desired, the right-turn traffic flow at each intersection could be varied to reflect the actual situation at each intersection.

For each right-turn traffic volume, the right-turners were required to make their turns by filtering through an opposing traffic volume of 1000 vph. Thus no exclusive phases or priority measures were used to facilitate right turns.

TABLE 3

EFFECTS OF CHANGES IN RIGHT-TURNING TRAFFIC VOLUMES

Performance Measure	Right-Turning Traffic Volume (vph)			
	0	60	120 (Base Case)	240
Average Unit Travel Time (min./km.)	2.67† (0.03)	3.20† (0.03)	3.50 (0.06)	4.43† (0.32)
Average Bunch Size	1.12 (0.05)	1.18 (0.04)	1.15 (0.05)	1.10† (0.02)
Average Waiting Time (min./pass.)	3.10† (0.15)	3.54 (0.20)	3.42 (0.27)	3.54 (0.16)
Probability of Standing	0.003 (0.003)	0.004 (0.003)	0.004 (0.004)	0.007 (0.007)

Note: Figures in brackets are the standard errors of the estimates of the mean

† Significantly different from base case.

The effects of varying the right-turn traffic volumes are shown in Table 3. An increase in right-turn traffic has had a significant and substantial effect on the average unit travel time along the route. Banning right-turn traffic at signalised intersections would appear to yield substantial improvements in tram travel time as indicated by the results for zero right-turn traffic. This is not to suggest, however, that right-turns should be banned; there may be other ways of reducing the effects of right-turners on trams such as exclusive phases and certain types of priority signals.

The effects of right-turning taffic on other performance measures are not nearly so dramatic. The effect on average bunch size is, in fact, somewhat surprising. The maximum bunch size occurs at a moderate right-turn traffic volume with smaller bunch sizes at either higher or lower right-turn traffic volumes. The smaller bunch size at lower right-turn traffic volumes is readily explained since the absence of right-turners means that trams are not unduly delayed at signalised intersections and this therefore prevents the formation of bunches. At higher right-turn traffic volumes the reason for lower bunch sizes is not quite so apparent. However, what occurs is that as well as right-turners forming a queue in front of a tram at signalised intersections, the right-turners also form a queue behind the tram and thus prevent a following tram from catching up to the leading tram. This enforced spacing of trams by right-turn queues prevents the formation of some bunches and hence reduces the average bunch size.

The effect of right-turning traffic on average passenger waiting time can be gauged by combining the individual effects on travel time and bunch size. Thus at low right-turning traffic volumes, both unit travel time and average bunch size are reduced and this results in a significant reduction in average pasenger waiting time. However at moderate to high right-turn traffic volumes, the increased unit travel time is counterbalanced by the reduced average bunch size and this results in no significant variations in average pasenger waiting time. Thus, while right-turn bans would reduce the average passenger waiting times, it appears that the waiting time is not sensitive to the volume of right-turning traffic, given that right-turns are permitted.

The final performance measure, the probability of standing, does not appear to be affected significantly by changes in the volume of right-turning traffic. The above analysis of the effects of right-turning traffic has been rather cursory and has not considered the effects of other right-turn control strategies in conjunction with changes in right-turn traffic volumes. A more detailed evaluation may be found elsewhere (Vandebona and Richardson, 1981b).

Changes in Total Passenger Demand

As shown in Figure 1, a critical input to a supply model is the pattern of existing passenger demand. The relationship between passenger demand and system performance is, in fact, the basis of many so-called supply models or "price-volume" curves. However, whilst the relationship between traffic volume and the price of travel is well established for road traffic in the form of speed/flow relationships, such a relationship is generally not well established for public transport systems. Indeed, Ruiter and Dial (1979) identify the development of such supply functions as a key requirement in equilibrium modelling of transport systems.

In an attempt to gain some insight into the relationships between passenger demand and route performance measures, the base case demand pattern was altered such that, with the same temporal pattern, the total number of boarding passengers was changed from 2400 passengers per two-hour peak period to be 1200, 3600 and 4800 passengers per two-hour peak period. The results of this analysis are shown in Table 4. It can be seen that each increase

TABLE 4 EFFECTS OF CHANGES IN TOTAL PASSENGER DEMAND

Performance Measure	Total 2-hour Passenger Demand			
	1200	2400 (Base Case)	3600	4800
Average Unit Travel Time (min./km.)	3.22† (0.06)	3.50 (0.06)	3.81† (0.08)	3.96†* (0.06)
Average Bunch Size	1.12 (0.03)	1.15 (0.05)	1.22† (0.07)	1.18 (0.04)
Average Waiting Time (min./pass.)	3.27 (0.15)	3.42 (0.27)	3.81† (0.35)	5.02†* (0.26)
Probability of Standing	0.000† (0.000)	0.004 (0.004)	0.068† (0.014)	0.131†* (0.007)

Note: Figures in brackets are the standard errors of the estimates of the mean.
† Significantly different from base case at 5% level
* Significicnatly different from next lowest pasenger demand case at 5% level.

of 1200 passengers per two-hour period brings with it a significant increase in average unit travel time and the probability of standing. Average waiting time increases significantly at higher demand levels whilst bunch size appears to reach a peak at a passenger demand of 3600 passengers per two-hour period.

The increase in the probability of standing is to be expected as pasenger demand rises, given that the frequency and capacity of the trams are held constant. The changes in unit travel time and average waiting time may be seen more clearly by referring to Figures 9 and 10, respectively.

It can be seen that unit travel time rises with increasing pasenger demand but, unlike the supply function associated with road traffic travel time, the curve shows a tendency to decreasing marginal increases, i.e., the unit travel time approaches a stable maximum unit travel time as passenger demand increases. The shape of the supply function obtained with respect to unit travel time agrees well with previous results obtained by Morlok (1976) for urban bus systems.

If, on the other hand, one examines the supply function with respect to passenger waiting time as shown in Figure 10, then it can be seen that the response to increasing passenger demand is one of increasing marginal increases, i.e., as passenger demand rises the rate of increase in waiting time increases. In this way, the supply function is more akin to the well-known flow/delay curve of queueing theory and road traffic performance. This is perhaps not surprising since the process of passenger arrivals and departures at tram stops is very similar to the process of vehicular flow through signalised intersections. In fact, the algorithm used to calculate passenger waiting time in this model was first developed for the calculation of vehicular delay at traffic signals (Richardson, 1980).

The effect of increasing passenger demand on total journey travel time will depend on the length of the trip being undertaken. Thus for short tram journeys, initial waiting time may predominate and hence give rise to an increasing marginal response supply function with respect to total journey time. However at longer journey lengths, in-vehicle travel time will be the predominant factor and hence a decreasing marginal increase in total journey time will result from an increase in passenger demand. Obviously, the overall supply function will depend on the relative weights to be given to the various performance measures.

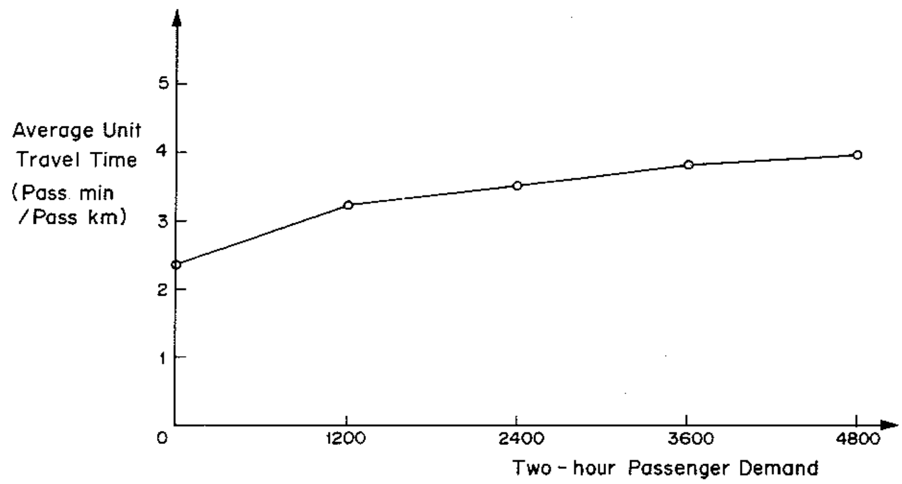

Figure 9. Variation in Average Travel Time with Increasing Passenger Demand.

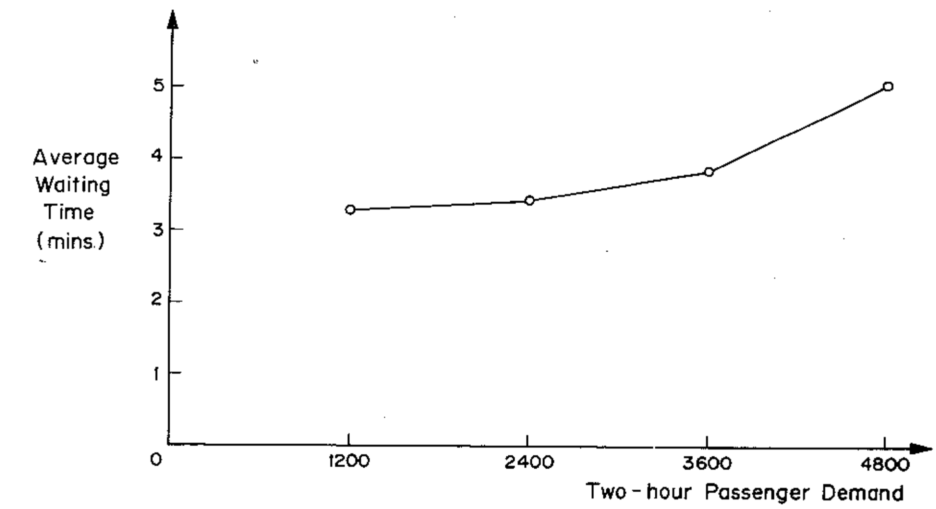

Figure 10. Variation in Average Waiting Time with Increasing Passenger Demand.

CONCLUSION

This paper has described the development of a tram route simulation model within the context of an integrated equilibrium model of a public transport system. The model has been used in a demonstration case study and has been shown to yield useful results in the analysis of several changes to the tram route characteristics, the external environment and the total passenger demand.

Further development of the modelling package will concentrate on devising methods by which the outputs of the supply model can be effectively interfaced with appropriate demand models. Such demand models may be of several types including demand elasticities, pivot-point logit analysis or functional analysis modelling. Whilst integration of the supply model with a demand model, and later a costing model, will provide a very comprehensive method of analysing system changes, it is obvious from the results presented in this paper that even at this stage of development the model is capable of providing a host of useful information on tram route performance.

INTRODUCTION

On Monday, 3rd November, 1980, the Brisbane City Council's Department of Transport commenced operation of a bus-bus interchange at Toombul Shoppingtown, which is located approximately 9 kilometres north-east of the city centre as shown in Figure 1.

The introduction of this interchange represented a major departure from the style of bus operations previously employed by the Council.

This paper initially describes investigations and considerations into location of the interchange; research into patronage and service levels; planning of the new services; layout and operation of the interchange and publicity involved in the introduction of the new system.

Since the opening of the interchange its performance and operation have been kept under constant surveillance. The latter part of the paper describes the experiences, both good and bad, encountered and measures taken to improve performance and assist user acceptance of the interchange.

EARLY INVESTIGATIONS

In 1974 a committee of officers from Brisbane City Council and relevant State Government Departments was established to investigate co-ordination of public transport in various areas of Brisbane.

In September 1974 this role was taken over by the newly constituted Metropolitan Transit Project Board (later to become the Metropolitan Transit Authority) who had the responsibility for formulating a suitable programme framework for Urban Public Transport.

One of the early projects approved for funding was a Bus-Bus Pilot Demonstration Programme.

Various sites for an interchange were considered around Brisbane, including some where private bus operators would be providing part of the "feeder" service to the interchange station and others that had the potential for rail to provide the line haul, or "trunk", service.

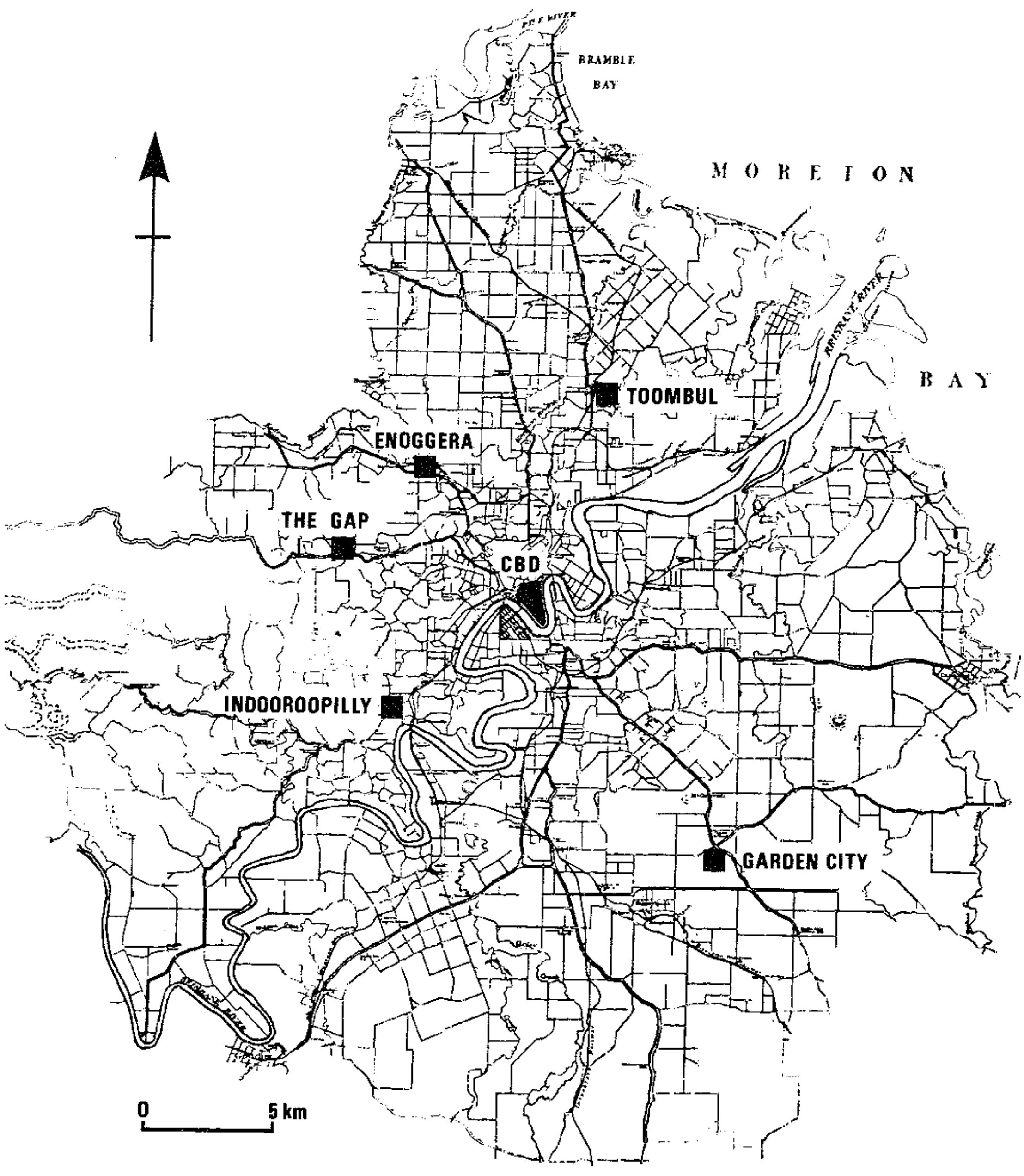

FIGURE 1 - Location of Toombul Interchange with respect to other Brisbane Localities

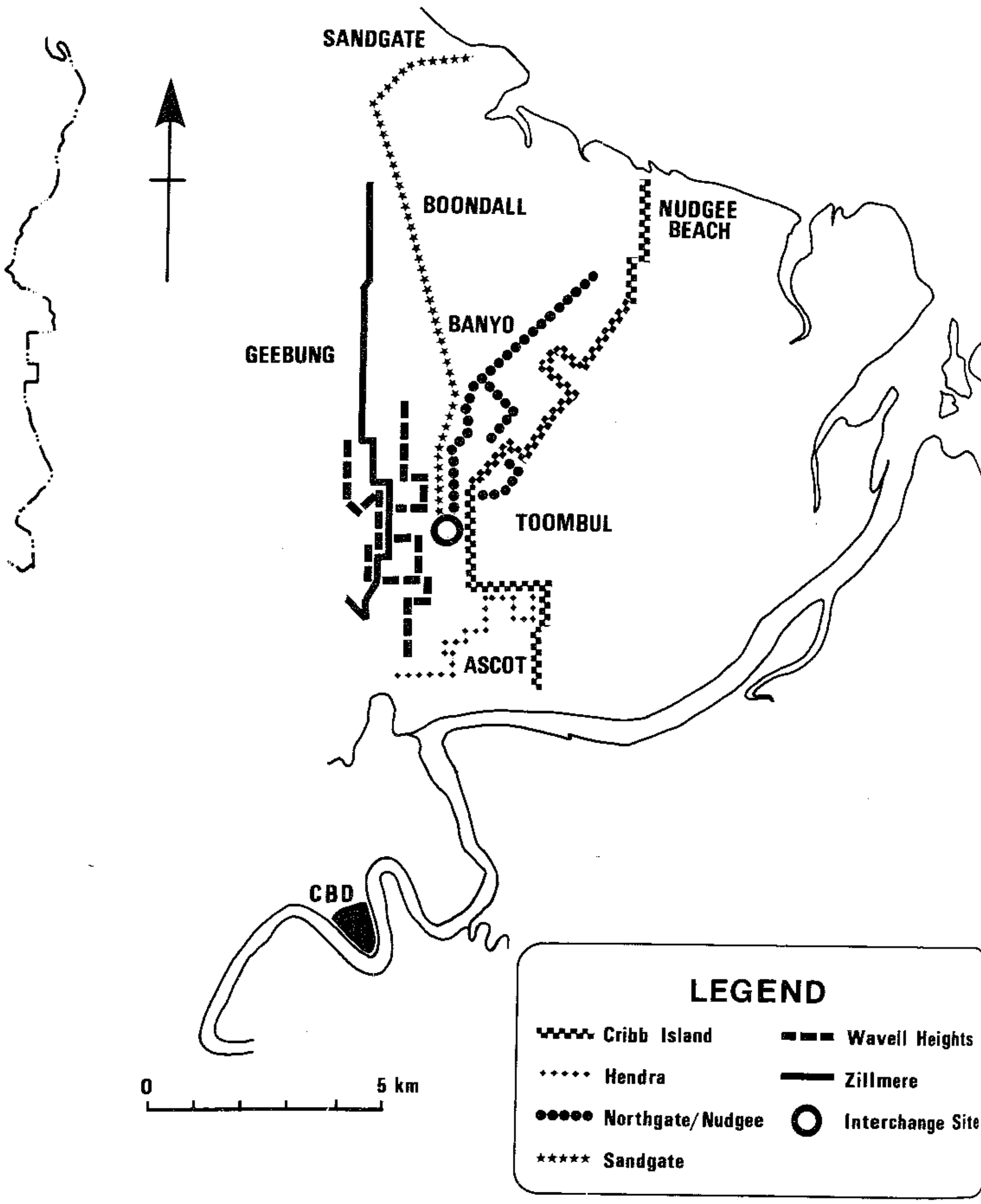

FIGURE 2 - Routes on which original survey data was collected.

The resultant route pattern adopted for the Interchange operations is shown in Figures 3 (Feeder Routes) and 4 (Trunk Routes).

With the decision made on routes to be included in the Interchange, detailed scheduling within certain constraints could commence. These constraints included:-

(i) a service level for the feeder routes of at least the same frequency as applied on the direct City service but where possible service levels to be improved;

(ii) transfer times to be kept to a minimum but not less than five minutes;

(iii) through-running buses to be allocated to routes which brought down the most passengers and to be shared over the feeder routes as evenly as possible;

(iv) that peak hour services operate as near as is practicable to present times;

(v) the trunk services via Sandgate Road and Ascot to retain the timetables which applied to those routes.

These policy constraints emanated from the desire to minimise the trauma for passengers by providing a basic service reasonably approximating that which existed before the interchange.

With the development of the schedule for the Interchange, all feeder routes (except the Chermside Cross-Country Service) obtained services of greater frequency. In some cases there was a dramatic increase in the number of bus trips per day (for instance parts of Banyo had an increase of trips per day from 14 to 24) whilst other areas only saw an increase of 2 trips per day.

Whether such increased levels of service could be justified will only be shown by the passage of time. It was, however, thought important to give the interchange every opportunity to succeed by erring on the generous side if there was any doubt.

On the Interchange to C.B.D. "trunk" route sixteen (16) inbound express trips were provided between 6.30 a.m. and 9.30 a.m. with the aim of decreasing travel time for passengers. This was considered necessary as it was expected that there would be some resistance to having to transfer between buses at the Interchange as has been reported by Philbrick (1977), MacDonald (1980) and Sullivan (1980) amongst others.

Increases of the line-haul trunk service Route 171 along Sandgate Road were made to cater for passengers transferring from feeder buses to the "all stops" 171 buses to alight between the Interchange and the C.B.D. and also for passengers who boarded between the Interchange and the C.B.D.

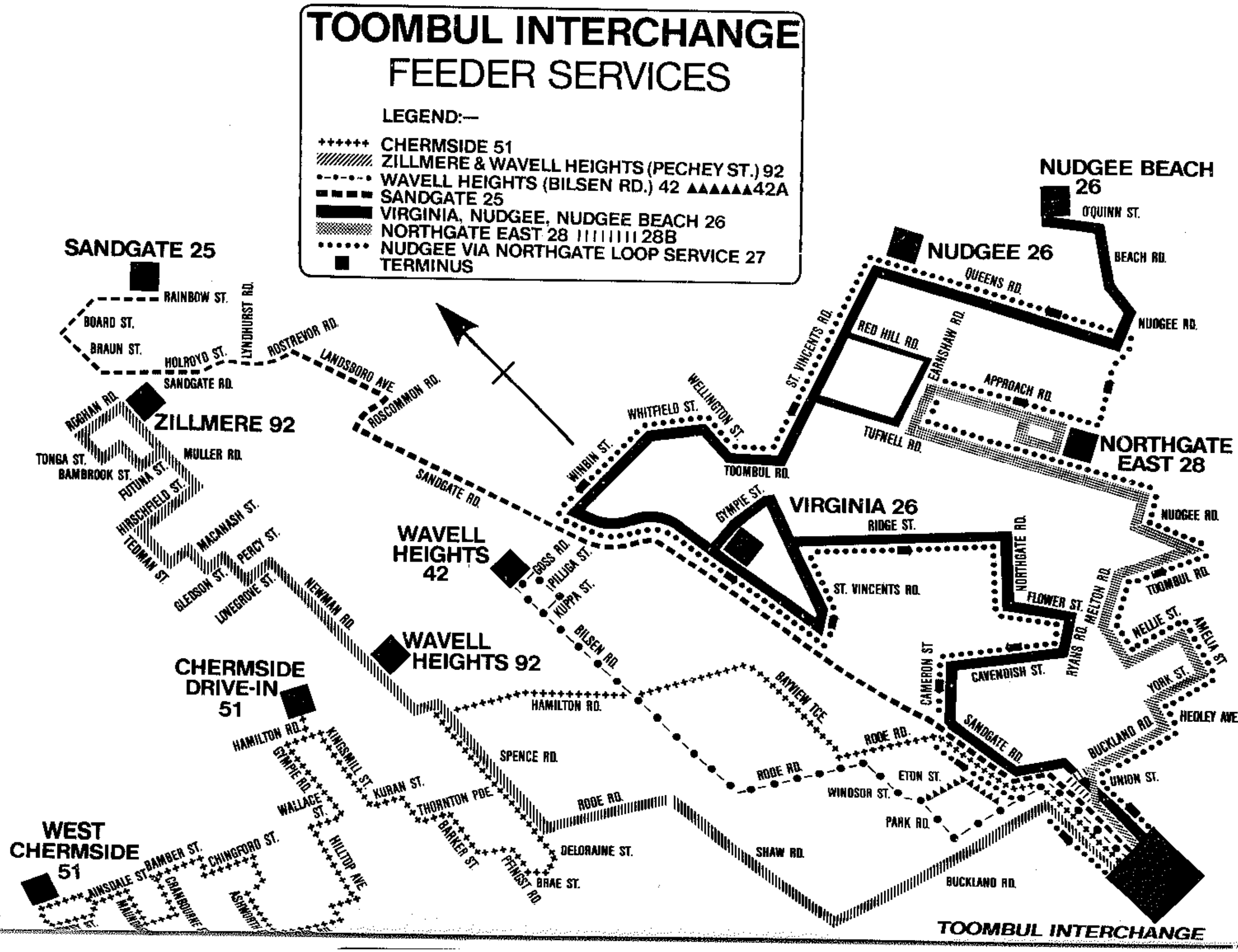
TOOMBUL INTERCHANGE
FEEDER SERVICES
LEGEND:—
CHERMSIDE 51
ZILLMERE & WAVELL HEIGHTS (PECHEY ST.) 92
WAVELL HEIGHTS (BILSEN RD.) 42 ▲▲▲▲▲▲42A
SANDGATE 25
VIRGINIA, NUDGEE, NUDGEE BEACH 26
NORTHGATE EAST 28 IIIIIIII 28B
NUDGEE VIA NORTHGATE LOOP SERVICE 27
TERMINUS
SANDGATE 25
NUDGEE BEACH 26
NUDGEE 26
NORTHGATE EAST 28
VIRGINIA 26
ZILLMERE 92
WAVELL HEIGHTS 42
WAVELL HEIGHTS 92
CHERMSIDE DRIVE-IN 51
WEST CHERMSIDE 51
TOOMBUL INTERCHANGE
RAINBOW ST.
BOARD ST.
BRAUN ST.
HOLROYD ST.
SANDGATE RD.
LYNDHURST RD.
ROSTREVOR RD.
LANDSBORO AVE
ROSCOMMON RD.
SANDGATE RD.
O'QUINN ST.
BEACH RD.
NUDGEE RD.
QUEENS RD.
RED HILL RD.
EARNSHAW RD.
APPROACH RD.
TUFNELL RD.
ST VINCENTS RD.
WELLINGTON ST.
WHITFIELD ST.
WINBIN ST.
TOOMBUL RD.
GYMPIE ST.
RIDGE ST.
ST. VINCENTS RD.
NORTHGATE RD.
FLOWER ST.
CAVENDISH ST.
RYANS RD.
MELTON RD.
NELLIE ST.
AMELIA ST.
YORK ST.
HEDLEY AVE.
BUCKLAND RD.
UNION ST.
NUDGEE RD.
TOOMBUL RD.
CAMERON ST
SANDGATE RD.
ETON ST.
WINDSOR ST.
PARK RD.
RODE RD.
BAYVIEW TCE
HAMILTON RD.
BILSEN RD.
KUPPA ST.
PILUGA ST.
GOSS RD.
MEGHAN RD.
TONGA ST.
BAMBROOK ST.
FUTUNA ST.
MULLER RD.
HIRSCHFIELD ST.
TEDMAN ST.
MACANASH ST.
GLEDSON ST.
PERCY ST.
LONGROVE ST.
NEWMAN RD.
SPENCE RD.
RODE RD.
SHAW RD.
BUCKLAND RD.
DELORAINE ST.
BRAE ST.
PFINGST RD.
BARKER ST.
THORNTON PDE.
KURAN ST.
KINGSMILL ST.
HAMILTON RD.
GYMPIE RD.
WALLACE ST.
HILLTOP AVE
CHINGFORD ST.
BAMBER ST.
AINSDALE ST.
CRANBOURNE
ASHWORTH

FIGURE 3

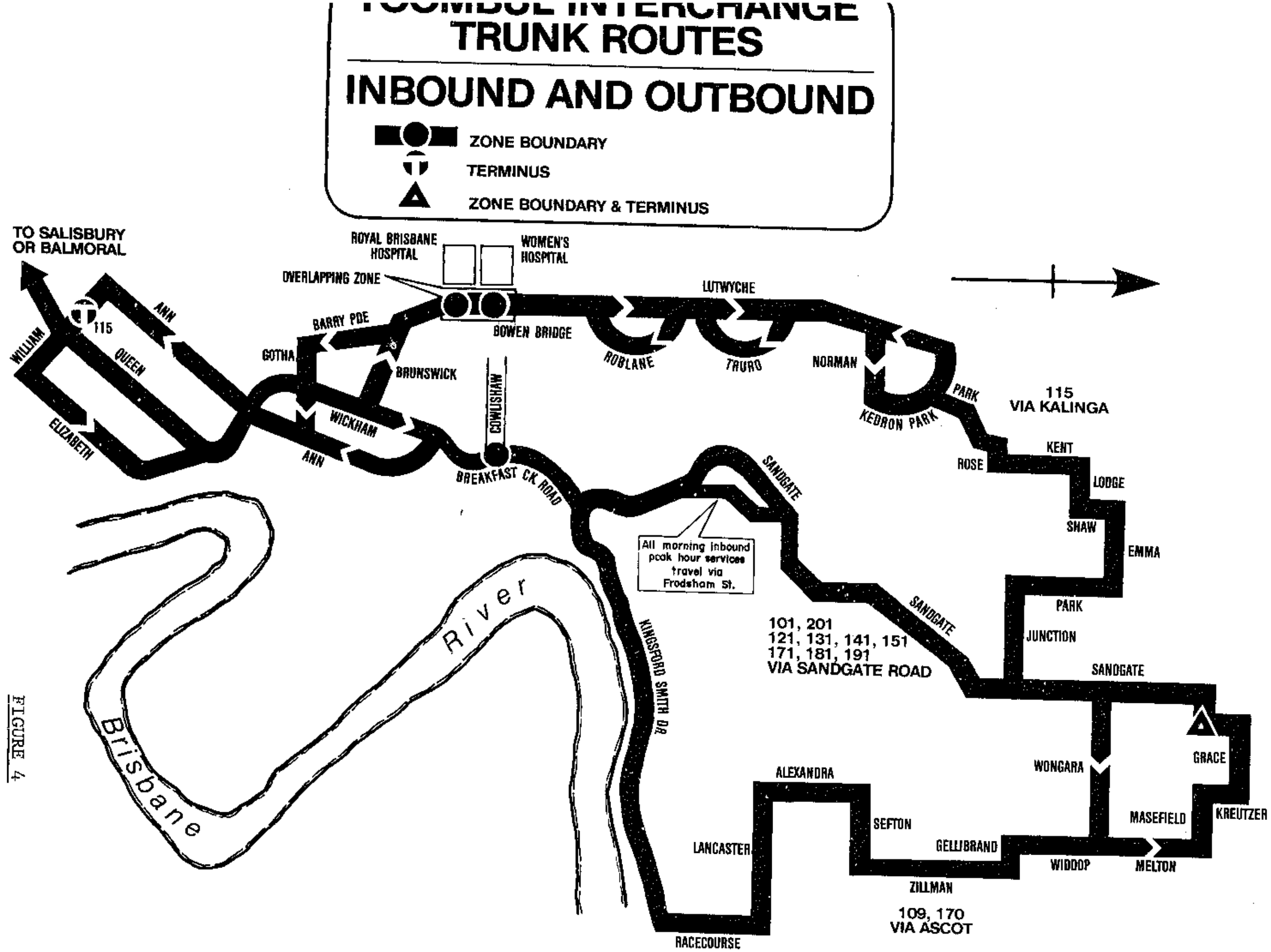
TRUNK ROUTES
INBOUND AND OUTBOUND
ZONE BOUNDARY
TERMINUS
ZONE BOUNDARY & TERMINUS
TO SALISBURY OR BALMORAL
115
WILLIAM
QUEEN
ANN
ELIZABETH
ROYAL BRISBANE HOSPITAL
WOMEN'S HOSPITAL
OVERLAPPING ZONE
BARRY PDE
GOTHA
BRUNSWICK
WICKHAM
ANN
BOWEN BRIDGE
COWLISHAW
BREAKFAST CK. ROAD
LUTWYCHE
ROBLANE
TRURO
NORMAN
KEDRON PARK
PARK
115
VIA KALINGA
ROSE
KENT
LODGE
SHAW
EMMA
PARK
JUNCTION
SANDGATE
SANDGATE
SANDGATE
All morning inbound peak hour services travel via Frodsham St.
101, 201
121, 131, 141, 151
171, 181, 191
VIA SANDGATE ROAD
KINGSFORD SMITH DR.
River
Brisbane
ALEXANDRA
SEFTON
LANCASTER
GELLIBRAND
ZILLMAN
WIDDOP
MELTON
WONGARA
GRACE
MASEFIELD
KREUTZER
RACECOURSE
109, 170
VIA ASCOT

FIGURE 4

Boarding passengers experienced no change in travel time compared with operations before the Interchange but those transferring and alighting were subjected to the five (5) minutes transfer time additional to their earlier journey.

It was calculated that the proposed schedule would result in a saving of ten (10) buses in the A.M. Peak and four (4) buses in the P.M. Peak even though the number of trips provided on services in the area has increased from 1493 trips per week to 1758 trips per week, an increase of nearly 18%. As the P.M. Peak is the Department of Transport's greater peak the effective saving of buses was four (4) buses. Furthermore six (6) Monday to Friday runs would be saved resulting in a reduction of seven (7) in the number of bus drivers required to operate at Light Street Depot.

THE INTERCHANGE

The actual Interchange facility is located in the Toombul Shoppingtown complex just off the major arterial road, Sandgate Road. The facility was built by the proprietors of the Shoppingtown at no cost to the Brisbane City Council and is maintained by the proprietors. The fact that the facility was built by the Centre reveals the mutual benefit which can be obtained when:-

(i) an Interchange is located at a node where significant numbers of passengers may wish to terminate or commence their journey;

(ii) private enterprise is aware of the potential increase in retail sales if residents in the catchment area of the retail centre have access to that centre on bus services which are both reliable and frequent;

(iii) the public transport operator is freed of making capital investment on Interchange facilities, there is greater opportunity to improve feeder services to the node which further enhances the attractiveness to the Centre proprietor providing the Interchange facility.

The layout of the Interchange, which has space for ten (10) buses as shown in Figure 5, was designed to minimise walking for the greatest number of passengers; i.e., zones were allocated to the feeder routes according to the anticipated daily loadings, the route with the highest expected loading being located adjacent to the main line-haul zone. The feeder route with the lowest number of expected passengers was located furthest from the main line-haul zone. A further area capable of holding three (3) buses is also allocated for storing buses which are not in service.

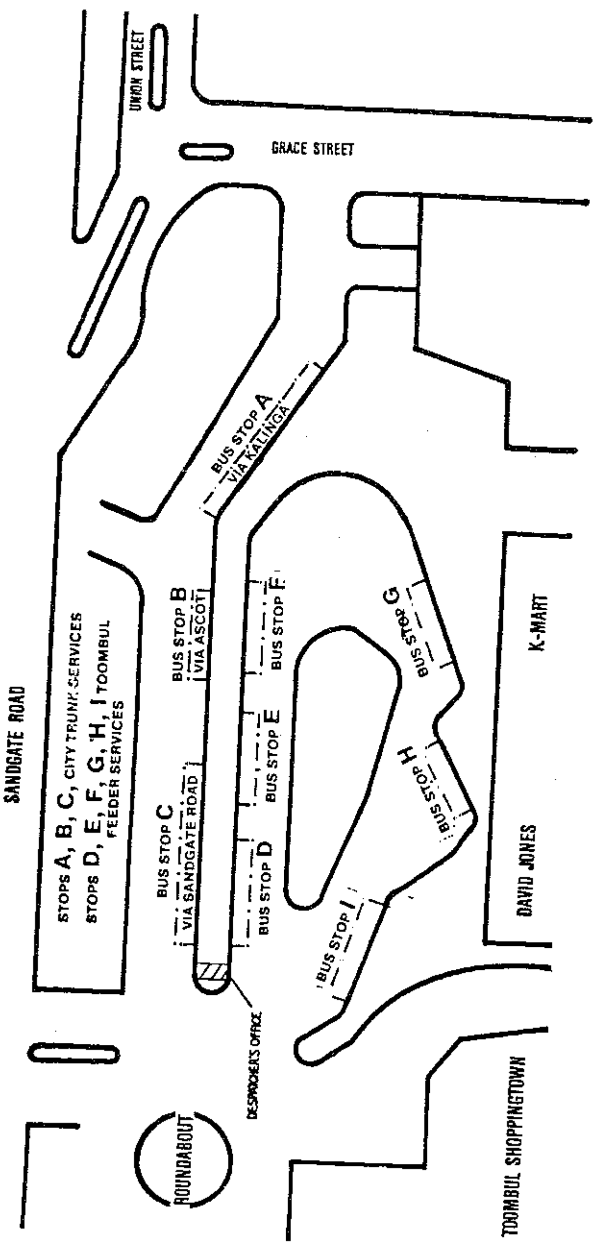

FIGURE 5

LAYOUT OF TOOMBUL BUS-BUS INTERCHANGE

At the head of each zone a system of lights have been provided to enable the Despatcher on duty to control departures of buses. The lights are controlled from the Despatcher's office and are used to assist him in ensuring successful co-ordination of buses. The system is simply a red and green light activated as required. In addition each zone has a P.A. loudspeaker installed through which the Despatcher can direct instructions to the bus driver and communicate to passengers on-board buses and at stops.

Minor operational problems have been experienced because of the location and design of the despatcher's office, the principal ones being:-

(i) because of the distance between the office and Zone A the despatcher is unable to read the destination blind and run number information;

(ii) because of the geometry of the main platform the despatcher can have problems observing the arrival of buses at the Zone A stop;

(iii) the despatcher's office was constructed with a solid "rear" wall which prevented him from seeing buses arriving from 'behind' him. Thus, he was unable to see bus run numbers or destination of those buses.

This problem is being rectified by insertion of a window in the rear wall.

These problems have highlighted operational requirements not previously fully appreciated and are to be kept well in mind in future interchange designs.

With the concentration of the Department's bus services at the Toombul Interchange, it was obvious that economies could be gained if a meal room was provided at the Interchange. Again, this facility was included in the infrastructure which the proprietors of Toombul Shoppingtown had constructed. Consequently, the Brisbane City Council was able to achieve these further economies by eliminating the need for bus drivers to return all the way to their base depot at Light Street Depot near the C.B.D. to have a meal. It was calculated that a minimum of eight hours per day has been saved owing to this facility because paid travelling time does not have to be rostered into daily work shifts.

PUBLICITY

The introduction of a Bus-Bus Interchange at Toombul Shoppingtown represented a major change to both commuters and running staff. The Council's bus system was radially oriented toward the C.B.D. and had evolved from the days when the C.B.D. was the major focus for Brisbane's population which was reflected in the route structure of the tram routes which since have been replaced by buses. Consequently, riders who were using the system were accustomed to route structures, ticketing arrangements and schedules which had been established for many years. To make the transition easier for these users and to inform potential riders of the new system a major publicity programme was undertaken.

Radio advertisements were placed on a number of Brisbane radio stations particularly those which had strong listening audiences in the north-east suburbs. The emphasis of these advertisements was on increased service frequencies and access. Also listeners were advised to obtain publicity material explaining the new Toombul bus connection. An inducement to read this material was a lucky number on each brochure which offered prizes donated by Toombul Shoppingtown if the winning number was held. Publicity material for the proposed Interchange was distributed to residents and bus riders in the area. Forty-eight thousand brochures were distributed to householders in the region by Toombul Shoppingtown and all bus riders on buses operating in the region were given brochures on the proposed system. The material was also made readily available at Council libraries and Alderman's ward offices, the Department's Mobile Information Centre was stationed in the area during the period of transition and the new system was given publicity in Brisbane's major daily newspaper and the local suburban newspaper. The Council's weekly television programme 'City Report' also featured the Interchange system.

The second, and equally important 'training' aspect was that the running staff operating and supervising the system had to be educated as to how it worked and to be motivated toward ensuring the successful implementation of the bus-bus Interchange.

To simplify the operation, initially some transfer was permitted on selected buses which used the Interchange terminal when it had been completed but before the official "full scale" system was commenced. This had the advantage of allowing bus drivers and supervisory staff to become familiar with the layout and style of operation, prior to the second and final stage when all routes involved would be operating at the Interchange, and also get regular passengers used to using the transfer capabilities of the interchange.

The final stage of training involved issuing each staff member with a hand-book containing all details of the system, such as routes, destination signs, transfer arrangements etc.

The Union were also kept fully involved, from formulation of running times to actual Interchange operation, and this assisted considerably in the smooth running that occurred.

TICKETING

It is considered that a basic requirement of an Interchange is that transfer should not involve the user paying any more for the journey than "pre-interchange".

Unless expensive electronic machinery is to be required it is necessary for the system to suit a simple manual operation.

In July 1980 the Council introduced a zonal fare system which assisted in the handling of the intricate requirements of a transfer system with a reasonable degree of efficiency.

There are, however, still considerable limitations in the ticketing system which limit "transfer without penalty" opportunity and introduction of a new system has been the subject of negotiations between the Brisbane City Council, Metropolitan Transit Authority and Queensland Railways for some considerable time. It is to be hoped that a system satisfactory to all parties can soon be agreed on and introduced to enable maximum potential of such interchanges to be realised.

PERFORMANCE

Running Times And Reliability

Prior to the introduction of the Interchange surveys were carried out to determine estimated trip times for each route and were used to formulate proposed schedules which, to a large extent, would determine the efficiency with which the operation performed.

In practice this method proved generally satisfactory and for the Express routes, Wavell Heights Route 42 and Nudgee/Virginia Route 26 Services there has been no need to make subsequent adjustments to the allowed running time. Table 1 below shows the level of reliability achieved in the first two weeks of operation. For the purpose of this exercise a bus was classed as late if it arrived more than three (3) minutes late.

TABLE 1

Reliability of Arrival Times Compared with Scheduled Times

Route	Reliability
Express Services	95%
Wavell Heights	98.5%
Nudgee/Virginia	93%

Other routes generally operated satisfactorily but were found to be less reliable at various times of the day. In all but one instance, which is detailed later, these services have been able to be modified and very few buses now run late. One particularly interesting problem occurred on the Sandgate and Zillmere feeder routes which basically recorded on-time arrivals at the Interchange but had a particular period when late running occurred. On these routes the late-running was confined to the A.M. peak and in particular to those buses "through-running" to the City as Express buses. This seemed to show on the part of the passengers a resistance to physically change vehicles as passengers were showing an obvious preference to travel on buses which are through-running. (This is discussed in more detail later). Consequently these particular buses were attracting patronage higher than the average for these routes during the morning peak and were therefore taking longer to reach the Interchange than was anticipated due to increased loading times.

The affected services were generally adjusted to leave the outer terminus about five (5) minutes earlier which preserved the desired connections at the Interchange whilst not upsetting passengers by occasioning too great a variation from the original bus times. It was felt that passengers would not be adversely disturbed if timetable variations were restricted to five (5) minutes or less. Duhs and Gibbings (1973) claim travel patterns are not affected where trip time alterations are not greater than five (5) minutes.

Subsequent checks of these buses have not shown any loss of patronage and in fact have revealed on these trips an increase in patronage. Whilst it is possible there are a number of factors which have caused this result it is contested that the improved reliability of the amended services could be contributing to this increase. An attitudinal survey conducted amongst bus users in October 1981, revealed that only 10% of respondents thought buses were rarely or never on time. A remarkable response when reliability is so crucial to a successful Interchange system and any missed connection for whatever reason detracts from a reputation for reliability.

The one problem to which a solution has not yet been found involves the main trunk-haul all-stops service, Toombul Route 171, which has consistently run late outbound, particularly between 11.00 a.m. and 2.30 p.m. Close scrutiny of this problem did not disclose any inadequacy in the running time but what became apparent was that buses were arriving late at Salisbury, the southern terminus of the Toombul 171 route. Layover time was generally only about four (4) minutes and therefore buses were leaving Salisbury late to return to Toombul Interchange. This situation is compounded if a bus has to be held at Toombul Interchange should a feeder bus be running late because late departure from Toombul will mean a late arrival at Salisbury. Consequently, without adequate recovery time to cushion these effects late-running will reverberate through the system.

Unfortunately, when the Interchange schedules were developed the consequences of not taking full cognizance of such aspects affecting reliability, as detailed by Sullivan (1980), were not fully appreciated and the continuing problem does not help with the users confidence in the system. This is especially so because the time of day when the problem occurs is when riders are casual rather than regular users of the system and the risk of missed connections adds to the anxiety experienced by such users.

Patronage

Although efficient schedules and reliability of service are important facets of a public transport operation as far as the operator is concerned the most crucial indicator must be public acceptance and use of the service. Much literature on bus-bus transfer systems emphasises how patronage has been attracted to such systems because of increased availability of access and increased frequencies. With the Toombul experience patronage levels have not, at this stage, increased but an apparent slowing of the patronage decline compared to the whole system has been recorded as indicated in Table 2.

TABLE 2

Variations in Population and Average Daily Weekday Patronage October 1980 to August 1981

	Population	Patronage
Brisbane City Area	-0.014%	
B.C.C. Transport Total System		-5.713%
Toombul Interchange Catchment	-3%	
Toombul Interchange Bus Routes		-5.14%

The comparative "increase" in Toombul patronage compared with total patronage figures could, to some extent, be because of the increased accessibility benefits which, from an attitudinal survey conducted in October 1981 amongst users of the Toombul Bus-Bus Interchange system, are well appreciated by patrons.

Respondents were asked to comment on various aspects associated with the Interchange and the great majority of responses indicated an awareness and positive reaction to the benefits available from the system.

Apart from specific questions respondents were also asked to list those features of the interchange that they most liked and disliked.

Improved access, convenience and increased bus frequency were listed by 66% of respondents as the features they liked best.

Transfer and Passenger Reaction

However politically popular or trendy Interchanges may be it must be realised that they are not all "good". For the passengers the basic requirement of an Interchange, namely the necessity to transfer from one bus to another, and the hassle and worry of co-ordination is a major cause of worry and dislike, particularly if they did not have to do so before the Interchange operated.

This 'resistance to transfer', mentioned earlier in the paper as having been a significant factor in Interchange operations according to some authors, has shown itself clearly at Toombul.

Not only did 48% of survey respondents (who listed a dislike) nominate 'the need to transfer' as their most disliked feature of the Interchange but passengers with the choice of 'through-running' or 'terminating feeder' buses have shown a marked preference for those 'through-running', as illustrated in Table 3 which shows, for comparable morning peak trips "before and after" Toombul, the percentage of the total inbound morning patronage carried on each bus.

TABLE 3

Passenger Resistance to Transfer
Wavell Heights Route 42

BEFORE TOOMBUL OPENED			AFTER TOOMBUL OPENED		
Trip Time	Passenger Load	% of A.M. Total	Passenger Load	% of A.M. Total	Variation
7.10*	22	16.2	42	33.1	+ 16.9%
7.23	21	15.4	8	6.3	- 9.1%
7.38*	27	19.9	34	26.8	+ 6.9%
7.46	23	16.9	12	9.4	- 7.5%
8.00*	43	31.6	31	24.4	- 7.2%
	136	100.0	127	100.0	

* Indicates Buses which through-run "post-Toombul"

From this there would appear to be considerable resistance to changing buses especially when it is realised that similar travel time savings are achieved by all five new trips compared with the "pre-Interchange" C.B.D. oriented trips. (In fact the best time saving is 13 minutes on the 7.46 a.m. trip which is serviced by a "terminating feeder").

If it is assumed that passengers previously travelled on the bus which delivered them to their destination of the most suitable time, then, to avoid the need to transfer passengers must travel on an earlier bus because the time savings achieved do not guarantee on time arrival if a later bus is caught.

Therefore, effectively the passenger has increased his journey time by travelling on an earlier bus than is actually necessary.

In the case of a move from the 7.46 a.m. to the 7.38 a.m. bus an increase in journey time of eight (8) minutes has occurred and a shift from the 7.23 a.m. to the 7.10 a.m. bus results in a thirteen (13) minutes increase.

It seems passengers are revealing a preference to incur a travel penalty of eight (8) and thirteen (13) minutes rather than the inconvenience of changing buses in a five (5) minutes transfer period. The assumption is that passengers are valuing transfer time at something greater than 1.6 times the equivalent journey time for the eight (8) minutes trip shift and 2.6 times for the thirteen (13) minutes trip shift.

Travel Time Savings

The above observation adds weight to the claims in the literature on the different values placed by users on the different components of travel time. A brief description of the conclusion of some writers is outlined below together with a Table showing the total savings in travel time accruing to bus passengers in the morning peak.

For example Lee and Dalvi (1969) do not impose any weighting for walking or waiting time compared with in-vehicle time whereas Pak Poy (1979) imposed a weighting of "times two" (x 2) for transfer time.

Furthermore, Duhs and Gibbings (1973) assert that a change of up to five (5) minutes in trip time does not affect a passengers decision to use public transport whereas changes greater than that do. This then raises the parallel question of "what is a worthwhile time saving?" (George and Shorey 1978).

It is contended that, if variations in trip times of less than five (5) minutes are not considered significant then, similarly, travel savings of less than five (5) minutes could also be considered not significant.

As an exercise therefore calculations have been carried out using all three methods, namely:-

Column 1 - Lee and Dalvi method - all travel components carry the same weighting.
Column 2 - Pak Poy method - transfer time component counts "double" in-vehicle time.
Column 3 - Adjusted Time method - travel differences of less than five (5) minutes are not considered and using Pak Poy weighting for transfer time.

The results of these calculations are shown in Table 4.

TABLE 4

Travel Time Savings (passenger minutes)

Route	(1) Lee & Dalvi Method	(2) Pak Poy Method	(3) Adjusted Time Savings
Northgate East	565	285	285
Nudgee/Virginia	354	84	174
Sandgate	1193	713	703
Wavell Heights	248	85	158
Zillmere	1222	872	808
Total	3582	2039	2128

From this it can be seen that, even when weighting of ransfer time is imposed, there have been considerable overall ime savings by introduction of the Interchange.

ONCLUSIONS

As is unfortunately often the case in the Planning and esearch field, there are few practical papers available describing ctual 'in field' results following introduction of well documented heoretical ideas, particularly papers dealing with operational indings.

This has made comparisons with other such projects very fficult.

It is apparent, however, that the results of the introduction of the Toombul Bus-Bus Interchange, particularly as far as resource savings and patronage have not been as dramatic as has been claimed in other centres such as New Delhi (Sharma) and Edmonton (Sullivan 1980) respectively.

This is put down to the fact that, because Toombul was the first such major innovation in a system that had been operating for many years, a policy decision was made to adhere as closely as possible to existing times and routes and hence minimise passenger disruption.

As a result a less than optimal system was no doubt introduced but one which had minimum adverse affect on the travelling public and the results have been encouraging enough to encourage detailed investigation of further bus-bus interchanges.

Since the opening of the Toombul Bus-Bus Interchange, in November 1980, we have seen the commencement of operation in April 1981 of a major joint venture, between Brisbane City Council, Queensland Railways and the Metropolitan Transit Authority, namely the bus-bus, bus-train Interchange at Enoggera.

Planning is also well advanced towards a bus-bus interchange at The Gap, about 10 km west of the C.B.D. and investigations are proceeding on further interchanges at Indooroopilly and Garden City.

The experience gained with the introduction of the Toombul Interchange proved invaluable in successful implementation of the Enoggera Interchange and it is to be hoped that lessons learned from these two operations will be put to good use in those to come.

Whilst the patronage level at Toombul has not increased, the rate of loss is less than that of the total B.C.C. operations and it is anticipated that, with time, the higher frequency of services and greater availability of destinations, through interchanging, will eventually result in increased ridership. This will particularly be so if an improved ticketing and fares system can be introduced.

This potential is particularly apparent from the Sandgate service which has shown an increase in ridership of 21% with a service increase of 20% during the period of comparison. It might be that for the other routes which have been established for about thirty years the old maxim "you can't teach an old dog new tricks" might explain the reluctance to adapt to a new system in spite of the obvious benefits.

Sullivan (1980) "advises" that an introduction rate of one interchange point a year can be considered a 'typical rate of progress'. This has been borne out by our experiences in the last twelve months, where:-

(i) introduction of both Toombul and Enoggera Interchanges within 6 months has imposed an almost unworkable burden on staff resources;

(ii) it is only after nearly twelve months that the 'fine tuning' of the Toombul system that the desired service reliability is being achieved and standard five minutes transfer times are fairly consistently being provided.

If I had to select one major finding from our experience of Toombul Bus-Bus Interchange (since reinforced by our Enoggera Interchange experience) it must be that:-

> With a given level of resources a far superior service, in terms of frequency and accessibility, can be provided with the Interchange concept than that provided with the traditional C.B.D. oriented radial service.

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