

TRAVEL DEMAND FORECASTS FOR A MAJOR TOLL BRIDGE - PROPOSED
GATEWAY BRIDGE, BRISBANE

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Abstract:

In recent years, route choice modelling, particularly where tolls are involved, has received much less professional attention than the closely related topic of mode choice modelling. However, route choice decision-making was central to the preparation of the demand forecasts for this major proposed crossing of the downstream reaches of the Brisbane River.

In late 1979, the Main Roads Department commissioned Rankine and Hill Pty Ltd, to prepare forecasts of the proposed bridge's usage over a range of tolls.

This paper describes the survey and analysis techniques which were employed in that project.

INTRODUCTION

The advantages of a downstream crossing of the Brisbane River have been recognised for many years. The planning of such a crossing has recently proceeded in conjunction with the planning of the new Brisbane Airport, the container port at Fisherman Islands, and further development of Brisbane's primary road network. In late 1978, the Main Roads Department invited tenders for the construction of the proposed toll facility which was to be either a six lane bridge or a four lane tunnel. In early 1980, the Queensland Government entered into an agreement with the successful tender consortium for the construction of a six lane bridge.

Prior to the final negotiations with the successful tenderer, Rankine & Hill Pty. Ltd., were commissioned by the Main Roads Department to prepare usage estimates of the proposed facility between Eagle Farm and Queensport (see Figure 1). These estimates were on the basis of usage in 1979, had the bridge then existed. Any growth in traffic between 1979 and 1985 (the projected bridge opening date), and any changes in the distribution of land uses in the region, were subject to independent review by the Department.

Therefore, the consultant's brief was confined to estimates only of the "1979 usage" with the current land uses, trip generation rates, cost and availability of alternative transport modes, etc. However, the projections were required to be classified according to vehicle type, since different vehicle types would attract different tolls, and to be related to a range of possible toll scales.

A review of the available literature, Australian and overseas, revealed no authoritative reference which could significantly contribute to the study. The only data sources relied upon were from the concurrent Brisbane Region Transportation Planning (B.R.T.P.) project and surveys specifically undertaken for this study.

STUDY METHODOLOGY OUTLINE

The study was undertaken using two separate sources of travel data. The first involved a series of roadside interview surveys to establish the existing pattern of river crossing trips, a proportion of which could be expected to divert to the proposed facility. The second source of information involved separately developed trip tables and provided an independent assessment. The trip tables of private vehicle travel were obtained from the B.R.T.P. project, while the commercial vehicle trip tables were synthesised from commercial and industrial establishment surveys undertaken specifically for this project.

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All of the road network data required (inter-zonal travel times and distances via all of the alternative river crossings) were provided from the B.R.T.P. project.

However, bridge usage was not estimated by the assignment of trip tables to the road network. It was considered that such assignments would have insufficient reliability for this investigation where traffic volume on an individual link was the issue. Instead, an empirical route choice model was used to predict the proportion of trips between each river-separated zone pair which would use the proposed bridge based on the alternative travel times, distances and toll costs. The sum of the diverted trips over all of the river crossing zone pairs represented the predicted usage of the proposed bridge.

From the two different trip record data sets, the route choice model made two assessments of the anticipated traffic volume from which a "best" estimate was subsequently derived. All of the trip data was classified by trip purpose and vehicle type so that the effects of the different tolls and toll sensitivities in the different categories could be evaluated.

SUMMARY DESCRIPTION OF THE DATA BASE

The following surveys were undertaken and existing data sources tapped in providing the total data base for the study.

Existing River Crossing Trips

A series of roadside interview surveys were undertaken on the southern approach roads to the Story and Captain Cook Bridges and on the Queensport vehicular ferry, these being the three existing downstream river crossing routes. All of the trips likely to be diverted to the proposed bridge were assumed to be from one of these routes.

The surveys were actually undertaken at 16 northbound or southbound locations on eight separate routes since surveys on the bridges themselves would have caused major traffic disruptions, but the results were the same as if the surveys were on the bridges themselves. With close co-operation between the police, the Main Roads Department staff who set up and dismantled the interview stations and the survey staff supervisors, only minor traffic congestion increases were produced.

The information obtained in the interviews was:

- .. Location, direction and time of day;
- .. Vehicle type, load and occupancy;
- .. Trip origin, destination and purpose, including intermediate destinations;
- .. Subjective response as to the likelihood of diversion to the bridge at various toll levels.

Over 15,000 successful interviews were recorded and coded. This represented an approximate ten percent sample of the total average weekday traffic volume on the three river crossings.

An expansion factor was derived and assigned to each individual interview such that the expanded total of all of the interview responses matched the late 1979 average weekday pattern of river crossing trips by the three routes. The expansion factors took account of vehicle type and period of the day.

Each interview record, together with its appropriate expansion factor was transferred to a disk file for further analysis. This data is now held by the M.R.D.

Alternative Route Travel Costs

Simulated road networks were developed for the current B.R.T.P. project and these were adjusted to represent the principal road network as it was in late 1979 and, for comparison purposes, as it will be upon completion of the proposed bridge.

From these alternative network descriptions, inter-zonal travel times and distances were derived for each river-separated zone pair (both minimum time and minimum distance criteria) via the existing vehicular ferry, the proposed bridge, the Story Bridge, the Captain Cook Bridge and the best of the other more westerly bridges.

B.R.T.P. Trip Tables

At the time of* this study, the B.R.T.P. project had not produced final person or vehicle trip tables. Zonal person trip productions and attractions had been finalised. However, the modal split and trip distribution models had not been fully calibrated. To assist this study, private trip tables were produced using simplified versions of the proposed models.

Being synthesised trip tables, they were very valuable for comparative purposes since they were free of the 'lumpiness' of the 'observed trip tables' developed by expansion of the river crossing trip survey data.

Brisbane Airport is close to the proposed bridge and it had not then been treated as a special generator in the derivation of the preliminary B.R.T.P. trip tables. Therefore interview surveys, similar to those used to establish the river crossing trip pattern, were undertaken on the approach roads to the airport. The results of these surveys were used as substitutes for those elements in the B.R.T.P. private vehicle trip tables relating to the airport zone.

Commercial Vehicle Trip Tables

The B.R.T.P. preliminary commercial vehicle trip tables were considered to be insufficiently reliable for this analysis. To supplement the trip generation data on which the B.R.T.P. trip tables were based, over 300 commercial and industrial establishment interviews were undertaken in the areas most likely to produce trips across the proposed bridge. To check the trip generation segments of these interview responses, gate surveys were undertaken at the most important of the establishments at which interviews were recorded. Trip generation rates were derived for the various industry categories, and these rates were dependent on zone location. Trip tables for light and heavy commercial vehicles were then prepared using zonal parameters on industrial activity extracted from Australian Bureau of Statistics figures by the B.R.T.P. project team. Using the river as the calibration screen line, these trip tables were adjusted so as to have maximum reliability in representing down-stream, river-crossing trip patterns.

THE ROUTE CHOICE MODEL

Route Choice Decision Making

Tripmaking involves a wide variety of choices with respect to destination, mode of travel, route, etc. It was assumed that the process of choosing between alternative routes conforms to the basic behavioural principle that each tripmaker acts to minimise what he thinks are his costs, but that individuals differ in their perception of the costs of the alternatives. Consequently, two tripmakers in the same situation do not necessarily make the same route choice, even though each of them makes a rational choice based on their own perceptions. The route costs perceived by an individual depend on the characteristics of the person, the nature of the trip, and the characteristics of available routes. The term 'route costs' was used to mean whatever combination of route factors influences the behaviour of the individual. For example, the factors could have included journey time, journey length, tolls, driving tension, avoidance of intersections, etc.

However, the precise manner in which these factors are combined to constitute perceived route costs is not explicitly specified by this behavioural principle. Linear additive combinations are commonly adopted on the basis of empirical performance. Just as individuals vary in their perception of the 'cost' of a particular alternative, they may also vary in their perception of the number of alternatives which they believe are available. This is as a result of lack of knowledge in many cases, but it can also occur because some alternatives are perceived as being so similar as to be indistinguishable, as far as making a choice is concerned. This latter situation can occur, for example, when two routes share a common path for much of their length.

Based on the above considerations, the techniques employed to model route choice in this study attempted to take full account of:

- (a) the nature of the trip;
- (b) the variability in individual tripmaker's perception of route costs; and
- (c) the perception of available route choices.

The principal data input to the model was the existing river crossing trip pattern information derived from the roadside interview surveys described earlier.

Travel costs were represented by the inter-zonal travel times and distances via all of the alternative river crossings derived from the B.R.T.P. network descriptions. These did not separately treat peak and off-peak conditions.

The Modelling Strategy

In recent years, very little research has been directed towards route choice decision making. Instead the analysis of route choice has been performed by default by the various trip assignment procedures which are available. The reasonableness of the results has usually been checked by the ability of the procedure to reproduce link volumes on a network. This method of analysis is probably satisfactory for most purposes when only general network effects are of interest. The accurate prediction of individual route choice decisions is of little direct interest in these cases. However, when interest is focused on only one link of the network, as it was in this study then confidence in the ability to predict route choice decisions becomes of paramount importance. Further, it was important to understand how the estimates of traffic on that link were derived.

The surveys conducted for this study made it possible to observe existing route choice behaviour. The chosen route was known. Since the route times and distances involved in using any of the alternative crossings was also available, the savings (or dissavings) associated with the chosen alternative was able to be determined. The strategy adopted was to develop relationships between the network travel times and distances of the available river crossing alternatives and the observed crossing choices. Once established, these relationships were applied to predict the effect of changes in the transport system on the choice of river crossing - in this case the provision of the proposed bridge.

One existing river crossing, the Sir James Holt Ferry, is a toll facility. The proposed bridge will also be a toll facility. The influence of tolls as well as time and distance on route choice was therefore central to this modelling exercise and close analysis of the choice of the Ferry crossing was a critical phase. There is little reported information on the influence of tolls on route choice either in Australia or overseas. However, the validity of transferring the findings of modal choice studies to a study of route choice is arguable. In modal choice studies, the major influence on choices are usually the attributes of the vehicles and, to a lesser extent, out of pocket expenses, travel time etc. In route choice vehicle attributes are not an issue. The effect of this on sensitivity to tolls, charges, etc., is not well documented.

The Perceived Route Choices

In defining the route choices, the first important step was to establish from the observed behaviour the number of viable alternatives which were being considered by tripmakers.

This could be ascertained, for each interview, by determining what the journey times would be for that particular origin-destination zone pair for routes including each of the available river crossings in turn. Assuming for the purpose of discussion that route selection on the basis of the minimum time criteria alone was appropriate, the rank order of the journey time of the route using the chosen crossing was then noted. (Route times were ranked in order of increasing magnitude). It was found that the great majority of tripmakers interviewed had chosen a crossing on either the fastest or second fastest route between their trip origin and destination, based on the network coded travel times supplied by the M.R.D. This was found to apply no matter which crossings were considered. Given that the four inner city crossings are not widely spaced, this was a result of real significance for the modelling structure. It implied that the perception of available routes was limited in most cases to two alternatives and that these could be defined from network

average travel times. Confining the analysis to route choice to only two alternatives greatly simplified the mathematical structure of the model and the testing procedures.

The influence of journey distances is ignored in this assessment, as is the effect of the toll levied on Ferry users. However, in view of the high correlation between journey time and distance, for routes other than the one including the Ferry, ignoring journey distance was considered to have little influence on the validity of the results. For the Ferry, the average terminal delay experienced by those who use it, was included in the journey time. Obviously this time penalty could not also account for the influence of the toll on route attractiveness, but it was probably sufficient to establish, in most cases, an approximately correct rank order for this route.

Characteristics of the Chosen Route

To establish the characteristics of the chosen route, the following information for each trip surveyed was assembled:

- .. The crossing used - Captain Cook Bridge, Story Bridge or Sir James Holt Ferry;
- .. The fastest crossing route which could have been used, other than the chosen crossing route - Captain Cook Bridge, Story Bridge, Sir James Holt Ferry, Victoria Bridge or William Jolly Bridge. This route could be faster or slower than the chosen route;
- .. The time and distance saved (or lost) by using the chosen route instead of the fastest alternative;
- .. The time and distance of the chosen route;
- .. The trip type,

Variability in the Route Choice Decision

The next step was to arrange the route choice data, described above, into a form which would allow the variability in route choice decisions to be analysed. Firstly, the trips were sorted into groups depending on the pair of perceived alternatives relevant to the particular origin-destination combination. The following choice pairings were identified:

- (a) Captain Cook Bridge (Fw) - Either Victoria or William Jolly Bridge (0);
- (b) Captain Cook Bridge (Fw) - Story Bridge (SB);
- (c) Captain Cook Bridge (Fw) - Sir James Holt Ferry (Fe);

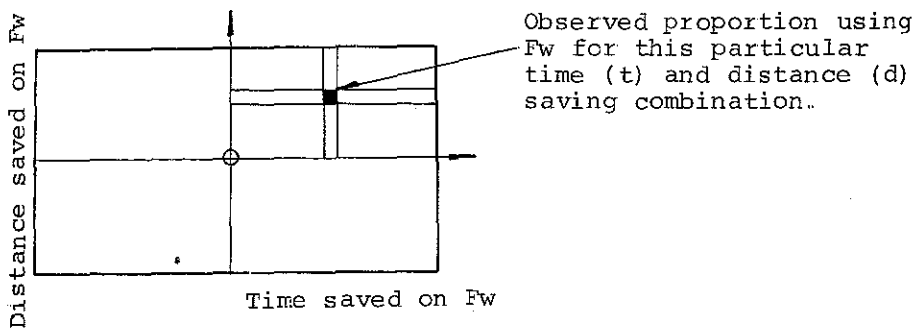
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- (d) Story Bridge (SB) - Either Victoria or William Jolly Bridge (0);
- (e) Story Bridge (SB) - Sir James Holt Ferry (Fe).

Other bridge or crossing pairings which were theoretically possible did not arise as viable pairs for the 15,000 odd interviews under study.

Initially, the second group (Fw - SB) was considered. For this group, it had been determined which tripmakers choose to use the Fw in preference to the SB in their journey, and vice versa. Consequently, it was possible to determine, for each of these trips, the time and distance advantages (or disadvantages) that choice of the Fw over the SB meant on average. For a given combination of Fw time-distance savings, the number of Fw users who did, and the number of SB users who could have enjoyed these savings were obtained. That is, even though faced with the same crossing choice decision in terms of the time-distance advantage of one alternative (the Fw) over the other (SB), some tripmakers chose to use the Fw and some the SB. Because the proportion of traffic interviewed varied from one crossing to another, it was necessary to factor down the trips made on the more highly sampled crossing, to achieve an equal sampling rate, before the proportion using the Fw in preference to the SB could be determined. This process was repeated for the full range of observed time-distance savings (or dissavings), to yield a matrix of the form shown in Figure 2.

FIGURE 2



The time savings were grouped in one minute intervals and the distance savings in one kilometre intervals. A similar procedure was adopted for the Fw - Fe, and the SB - Fe groups. A separate matrix was developed in each case for each trip type.

However, for the Fw - 0 and SB - 0 groups, only part of the route choice decision was observed - those who choose to use the Fw and those who choose to use the SB. Nothing was known about the number of users of the 0 alternative. These groups were consequently excluded from the route choice model development although this data obviously had an important role to play in other facets and later stages of the investigation.

The variability in route-choice decision-making had been demonstrated. However, the freeway and the ferry routes both provided a standard of travel which could have influenced route choice for reasons other than relative journey times and distances. Freeway travel provides smoother travelling conditions; while use of the ferry involves waiting delay and uncertainty concerning the availability of a space on the ferry. If such influences were significant, they should have been reflected in the observed route choice decisions. Routes using either the New Victoria, William Jolly or Story Bridge were treated as being the same general standard of road.

Model Calibration

The model form involved differentials of travel time, distance and toll and their associated parameters. The parameter values for time and distance were derived from records of choices not involving tolls (e.g. Fw vs SB). These parameters were constrained to remain constant where one route had a toll (ie the existing ferry). Therefore, the calibration of the route-choice model was performed in 2 stages. In stage 1, attention was directed only at the Fw-SB dichotomous or binary choice. In stage 2, dichotomous choices including the Fe (and hence tolls) could be considered.

It was assumed that the distribution of perceived route costs were normally distributed. It followed, therefore, that the distribution of the perceived differences in route costs could also be assumed to be normally distributed. The logistic distribution, being an excellent approximation to the normal distribution, was used to represent the probability of using one route given the relative average perceived costs of the two alternative routes.

The major decision at this stage was the choice of the functional form of the perceived route 'cost'. A linear additive form was selected incorporating a constant for the particular river crossing, the route travel time and the route travel distance. The total route travel cost was arranged to have the units of time. (Tolls were not considered until a later stage).

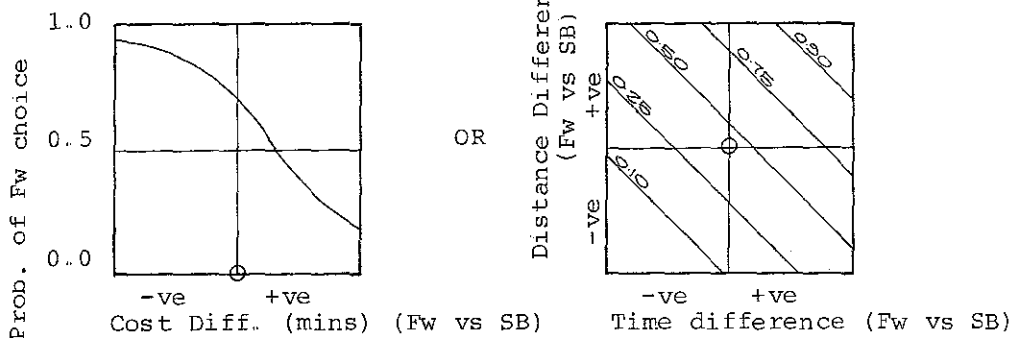
The logit analysis could have been performed on either data grouped accordingly to time-distance relativities or on individual data. A grouped data analysis was adopted. For a given combination of travel time and distance differentials, the total number of tripmakers making the route decision and the proportion of them choosing each of the routes was noted. The set of all such proportions was determined for all of the travel time and distance differentials. Since the observations in each time-distance combination were independent, the observed probabilities were binomially distributed about the true probability. The resultant model was heteroskedastic and satisfied the requirements of generalised least squares. The generalised least squares estimate of the true probabilities were completed using a weighted regression analysis.

Some care had to be exercised in the application of this procedure for two reasons. First, the time and distance savings were moderately correlated (r^2 approximately 0.5). Consequently the predictor variables had to be transformed into uncorrelated composites before applying the procedure. Secondly, the coefficient standard errors, etc., normally produced by least squares analysis packages had to be modified before they could be validly applied to the generalised least squares analysis (treated as either a weighted regression or an ordinary least squares analysis on transformed variables).

An individual data logit analysis would have had the advantage over the grouped data analysis of not relying on the assumption of reasonably large numbers of observations, not having to assume that each observation within each time-distance differential combination had the same probability of exhibiting the choice being modelled, and not requiring grouping of the data. However, access to an appropriate maximum likelihood estimation package would have been required. Further, that procedure would still have assumed that the route choice probabilities expressed in terms of the relative perceived costs were exact. At that stage, no procedure for adding a stochastic term for individuals to the model had been determined.

The difference in the standard of travelling conditions over the Captain Cook Bridge (Fw) as opposed to the Story Bridge (SB) required the addition of a constant to this route to explain the Fw - SB route choice. Graphically, the route choice model could be represented as shown in Figure 3.

FIGURE 3



In the second stage of model calibration, attention was directed to the SB - Fe and Fw - Fe choice alternatives. The model parameters determined from the Fw - SB first stage route choice consideration were necessarily assumed to remain unchanged. The objective of this stage of the analysis was to determine a value for the parameter to be added to the journey time of all routes using the Ferry (Fe), to reflect the average time valuation of the toll imposed thereon.

This was done for the Fw - Fe and the SB - Fe choices; and the parameter value selected on the basis of a goodness of fit test which was somewhat similar to a chi-squared test. The results of this procedure, particularly the dollar value of time that was derived, were compared with values reported in the literature as an independent test of the model structure and its embodied assumptions.

The presence of a toll on one of the crossings created some difficulties in selecting choice pairs. This was referred to earlier. The main problem arose from uncertainty as to the stage in the route choice process at which the effect of tolls is evaluated. It was assumed in this analysis that toll is combined with the other route choice characteristics of time and distance at the stage when the two viable routes have been defined and the final choice is being made. It remained uncertain that this measure of total route cost was the appropriate one to use in defining the final choice pair rather than all or part of the toll being excluded from consideration until the next stage of decision making.

Therefore, approaches ranging from total exclusion to full inclusion of the toll in defining the choice sets were tested in the calibration phase. While introducing a range into the possible value of time, no significant difference in the predicted use of the down river crossing over a wide range of potential tolls was produced. This was essentially because the greater the influence that the toll was permitted to exercise in defining choice pairs, the fewer pairs contained the Ferry as a perceived choice, and hence, the smaller the number of trips predicted to use the

ferry at a given time penalty. To compensate for this effect, it was found, in calibrating to the existing choices, that the value of time determined increased with increasing toll influence.

APPLICATION OF THE ROUTE CHOICE MODEL

The calibrated empirical route choice model was then applied to cross river trip data developed both from the Rankine & Hill surveys and the B.R.T.P. modelling.

In the prediction phase, the choice pair to be considered in each case was defined as the two routes of minimum total cost, ignoring tolls. For each river crossing zone pair or trip record, the model was used to make new estimates of river crossing traffic volumes by the different routes. The procedure was first checked against the existing road network to check that the existing pattern of river crossing traffic movement was accurately reproduced.

The expanded survey data effectively represented a partial "observed" trip table although it was not used in that way to provide the facility usage estimates. The route choice model established the proportion of trips which would divert to the facility given any set of relative travel costs on the alternative routes. Each trip record was expanded, and the model estimated the proportion of such trips likely to divert to the facility. This was repeated for each trip record and the number of diverted trips progressively accumulated.

The model was first applied assuming that the proposed bridge had no toll. Hence the toll differential aspect of the model had no influence. Subsequently, the model was applied at various proposed bridge tolls to ascertain the sensitivity of the usage to toll.

The usage estimates were categorised primarily by trip type. Some private trips are made in commercial vehicles and some commercial trips are made in private light vehicles. For this reason, there was not exact equivalence between private trips and light vehicles.

Tolls will be imposed on the basis of vehicle type rather than trip type. However, the correlation between vehicle type and trip type was considered to be sufficiently high to produce no major inaccuracies in assuming complete equivalence.

FINAL DEMAND ESTIMATES

Separate usage estimates of the proposed bridge based on the interview survey data and the synthesised trip tables were made. Traffic diverted from the existing crossings will cause travel time reductions on those routes. However, growth

in traffic between 1979 and the bridge opening date, will compensate for this effect. Hence, it was considered that no special allowance needed to be made for this effect.

Construction of this bridge will significantly reduce the cost of cross river trips in the down river area. This reduction will lead to additional trips being generated in this area and also some re-distribution of the existing trip patterns.

Separate adjustments of the demand estimates were made to reflect the effect of these generated and re-distributed trips. These adjustments were made on the basis of the reduction in average river crossing trip cost and an assumed travel demand/travel cost elasticity.

Finally, best estimates of bridge usage over a range of toll values were made. These took account of the route choice model predictions for both the interview survey data and the synthesised trip tables, the subjective responses given by the roadside survey interview respondents, and the adjustments for generated and re-distributed trips.

CONCLUSIONS

Credible usage estimates of the proposed bridge were the primary aim of this study. Duplicated data sources were used at virtually every stage to provide both the estimates and simultaneous checks. None of the separate analyses produced final estimates substantially at variance with those produced from alternative data sources. This considerably enhanced the final credibility of the usage estimates and increased the confidence possible in their application.