Computer Assisted Public Transport Network Planning: An Operator Perspective

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Abstract:

In common with most public transport organisations in the world today, the State Transport Authority in Adelaide is continually looking for ways to provide the most effective and efficient public transport system possible within the limits of the financial resources available. With this objective in mind, the task of the organisation then becomes very much one of using its resources so as to maximise the number of users of public transport in the area served by the organisation.

One tool that can assist in the assessment of the relative merits of various service options is a computer model of the public transport network.

This paper describes some of the benefits obtained and some of the lessons learned by the State Transport Authority in establishing, with the help of consultants, the 'IMPACTS' computer model to simulate the public transport network in a number of sectors of the Adelaide metropolitan area, and in the assessment of options for changing services in these sectors. The benefits include the ability to quickly and accurately assess the changes in resources required to implement a particular option, and at the same time understand the likely impacts on users. The lessons learned include the time and resources required to collect, code and analyse survey data, the process needed for identification of options to be examined, the 'learning curve' required for competency in the use of the model, the methods of interpretation and presentation of results and, most importantly, the ways of gaining credibility for the process throughout the organisation

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Introduction

Computer based models for evaluating changes to urban public transport networks have been available for over 20 years. In recent years they have become considerably more powerful, flexible and user-friendly with the introduction of more powerful PC's and improved graphical presentation methods.

Most usually, these planning models have been developed and applied by specialist consultants on behalf of planning and policy bodies to address strategic transport planning issues in urban areas. Most of these models have been developed principally to address highway planning issues with public transport being given less attention. Even where models have been applied specifically to public transport planning issues, these applications have usually been undertaken by external consultants on a one-off basis.

In 1990 the State Transport Authority (STA) of South Australia became the first major public transport operator in Australasia to adopt computer based network planning models as an integral and permanent component of its in-house service development process. This paper describes the STA's experience in introducing network modelling and focuses on the costs and benefits experienced and the lessons learned from the point of view of an operating authority. In particular it:

- outlines the background to the development of network models at the STA;
- presents a brief overview of the network planning process and the modelling system used by the STA;
- discusses the applications and benefits resulting from the use of network modelling; and
- reviews the experiences and lessons learned to date.

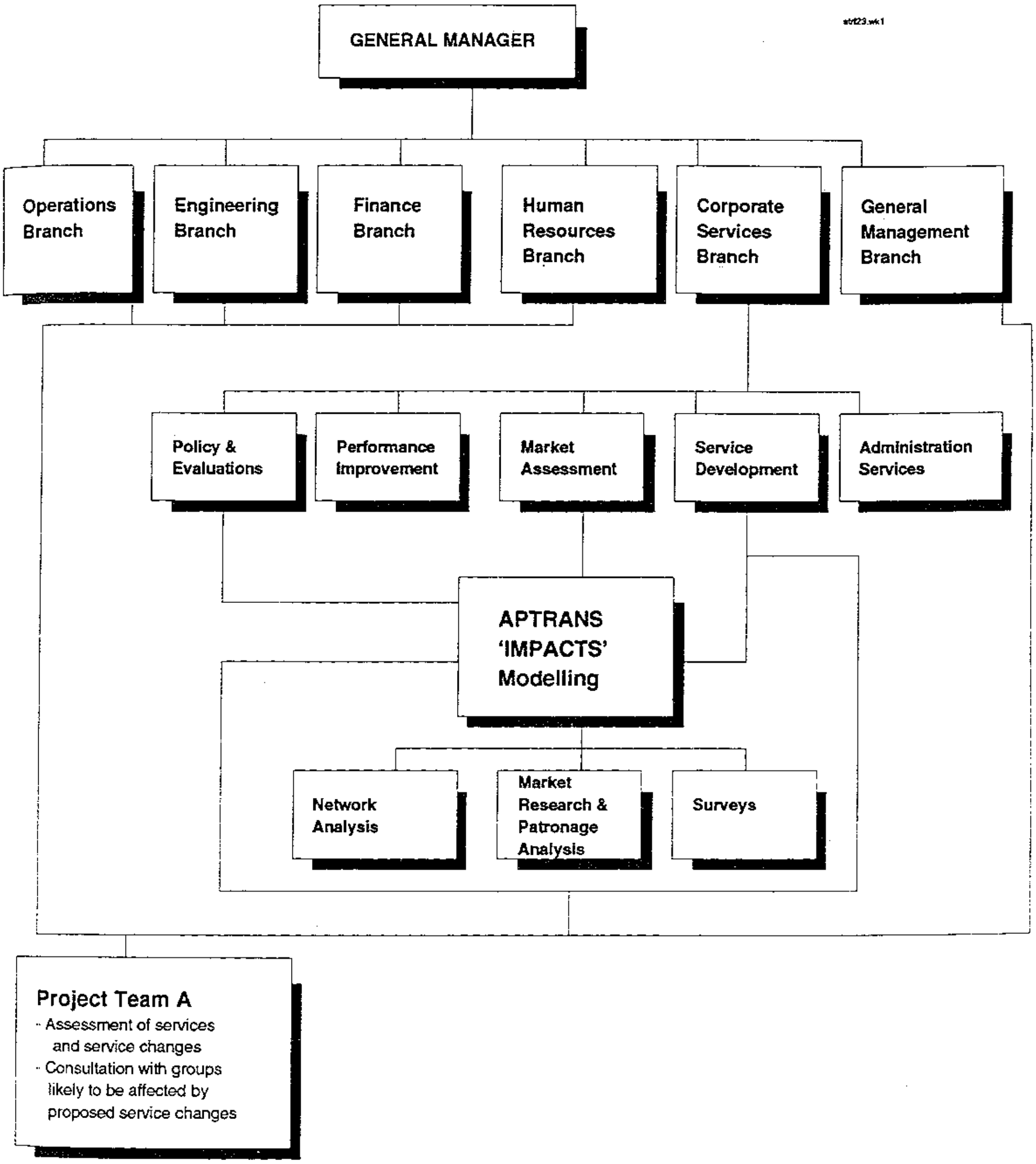
Background to public transport network planning at the STA

Over the five year period 1985/6 to 1990/91 the patronage on STA services fell by 15% from 67M to 57M per year. Over the same period government funding support declined from $180 M p.a. to $160 M p.a. (in $1991). With this fall in financial support (which seems likely to continue in future) the STA is under strong pressure to reduce its levels of service and increase its fares so as to meet financial targets. However it is simultaneously under public pressure to improve (or at a minimum maintain) its levels and quality of service for the social, community and environmental benefits they may bring. Such improvements are also essential if the recent decline in patronage is to be slowed or reversed.

These conflicting pressures have forced the STA to have a fundamental look at its route network strategy and structure of services. As in most other cities, the Adelaide network is predominantly radial, focusing on the CBD, and has tended to simply extend radially as the city expanded. It is essential in the present circumstances that services are designed to satisfy the various expectations of the community as efficiently as possible within the funding levels available from Government. Hence there is a need for technical tools to help in this service review and design task.

An independent review of public transport services in Adelaide (Fielding, 1988) recommended the adoption of public transport modelling tools as a means of assessing alternative ways of running the network and in particular to examine ways of better utilising the strengths of the train system.

Figure 1 : Public Transport Network Modelling Within the STA



Given this background and the 'Fielding' recommendations the STA developed a specification for the provision of a computer-based network modelling package and the associated survey and professional consultancy resources. As a result, Travers Morgan was appointed in 1989 to supply its IMPACTS (Integrated Models for the Planning and Costing of Transit Systems) package to the STA for in-house use, and to assist in survey planning, model development and training of STA staff.

The STA has established an Adelaide Public Transport Network Study (APTRANS) team, to undertake network service reviews progressively over the whole STA system, using IMPACTS as its main analytical tool. The APTRANS team includes STA staff involved in network development, model running and option evaluation.

Figure 1 shows how the APTRANS team fits within the STA organisation. The development of network and service options for evaluation through IMPACTS has been very much a joint effort between the Service Development Department and key personnel from other branches of the STA. Recently the option development and review process has been channelled through a special project team charged with detailed development and implementation of the service strategies set out in the STA 1992 Corporate Plan.

Overview of the modelling process

The key components of the computerised network modelling process are:

- A computer-based version of the public transport network, with representations of routes, stops, headways, section distances, speeds, modes, walk times, etc throughout the network.
- A matrix of passenger origin-destination (O-D) movements which is coded to zones.
- A set of procedures for assigning passenger movements to the network and deriving times and costs for trips between each O-D pair.

Once a 'base' case network is developed and the model validated for the existing situation, changes may be made to the network and the effects of those changes on users and operator resources evaluated with the model. Network change may involve the addition of new services or new modes, changes in service frequencies and changes in existing routes. Figure 2 shows a schematic diagram of the modelling process, showing the key inputs and outputs

Model development at the STA

In 1990 the IMPACTS system was first introduced at the STA and surveys were undertaken on the first of five corridors covering the whole city

Modelling has been conducted using a 'sector by sector' approach. To date models have been developed for sectors in the North West, South West and North of Adelaide and models for the rest of the city (East and North East) will be ready by the end of 1992. Some option evaluations have been conducted on all the modelled sectors (e.g. Travers Morgan 1991b), although the first sector completed (the North West) has had over 50 separate service

Figure 2 : Overview of the Public Transport Network Modelling Process

ATRF22.WK1

A. Building of Base Model Inputs - Existing Situation

DEMAND
- Origin and destination survey of existing passengers
- Information collected
  - size of demand (loadings)
  - passenger origins/destinations
  - services used
  - market information (age/sex/car usage/income etc)

SUPPLY
- Code up a representative network
- Information collected
  - stop/station locations
  - route stopping patterns
  - headways/frequencies
  - links between stops
  - travel times
  - mode characteristics

B. Develop Network Service Change Options for Assessment

- Generate list of service change options
- Define option packages for testing
- Adjust base network supply inputs for each test

C. Validation of Existing Model

MODEL RUNS OF BASE NETWORK
- Assess predicted passenger loadings for accuracy to real world
- Calibrate model sensitivity to known elasticities
- Adjust model parameters as neccessary to improve the base model performance

D. Testing of Options

MODEL RUNS OF OPTION NETWORKS
- Determine changes in demand
  - loadings on routes
  - change in travel times for passengers
  - benefits/disbenefits in terms of 'generalised time'
  - fare revenue
- Determine changes in operating resources
  - vehicle hours
  - vehicle kilometers
  - vehicles required
- Estimate cost impacts of change in operating resources
- Assessment and development of option packages for further testing
- Review results & identify scope for improving options

change options tested so far (State Transport Authority, 1990).

Table 1 shows some indicators of network size for the peak networks of the sectors currently available. In total (including off-peak periods) some 64,000 weekday trips and 364 routes have been modelled over 620 zones

Table 1: Measures of A.M. Peak Network Size - APTRANS Sectors Modelled To Date

	Sectors		
	North West	South West	North
Demand Inputs			
- Trips	12,156	15,941	13,084
- Origin & Destination Pairs	2,984	4,528	4,414
- Zones	162	248	210
Supply Inputs			
- Routes	72	154	138
- Stops/Stations	471	687	590
- Links	828	1,026	1,584
- Modes			
Bus	✓	✓	✓
Rail	✓	✓	✓
Tram	⊠	✓	⊠
Park & Ride	✓	✓	✓

Table 2 shows estimates of the staff resources required in surveys, data analysis, model development and network coding for the North West corridor. The corridor has a resident population of some 275,000 people with some 32,000 public transport trips being made in the weekday a.m. peak and inter-peak (the time periods surveyed). This was the first corridor studied and resource requirements have been reduced by around 40-50% in subsequent corridors with the benefits of previous experience.

It is clear from Table 2 that the surveys and subsequent coding are the most labour intensive components of the whole modelling process. On board O-D surveys were involved with sample surveys being equivalent to 57% of daily a.m. peak passengers and 60% of daily inter-peak passengers in the corridor. While such surveys are expensive, they are essential for any systematic service review process and the results are useful for purposes other than network modelling. For instance the market information collected in the surveys have been used for detailed market analysis of the STA's patronage and for analysis of the incidence of subsidies (Travers Morgan 1991a, 1992a, 1992b). Surveys at this level of detail are not likely to need repeating within at least 5 years, as the matrices could be updated in the shorter term from trends in passenger counts. Thus the costs involved in the survey/analysis process will continue to bring benefits for at least 5 years.

Table 2 : Resource Requirements to Develop the North West IMPACTS Model

	Persons	Weeks	Person Weeks
Demand Aspects			
- Survey Preparation	3	4	12
- Survey	20	6	120
- Data En-Coding	6	6	36
- Survey Expansion & Matrix Building	2	2	4
Sub-Total		20	172
Supply Aspects			
- Network Coding	2	4	8
TOTAL	-	24	180

The IMPACTS model

A variety of software packages are available which undertake public transport network modelling. The STA have adopted the IMPACTS (Integrated Models for the Planning and Costing of Transit Systems) system supplied by the consultants Travers Morgan Pty Ltd.

IMPACTS has been developed in Australia and New Zealand over the last 5 years, although its distant origins were in Europe (Travers Morgan, 1975). It has now been used by Travers Morgan in studies in most major Australian and New Zealand cities and also in the UK. Its application by the STA in Adelaide was the first occasion in which a large operator has acquired it for 'in house' use on a permanent basis

A technical description of IMPACTS was given in an earlier paper at ATRF (Wallis et al, 1989) Particular features of the system which are not shared by other such models, include:

- It has been developed specifically for public transport system modelling, whereas many models treat public transport in much less detail as an adjunct to a highway based model.
- It has an 'open-architecture' allowing the greatest flexibility over the various input parameters and ways of using the system which is in contrast to simpler 'black box' models.
- It operates on a standard IBM or compatible personal computer.

- It may be used to evaluate services at a high level of detail, for broader corridor studies or at a system-wide strategic level.

- It incorporates an 'elasticised' matrix approach by which the demand level on each O-D movement is sensitive to the ease/difficulty of making that movement.

- It allows specific consideration of 'Park and Ride' passengers (a significant group of users and a market area for possible patronage growth).

- It allows ready identification of 'winners' and losers' resulting from any proposed service change. This diagnostic facility is invaluable in providing decision makers with advice on the likely impacts of any service change and in assisting analysts to optimise proposals.

- It provides good estimates of the effects of any options on operator resources (peak vehicles, vehicle kilometres etc); and also includes a module which enables the changes in operating costs to be estimated (given appropriate unit cost inputs)

Applications and benefits of network modelling in the STA

Some of the particular applications and benefits that have resulted from the modelling process (to date) have included the following:

Improved speed, accuracy and turnover of service change evaluations

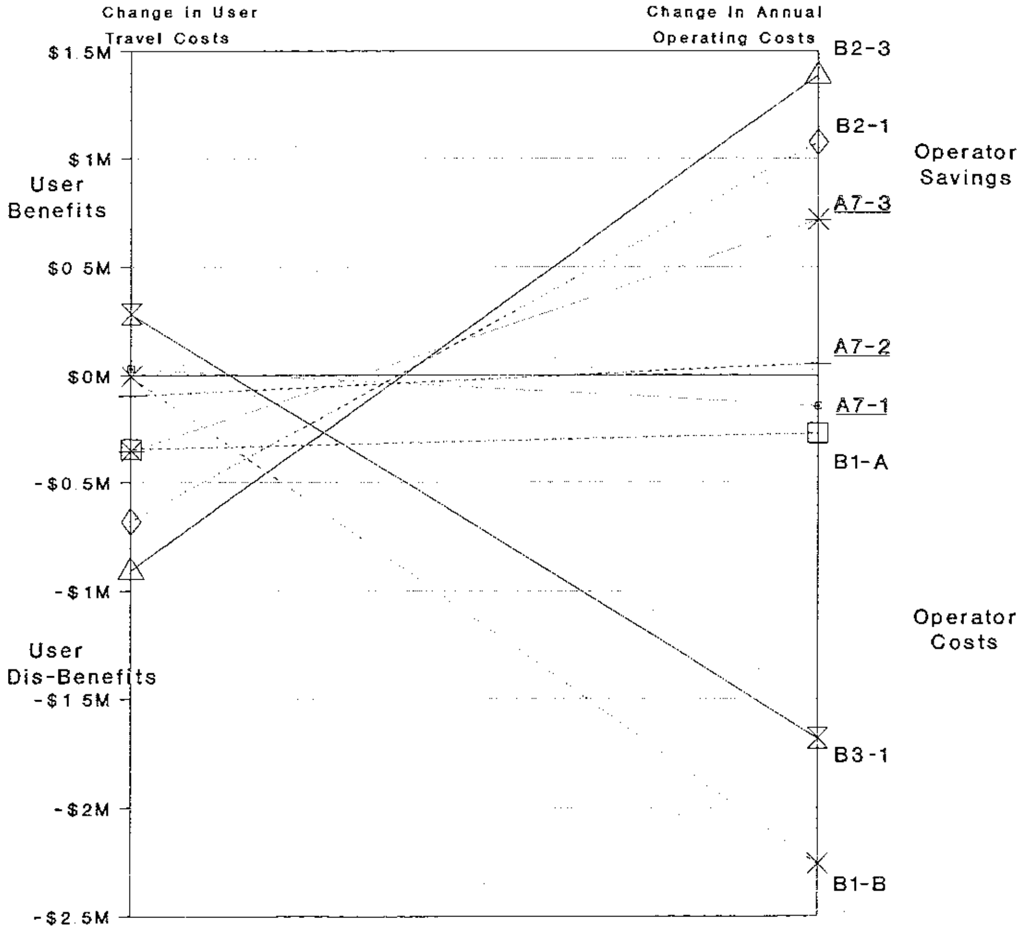
The most obvious benefit has been the ability to quickly and accurately assess the likely effects of any suggested changes in service delivery without actually implementing or trialing the changes to see what happens. Once the model is built, smaller scale service changes can be tested within a few minutes. Larger network evaluations require more time to isolate and code each type of change although this usually takes a few days rather than the weeks that a manual assessment may take. It is also unlikely that such large scale network reviews could be undertaken manually to the level of detail possible through computerised modelling

The accuracy of the system has been demonstrated in a recent real world implementation of a service previously modelled using IMPACTS. This involved the introduction of a new express 'Transit Link' high frequency bus service linking a regional centre to the CBD. The modelling prediction of peak loads were very close to actual experience with predicted shifts in patronage from other buses, car drivers and generated trips being within two percentage points of actual behaviour suggested by retrospective market research studies. Predictions of these effects are often as valuable as the net (total) demand predictions themselves, as they indicate where re-allocation of resources can best be made

The computer model has also made it possible to evaluate more service change options than would otherwise be the case with manual evaluations. Packages of service change measures can also be tested in a variety of combinations relatively easier. This indicates the combined effect of service changes, something that can be a time consuming and difficult effect to forecast manually

Figure 3 : Example Evaluation Results Overview

Changes in User and Operator Costs and Benefits by Option



Details of Options Evaluated

New Concept Options (A7 Series)

A7-1	Transit Link (express bus) services from city to West Lakes Mall shopping centre.
A7-2	Transit Link (express bus) services from city to West Lakes Mall shopping centre. Plus withdrawl of Grange railway
A7-3	'Fielding changes' - truncate long distance bus route ends.

Rail Oriented Options (B Series)

B1-A	Bus routes re-directed to rail stations. Direct bus routes reduced.
B1-B	Bus routes re-directed to rail stations. Rail service increased (headways halved)
B2-1	Grange & Glanville to Outer Harbour rail services deleted.
B2-3	All rail services deleted & bus services adjusted to compensate for increased demand
B3-1	Rail service increased (headways halved), & smaller rail sets used.

Formalised evaluation of diverse options

Another key benefit has been the ability to assess options of a very diverse nature using the same formalised process This cannot be over-estimated since much time can be spent discussing the relative merits of such divergent measures as improving service frequencies in one area compared to improving the coverage of routes in another The results allow trade-offs between operating cost effects and user benefits for all options evaluated.

Figure 3 shows an example summary evaluation for a range of options in the North West Corridor. It shows how changes in travel costs incurred by passengers can be traded-off against changes in costs to the public transport operator. Passenger travel costs are the total generalised cost of travel measured in terms of travel time and valued in dollars by applying a value of time. Changes in operator costs consider the effects of each option on fleet size, vehicle hours and vehicle kilometres. Unit costs are applied to these resource effects and changes in passenger revenues factored in to estimate the net effect of each option. In the example shown there are no options providing both user benefits and operator savings. In every case involving net benefits to users, there are increased costs to the operator; whereas savings to the operator in every case result in passenger dis-benefits, although some options are significantly better than others in this regard. Such a pattern of results frequently occurs in initial option evaluation, although experience is that the results can often be improved after review of the initial model results

After some considerable work on the North West a package of measures have been developed which generate both net user benefits and operator savings. The package includes the redeployment of bus capacity from poorly patronised services to high demand routes. Operator savings result from better vehicle utilisation while user benefits are generated by the higher frequencies There were some losers on the network, from passengers on poorly patronised routes where frequencies were reduced; however the dis-benefits faced by these users were far outweighed by the user benefits on the rest of the network.

Assessment of network-wide consequences of service changes

Network models also assist in identifying the wider network effects of changes in services. For example Figure 4 shows the change in demands on each part of the South West network resulting from the introduction of a bus-rail inter-change at Tonsley. The left hand diagram shows the northern part of the network with bands on links where passenger flows have increased as a result of the introduction of the inter-change package The size of the bands indicates the size of change i.e. wider bands indicate bigger changes in demand. The right hand diagram shows a similar diagram for decreases in passenger flows resulting from the option. These diagrams illustrate the quite complex effects of the introduction of the inter-change. Some of these effects are described on each of the diagrams Indications of where passenger flows decrease and the size of these decreases assists in evaluating where bus capacity may be saved or re-deployed Predictions of the size and locations of increased flows provide an indication of where additional capacity may be needed.

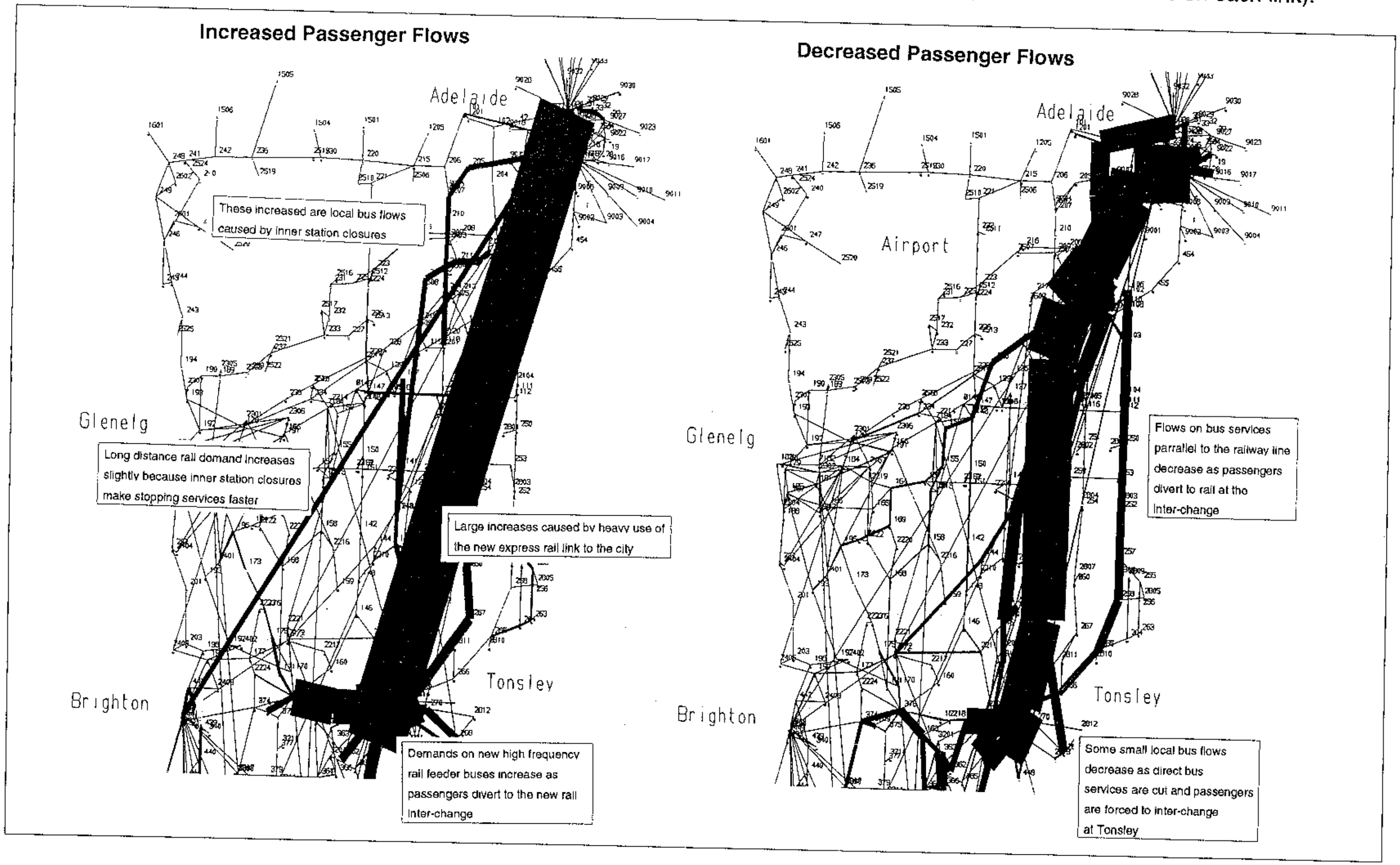
Use of graphics to assist in understanding of impacts

An important feature of the system has been the use of computer graphics to display results in a form that assists the understanding of both planners and decision makers. Figure 5 shows an 'accessibility' plot for the North West corridor under a package of service change options

Figure 4 : Change in Forecast Network Passenger Flows Resulting from the

Figure 4 : Change in Forecast Network Passenger Flows Resulting from the Introduction of a Package of Rail Inter-change Measures at Tonsley

(Diagrams show changes in passenger flows with the size of changes indicated by the widths of bands on each link).



focussing on light rail replacement of the heavy rail service. It shows for each zone the net effect of the option on passengers in terms of travel time (including waiting time, walking time, transfer time and fare). Areas with an improvement in travel quality have a B (benefit) and those with a net disadvantage have a D (dis-benefit). The size of the indicator (B or D) indicates the net size of benefits or dis-benefits. Diagrams such as this have been widely used to describe the distribution of winners and losers to authorities not concerned (or interested) with the intricacies of the public transport network. They also assist in easily identifying (and hence ameliorating) problem areas, or locations where options have a negative influence.

Use in 'optimising' options

As noted earlier, the model can also be used to optimise the performance of an option or package of options. Since it is possible to identify passengers who benefit or dis-benefit from a service change it is also possible to identify which part of the service change package is responsible for those who dis-benefit and why. These dis-benefits can then be reduced or eliminated by modifications to the options modelled. For example the package of options suggested for the large scale bus/rail inter-change mentioned above, showed that minor changes to the main line rail services (which were a secondary aspect of the package) could result in dis-benefits to passengers that far outweighed the benefits of adding a new express rail service to the inter-change and feeding more buses to it (the main part of the package). These factors were used to develop a revised option package which improved the net effects on public transport passengers from a small dis-benefit to a reasonable net benefit.

Lessons learned from the network modelling process

Now that the STA has been using computer-based network modelling for some two years it is possible to make some more informed observations on the lessons that have been learned during that period.

We now have a clearer understanding of the time and resources required to build the models including the passenger survey/analysis and network coding inputs. As described earlier (Table 2 etc.) the resources required are quite substantial; this highlights the need for careful consideration of sample sizes, sampling methods and efficient survey planning and management. A large proportion of the resources involved would be required for any major service review whether or not computerised network models are used.

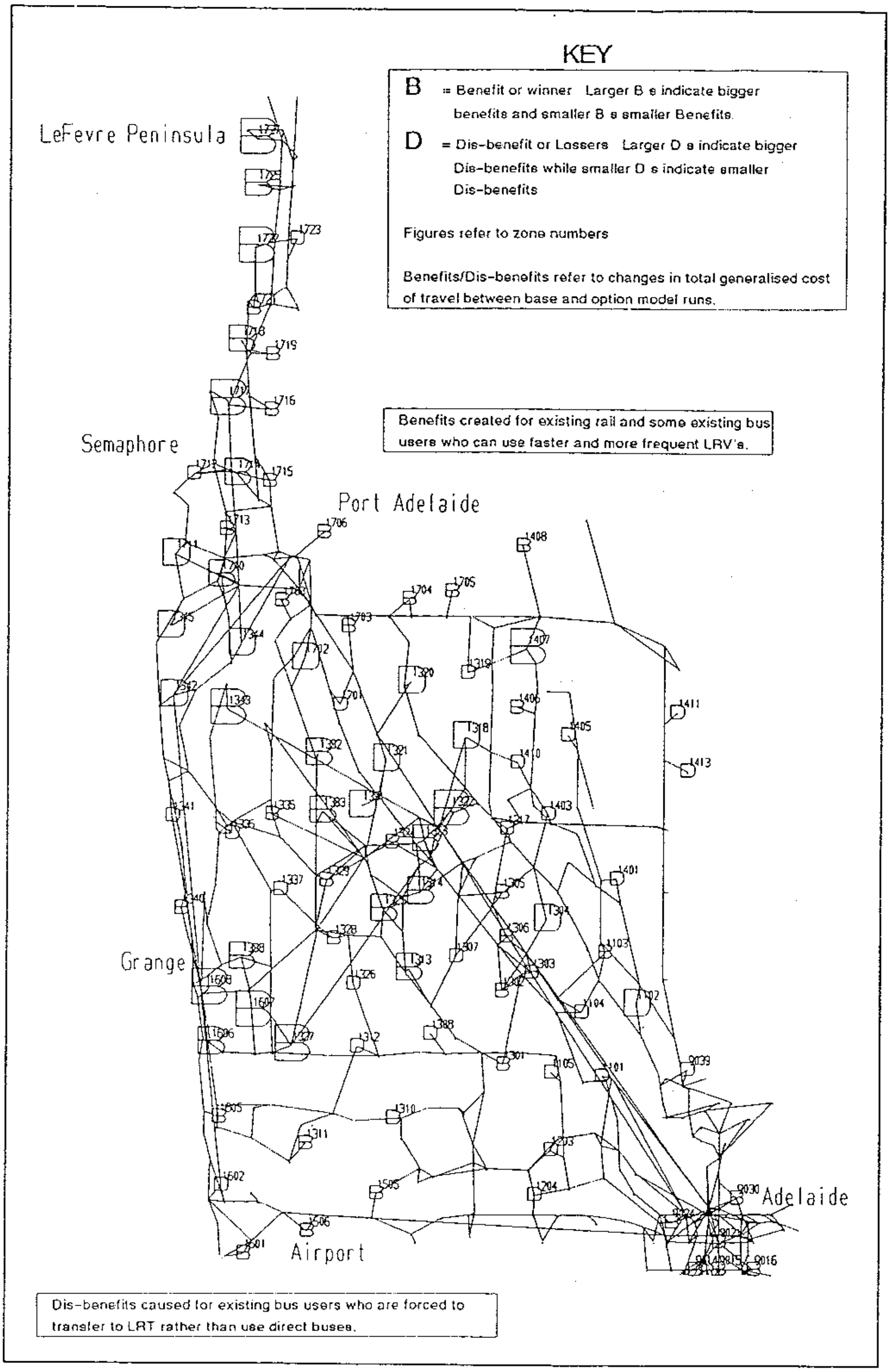
Another important lesson has concerned the way that service change options are developed and tested. It may be relatively easy to code and assess a package of service change options but more difficult to say what the individual effects of each measure within the package are on the demand and supply of services. Network models and passenger movements can be very complex. Because of this it is often difficult to separate the demand effects of two or more changes in the same area. Hence building and testing options should be a careful process of isolating the important aspects of each option and modelling these separately.

There is also a considerable 'learning curve' which planners new to public transport modelling must climb. This is important and must not be underestimated since like any tool public transport modelling is only as good as the person using it. Learning how to use the model has certainly been made more difficult by the 'open architecture' of the system since

Figure 5 : Distribution & Size of Public Transport User Benefits & Dis-Benefits

(Distribution of Winners and Losers)

Results are for Option D1 - LRT replaces heavy rail plus all direct bus services are cut to feed to local LRT stops



there is limited error checking and the user must be aware of steps in the modelling process that precede many modelling tasks It is possible to configure the system to be more defined although this severely limits the flexibility and range of its uses

The difficulties associated with the 'learning curve' are somewhat symptomatic of the specialist skills required in managing and operating the network model. Clearly all operating staff must have a sound knowledge of personal computers however network modelling also requires skills which are often polarised in public transport organisations; a knowledge of market research and a knowledge of operating schedules and timetables Since the system simulates both supply and demand, skills in both areas are required in the modelling team.

An important task for the modelling team within the STA has been to build credibility for the system and the results it produces A forecasting system which no one believes is of little use to anyone. This has been a delicate task since the modelling process is costly and provides little early benefits in terms of results. Also in the early stages the team were at the lower end of the learning curve and unfamiliar with all the systems and their capabilities. It is also fair to say that the use of modelling and computers generally as a predictive tool is often viewed suspiciously by those unfamiliar to them. The benefits of public transport modelling must be assessed over a longer time frame. Initially it has been useful to conduct more detailed manual evaluations of service change options alongside the IMPACTS predictions to assure other departments that the results are reliable. It is also fair to say that in many cases the modelling process has led to changes in the conception of operating staff about the 'right' solution, and this has been a valuable benefit of the process.

A major issue has also been the need to establish the most appropriate means of presenting results. Network simulation models are capable of generating large amounts of information but often in a format which is not very helpful to planners and decision makers. Graphical displays of option results (such as those shown in Figures 4 and 5) have proved to be very effective in showing the spatial distribution of network effects They make it easier for those unfamiliar with, and uninterested in, the detailed modelling process to understand how results have been generated and to grasp the network-wide influences of service changes.

Summary and conclusions

This paper has outlined the development of computer-based public transport network modelling in Adelaide as an integral part of the STA's APTRANS service review process. It has discussed the benefits and costs resulting from the modelling process and lessons learned. The STA is the only Australasian operator to have established such a modelling process in-house for use on an on-going basis

To date the modelling process has been used as the major tool in assessing operator and user costs and benefits of a range of network and service changes in each corridor served by the STA Key benefits from the systematic modelling approach have included the production of more accurate and defendable results for a diverse range of options in different locations; rapid provision of these results (once the model is established), and the ability to test more options than would be possible without such an approach

Further short-term tasks in the APTRANS/IMPACTS work will include the final development of the models for the North East and Eastern corridors. In the longer term a metropolitan-wide network model and a city centre model may be constructed for strategic evaluation purposes.

There is also scope for greater feedback from actual experience with new service changes to the modelling that was undertaken before these changes. This would involve adjusting various modelling parameters to conform to demand elasticities apparent in actual service changes. This should improve the accuracy of future predictions.

There is also the possibility of more flexible use of the modelling system for more strategic evaluations. It is possible to factor existing trip matrices to represent future changes in land use and to plan (and optimise) the future public transport networks around these new demand patterns. This has obvious uses for planning future resource and financial capacity and has previously been carried out using IMPACTS in Perth (Travers Morgan 1990) and other cities. This is a potential future use of the models in Adelaide as well.

From a financial viewpoint the APTRANS/IMPACTS project has clearly been well justified purely on the results of benefits in the first (North West) corridor. The results of the service changes recommended in this corridor realised some $1.3M per year savings in operating costs (including 8 buses) while also resulting in net benefits to passengers and predicted patronage increase as a result.

A final issue is whether the STA adopted the right course by installing the models in-house rather than appointing an external consultant to undertake a once-off service review exercise. Our view is that this was the right decision. All the indicators are that APTRANS is not going to be a one-off exercise; it would seem important that a major operating authority such as the STA has its own on-going capability to evaluate service changes, using the best practicable techniques, so as to be able to rapidly respond to changing patterns of demand and financial constraints. While the learning curve for the STA has been quite steep, we believe the wider long term benefits considerably exceed the costs.

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