Introduction

Rail Infrastructure Corporation[1] (RIC) has the responsibility to maintain, grow and adapt the New South Wales rail network for the use of passenger and freight traffic and also so as to meet a variety of environmental and transport policy goals. The Strategic Business Development (SBD) unit within RIC has the primary responsibility to plan for the long term development of the network in pursuit of these goals. To inform the planning process in as robust and defensible a way as possible we (the SBD unit) identified the need for a strategic demand forecasting model.

The purpose for the model can be summarised as;

- Giving guidance to planners and policy makers on the development of the Sydney rail network over a 10 to 20 year planning horizon; and
- Assisting in the development of a more formal strategic network planning process capable of being updated on a regular basis

Since 1996, Sydney's rail system has enjoyed tremendous growth in patronage—16.5 per cent to 2000 in the morning peak—to the extent that many planners have been left scratching their heads in puzzlement given that population is estimated to have grown by only 6 per cent over the period. It is worth mentioning that rail patronage growth in excess of population is not unique. Over the last twenty years, between 1980 and 2000, rail patronage has grown at 1.6 per cent per annum on average yet population growth has averaged only 1.2 per cent annually. Some of the answers to this puzzle are given in the NSW Department of Transport's Household Travel survey (NSW DoT 2000) which indicates an annual average growth in the weekday trip rate for all modes and purposes of 0.9 per cent per person between 1991 and 1998. Nevertheless, this alone does not explain the more recent acceleration in patronage growth.

Contributing substantially as a driver to this increase has been growth in Sydney's CBD employment. Yet some rail lines, most notably the Illawarra line running south of Sydney towards Wollongong, have experienced even greater growth. This begs the question as to why this should be the case. It would be pleasing to announce Sydney had adopted an integrated transport policy much lauded by many commentators (Vuchic 1999), but sadly this is not the case. The answer may lie more in the operation of market forces having created the 'transport/land use integration' model that town planners are sometimes cited as having created in Toronto (Newman & Kenworthy, 1999). Around rail stations in Sydney's south, there appears to have been a rush of high density residential development which has presented us with an image of progressive urban consolidation potentially spreading across all rail lines and resulting in further huge increases in patronage over the next five years. Whilst such a prospect seems unlikely, particularly since Toronto's example is under considerable scrutiny and its reputation by no means undisputed (Mees 2000a & 2000b), it has not prevented us

[1] In late 2000, following the recommendation of the McInerny report into the Glenbrook rail accident of late 1999, the NSW Government legislated to merge Rail Access Corporation (the infrastructure owner) and Rail Services Australia, (the rail service maintainer), into a new organisation named the Rail Infrastructure Corporation, effective from 1st January 2001.

from seriously questioning whether rail is under going a true renaissance in people's travel habits or, for example, is simply a residual beneficiary of the current economic cycle. These complex issues provided a further justification for developing a tool to more fully understand the demand for rail.

Sydney's Demographic Future

Sydney's employment and population level from 1996 is projected to grow by just over 22 per cent to 2021, whilst employment is forecast to keep pace. Employment growth is the key driver of peak period rail trips as we have seen over the last few years with strong growth in City Rail's passenger volumes across most lines. Simplistically this rise in population along with a commensurate increase in employment might translate to a rise of around 22 per cent in rail trips—assuming no increase in the trip rate or other socioeconomic effects—requiring an associated increase in train numbers. Rather than assuming the distribution of growth in rail trips would be close to and accessible to rail stations, our modeling exercise enabled us to test whether rail would *really* provide a serious transport opportunity in areas where population growth was forecast.

This relatively modest growth in rail trips of around 22 per cent over 20 years represents a 'Business As Usual' strategy for the rail network. Yet, if State Government policy along the lines of 'Action For Air' (AFA, New South Wales Environmental Protection Authority, 1998) is pursued, the public transport mode split for the journey to work travel purpose will have to rise from the current 21 per cent in the Sydney region to around 30 per cent. Although considerable doubt surrounds the absolute value of Australia's existing greenhouse emissions driving this target (Creedy, J. and Martin, C. 1999), if the AFA target were achieved the result for rail could be an increase of around 60-70 per cent in the number of trips over 1996 and might be even higher depending on how you interpret the AFA target. This is derived from an additional 1.2 per cent per annum average growth in rail trips on top of the 0.8 per cent annual average growth deriving from straight expansion in land use. Whilst greater employment concentration along rail line will help, much of this growth in rail trips can only occur with both an extension of the reach of the existing rail network as well as in increase in the capacity of the network.

From a modeling point of view these scenarios present a challenge. Should we develop a model assuming that state government policy through a combination of Travel Demand Management and environmental regulation in conjunction with wider global trends in oil prices and environmental concerns "deliver" an additional 40-50 per cent trips over those produced from the increase in population? Or should we develop plans for a future rail network for Sydney which by 2021 attracts the additional 40-50 per cent of trips? In the latter case we might have to extend lines deeper into the car dependent western and north western suburbs of Sydney or alternatively concentrate on relieving rail passenger congestion on the Inner West, Illawarra and Lower North shore lines, or maybe even both. Then again an additional 40-50 per cent in rail trips is a very large increase in demand. Since the Corporation has a responsibility as the owner of the rail assets on behalf of the Government and people of New South Wales to plan responsibly and use public money prudently we have to take as realistic a view as possible about likely outcomes. It would be unwise to focus exclusively on broad targets set by environmental planners without at least addressing the implications of these targets.

Broadly then, we considered three future scenarios:

- 'Business As Usual' with rail's mode share unchanged but peak rail trips rising along with employment and population growth;
- A more bullish view driven by environmental policy (or possible necessity) in which some how public transport mode share would rise so boosting rail's total trips by around 60-70 percent over the period 1996 to 2021; and
- A third view was an attempt to look at what was seriously achievable with new lines and some policy instruments.

All of this was to be represented using the demand model as a means to give the assessments some rigour and provide technical input into the AFT process of transport project development.

Table 1 Sydney Statistical Division Population and Employment Forecasts

Year	Population	Yr/Av	Employment	Yr/Av
1996	3,881,100		1,784,342	
2001	4,075,100	1.0	1,867,591	0.9
2006	4,247,000	0.8	1,945,561	0.8
2011	4,413,100	0.8	2,024,122	0.8
2016	4,578,500	0.7	2,117,196	0.9
2021	4,737,700	0.7	2,202,183	0.8
2026	4,883,400	0.6	2,277,200	0.7

Sources: 1) Department of Urban Affairs and Planning (1999), 2) Employment Forecasts – Transport Data Centre, July 2000.

Each of these demand scenarios was to be tested in RIC's model, named the Rail Travel Model (RTM), although currently only the 'Business As Usual' scenario has the detail needed for modeling. By using a transport model developed within an EMME/2 environment, we were also able to pull out not only demand statistics but also data which can be used in economic and financial appraisal. This means that in testing future year rail networks, which represented a combination of new rail projects added to the base rail network, we were able to feed EMME/2 output into an economic evaluation framework. In turn this was to be fed into a wider multi criteria assessment of specific transport improvements including a range of environmental, social and economic issues.

Action for Transport 2010

Action for Transport 2010 (NSW DoT 1998) was the most recent integrated transport strategy for the Sydney region with contributions from all transport agencies. Since AFT was prepared nearly three years ago and whilst it remains the central transport strategy against which nearly all new large transport projects are measured and tested, it was widely accepted that this was the start of a more considered approach to Sydney's transport planning framework.

The need to build upon the thinking in AFT triggered a requirement to develop within the rail agencies a capability to test and evaluate the impacts of rail projects across the network. Further more, since AFT's publication in 1998 potential new projects have emerged in addition to those included in AFT which planners have been asked to consider, but which had not been formally evaluated and tested against other priority projects. RIC had a need to build on the planning issues surrounding the rail projects identified in AFT, identify potential new projects and provide some further robustness in the overall network wide project costs and benefits.

Emerging from this process, the Corporation identified a need for a strategic planning or 'sketch planning' tool to evaluate the benefits of specific projects. Such a tool would provide a range of project evaluations but most critically of all they would be tested using common criteria permitting across project comparisons and even project rankings. It was also agreed that this 'tool' was to be largely for internal use or for use between RIC and the New South Wales Treasury/ Department of Transport. It was not seen as a means of supplanting the usual detailed analysis undertaken on a project specific basis associated with feasibility assessments. Neither would it—or could it—replace analysis employed during an Environmental Impact Statement (EIS) process. Nevertheless 'sketch planning' tools have a place in transport infrastructure assessment (Kilsby et al. 1992).

Following a review of modeling approaches available, it was resolved that an integrated land use and transport system model would provide the best approach (BTCE 1998). Although RIC's principal concern was in the use of the rail outputs—and inputs—of the model, transport policy needs to take an integrated approach in order to achieve allocative efficiency across the transport modes (Hibbs, 2000). To this end, it was resolved to make use of the New South Wales' Department of Transport Strategic Travel Model, maintained by the Transprot Data Centre (TDC) within the DoT and currently operating in the EMME/2 transport modelling package. Updating and maintaining STM therefore remains TDC's responsibility enabling RIC to continue to benefit from any STM technical improvements through a licensing agreement between TDC and RIC.

The Corporation's need for a Demand Model

The Strategic Business Development unit within RIC is largely responsible for the conception, planning and initial development of new metropolitan rail infrastructure projects. Much of its work has been involved in the planning of specific new lines and examining the case for projects on a piecemeal basis. Yet we were increasingly being asked questions which required us to have an understanding of the impact of rail projects on other modes of travel. The 'Future Directions' study in 1991 (referred to in Kilsby, D., Prince, P. and Stewart D.1992) was a major study in the examination of overall impacts across both highway and public transport networks of specific transport network changes in New South Wales. Whilst RIC's evaluation model had no pretensions to emulate the work of Future Directions, which looked at a range of transport options, we were motivated out of the same desire to consider at a network wide level the impact of a range of small, medium and large rail projects on the whole rail network. The difference being that the purpose of the Corporation's model was primarily to examine impacts on the rail system (although of course the model covers none rail modes as well) whilst the Future Directions study was explicitly multi modal. To this extent, TDC's strategic model was ideal for our purposes.

With this wider planning objective in mind we had several broad impact assessments which needed examining with the model. One was the need to review the impact of the New South Wales government environmental targets on rail usage and the other was a consideration of the forecast rise in population over the next twenty years.

The Sydney Travel Model[2]

With this goal in mind, after some broader considerations of modeling practices (BTCE 1998) we resolved to use the New South Wales Department of Transport's "Sydney Travel Model", to which RIC was already a sponsor. The Transport Data Centre (TDC), part of the NSW Department of Transport (DoT), has devoted several years and a great deal of resources into the development of the Sydney Strategic Travel Model (STM). This model is desk top computer based and largely operated within the EMME/2 transport planning model (Milthorpe, Daly & Rohr, 2000). Early on in the development of the STM, TDC requested sponsorship from other public transport agencies with an interest in the development of such a model and RIC agreed. As a sponsor having made a commitment to the model we wish to continue to make use not just of its output but of the model itself.

The area covered by the model the Sydney statistical division (Sydney SD), shown in Figure 1. This area includes Sydney, the Blue Mountains and the Central Coast (Gosford and Wyong). This is an area covering 12,100 square kilometres (4,700 square miles) and in 2000 had an estimated population of 4,085,000 (ABS, 2001). Over the last five years population growth has averaged 1.3 per cent per annum, a figure slightly ahead of the growth rate for the whole of the state which was 1.1 per cent on average over the same time period. Since the population for New South Wales is estimated to have reached 6,463,000 in 2000 (ABS, 2001), Sydney SD represents 63 per cent of the state.

[2] This section of the paper relies on technical information and summaries contained in a range of reports produced during the development of the Sydney Travel Model produced by consultants and other parties. In particular the paper by Milthorpe, Daly and Rohr, has provided a useful source.

Source; Milthorpe, Daly & Rohr, 2000

Figure 1: Sydney Travel Model, extent of Sydney SD Coverage

STM covers metropolitan Sydney, the Blue Mountains and the Central Coast (specifically Gosford and Wyong) covering a population of around 4 million people. The model has over 900 zones, seven modes (car driver, car passenger, rail including bus access to rail, bus only, bike, walk and taxi) and currently uses 1996 Journey to Work (JTW) and 1997/8 Household Travel Survey (HTS) data. Currently STM is a JTW model for four time periods and these are morning and evening peaks plus the daytime (between peaks) and evening/night. Expansion factors are used to move from JTW trips to all purposes. It is acknowledged that these expansion factors present limitations but Stage 2 of STM's development (which is currently being undertaken) is directly addressing this issue.

Four periods of the day are covered in the model:

- morning peak;
- evening peak;
- daytime (between the peaks);and
- evening/night.

The movement between congested peaks and the less congested day and evening/night periods was modelled using 'shoulder' periods.

Seven modes were defined and implemented in the mode choice models:

- Car driver;
- Car passenger;
- Rail (possibly with bus access);
- Bus only;
- Bike;
- Walk;
- Taxi.

Two separate model components comprise the transport modelling system at the heart of the Rail Travel Model:

- The population model; and
- The transport model.

Dealing with each in turn, the population model is further composed of other elements, namely 1) a prototypical sampling procedure (PROTOSAM), 2) a licence-cohort projection module and 3) a licence-holding and car ownership model. Each model uses sample enumeration procedures and is run outside the EMME/2 environment. Currently the car ownership forecasts do not take account of changes to accessibility.

Covering the transport model, this system is run entirely within the widely used transport modelling package EMME/2. Since the transport model represents the main component of the system, all network options including for instance the testing of new rail lines, are being implemented in this part. It is in this model that the mode-destination and choice models are applied followed by factors applied to the output in order to produce mode specific matrices for assignment.

Since RIC was concerned with the development of a "strategic model" for network testing of a wide range of strategies and options, it was felt that we did not wish to be too closely involved in all aspects of the model's operation. Since the design of the overall system is such that the population forecasting component is assumed not to be too closely influenced by transport network conditions, the two model's do not need to be run iteratively. Hence, this module is run once only, perhaps just once for each forecast year, before the travel demand module is then used to assess infrastructure option. Clearly transport infrastructure does influence population location acting on both the composition and the density (for instance around railway stations) of the population. Modelling these effects whilst of importance, was considered beyond the scope of this piece of work at present.

STM was clearly a detailed, well considered travel model and was therefore sensible for RIC to make use of it, despite the complexities involved in using EMME/2, rather than develop an alternative, entirely new model. However we wished to develop an interface to this model that obviated the need for RIC to develop specialist EMME/2 transport modeling skills, instead confining our use to the role of broadly defining inputs and focusing on specific key outputs.

RIC's interface with STM

RIC wished to develop a model that avoided staff with in the organisation becoming specialist EMME/2 modelers whilst at the same time still being able to interact and interrogate the STM. The updating and development of the STM itself remains the preserve of the Department of Transport through TDC, although there remain opportunities for related work on the base and future rail networks and other issues at a joint level later on. Nevertheless, it was our primary objective in RIC to keep the model relevant and widely used within the Strategic Business Development unit by making the operation of the model (i.e. the RTM) as straightforward and as simple as was reasonably possible.

We set about specifying a model functionality that would meet these very general needs of simplicity and ease of operation. Yet, as with all projects involving models this task still provided many complexities. As a starting point we wanted the RTM to be developed in a software environment that was generally available (not proprietary) and for the computer code to be readily understandable by a third party. In the event we opted for an Excel environment with a Visual Basic interface. We also required the RTM to be able to invoke EMME/2 in order to run the macro's related to the operation of STM.

Challenges Presented by the Development of the RTM

The development of the RTM presented RIC and TDC with a range of technical challenges. This was caused by the necessary and quite legitimate technical and geographical limitations of STM in terms of its existing functionality.

- Development of hybrid runs, since a typical full run of STM takes between 6 and 8 hours which was unacceptable for a model conceived as a 'sketch planning' tool;
- STM's geographical coverage does not include major parts of the metropolitan electrified passenger rail system making it necessary for us to extend the coverage with in the RTM;
- Manipulation of land use scenarios. We wished to develop population and employment scenarios in which revised distributions were possible over and above TDC's projected scenarios to 2026. We also needed to look at forecasts out to 2051; and
- Finally, it was necessary to incorporate freight usage when calculating total gross tonnes kilometres (GTK)across the network.

Developing Hybrid Runs in STM

Of the complexities presented by running STM one of the major challenges was the time taken in a typical 'full run' of STM, typically in the region of between 6 and 8 hours. As a result it was necessary to develop 'hybrid' runs of STM in which for example certain cost skims (for instance on the highway network) are left unchanged—but preserves the potential for mode shifting across trip tables—in order to speed up processing time for particular types of model 'runs'. This becomes particularly relevant when assessing the differences between alternative train frequencies/ train head ways of rail services on a planned new rail line, where changes between two or three timetables might well have relatively small impacts on highway travel times. We also wanted the RTM software interface with STM to interpret results from that model and in places interpolate or extrapolate between results from different model runs in order to evaluate results between alternate scenarios. This enables us to avoid continually re-running the full STM process which takes time.

Incorporating Freight for Asset Planning

One of the purposes of our approach was to develop a strategic demand model that provided data for long term capital and maintenance planning within the whole metropolitan network including the freight as well as passenger. In determining the level of maintenance required across the rail network in Sydney, the volume of gross tonne kilometres (GTK) over specified rail links is used to measure track damage. Whilst rail freight's usage of the metropolitan network is minimal compared to that of rail passenger's usage, it was still important to include the volume of freight GTK in order to obtain a full picture of track usage. Passenger GTK is calculated in the RTM interface from outputs produced by STM. Base year freight GTK is loaded into RTM and sourced externally, although within RIC. Freight GTK forecasts concentrate largely on a much shorter time horizon, mostly three to five years forwards, at most. Nevertheless, freight forecasting can take a longer time horizon on a piece meal basis depending on the needs of the project. For instance the Sydney Newcastle Rail Up-grade Project (SNRUP) has incorporated a much longer view on central and north coast freight movements than is traditionally taken at RIC, in this case using forecasts out around twenty years. Of course this did not resolve the need to address the shortage of long term freight forecasts at the metropolitan level. In the event we assumed a range of scenarios, from zero through to 3 per cent per annum growth over a twenty year horizon. These scenarios incorporate both long term and more recent trends in freight tonnage growth. As currently conceived, no attempt was made in the model to address the issue of competitive neutrality between road and rail (BTCE 1999).

Developing Alternative Population and Employment Scenarios

Certainly there was a need to define alternative demand scenarios aside from the 'Business As Usual' approach representing our medium growth scenario, it was left unresolved as to whether these were demand lead—through perhaps Travel Demand Management (TDM) policies—or supply induced—namely by creating a more attractive rail network. Both approaches require either the making of some heroic assumptions about the impact of TDM or the spending of billions of dollars in creating an ever more attractive rail network. Neither approach has been tested as part of the current work program but is on the agenda for the future. Instead, the alternative land use scenarios which we have incorporated in to the RTM involve two elements. In the first instance, existing NSW government population projections have been developed to 2026 (Department of Urban Affairs and Planning 1999) but we wished to have the ability to develop alternative population—and ultimately employment—distributions driven mainly by alternative release area and economic development options. Secondly, rail infrastructure has a life any where from 50 to 100 years, longer than a typical planner's time horizon. This meant forecasts to 2026 were too short term and therefore required us to have the ability in the RTM to add in forecasts out to 2050. Given RTM was conceived of as a 'sketch planning' tool, forecasts this far into the future are inevitably largely indicative rather than conclusive.

Geographical Coverage of STM

A final area of development of the RTM was in the coverage of STM's rail network. As currently configured, STM's full operation only covers Sydney SD[3] even though historically the model has covered the Hunter and Illawarra regions (STM's zone system extends to these regions). Since CityRail's passenger electrified network extends deep into the more populous areas of these two regions—and therefore RIC's Metropolitan region's infrastructure responsibilities—it was necessary to extend RTM's coverage of the rail network, beyond Sydney SD. This meant both developing the rail network further with the addition of a service pattern or time table coded into EMME/2 and the production of a rail trip table for the area outside of Sydney SD. Whilst coding the timetables was simple, creating rail trip tables presented us with a range of choices. One solution would have been to try and extend STM beyond Sydney SD. Since STM is a journey to work model, the expansion to all purposes and specific times of day would have required Hunter and Illawarra HIS or HTS data. Both data sources are for different reasons, largely incomplete rendering the simple extension of STM problematic. Instead, using ticket data and barrier counts a rail matrix was seeded using a Public Transport cost skims and developed using various matrix manipulations.

Outputs from the Model

In its final form RTM produces a number of key outputs needed for strategic planning, rail operations and capital and maintenance planning. For each model run these outputs include;

- Gross Tonne Kilometers (GTK) by line sector;
- The ability to produce a station to station O/D matrix;
- Peak period train demand (for a given timetable); and
- Average load factors by line sector.

In addition, the model provides crucial information when producing strategic level investment appraisals and economic evaluations, that is;

- Passenger volumes by mode
- Passenger kilometres by mode;
- Transit and highway vehicle kilometres by mode;
- Passenger hours by mode;
- Transit and highway vehicle hours by mode; and
- Highway stopping and delay times.

We are also able to examine the impact of pricing changes on transport usage (this relates only to what is achievable within STM). This option involves detailed network coding and has not yet been tested. Within the limitations of STM, the pricing analysis will be able to

[3] Sydney SD presently covers forty five local government areas, bordering Wyong on the central coast to the north, the Blue Mountains in the west and Sutherland/ Wollondilly to the south and south west.

include assessing the impact of either network wide or link specific “premium” pricing, for example in assessing possible private sector initiatives for rail projects (Neutze 1997). Although it is acknowledged that the evidence for private sector involvement in infrastructure provision remains mixed (BTCE 1996).

Future Developments of the Rail Travel Model

We expect the model’s development to be an on going process. Further enhancements are likely later on since already we have identified a need to improve the model. We resolved to make the model (i.e. RTM) sufficiently “transparent” in design and with the necessary documentation so that further development was possible without becoming dependent on a single software developer/ consultant. RIC was keen to avoid either developing a ‘black box’ or becoming overly dependent on a single consultant. We expected that additions to the RTM will be required as both as STM evolves and as RIC data/ reporting requirements change.

Some improvements to the model we are contemplating include;

- Improvement to the rail network to more accurately reflect interchange opportunities at stations and hence improve the assignment;
- Refinement of the base rail trip table. The current trip table is based on 1996 census journey to work, yet with the huge growth in rail travel over the last four or five years, this trip table may be out of date.
- Incorporate a clearer view of off peak travel movements; and
- Refine the accuracy of the market/demographic growth model.

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