# Reducing Risk in Toll-facility Forecasting

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## Abstract

This paper is intended to assist in reducing risk in planning Toll-facilities, particularly where traffic or patronage forecasting is a critical component.

It briefly discusses a number of toll facilities in Australia which have been technical successes but which have resulted in financial difficulties, in costly litigation or have been sold for less than their cost. This has made Australian investors very cautious of this industry. There has been a number of contributing causes.

State Government Agencies responsible for transport in Australia have typically awarded concessions on a greatest return basis and the competitive nature of the bidding process has undoubtedly contributed to traffic and revenue over-estimation.

The paper discusses a number of case studies, which illustrate several causes leading to over-estimation or under-performance of both road and transit private concession projects. However, over-optimistic traffic or patronage forecasting has been the major contributing factor in all cases and the bulk of the paper concentrates on methods to provide greater confidence and reliability in these forecasts.

To illustrate the value of Peer Reviews, the paper lists a number of forecasting modelling deficiencies that have been observed, in the author’s experience, during Peer Reviews on toll forecasts which may have contributed to over-estimation or to misunderstandings.

The competitive and commercial nature of toll concessions precludes the wide distribution of the research and development of forecasting models and the discussions arising from Peer Reviews. It is only in Conferences, such as this, that these issues can be aired and, in doing so, it assists our professional opinions and our work to converge on “world’s best practice” and the results should assist in restoring investor confidence in this industry.

## Introduction

[Australia](http://www.wsj.com/articles/SB10001424052702303874504579377883853393844) needs to build new urban roads and rail lines to replace and expand its congested transport systems, with the nation’s policy body Infrastructure Australia predicting a 45% population increase in major urban centres over the next two decades. They forecast that transport congestion in major cities will cost the economy over A$50 billion a year in lost production without urgent upgrades.

Australia’s existing urban toll roads have made a great difference to traffic flows in Sydney, Melbourne and Brisbane and have been a great boon to travellers in these cities. Technically they have all been successful. However their financial history is chequered and several have been placed in administration and/or are subject to litigation. Usually overoptimistic traffic forecasts have been a major contributing cause.

This is not exclusive to Australia and one international research study[[1]](#footnote-1) into 32 toll facilities on the accuracy of traffic forecasts illustrated that, where Banks commissioned the forecasts the results were, on average, 21% too optimistic. When the forecasts were carried out for proponents the results were, on average, 36% too optimistic. This report states that

*‘Some of the case studies were accompanied by commentaries providing reasons for the predictive failures. Almost without exception, the reasons lay external to the traffic model itself-and stemmed from inaccurate or inappropriate assumptions made regarding key input variables. Typical reasons included:-*

* *High toll tariffs and a miscalculation regarding users' willingness to pay,*
* *Recession/economic downturn;*
* *Future-year land use scenarios that never transpired;*
* *Time savings that were lower than expected;*
* *Improvements to competitive (toll-free) routes;*
* *Considerably lower usage by trucks; and*
* *Lower off-peak/weekend traffic’.*

These issues should have been assessed in the risk analysis but the report also states that the results were *‘start-of-operations (first-year) forecasts’*, which also suggests that ramp-up was not included. This could account for much of the reported inaccuracy.

While by no means all of the toll projects in Australia have disappointed their financial backers and some have been very successful, nevertheless sufficient have had problems to cause real industry concern. This paper discusses some of the toll road failures in Australia, the apparent reasons why they occurred and it makes suggestions how the risks in traffic or patronage forecasting for future works might be reduced.

## Some Cases of Failure primarily due to inadequate Traffic Forecasts

Some recent cases[[2]](#footnote-2) of financial failure in Australia are:-

* Sydney’s **Lane Cove Tunnel**, opened in 2007, went into receivership in 2010 and was purchased for about 60% of its initial cost. It has been the subject of a lawsuit, whereby two investor funds sued the two consultancies that provided traffic forecasts for the tunnel on the grounds that they *"failed to exercise reasonable care and diligence"* and that they made *"misleading or deceptive"* traffic predictions. Their forecasts were more than twice the actual traffic flows observed 5 years later;
* Sydney’s **Cross City Tunnel** was completed in 2005 and has twice been placed in receivership. It is currently valued at half of its original cost and has been purchased by an operator with the advantage of owning an abutting toll road. Eight years later the traffic flows were 40% of the original traffic forecasts on which the concession was based;
* In the first six months of operation, Melbourne’s **EastLink** Toll Project made losses sufficient that it had to be refinanced and its traffic forecasts rewritten, due to lower than expected traffic volumes;
* Brisbane’s **Clem 7** toll road, opened in 2010 did not collect sufficient toll revenue to pay the interest on its debt and became a financial disaster primarily due to incorrect predictions of traffic volume. The actual traffic was less than a quarter of the forecast flows and the consultants paid out A$280 million in settlement of the class action against them;
* The owners of Brisbane’s **Airport Link**, which opened in 2012, placed the tunnel into administration due to low traffic levels, which attributed to the project going into debt greater than the project’s value. The traffic volumes, albeit probably still in ramp-up, were about one quarter of the original forecasts; and
* Brisbane’s **RiverCity toll road** project was sold for only 28% of its cost after it attracted only a fraction of the traffic which had been forecast.

Naturally, these financial failures have meant that confidence in toll projects is minimal despite the successful performance of other PPP projects. The forecasts in each of these cases were prepared by different but reputable consultants all with an international reputation. Therefore, in addition to undoubted problems of forecasting, procurement and other issues may also have contributed to these over-estimations. However it should be noted that most of these projects failed within the first few years and therefore unforseen land-use, network or demographic changes could not have been responsible.

## Some Case Studies showing Reasons for These Failures

Not all financial shortfalls should be attributed solely to the traffic forecasts. The following case studies refer to incidents which have contributed to financial problems with PPP investments, where the traffic forecasts were not the primary cause.

### Ramp-up

The most anxious time for any project is the first few years because the interested parties are most anxious to see the results of their investment. But, on the other hand, the traffic or patronage takes time to grow to its expected volume. Apart from investor anxiety, slow early growth may also create the need for unexpected additional cash inputs to cover operating costs.

The problem is that there is no known scientific method of predicting how long this “ramp-up” period will take and it is necessary to estimate it by reference to other similar projects. Unfortunately they tend to vary substantially from less than one year to over four years even in the same city. It is therefore necessary to be very patient while closely observing the traffic growth and traffic diversion from other routes and modes. A project’s success should never be judged by its performance in its early years.

### Risk Evaluation

Risk analysis is sometimes confined to the construction process and does not include financial or forecasting risk. Often where this was included it was insufficiently comprehensive and failed to acknowledge variations in the business cycle and other issues. Most of the financial assessments for the above financial failures in Australia were undertaken during the peak of the business cycle. The failures tended to occur at the bottom of the cycle.

For instance, it is normal for the value of travel time, an important perceived ingredient in toll road planning, to be varied in line with real GDP per person[[3]](#footnote-3). Thus it should be lower during the trough of the business cycle as occurred soon after 2008. This effect presents difficulties during the modelling calibration and process and is therefore not usually included in the risk analysis at this stage but left to the financial analyst to ponder. Similarly, volatile fuel prices affect traffic but are difficult to build into the forecasting process even if their price changes are anticipated. These are real risks and they can be modelled.

### Risk Sharing

No Australian Government Highway Agency has adopted a risk-sharing approach to tollway PPP concessions similar to that adopted in Korea. Australian Agencies retain control over toll prices or transit fares but accept no responsibility for traffic or patronage shortfalls and are, for all practical purposes, immune from litigation because they take no responsibility for financial performance. Dr Robert Bain[[4]](#footnote-4) has said that one of the reasons for so many toll project failures was that the concession award procedure was structured for the highest bidder to win the concession. The public sector is the concession granter, and at least part of the problem lies with the way the public sector has designed the concession procedure.

Apart from the Government agency, there are at least four parties involved in a bidding consortium – the construction firm (who normally only bears the risk of staying within budget) – the operator (who also only bears the risk of staying within budget) - the Institution lending money (which has first call on equity and therefore expects to bear just a little financial risk if any) – and the equity holder which bears almost all of the risk.

All parties other than the equity holder are usually keen to win the bid and even the equity holder wants to recover the cost of the bid. The Government Authority’s attitude may be summed up as “If the private sector is prepared to take the risk, at no cost to Government, then we are prepared to let them make their forecast rate of return/profit”.

There is little restraining influence on undue optimism. Prudent acceptance of risk, coupled with due diligence in management, is the hallmark of responsibility.

In the public interest it would be prudent for Australian Highway Agencies to accept a proportion of financial risk as Governments can normally borrow at cheaper rates than their PPP partners and are usually in a stronger position to avoid litigation or to afford the penalty of failures. It would also provide a greater incentive for them to ensure that their understanding and actions contributed, through due diligence, to success, particularly their scrutiny of the traffic forecasting process and results.

It is therefore encouraging to note that, for the WestConnex toll-road project in Sydney the funding for the initial stages is be funded through **public capital** contributions[[5]](#footnote-5). Private sector capital can then be raised against tolling revenue from Stage 1 to fund subsequent stages. It is understood that the State Government intends to sell the project as a going concern after the first stages have proven to be a sound investment.

### Ensuring Government Commitments are enacted or retained

The preparation of competitive bids for infrastructure projects, particularly transit projects, can cost millions of dollars and several years. There is seldom any reward for this effort, particularly for losing tenderers. This is particularly poignant when the project does not proceed (as happened with the Very Fast Train bidding in Australia and USA) or if a portion of the project (the best part) is withdrawn during planning as happened in Korea.

One Australian State Government, after defeating the previous Government in an election, stopped a tollway project after construction had commenced at a considerable public cost in compensation. This form of sovereign risk needs to be minimal if investor confidence is to be retained. Stopping a commenced project should transparently reflect sound economic sense if this sovereign risk is to be ameliorated.

One of the Sydney toll roads operate on a partial “shadow toll” whereby the Government reimburses tolls for residents in some areas as a matter of social policy. Electoral uncertainty means that it is difficult to assess the risk of any repeal of this rebate policy, which would have a significant effect on traffic. However it has been mooted.

### Relying on Inter-agency Cooperation

An Asian rail transit project was opened in early 2005 and by late 2007 its patronage still fell 45% short of the forecasts. While ramp-up periods for rail projects are usually longer than those for toll roads, this shortfall could not reasonably be attributed solely to ramp-up. An investigation found that, amongst other factors, the original forecast assumed that promised bus integration measures would boost the rail patronage by 15% to 18% and that this increase would be achieved quickly. However, no action was taken to co-ordinate mutual fares or feeder services with the bus lines.

### Bidding Assumptions

It is reported that bidding for the operation of the Melbourne Tram System assumed a 20% loss of fares whereas fare evasion was actually approximately 40% on some lines[[6]](#footnote-6) (until improved ticketing systems were installed). The Government Agency involved may have been vaguely aware of this but had no reliable data at the time of bidding.

### Future Network Competition

Travel throughout a city is ubiquitous and no project with a concession life of 30 years can expect that, within this period, there will be no other projects that will compete for traffic with it. Alternatively another project may create sufficient congestion elsewhere to reduce the effectiveness of the concession.

The Sydney tollway concessionaire was asked by the Government Agency to consider providing another entrance ramp to his operating project, at his expense, which would add traffic to an un-tolled part of the concession (it was spot-tolled). Their consultant[[7]](#footnote-7), after investigation, recommended refusal as, although the new ramp would attract some traffic from a different source, the congestion created on the un-tolled section would reduce the traffic flowing through to the toll booths. Eventually another lane was added throughout the length of the toll-road.

### Unintended Consequential works

Unintended “consequential works” are those not within the contracted concessional work, but consist mainly of improvements or modifications to intersections leading to ramps or within the sphere of traffic influence of the project. They may include signs and utility relocations, bus stops etc. It is important to anticipate consequential works and, at least, to ensure that their cost is included and/or responsibility for them is fully understood and documented.

In one Korean project an intersection leading to a tollway ramp proved to be inadequate but, it being outside the concession, the tollway concessionaire could not make the necessary improvements and the local responsible authority took no ameliorative action despite earlier pre-construction representations. The consultant estimated that it cost the tollway operator an unanticipated 3,000 vehicles per day[[8]](#footnote-8). The Lane Cove Tunnel project Concession required the owner to monitor and treat unintended consequential works, such as nearby intersections, for a period of five years after the tunnel opened.

### Heavy Vehicles

Heavy vehicles pay higher tolls but, theoretically, have more to gain by avoiding signalized intersections and being able to travel at economical speeds. Nevertheless, they appear to be slow to take up toll road opportunities. It may be the driver, rather than the freight forwarder, who has to pay tolls. Trucks seemed to avoid Sydney’s M7 toll road when first opened[[9]](#footnote-9) and in one of Korea’s urban toll roads the proportion of heavy vehicles grew by 33% in two years after a slow start. Ramp-up for trucks probably needs to be treated separately.

The New South Wales Government proposes[[10]](#footnote-10) to force trucks to use the proposed NorthConnex toll project under Pennant Hills Road (perhaps by regulation or legislation) and this is assumed in the traffic forecasts.

### Client “Push”

A number of the Australia toll road concessions were awarded to the bidder offering the largest upfront payment to the State. Dr Bain[[11]](#footnote-11) reported *"That is a recipe for disaster"…..* *Without checks and balances in place, the bidding process simply turns into a competition on traffic numbers. Toll road traffic generates revenue and the largest upfront payments can only be justified by those with the highest traffic forecasts. The whole process becomes skewed and the numbers get bent out of shape as a result. Considerable pressure is placed on traffic consultants to come up with the 'right' numbers; numbers that meet the requirements of the financial model."*[[12]](#footnote-12)

While this is hardly flattering to the consultants concerned, it may well have occurred, for one of the financially failed projects listed above had traffic forecasts in the winning bid 40% higher than others prepared for the same project and they were well in excess of the Government Authority’s own forecasts.

In addition, the project designs for two Sydney toll projects were expanded by the bidding consortium[[13]](#footnote-13) with expanded scope and consequent capital costs as well as the traffic forecasts so there may have been undue pressure from the lenders and construction partners as well.

### Be aware of Public Reaction

One project in New Zealand failed because it opened soon after the toll on an earlier toll project had been removed after its investment had been repaid. The public resented the new toll and avoided the project, having just been relieved of the toll on the earlier project.

### Listen to advice

Finally, it is advisable to listen to consultant advice. Consultants are naturally somewhat reluctant to give clients bad news and may put it less directly than normal and maybe in fine print. But consultants have responsibility to the investing public as well as their direct clients. They bear full liability for their work and they must tell the bad news as well as the good.

One Client, a lender albeit bearing little risk, was so committed to the loan for one transit project that advice relating to project staging to optimise the result fell on deaf ears.

The proposed toll price on one toll project was increased almost three-fold during the late stages of planning and the consultant reported in writing, at the last minute, that this would decimate the projected traffic and consequent revenues.

On another transit project the owners were advised to provide reduced fares for a period after opening and to try to coincide the opening with a major event, such as an international football match. This advice was aimed to reduce the ramp-up period by allowing patrons an early familiarity with the benefits of the project and the expected patronage effect was documented. Failure to implement this advice contributed to a substantial patronage shortfall in the first years of operation.

## Forecast Modelling Problems

Although the above situations have led to problems by themselves, inadequate traffic forecasts are the most prevalent cause of financial failure and are usually at least a major component of the problem.

Government guidelines for model calibration and validation procedures are known to all competent forecasters but they are not always required to report their results to their private clients, who need to be more aware of their value in reducing risk. They do not, of themselves, influence the financial results but they ensure a firm foundation on which the forecasts are to be based.

### Model Calibration

Model calibration seeks to ensure that the travel model accurately reflects the current travel characteristics and traffic or patronage data. Calibration is carried out for a specific time period for which all land-use, traffic and travel characteristics are known. It is desirable that the travel model is built to represent the latest year for which this data is available, and, while traffic and land-use data is usually currently available, it is not always the case that household interview survey data is current. However, characteristics such as average trip lengths, trip rates and mode choice do not change that quickly over time. A model is usually calibrated for both the AM and PM peak hours but Saturday peaks may also be of interest and off-peak traffic assessment can be equally vital. Calibration should apply to the whole area for which the model is built not just the area immediately surrounding the concession.

A traffic model is calibrated to reproduce known travel characteristics within specified statistical limits. While traffic count data are the most obvious that the model should replicate, these are not sufficient by themselves, and other variables including trip rates, trip cost distributions, travel speeds, and mode choice need to be also calibrated. These factors are all inter-related and the process of calibrating a model is therefore an iterative one in which initial estimates of trip costs, travel generation, mode choice and traffic and patronage assignment are processed and then amended. Each model component has to be calibrated in a synchronized manner with all other components.

### Model Validation

Most Australian Government Highway Agencies have Standards or Guidelines for transport model validation to illustrate accredited performance. Model validation is an independent check of the calibration and is carried out with a separate set of data, which may be for the same year as the calibration or may be for an earlier period. The following general conditions are usually required by International Government Agencies:-

* Validation must be prepared before or without matrix estimation;
* Validation should be against independent data from that used for calibration;
* Validation should be on a link and screen-line basis;
* Validation should be presented in terms of absolute and percentage differences as well as the R2 and the %RMSE statistic;
* Validation should include a selection of journey times for different locations on different weekdays during the peak hours;
* Validation may be on an all-day or peak hour basis, but different criteria will apply;
* Where peak period validation is used, a one-hour peak is usually specified, and
* Screen-line validation may be 2-way or directional, but with different criteria.

Where model validation guidelines exist they generally cover all aspects of the urban transport model that is trip generation, distribution, mode split and highway and transit assignment. However, this is seldom reported, the validation reports usually only referring to the highway assignment model.

In this respect practitioners in Australia tend to use one or other of the United States of America criteria (NCHRP 255[[14]](#footnote-14)) for link and/or screen-line per cent difference comparisons, without using the R2, %RMSE or GEH statistic[[15]](#footnote-15).

However, the R2, and %RMSE statistics present little additional computation and should not require much additional effort or cost if used as specified in the guidelines.

However, it may not be sufficient to rely on validated model convergence characteristics as the sole criteria of a satisfactory assignment result. This is because the network total cost may have reached a level close to its minimum but some traffic volumes may still be switching between routes of approximately equal cost. Therefore another test is suggested called “consistency”.

The consistency of an assignment refers to the extent to which link volumes change between successive cycles. If they change by a significant amount then there cannot be much confidence in the resulting forecasts and further cycles may be necessary even though there is adequate convergence as indicated by the cost criterion. The UK validation guidelines include this test (called their “P” criterion). This test does not seem to have been applied in Australia.

Modelling practice will improve over time if Government Agencies concentrate their checking processes on the logic employed in the modelling process as well as on the accuracy which it is expected to achieve. While it is, of course, necessary to specify achievable levels of accuracy to protect the public, it is equally important to encourage an environment where the reasons for modelling error are clearly understood and documented and that innovative solutions are encouraged.

### Peer Reviews of Forecasts

Calibration and validation, although absolutely necessary, only ensure that the “Base Year” is accurately modelled. They do not ensure that the forecasts are valid. The most effective method of reducing forecasting risk is to employ an independent expert to conduct a Peer Review. The focus of a Peer Review needs to be clearly directed in the interest of the public and the client. On the other hand, issues exposing professional differences need to be tactfully discussed in the recognition that different professionals hold different views about the significance or validity of particular issues. These differences in opinion can be discussed as such. Nevertheless, when the methodology is muddled, it needs to be criticised. As with any other audit process all issues raised need to be dealt with as an expression of due diligence.

It is important to recognize that a report’s conclusions may be realistic even if the modelling processes are muddled or their descriptions are opaque. However, it is not sufficient simply to have realistic conclusions, because the various stakeholders need to be convinced that all issues have been fully and professionally addressed. This means that the methodology employed needs to be logical, comprehensive and adequately explained.

Further, the projects normally will have been carried out within an historic or political framework and according to strict budgets and terms-of-reference. While these may have limited the scope of those concerned, it is necessary to take the view that each report must stand on its own merits as it stands, irrespective of any imposed limitations. There are no excuses and **forecasting liability is not diminished by imposed restrictions**.

Unfortunately muddled or deficient methodology is frequently encountered in Australia and elsewhere, even for major toll roads, where substantial funds are to be invested. Quite often deficiencies have been encountered in practice.

### Deficiencies Encountered during Peer Reviews

The author has observed the following deficiencies during Peer Reviews[[16]](#footnote-16):-

* One model for a city of more than 3 million people was postulated on only 100 land-use zones. There is no recognised standard for the intensity of zones for various city sizes but this was considered to be insufficient;
* Another study was solely based on all-day traffic and did not analyse peak hour traffic. It therefore could not cope adequately with capacity issues, particularly at intersections. Capacity constraints limit future traffic growth and toll revenues. Therefore peak hour capacity limitations need to be taken fully into account;
* Some studies did not include public transport competition at all;
* Many studies are based on the travel by residents only and do not include tourists or visitors with different travel patterns;
* In some instances, where mode choice was ostensibly taken into account, there was no evidence that choice between public and private travel was modelled on a zone-by-zone basis. Instead a fixed allowance for public transport was simply made across all zones;
* Some transit studies were based on peak hour assessments only and ignored the off-peak contribution of shoppers, students and visitors to daily patronage;
* Adequate evidence of vehicle occupancy is often omitted and sometimes vehicle-occupancy is omitted altogether. Vehicle occupancy varies by purpose and by location and so affects traffic assignments; and
* Some did not adequately estimate ramp-up effects or omitted them altogether.

Those deficiencies, although serious, are fairly obvious and do not require further discussion. However there are deficiencies which involve more serious discussion. They include the following:-

* Definition of the Generalized Cost Equation - Few studies include Central Business District parking costs in the Generalised Cost equation. While there are some perception problems, parking charges can dominate the perceived cost equation;
* Expanded Journey-to-work Matrices – Several studies use matrices derived from Journey-to-Work data despite the fact that the journey to work in most cities is not dominant even in the peak hours;
* Generation based on Home-based travel – Some studies ignored non-home-based trip generation and attraction;
* Ageing population issues - Few studies adequately cope with ageing demographic effects in future forecasts;
* Matrix Estimation – Many studies use matrix estimation to enhance their model calibration but by doing so destroy the logic of the original matrix and restrict the credibility of their forecasts;
* Modeling feedback – The fact that congestion influences trip generation, distribution and mode split is sometimes ignored;
* Induced Traffic - Few studies allowed for induced traffic. The extent of this induced travel is unlikely to be very great but can be significant;
* Congestion – Many studies tend to over-estimate future congestion, which leads to several undesirable consequences;
* Expansion factors - Several studies assumed a peak hour to daily expansion factor without evidence and some did not adequately cope with weekend traffic issues. In some locations Saturday peak hours exceed weekday peaks and this may limit future capacity;
* Risk analysis - Few studies include an overall risk analysis; and
* Many studies do not include validation reports and particularly consistency checks.

**Not integrating tolls into costs** - Several studies omit the toll charges in the initial assignment but then employ a toll diversion model, which is applied after the no-toll assignment. It diverts traffic away from the toll facility according to a pre-determined diversion curve but ignores the effect of the toll on trip generation, distribution and mode choice. A more appropriate method is to include (or exclude) the toll in the comprehensive model for the test (or base) case. This would then allow the toll to influence trip generation, distribution and mode choice and thus provide a more logical method. It enables the optimal toll rate to be assessed which gives maximum revenue and thus avoids charging high tolls.

**Factored Journey-to-work matrices** - Apart from the fact that commuting is usually less than 50% of peak travel a further problem with using factored work trips matrices is that this commonly leads to lower car-occupancy assumptions consistent with journey-to-work car occupancies. It also omits all non-home-based traffic, which can amount to about 40% of all trips even in peak hours.

In Australia the **influences of age on travel** characteristics are:-

* Trip rates per person increase up to about age 35 but then decline quite rapidly;
* Transit choice declines after the school years until age 35 and then increases again until about 65;
* As population ages, travel purposes change. Initially school is dominant, then work, then social, shopping and recreational travel; and
* Travel during peak periods decreases with age.

An emphasis on journey-to-work travel will become even more misplaced in future as commuting becomes less important.

**Model algorithm differences** - Perhaps the first point of interest, when reviewing a modelling report, is whether the work was performed using TRIPS, TRANPLAN, EMME2 or one of the other commercially available assignment models. This is because there is so much commercial discussion about the relative merits of these software packages even though, in terms of their algorithmic content, there is very little difference, excepting for node-delay assignment models such as NETANAL or the real-time micro-simulation models such as PARAMICS or VISSIM. However, problems can arise as illustrated below.

One study[[17]](#footnote-17) employed the TRIPS assignment software, whereas another study[[18]](#footnote-18) of the same project employed both the TransCAD software and also the NETANAL software.

There are no major theoretical differences between the TRIPS and TransCAD software in the manner in which they were reported as employed for the analysis. Both studies employed very similar networks and trip tables so very similar answers should be expected.

The NETANAL software, however, incorporates node-delays into the assignment process and this is capable of providing an analytical advantage. (Although this feature is partially available within the TRIPS package, it was not reported as used for the study). The results gave negligible difference between the TRIPS and TransCAD software results but the NETANAL results are widely different for some sections of the road. No explanation for this difference was provided, however it is probably due to the fact that NETANAL assignment diverts more traffic from the surface street network because it determined that the intersections on the streets were congested, whereas the new expressway had no intersections. In addition NETANAL (and SCATES) have no weaving function for freeways and this was an issue as ramp spacing was likely to be sufficiently close to influence lane capacities.

The comparison was complicated by the fact that the assignments were not iterated (so that congestion fed back into the trip generation, distribution and mode split sub-models). Had this been done, the difference between NETANAL and the other two models may have been at least partially resolved.

The same problems arose for Sydney’s Cross-city Tunnel[[19]](#footnote-19).

**Overestimated congestion** - Street congestion, together with parking prices, is becoming the primary reason for higher estimates for mode split. Estimates of street congestion lead to the analysis of emissions, accidents and future infrastructure costs. Over-estimating future congestion can, therefore, lead to unrealistic expectations for future mode split, futile concerns about environmental issues or to unnecessary unfavourable planning consequences.

However, it is very common for studies to over-estimate future street congestion (even if they ignore induced traffic) for the following reasons:-

* Required future road (or public transport) infrastructure are not included in the future traffic models;
* Future capacity parameters tend to increase over time; and
* The methodology employed does not allow congestion to dissipate, either by diversion or peak spreading.

The first reason is rather inevitable most of the time because studies (in most instances) cannot cope with the full iterative planning work needed to include all necessary future road-works. Nevertheless, future transport projects may complement or compete with the project under investigation so every effort must be made to be inclusive.

**Increasing delay tolerance** - Congestion, in terms of intersection delays or peak spreading tends to become more acceptable over time and it is probably prudent to allow an increase in capacity parameters rather than allow the analysis to be influenced by excess congestion. In addition, improved technology, such as ramp metering and electronic tolling, are increasing the capacities of toll roads. In addition autonomous vehicles will increase capacity in future.

**Sequential rather than iterative modelling** - However, the main cause for over-estimating congestion is the use of sequential models, rather than iterative ones, which, by influencing trip generation, distribution and mode choice, permit congestion to be dissipated through the network. This cause can be corrected by using models with a full logical construction.

**Expansion factors** - It is quite common to adopt a figure, such as 10, to expand a peak hour traffic figure to its all-day equivalent. Similarly it is also common to adopt an arbitrary figure to expand an all-day traffic estimate to its annual equivalent. For instance one study in Korea arbitrarily adopted a figure of 330, whereas an examination of the Korean Department of Highways and Transportation Traffic Counts shows that the expansion factor on all nearby National Highways varies between 357 and 377.

These expansion factors vary considerably in practice and, as they directly affect the annual revenue estimate for toll facilities, it is necessary, in any peer review, to examine the supporting research for the factors used in any forecast.

Published hourly traffic count data is available every three years for roads in Metropolitan Sydney from the Roads and Traffic Authority. This data was analysed to determine the average AM peak to Daily expansion factors for all of the 206 road sections for which this data was available. Overall AM Peak to Daily expansion factor for the 1999 data was 13.08 and this ranged up to almost 20 and as low as 8.3.

Further evidence in Sydney suggests that expansion factors for tolled roads are about 15% less than that for similar un-tolled roads[[20]](#footnote-20). Therefore it is important to model off-peak traffic to attempt to establish the appropriate expansion factors. Toll roads are less attractive in off-peak hours when alternative routes are less congested.

Traffic count data from the above source was further analysed to assess the extent of the Weekday to Annual expansion factors currently being experienced in metropolitan Sydney. They ranged from 315 to over 400. The results show that there is limited average difference between roads in different parts of the city although the Weekday to Annual Expansion factor in outer areas does reflect higher weekend traffic.

**Ageing Population** - One would expect some peak spreading as volumes increase. In addition any ageing population analysis suggests that Peak to Daily factors would increase over time. Further, it could be considered that, as affluence increases, more people will travel away from cities on weekend trips so that the Daily to Annual expansion factors may also increase. The analysis results[[21]](#footnote-21) showed that there is evidence that the Peak to Daily expansion factor has been increasing over time. This is an international trend and it is suggested that future AM Peak to Daily expansion factors could be expanded by about 1% each year. Conversely there has been little change in Weekday to Annual expansion factors over the period for which RTA data was analysed.

## Issues our normal forecast modelling does not do very well

The above issues are ones which are within our current modelling practices and should be activated whenever forecast modelling is undertaken. However there are some issues with which our current modelling practices cannot cope without further research and development. Some of these can be modelled but have not yet been adequately researched or applied.

### Calibration Data Volatility

Often the traffic count data, which forms the basis for calibration, is a spot count and its variation is not known. It can be volatile. As an example, the Morning peak hour for a busy urban arterial had a 4% variation between weekdays but a 17% daily variation between weekdays. Therefore a daily forecast based on expanding a peak hour forecast could be substantially in error. Further, for the same road, the daily traffic varied week-to-week by 12% (after growth and seasonal adjustments) throughout a year. These variations could compound.

Similarly, attention has been drawn by others[[22]](#footnote-22) to inadequacies in the use of stated preference data used for the value of time, which is especially important in toll-road applications as savings in time is the main issue in most cases. In particular there is seldom adequate data for trucks and emergency vehicles.

### Peak Hour Complexity

Morning and evening peak hours are those most important for modelling because they define the capacity requirements for roads and transit services. The problem is that commuting peaks, tradesmen peaks and school peaks occur at different times.

Different modes have different peak hours and those with longer trips typically create peak hours at different times than those with short trips. Therefore the selection of a peak hour for patronage modelling needs careful attention. Further these characteristics may change over time.

**Different Peak Hours in different parts of the City.** As most assignment modelling is for a single peak hour, it is assumed that all trips generated within that hour contribute to congestion. However, some trips may be complete before others start. This implies that congestion in different parts of the city occurs at different times.

This means that, for a toll-road with spot tolls, the peak hour should be calculated to show the maximum peak hour at the spot-toll location, not the average city peak hour, which is likely to be at a different time. This could account for incorrect traffic forecasts.

There are assignment models available which simulate congestion build-up at different times during the peak period, which can overcome these assumptions. They are called ‘Time-Slice’ or ‘Peak Spreading’ assignment models.

As an illustration, the traffic on ten links along a toll-road was estimated from Household Interview Data in a Papua New Guinea city over six successive quarter-hour periods so assess different peak hours at different locations along the toll-road. This was simulated with a “time-slice” model. The results showed that for most of the links the peak hour encompassed the last four quarter-hourly periods but for some links the worst peak was the first four quarter hours.

The spot-toll location was one of the latter but the modelled peak hour was the last four quarter-hours because that fitted most links. As a result the tolled-flow would be underestimated by 9 %.

**Toll sensitivity and market segmentation**. While many models segment demand by income, age, travel purpose and mode, choice for tolled routes is seldom related to these market segments[[23]](#footnote-23). Toll sensitivity should be expected to vary with age, income and travel purpose.

**Toll sensitivity with travel distance**. Toll elasticity has been shown to be sensitive to travel times or distances – longer trips have a lesser toll price elasticity and are more likely to select the toll route. This emphasises the important of ensuring that trip length distribution is properly calibrated. A New Zealand toll project failed simply because the toll-road was too short[[24]](#footnote-24).

However that is not the only issue with trip length. Those with longer trips usually start their car trips earlier so that they peak earlier. This compounds the above peak hour issue because the sensitivity to tolls will be different if the wrong peak hour is chosen for forecast modelling.

It is also important to note that peak hours may be different on toll roads than on nearby arterials and that trucks, paying higher tolls, may peak at different times than other traffic, so research is necessary for adequate forecasting.

**Different peak hours for different modes.** Similarly the peak hour for transit patronage is usually different from that for motorists. On average in Sydney Transit trips start earlier than car trips and their 30-minute peak is over before the 30-minute car peak begins.

As congestion is an important incentive for transit ridership, this implies that road congestion should be modelled for the relevant peak hour for the appropriate transit modes, if transit patronage is the forecasting objective. This could account for overestimation of transit patronage forecasts.

### Future driving conditions

**Autonomous driven cars**. As early as 2020 it is expected that cars will have at least some of the features which herald full autonomous driving. These will include:-

* Radar and camera detection systems to enable safe distance following, to interpret lane markings and allowing the car to stay in its lane or switch into others to overtake other vehicles or follow a different road;
* GPS and sensors to identify the car’s position on the road, allowing it to respond to live traffic updates;
* Emergency Stop Systems; and
* Autonomous Valet Parking.

These innovations will be capable of changing our measures of road capacity as the variations in human driving characteristics are levelled to produce more consistent driving behaviour and therefore less volatile and higher flow rates.

These vehicles will be more effective on freeways and toll-roads which are unencumbered by intersection stops and will therefore have a greater tendency to seek these roads

## Problems in Industry Cooperation in Dissipating Knowledge

This paper has pointed at Consultant, Corporate and Government inadequacies in the delivery of PPP toll projects in Australia and elsewhere.

It suggests that Governments should accept more responsibility in the public interest and perhaps follow the Korean model for risk sharing. It stresses the importance of fully securing inter-agency cooperation and consequential works agreements before commitment and it also point to risk issues that are difficult to model and so are often omitted.

The paper also lists a number of forecasting modelling deficiencies that have been observed through Peer Reviews on toll road forecasts which may have contributed to over-estimation or to misunderstandings.

It is to be hoped that the spate of failures in Australia will lead to greater industry cooperation to help to avoid problems in future.

Where information is released within the industry, this should eventually lead to appropriate research and development to correct the problems, to improve the technology accepted as “common practice” and to add to the knowledge base from which practitioners can draw.

However, studies carried out for commercial reasons, are seldom released publicly or within the industry and much of the research they contain remains in private hands and is not released to the public domain. Much of this work is of high quality and contains important research.

However, if commercial clients do not have Peer Reviews and/or are not aware of better practices and therefore accept inadequate work, then there is no process by which corrective actions can be taken. Further, where commercial clients do become aware of deficient practices, they may be even less likely to make them public.

Therefore the most suitable commercial process which tends to lead to better practices is an independent Technical Audit or Peer Review. Despite the constraints presented by professional ethics, commercial property rights and confidentiality, this involves discussion with our peers and the sharing of our research. There is no excuse for silence or prevarication because the Peer Reviewer is equally liable for the forecasts.

There should be no constraints on sharing our experience in Conferences like this one.

Desirably, we should all be aiming to achieve “world’s best practice” in our work and that our professional opinions converge on this practice. Further we should be aiming to adapt our modelling practices to cope with at least the issues raised in this paper, to seek out research opportunities, and, despite private investment and ownership, be prepared to share this innovation in the public interest.

Then we might expect that the investing public will eventually regain confidence in this important sector of public infrastructure.

If we cannot improve our current forecasting practices we will be even more vulnerable with the imminent arrival of autonomous vehicles, which will increase the importance of freeways and toll-roads in the coming years and require different analytical methods.

## Acknowledgments

This paper, by its very nature, requires that some protection is provided to the various firms and agencies involved in the case studies discussed. Therefore the direct reference to sources, normally expected in a professional conference paper, has, of necessity, been omitted where this protection is needed.

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2. This section is primarily based on Web or Newspaper articles but confirmed by personal correspondence. [↑](#footnote-ref-2)
3. See TunnelTalk July 2016 discussion attributed to Dr John Rose University of Sydney Business School [↑](#footnote-ref-3)
4. “Error and optimism bias in toll road traffic forecasts” Robert Bain [↑](#footnote-ref-4)
5. WestConnex Business Case [↑](#footnote-ref-5)
6. Personal correspondence [↑](#footnote-ref-6)
7. R J Nairn & Partners Pty Ltd [↑](#footnote-ref-7)
8. Scott Wilson Nairn Pty Ltd [↑](#footnote-ref-8)
9. Personal correspondence [↑](#footnote-ref-9)
10. Personal correspondence [↑](#footnote-ref-10)
11. Dr Robert Bain op cit [↑](#footnote-ref-11)
12. See TunnelTalk July 2016 [↑](#footnote-ref-12)
13. Personal correspondence [↑](#footnote-ref-13)
14. “Model Validation and Reasonableness Checking Manual” prepared by Barton-Aschman Associates and Cambridge Systematics 1997 [↑](#footnote-ref-14)
15. See Appendix B of the United Kingdom’s Department of Transport’s Design Manual for Roads and Bridges [↑](#footnote-ref-15)
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24. Road Pricing – “Tauranga: New Zealand's toll road capital got one wrong”. [↑](#footnote-ref-24)