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Paper title: **Modelling or muddling**

Author(s) name(s):   R J Nairn

Organisation(s):

Contact details:

Postal address:	13 Tanumbirini Street
	Hawker ACT 2614
Telephone:	(02) 6254 2782
Facsimile:	(02) 6254 2782
email:	rjnairn@webone.com.au

Abstract (200 words):
Modelling practice in Australia ranges from innovative, through competent to thoroughly muddled insofar as the logic is concerned, even though the final traffic forecasting results might be acceptable for practical purposes. The main area where practice has often been thoroughly muddled is in the construction and use of trip tables but matrix estimation techniques have been used to restore these to lead to acceptable traffic forecasts even though the logic of their construction is aborted. In addition, the range of different assignment techniques used in Australia has been widening and there are several examples where inappropriate models have been used with surprising (or perhaps dangerous) results. A brief description of the basic logical differences in these models is given. The key to understanding why these examples are inappropriate is to recognise that trip generation, distribution and mode split are all functions of interzonal trip costs and therefore each of these models needs to be iterated with the congested outputs of the assignment models. This goes some way to ensure that network congestion is not overstated and that traffic on relatively uncongested toll-roads or freeways is more accurately represented. Further, all possible future road and public transport facilities should be coded in future networks to ensure that excessive congestion is treated. Overstating congestion can lead to equally surprising traffic forecasting results. The paper leans on the authors experience in carrying out traffic modelling projects in Australia and overseas and in auditing the work of others.

Introduction

This paper derives from the author's experience as a traffic forecaster or in peer review roles for traffic forecasting projects for major infrastructure investments mainly in Australia, China and South Korea.

The focus of a Peer review needs to be clearly directed in the client's interest. 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 points of view. These differences in opinion can be discussed as such. Nevertheless, when the methodology is muddled, it needs to be criticised.

In carrying out a peer review of the reports for these projects, it is necessary to take an holistic view. It is first necessary to focus on the original intentions expressed in the objectives and brief and, in particular, ask if the current proposals for the project reflect the principles and issues raised in the initial planning studies.

It is then necessary to enquire whether the reports answer all likely questions within their scope and pay attention to the following:-

> ➢ Do the reports clearly state the objectives and the assumptions on which they are based?
> ➢ Is the methodology employed logical? and
> ➢ Are the conclusions convincing?

It is important to recognize that a report's conclusions may be realistic even if it does not address these questions and if the modelling processes are indeed 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.

It is normal to comment upon issues of methodology by using the following terminology:-

> ➢ Best Practice – The reviewers know of no better methodology;
> ➢ Common Practice – The methodology used is commonly found in other similar work carried out by other practitioners, but is not the best practice available;
> ➢ Acceptable Practice – The methodology used involves new ideas, which lack the support of being in common practice but are considered to be quite acceptable; and
> ➢ Deficient – the methodology used, or the explanations provided, is thought to be insufficient or flawed by the reviewer.

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

Frequently encountered modelling deficiencies

In carrying out peer reviews, the author has come across the following deficiencies:-

➢ 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;

➢ 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;

➢ 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.

These 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 Generalised 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;

➢ Journey-to-work Matrices – Several studies use matrices derived from Journey-to-Work data despite the fact that the journey to work is not dominant;

➢ 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;

➢ Modelling feedback – The fact that congestion influences trip generation, distribution and mode split is often ignored;

➢ Assignment processes – Despite similarities between the most utilized models, some models create differences; and

➢ Induced Traffic - Few studies allow 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 lead to several undesirable consequences;

➢ Expansion factors - Several studies did not adequately cope with weekend traffic issues. In some locations Saturday peak hours exceed weekday peaks and this may limit future capacity; and

➢ Risk analysis - Few studies include an overall risk analysis.

Each of these deficiencies is discussed in this paper.

Definition of perceived generalized cost

Many studies, for instance Halcrow Fox (2000), only use time cost plus toll charges converted to time. However the normal car generalized cost equation ought to be as follows:-

Car generalized cost = Vehicle Operating Cost + Time Cost + Toll charge + Parking charge

For instance, if it is assumed that a car travelling to Sydney's CBD travels 25 Km and takes 40 minutes with the perceived VOC averaging $0.16 per Km and the perceived value of travel time is $21.00 per vehicle per hour. Also assume that the average toll paid is $3.00 and the CBD parking charge is $18.00 per day. This leads to a typical car generalized cost equal to:-

Typical car generalized cost = 25*$0.16 + $21.00*40/60 +$3.00 + $18.00
$4.00 + $14.00 + $3.00 + $18.00 = $39.00

It can be seen that the perceived VOC is only a small proportion of the total generalized cost and it is probably not too critical if is left out. However, in the example above, the parking charge is 46% of the generalized cost, which is very significant.

A similar example for Canberra, with very different costs, where a car typically travels 10 Km in 12 minutes to the CBD and there are no tolls and CBD Parking was $4.00 per day, would be as follows:-

Typical car generalized cost = 10*$0.16 + $21.00*12/60 + $0.00 + $4.00
$1.60 + $4.20 + $0.00 + $4.00 = $9.80

Here the parking charge is 41% of the generalized cost. Even if we consider vehicle occupancy and that the generalized cost is shared equally between car occupants, the parking charge is still 41% of the typical generalized cost.

Despite the significance of parking charges, it is rare to find them included in generalized cost equations.

It is appreciated that there is difficulty in defining perceived parking charges as the driver is not always directly responsible for the charge and therefore may not perceive its full effect. Brown (1997) reports that, in the 1997 Canberra / Queanbeyan Household Interview Travel Survey, of the drivers who paid parking fees, 89% bore the cost themselves without reimbursement. This proportion is likely to be much lower in Sydney and Melbourne but the author knows of no reliable surveys into the perceptions held by drivers into parking fees.

It is also noted that, in the examples given above, the toll charges are not very dominant despite the fact that they politically important in some areas. However, because of this sensitivity, it is usually necessary to assess the degree to which increases in toll rates influence the traffic flow and revenue accruals.

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.

Trip tables from ABS Journey-to-Work data

It is quite common to use the ABS Journey-to-Work data to derive morning peak hour trip matrices. These matrices are then factored to produce the required number of trips.

The problem is that trips to work comprise only a fraction of the total morning peak hour trips as illustrated in Table1. Journeys to school, shopping or other purposes clearly have a different range of destinations, so that the actual matrix must be quite different from the JTW matrix.

Table 1. Metropolitan Sydney AM Peak Trips by Mode and Purpose

Mode	Home	Work	Shop	School	Pers Bus/Other	Total
Car	8.26%	25.50%	5.16%	8.80%	25.87%	73.59%
Public Transport	0.06%	3.64%	0.18%	5.40%	0.30%	9.59%
Walk/Cycle/Other	3.70%	3.22%	2.00%	3.28%	4.61%	16.82%
Total	**12.02%**	**32.36%**	**7.35%**	**17.49%**	**30.78%**	**100.00%**

Source: Analysis of Ministry of Transport Household Interview Travel Survey data 2001

A further problem with assuming that work trips dominate the morning peak hour is that this commonly leads to lower car-occupancy assumptions consistent with journey-to-work car occupancies. Journey to work car-occupancies in Sydney were 1.14 at the time of the above survey but AM peak car-occupancies were 1.47.

Travel demand and the ageing population

Nairn (2002b) provides an analysis of the data from the 1997 Canberra/Queanbeyan Household Interview Travel Survey and the 1991 Sydney Household Interview Travel Survey, which shows the following influences of age on travel characteristics.

➢ 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.

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

There is sufficient divergence in age profiles between different zones that these influences should be built into any model, both "base case" and future forecasts. If the average effect of ageing is applied to the age profile of several Sydney Local Government Areas, then these effects can be illustrated. In Table 2, two LGAs are compared with Campbelltown to show the computed differences in AM peak trip rates and Mode Split due to ageing alone.

Table 2. Comparative trip rates and mode split due to ageing alone

LGA	AM Trip Rate	AM Mode Split
Campbelltown	100.00%	100.00%
Hunters Hill	92.01%	103.08%
Leichhardt	95.08%	85.53%

Source: ABS 2001 Census Age Profile data and analysis of 1991 Sydney Household
Interview Travel Survey

Matrix estimation or "iterative validation"

It is frequently the practice that the trip matrices, however they are derived, are changed, in an iterative process, until the resulting traffic assignment closely fits observed traffic volumes to provide "competent" validation. The process is usually carried out using Matrix Estimation software.

While this process no doubt improves the traffic calibration, *it totally destroys any logic used in the process of producing the trip matrices.*

This process cannot be used for assignments for future years as there are no observed future street volumes. Whatever the gain in obtaining better street volume validation in the base year has been completely lost for future year forecasts. They also should not be regarded as reliable for testing major road improvements in the base year as they do not account for induced traffic or redistribution effects from the improved roads.

These matrices are then sometimes expanded, using FRATAR techniques, to provide trip matrices for future years, which are then used as the basis for future traffic assignment. This expansion process is likely to overstate future street congestion because it ignores the fact that this congestion may alter trip generation, distribution, mode split and vehicle-occupancy, all of which may reduce street volumes.

Modelling feedback

If the above "short cuts" are not employed then most studies employ a traditional "four-step" sequential process – trip generation, trip distribution, mode split and trip assignment

This technology does not recognize that travel demand is an economic function so that trip generation is a function of perceived travel costs. As travel costs are not fully known without considering congestion, this means that trip generation should be acknowledged as an output of the "four-step" process – not a fixed starting point or input. The process needs to be a circular or iterative one in which congested travel cost skims are fed back into the trip generation, trip distribution and mode choice steps. This process was first described in LUK (1978) and is now becoming more common practice.
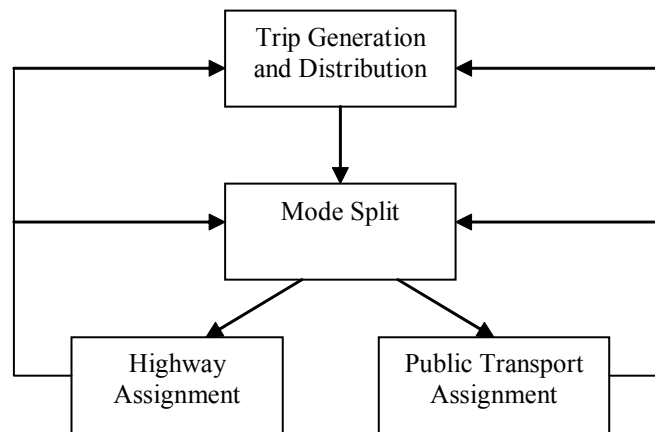
The process is illustrated in figure 1.

Figure 1. The feedback or iterative process allowing congestion to influence trips

This process makes sense only if it is proven that travel costs influence trip generation. Nairn (2002a) provided the method for derivation and illustrations of Sydney's travel demand curve, illustrated in figure 2, to prove this point.
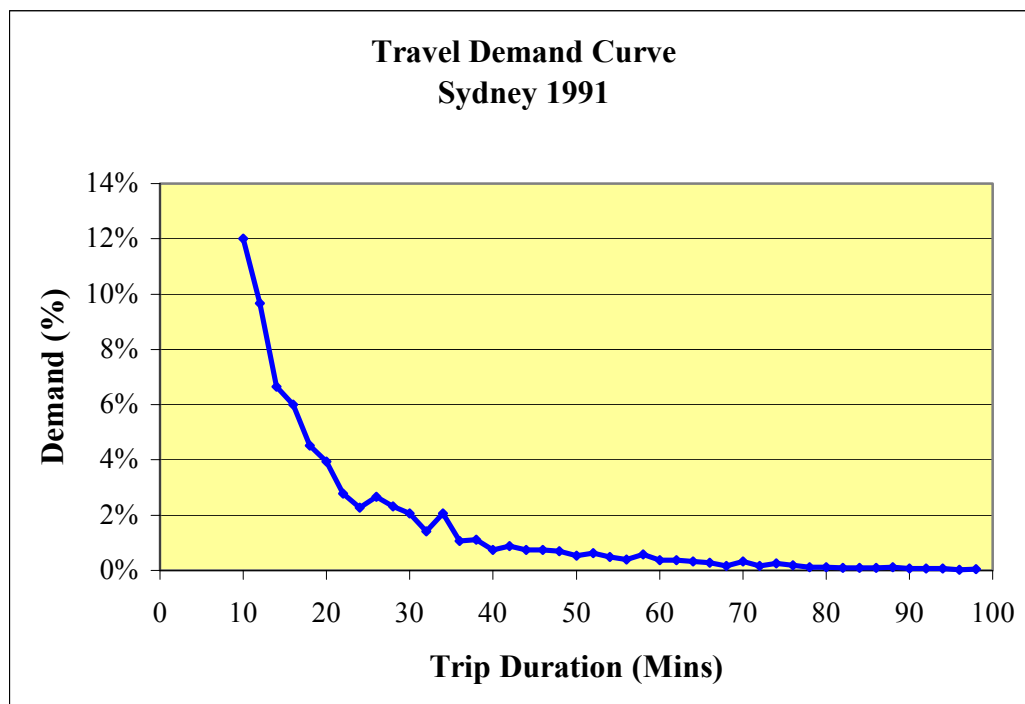

Figure 2. Sydney's travel demand curve from Nairn (2002a)

The figure clearly shows that trip rates are dependant on travel times in Sydney. Models, which are built using this iterative process, will not only be more sensitive to congestion but automatically provide induced travel, whenever a transport improvement results in lower travel costs.

Assignment processes

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 as assignment models, there is very little difference excepting for node-delay assignment models such as NETANAL or the micro-simulation models such as PARAMICS or VISSIM. However, problems can arise as illustrated below.

One study employed the TRIPS assignment software, whereas another study 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 are shown in Table 3 for several sections of the road being analysed.

Table 3. Comparison of traffic forecasts using different software

Section	TRIPS	Difference	TransCAD	Difference	NETANAL
Section 1	51,350	-0.7%	51,000	9.4%	55,800
Section 2	44,500	-1.6%	43,800	**20.0%**	52,500
Section 3	37,900	0%	37,900	**35.3%**	51,300
Section 4	52,600	1.7%	53,500	1.5%	54,300
Section 5	52,600	-4.2%	50,700	-3.2%	49,100

There is 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.

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.

Diverted and induced traffic

A new road will typically divert traffic from other roads. Discussion of traffic diversion is important to lend credibility to the traffic estimates but also of interest to commercial interests on the roads from which traffic is diverted.

The figures 3 and 4, from Scott Wilson Nairn (2003), provide a typical illustration of how traffic is diverted onto a new Expressway in Korea. Figure 3 shows that most of the traffic flows directly from National Expressway No 1 (North) and National Expressway No 5 (South). Figure 4 shows the roads from which the traffic is diverted. The line width is intended to represent the amount of traffic diverted from each road.
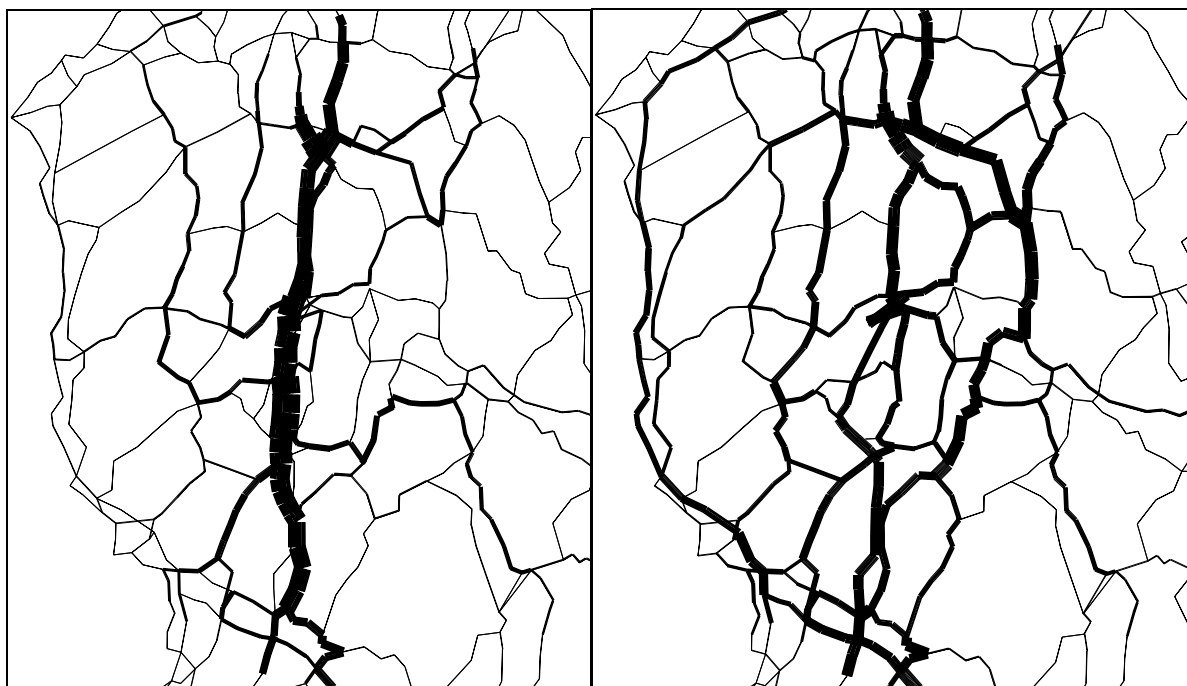
Figure 3 Source of Traffic on Expressway   Figure 4 Traffic Diverted from other Roads

Clearly the new road diverts some traffic from many roads in the region, reflecting the ubiquitous nature of traffic origins and destinations.

A new road, provided it reduces travel costs, can be expected to generate traffic, which did not exist before. This is called induced traffic. A model, in which trip generation is an economic function dependant on congestion, will automatically produce induced traffic if travel costs are reduced.

In a recent study, 8% of the traffic, which is forecast to be attracted to the proposed Western Sydney Orbital, is likely to be induced travel. This is not a high proportion but it is significant, representing about two year's traffic growth. In other reports it has been shown to be greater than this. *For the Lane Cove Tunnel induced traffic was estimated to be approximately 12%.* Table 4 shows the estimated source of traffic in the Lane Cove Tunnel.

Table 4. Source of traffic on Lane Cove Tunnel

Source	No Toll	With Toll
% Induced	11.02%	11.95%
% Diverted from Public Transport	2.61%	2.15%
% Diverted from other roads	86.37%	85.90%
Total	100.00%	100.00%

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.

The first reason is rather inevitable most of the time because the studies (in most instances) cannot cope with the full iterative planning work needed to include all necessary future road-works.

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.

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 the ISIS report on the Taejon Riverside Expressway 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. *Scott Wilson Nairn (2002) reports that 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 suggests that expansion factors for tolled roads are about 15% less than that for similar untolled roads.

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 little difference between roads in different parts of the city although the Weekday to Annual Expansion factor in outer areas does reflect higher weekend traffic.

One would expect some peak spreading as volumes increase. In addition the ageing population analysis suggested that Peak to Daily factors would increase over time. Further, it could be considered that, as affluence increases, more people will travel away from Sydney on weekend trips so that the Daily to Annual expansion factors may also increase.

The results showed that there is evidence that the Peak to Daily expansion factor has been increasing over time and it could be assumed that this trend will continue. 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 has been analysed and it is suggested that this factor be held constant for future years.

Risk analysis

The usual approach to risk analysis is to discuss the most important risk factors, such as capacity limitations, the impact of other planned projects and the lack of owner control over external issues such as the general economy.

Another approach to risk analysis is to employ "stochastic" assignment techniques in which the perceived value of travel time and/or vehicle operating costs is randomly selected within given limits during the assignment process. This results in a different answer each run.

In one recent study the model was run twenty times and the different results were assembled. They varied between 6,500 vph and 5,300 vph with a mean of 5,900 vph and a standard deviation of 400 vph. In other words, using this form of modelling, the traffic estimate for the project was 90% reliable within 400 vehicles per hour but may occasionally vary up to 600 vehicles an hour in the AM peak period. (Scott Wilson Nairn 2004).

Some users employ a more elaborate Monte Carlo approach by assessing the maximum and minimum effect of a range of input factors on the result and randomly selecting the effect within this range in a model, in which the risk factors are acknowledged as cumulative. The model may be run 10,000 times to indicate the probable answer. Scott Wilson Nairn (2003) derived the risk ranges for five input variables as shown in Table 5.

Table 5. Range of values for risk analysis

Risk Factor / Year	2013		2023	
Variable	**High**	**Low**	**High**	**Low**
Population Growth Rate	101%	94%	103%	96%
Value of Travel Time	102%	98%	102%	98%
Future Trip Generation Rates	101%	98%	102%	97%
Peak-AADT Expansion Factor	115%	95%	115%	95%
Day-Year Expansion Factor	112%	95%	112%	95%

The risk evaluation was run for two future evaluation years as the potential error in each variable is likely to be greater in different years. The risk evaluation model provided the potential risk outcomes as shown in Table 6.

Table 6. Risk evaluation results

Year	Overall Potential Risk
2013	-4.77%
2023	-6.62%

This process does not produce the absolute worst case answer as it is highly unlikely that all the variables should be in error to the maximum amount at the same time. It does, however, provide a suitably reserved guide for those involved in debt risk.

Conclusions

This paper has sought to identify unsatisfactory modelling practices in use in Australia and in Korea and to suggest how they could be improved. The author is well aware that practitioners are often severely limited by finance, which itself is sometimes constrained by the uncertain state of the project in its preliminary stages.

There are, in addition, several consequences of these poor practices, which affect us all. These poor practices occur in studies for both Government and private commercial clients. Usually the reports from studies for Government clients can be obtained publicly in due course, so that their technical material can be examined publicly and the supporting research tends to enter the public domain.

Where unsatisfactory methodology is released to the public, this should eventually lead to appropriate research and development to correct it, 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 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 are not aware of any deficiencies, then there is no process by which corrective actions can be taken. Where commercial clients do become aware of deficient practices, they are even less likely to make them public.

Therefore the only commercial process which tends to lead to better practices is 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. Despite this, at present, it is probably fair to say that poor practices have led to insufficient research into several important issues such as:-

  ➢ The perceived parking charge rather than the nominal or actual parking charge;
  ➢ The effect of electronic tolling on demand perceptions;

Desirably, we should all be aiming to achieve "world's best practice" in our work and that our professional opinions converge on this practice. In view of this objective, the opportunity to present discussion papers such as this one is highly valued by the author.

Acknowledgements

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