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Proposed improvements to microeconomic evaluation of road projects in a congested urban network

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Abstract

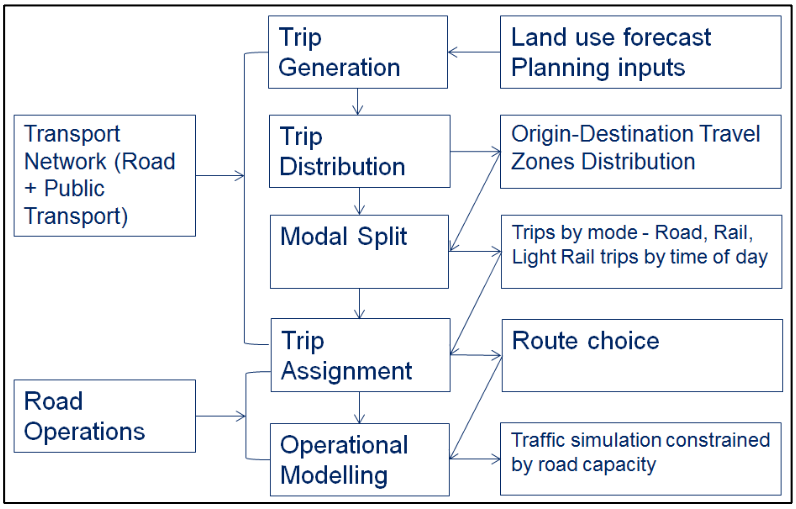
Congested road networks manifest as slow speeds and traffic delays for road users. With current traffic modelling tools and economic analysis methodologies, a transport project in a congested road network could generate an unrealistically high Benefit Cost Ratio (BCR). This could introduce “optimism bias” and distort investment decision making. Based on first-hand economic analyses of urban road projects, we have developed a method to improve economic appraisal methods of congested road network in general and deal with the ‘Unreleased Demand’ phenomenon in particular. The improved approach has been tested in six road projects in NSW that have generated more realistic economic results. This paper reports the improved approach to elicit comments from the transport evaluation community to further refine the methodology.

1 Introduction

The phenomena of ‘Unreleased Demand’ (UD) arises as a result of a temporal computation mismatch between different scale transport models (strategic, mesoscopic and microscopic). The economic evaluation of a road project starts with Strategic Transport Modelling in that travel demand is estimated from land use, population and employment patterns. The travel demand (in terms of the number of trips) is then geographically distributed between origin-destination zones (i.e. OD pairs). Dependent on the available transport network, trips between OD pairs are split between available transport modes (e.g. car, train, bus, cycling, walking and other such as taxi). For those trips that use road, trips are further assigned to different routes by applying a utility model incorporating both driver behavioural choice from a user cost minimisation algorithm and other random components. Modelling is produced by a deterministic probability frontier by sampling large numbers of combinations of variables to estimate route choice by minimising composite trip purposes. Input factors may include driver habit, local knowledge, numbers of vehicles attached to households, proximity of activity centres and personal preferences. The strategic modelling process has been known as the Four Step Demand model including trip generation, trip distribution, modal split and trip assignment illustrated in Figure 1.

A strategic model is able to provide hourly traffic volumes (in both directions) for a particular road section as well as estimates of Vehicle Hours Travelled (VHT) and Vehicle Kilometres Travelled (VKT) which form key inputs to an economic appraisal of any proposed road investment project. In a strategic model, the modal split and trip assignment are generally not constrained by road capacity, which means that the traffic volume assigned to a road section could be higher than the road capacity (i.e., the Volume Capacity Ratio is more than 1). If this happens, the model assumes that the travel speed would be reduced but all trips are assumed to occur.

Figure 1: Land use and transport demand modelling for a typical road project



As the Business Case progresses, more advanced operational modelling is required to provide inputs for concept or reference designs and more detailed economic benefit assessment. Most operational modelling uses computerised micro-simulation. In microsimulation models, trips of excess demand are queued outside the model and are only released when sufficient road space is available. At this stage, the traffic throughput for a road section would be constrained by road capacity.

A mismatch from strategic demand modelling and simulation model has been frequently observed on roads servicing high demand areas. These roads are characterised by road congestion in peak hours. The Unreleased Demand is defined as the difference between higher level demand from strategic modelling and capacity constrained operational modelling. Many strategic models (including STM) use fixed factors to allocate demand to time periods. This may limit the ability of these models to account for peak-spreading (i.e. retiming of trips in response to congestion). Table 1 provides a general description of strategic and simulation models typically used in NSW.

Table 1: Strategic and operational travel models

Analytical level	Model	Key features
Strategic demand models	STM	Strategic Travel Model (STM) is a demand forecasting tool developed and maintained by Transport for NSW Transport Performance and Analytics (TPA). The model is used for forecasting travel patterns for the Greater Metropolitan Area of Sydney (GMA) under different land use, transport and pricing scenarios
	PTPM	Public Transport Project Model (PTPM) developed by TPA to provide project-level demand forecasts of rail, Metro and bus priority projects
	STFM	The Strategic Traffic Forecasting Model (STFM) developed by RMS for the assessment of road infrastructure projects
	SMPM (WRTM)	Strategic Motorway Projection Model (SMPM) is an update to WestConnex Road Traffic Model (WRTM). It is a strategic traffic model, similar to STFM, but with specific application to toll road / motorway projects
Operational Models	VISSIM / AIMSUN	This type of modelling can provide a better representation of queuing, congestion and delays in at-capacity urban networks. It uses dynamic, stochastic, discrete time modelling techniques to simulate the movement of individual vehicles based on car-following, lane changing and gap acceptance algorithms. It requires significant network detail (including link, intersection and signal operation detail).

2 Review of current practice – how UD has been dealt with in traffic modelling and economic appraisal

A literature review indicates that the economic appraisal of a congested road network is not a well researched field. Preliminary analysis has been undertaken by RMS (2017) that endeavours to provide an interim guidance for traffic modelling and economic analyses. It recommends adjusting for UD when it exceeds 5% of potential trips. Recommended interventions fall into three broad categories, including:

- Traffic modelling adjustment to reduce the number of Unreleased Trips, by modifying the model network and/or demand to facilitate greater throughput in the model
- Normalise simulation modelling outputs to include the impacts of incomplete and Unreleased Trips
- Amend the economic analysis methodology to reduce the potentially overestimated benefits.

Techniques for these may be used in combination. Selected methods and/or combinations could form the basis for a range of sensitivity tests in the economic analysis. A summary of these interventions is as follows.

2.1 Traffic modelling adjustments

Each Australian capital city has its strategic travel demand model (see Table 2). In these models, congested cost is reflected in the Generalised Cost specification that captures Travel Time, Vehicle Operating Cost, Road Toll and Public Transport Fare. A project in a very congested location would not receive any special consideration.

Table 2: Urban transport models used in Australia

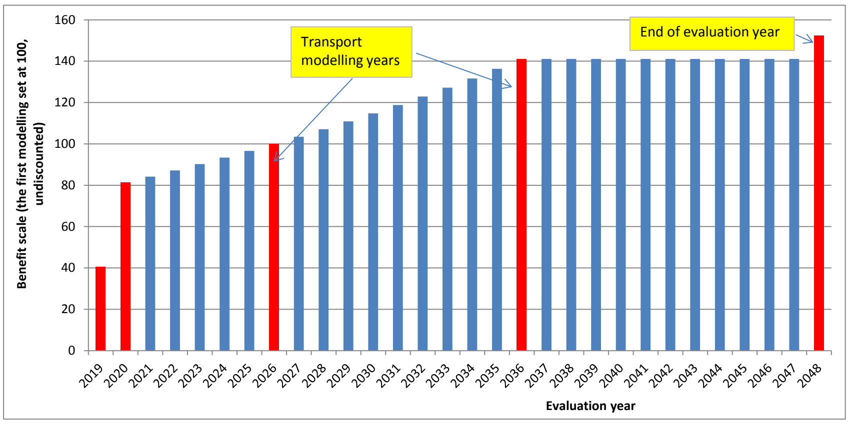
Organisation	States	Model
Transport for NSW	NSW	**STM** - Sydney Strategic Transport Model **PTPM** - Public Transport Project Model
Roads and Maritime Services (RMS)	NSW	**SMPM** – Strategic Motorway Planning Model **STFM** – Strategic Traffic Forecasting Model **WRTM** – WestConnex Road Traffic Model
Transport for Victoria	Victoria	**VITM** - Victorian Integrated Transport Model
Department of Transport and Main Roads	QLD	**BSTM**: Brisbane Strategic Transport Model
Department of Transport Western Australia	Western Australia	**STEM:** Strategic Transport Evaluation Model
Main Roads Western Australia	Western Australia	**ROM24**: Regional Operations Model
Department of Planning, Transport and Infrastructure	SA	**MASTEM**: Metropolitan Adelaide Strategic Transport Evaluation Model
Department of State Growth	Tasmania	**GHUTDM**: Greater Hobart Urban Transport Demand Model
Department of Infrastructure, Planning and Logistics	Northern Territory	**DSTM**: Greater Darwin Strategic Transport Model
ACT Government	ACT	**CSTM**: Canberra Strategic Transport Model

If a project has a large impact on travel demand that generates a significant level of Induced Demand, a Variable Demand Modelling approach is undertaken. It is assumed that the most small to medium projects would not change the overall demand thus a Fixed Demand Modelling approach has been used for over 90% of business cases. The UK Department of Transport (2017) explain why and when a Variable Demand Modelling is needed. In essence, the commissioning of new road network capacity has the effect of marginally reducing congestion, especially in the local area that acquires this additional capacity. This reduction in congestion has the impact of ‘attracting’ more road users as the Generalised Cost of using this new infrastructure falls. Latent Trip Demand ensures that additional road capacity is utilised. In Australia, Bray (2005) provides economic appraisal approaches for estimating Road User Surplus, Perceived User Cost and Resource Cost Correction. The literature review has not identified any other published studies on dealing with Unreleased Demand in Economic Appraisals in Australia; hence there is a need for a conceptual and practical approach as identified in this paper. While there are limited published studies on economic evaluations of the Unreleased Demand, Roads and Maritime Services (2016, 2017) has previously developed the interim practice and modelling directions to help ameliorate some of the problems. There are 5 interim solutions provided as part of RMS studies:

- ***Capping benefit at the last model year***

As illustrated in Figure 2 for a hypothetical project, the traffic modelling has been undertaken for 2026 and 2036, which provides for benefit growth between the two model years using a linear interpolation. Before the first model year, the benefit can be extrapolated using the growth rate estimated between the model years. A benefit ramp-up can be built in the model allowing driver behavioural adaptation immediate after the Project Open-To-Traffic. The benefit is capped at the second modelling year to limit the benefits as volumes approach capacity, and to allow for modelling uncertainty over a 20 year forecast horizon. The Residual Value is added to the end year of the project evaluation. This has the impact of constraining Trip Volume Benefits to partially allow for the phenomena of Unreleased Demand.

Figure 2: Benefit profile and benefit capping 100



Note: In economic appraisal, the project benefits are estimated at the modelling years (eg, 2026 and 2036). The benefit in 2026 was scaled to 100 for the purpose of the presentation.

- ***Encourage traffic modellers to apply peak spread to alleviate aspects of the peaking phenomenon***

Applying a peak spread in the Base Case will need to reflect driver behavioural changes when facing a congested network. Key behavioural changes include re-timing (shifting the trip to off-peak hours), re-moding (shifting to public transport or active transport) and re-routing (shifting to a different route). Traffic modellers would also consider the road congestion outside peak hours and remaining capacity to accommodate those Unreleased Demands, measuring the congestion level on other alternative routes, availability of a public transport option, and taking account of bus or train overcrowding. Typically the required information of a peak spreading specification is unavailable for most projects, suggesting that this solution has a limited practical use.

- ***Where possible encourage the use of add-in software to address the issue of unreleased trips***

Computer ‘plugins’ have been used by RMS to ascribe road user’s economic values to Unreleased Trips (RMS 2016). A normalisation procedure has also been used for the traffic modelling output from VISSIM models (e.g. Arcadis 2018) to adjust VKT and VHT estimates for incomplete trips during the simulation period. This solution has been successfully implemented in most urban project modelling and economic analysis in RMS. Kinnear, Tudge and Wilson (2005) implemented plugins for benefit evaluation, route choice, lane choice, model gridlock clearance and public transport scheduler in Paramics.

- ***Designate the use of ‘capacity capping techniques’ in mesoscopic and micro-simulation models***

An approach that has been used in recent mesoscopic modelling studies for RMS and TfNSW is to apply ‘capacity capping’ techniques, where iterative procedures are undertaken to identify peak capacity constraint points in the modelled network and constrain growth in OD demand through these points that had been forecast in strategic models. Trips over the capped volume are then reassigned to other routes in the network. Trips in excess of the capped volume are then reassigned to other routes in the network.

- ***Where the above are not possible, Volume/Capacity ratio of 1.2 is used as a proxy in the economics model to cap vehicle growth including both vehicle hours and vehicle kilometres travelled***

This solution has not been successfully applied to economic appraisal practice. Applying a Volume Capacity Ratio of 1.2 would require re-estimate of VKT, VHT and speed for directly impacted road sections and/or modelled local road network. It would require another traffic modelling computation that has been outside the scope of economic appraisal in the current assessment framework.

- ***Other traffic modelling adjustments***

In addition to the above specific traffic modelling adjustments, some general adjustments have also been proposed including:

- When modelling generates significant levels of Unreleased Demand, a good sanity check should be applied to all components of the demand forecast.
- Limit demand for short trips on the basis that they have a higher likelihood of mode shift
- Identify local congestion and allow for small low cost improvements (e.g. signal optimisation, parking removal)
- Include some minor physical works and major projects (that are funded) but not yet scheduled which would ameliorate congestion
- Expand the spatial footprint of the model to include feasible alternate routes
- Expand the spatial footprint of the model so that the Unreleased Demand which currently sits outside of the model (and hence is not counted in the reported VKT, VHT and Stops totals) becomes incorporated into the modelled results
- Run the model for longer time periods to provide more time for congestion to dissipate and thus permit entry of more of the unreleased vehicles
- Identify the origins and destinations of the completed trips, and use this matrix as the basis for comparison between the Base Case and various option(s).

2.2 Normalise the outputs of simulation models

To ensure that results from simulation modelling are normalised and thus suitable for use in economic analyses, the values of VHT, VKT and Stops have been adjusted for the presence of incomplete trips to reflect a more realistic and consistent representation of the performance of the model networks. These adjustments can include:

- *Average number of stops per vehicle* = total number of stops reported / (number of vehicles that left the network + half the number of vehicles remaining in the network)

- *Total number of vehicular stops* = Average number of stops per vehicle * (number of vehicles that have left the network + total vehicles in the network + number of unreleased vehicles)
- *Average travel time (VHT)* = total travel time as per model output / (number of vehicles that left the network + half the number of vehicles remaining in the network)
- *Average trip length* = total distance travelled as shown in the model output / (number of vehicles that left the network + half the number of vehicles remaining in the network)
- *Total travel distance (VKT)* = Average trip length * (number of vehicles that have left the network + total vehicles in the network + latent vehicles). This adjustment apportions the derived average trip length to the total vehicle demand.

The normalisation is undertaken for the simulated local network. The normalised results used for economic analysis, by the way of addbacks (Shteinman, Chong-White and Millar 2011), would have captured all 'latent delay' (i.e. delay associated with unreleased trips) as an additional user cost, and assigned the network's average trip length, average trip duration and average number of stops to those trips which did not enter the modelled area. Note that this is a conservative approach; since average delay per vehicle would likely rise had the unreleased vehicles been able to enter the modelled network.

2.3 Amend the economic analysis methodology

RMS (2017) has also proposed some amendments of the economic analysis methodology as follows:

- Reduce the analysis period from the standard 30 years
- Use FYRR not BCR to rank and justify proposals, as it is not affected by future severe congestion effects
- Apply the benefits in Year 1 to every year of the analysis period (conservative)
- Allow the Year 1 benefits to grow in line with the underlying traffic growth in the network or region (less conservative).

3 Problems of current economic methods in dealing with Unreleased Demand

Current interim solutions focus on methods of reducing the amount of Unreleased Demand. However, these interim solutions lack the capacity for solving economic modelling problems when some Unreleased Demand are still presented after all feasible modelling solutions have been exhausted. The objective of this paper is to provide solutions for transport economists to build an economic model for a road project in congested road network and estimate economic impacts of Unreleased Demand via a new approach.

Table 3 presents the estimated Unreleased Demand of four roads in Sydney urban network. In the forecasting period from 2021 to 2030, the Unreleased Demand accounts for 5% - 26% of the total demand in the Base Case. The UD increases to 11% - 31% of the Total Demand in the forecasting period from 2031 to 2040. A high level UD indicates a high level of latent demand and congestion. In the Project Case, there is some UD during peak hours, indicating the additional capacity added by the Project whilst reducing congestion could have released some latent demand.

Table 3: Sample of UD of selected projects

	Forecasting period 2021-2030		Forecasting period 2031-2040	
	Base Case	Project case	Base Case	Project case
Project A: JRD (4-hr AM & PM peak)				
Modelling Year	2025		2035	
UD	7,261	871	17,039	1,281
Total demand	49,120	49,120	56,911	56,911
% of UD	15%	2%	30%	2%
Project B: KGR (4-hr AM & PM peak)				
Modelling Year			2031	
UD			12,850	5,116
Total demand			72,523	72,067
% of UD			18%	7%
Project C: SSU (2-hr AM & PM peak)				
Modelling Year	2026		2031	
UD	10,906	3,083	13,309	4,586
Total demand	42,597	36,890	43,403	37,877
% of UD	26%	8%	31%	12%
Project D: - HLD (2-hr AM & 2-hr PM peak)				
Modelling Year	2026		2036	
UD	2,980	1,120	6,910	2,220
Total demand	62,980	65,770	65,610	69,860
% of UD	5%	2%	11%	3%

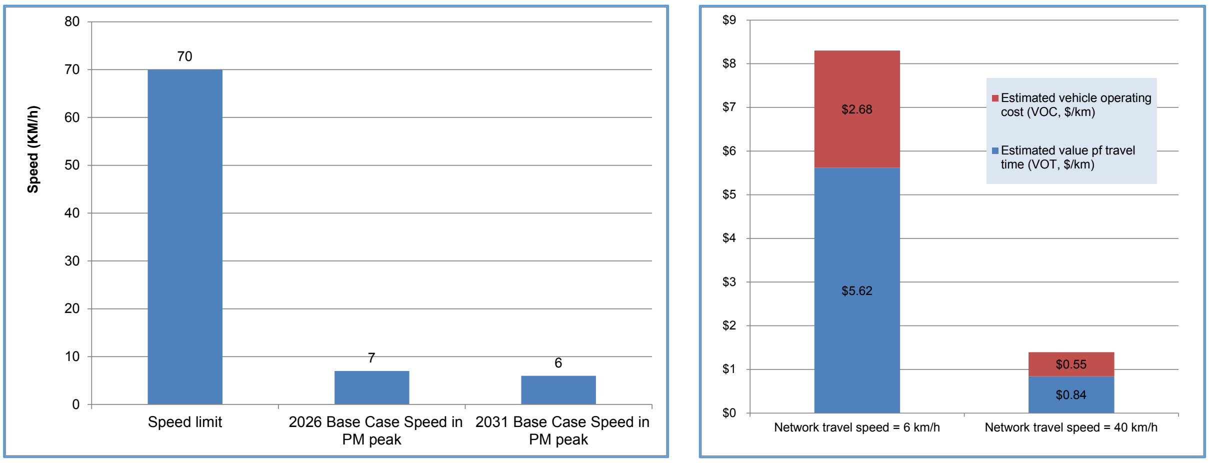
Notes: The project names have been coded for commercial reasons

UD presents four challenges for economic modelling:

- ***Challenge 1:*** *Excessively high demand above road capacity typically leads to an unrealistically pessimistic Base Case specification*

Take Project C (Stacey St Upgrade in the Table above) as an example, in the Base Case, the modelled network travel speed is 7 km/h in PM peak hours in 2026 and further dropped to 6 km/h in 2031, as shown in Figure 3.

Figure 3: Modelled base case speed & estimated road user costs in presence of the UD



Note: The dollar value is on per vehicle kilometre. Estimate is based on TfNSW (2018) values

The pessimistic prediction of traffic performance in the Base Case is unrealistic because the existing traffic model does not capture certain traveller behavioural changes when confronted with a congested road route. As congestion increases, some drivers may leave home earlier in order to get to work on time (i.e. peak spreading), even if it means they arrived at work earlier than the Preferred Arrival Time (PAT) (KPMG 2018). Others might leave home later to avoid congestion, even if it means they arrive at work later than their PAT. Drivers may also explore and use other routes. Some people might start cycling or walking for short trips as 6 km/h is equivalent to walking speed and slower than cycling. People may shift to public transport if a viable option is available. In the long term (e.g. more than 5 years), people might decide to change their location of residence and/or employment in response to congestion. Current models have not been designed to fully represent these changes.

- ***Challenge 2:*** *Changing demands between the Base Case and the Project Case makes the economic modelling more challenging*

Fixed demand modelling is sufficient for most small and medium sized projects. Variable demand modelling should be considered if a project in question changes transport conditions sufficiently to generate Induced Demand. Theoretically, if the geographic area of traffic simulation model captures all major changes of route shifts, the Total Demand in the Base Case and the Project Case should be the same. Table 3 shows this may not always be the case. In Project C, the Total Demand reduced by 13% from the Base Case to the Project Case, while for the Project D, the Total Demand increased by 4% in 2026 and 6% in 2036. A reduction in the Total Demand means that some trips have shifted away from the modelling area (unlikely to occur), while a net increase in trips means that some trips have shifted from other routes to the Project area. Changing the level of demand between the Base Case and the Project Case requires more complex economic modelling.

- ***Challenge 3:*** *Methodology for estimating economic benefits of UD has not been established*

Unreleased Demand is a concept that is generated from traffic modelling software that perform different scales and/ or functions of the overall traffic modelling process. The microsimulation model gives the maximum throughput in a given period (e.g. 2-hr AM peak) in the modelling network. The demand that exceeds the capacity can be classified as "latent demand" which would not be observable. The economic cost attached to UD has not been discussed in any known guidelines.

- ***Challenge 4:*** *A road project in a congested network can result in an unrealistically high economic appraisal result [i.e. a high Benefit Cost Ratio (BCR)]*

As illustrated in Figure 3, if the modelling speed in the Base Case is 6 km/h, the user cost is estimated at $8.3 per kilometre travelled (comprising the Value of Travel Time of $5.62 and Vehicle Operating Cost of $2.68). If a Project (e.g. road widening) can increase the speed to 40 km/h, the road user cost will drop to $1.40 per kilometre travelled. In this example, the road user benefit is likely to be overstated.

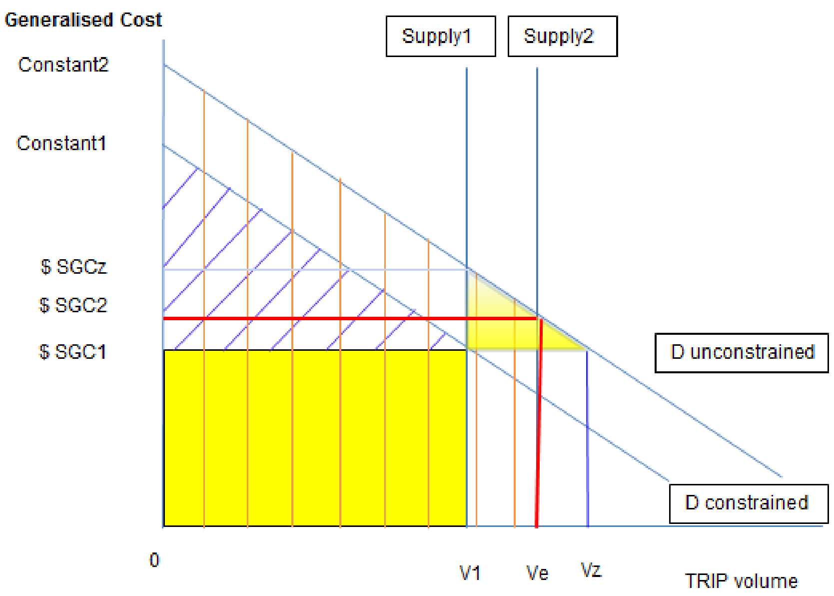
4 Proposed *ex post* solutions for better reflecting the impacts of UD in economic appraisal in congested urban roads

Based on first-hand economic analyses of urban road projects, the authors have developed an *ex post* methodology for evaluating congested urban roads. This methodology will be further tested in road projects in NSW.

4.1 Theoretical foundation

The phenomena of UD arises as the temporal computation mismatch between different scale traffic demand simulation models (strategic, mesoscopic and microscopic) – analogous to queuing.

Figure 4: UD with Consumer Surplus and Producer Surplus impacts



A possible approach to adjusting for UD would be to utilise the demand simulation models in a way that computes the maximum (allowable) volume of trips, while then adjusting the results *ex post* for UD trip volume, using an orthodox Demand-Supply equilibrium analysis as shown in Figure 4, that represent the following economic values:

$$\text{Consumer Surplus\_1} = \int_0^{V1} [D(V)dV - SGC1]dV$$

Producer Surplus_1 = $\int_0^{V1}[SGC1 - S(V)]dV$

Consumer Surplus_2 = $\int_0^{Ve}[D(V)dV - SGC2]dV$

Producer Surplus_2 = $\int_0^{Ve}[SGC2 - S(V)]dV$

Therefore:

<u>Proposed Unreleased Trip Adjustment</u> = [CS_2-CS_1] + [PS_2-PS1]

=$[(\int_0^{Ve}[D(V)dV - SGC2]dV)-(\int_0^{V1}[D(V)dV - SGC1]dV)] + [(\int_0^{Ve}[SGC2 - S(V)]dV)-(\int_0^{V1}[SGC1 - S(V)]dV)]$

≈[(Constant2 – Constant1)xV1]+[(SGC2-SGC1)x(Ve-V1)]+[(Ve-V1)xSGC1]+ [(SGCz-SGC2)x(Ve-V1)x0.5]

D: Demand (trip volume)

V1: Volume (Constrained with Unreleased Trips)

Ve: Equilibrium Trip Volume (Unconstrained)

Vz: Dummy Intercept - Volume

SGC1: Constrained Social Generalised Cost = Perceived Cost + Unperceived Cost + Resource Correction

SGC2: Unconstrained Social Generalised Cost = Perceived Cost + Unperceived Cost + Resource Correction

SGCz: Dummy Intercept - SGC

S1: Demand Constrained (trip volume)

S2: Demand Unconstrained (trip volume)

Constant1,2: Y – slope x (Trip Volume)

Data for calculating the SWUTA[1] (adjustment)

Social Generalised Cost (calculated for Constrained, Unconstrained and Dummy Intercept)

= [Perceived Cost + Unperceived Cost + Resource Correction] = [whole of life (∑ Capital Costs + Operational (Recurrent Costs, including refurbishment, maintenance, etc))] + [Environmental Costs + Health Disbenefits, etc] + [Resource Correction]

- Note that Health Disbenefits are small and are therefore typically excluded from analysis.
- Resource Correction adjustment is typically excluded.

Trip Volume equilibrium (calculated for Constrained, Unconstrained and Dummy Intercept)

- Note: Constrained = Maximum Trips that can be loaded to Mesoscopic and Microscopic models.
- Unconstrained = Maximum Trips + Unprocessed/ Unloaded Trips (‘UD’)

Y-Intercept Constant

Constant x = SGCx – [[(Ve – V1)/ (SGCz – SGC2)] x [Trip Vol.]]

4.2 Base case adjustment

The current practice usually defines the Base Case as the “Do Minimum”. Typically, the modelled traffic demand is assigned to a road network thus the network performance can be pessimistic when forecast to an evaluation period of 30 years.

[1] *SWUTA: Stevens-Wang Unreleased Trip Adjustment

The modelled Base Case should be verified and adjusted if necessary before estimating incremental benefits.

Firstly, the Base Case adjustment should consider a reference Base Case that is an acceptable minimum Level of Service. The network performance below it would likely trigger an intervention either by major maintenance or capacity expansion. Terrill et al. (2018) has pointed out that current evaluations do not acknowledge that there is a reasonably predictable minimum spend each year. Over the past decade, for example, "annual expenditure on new transport infrastructure in NSW was never less than $5.7 billion; in Victoria never less than $2 billion; and in Queensland never less than $2.7 billion. Because there is effectively a minimum amount that governments spend each year on transport infrastructure, assessing projects against a world in which no more infrastructure is built (or only the "minimum" of already committed projects are built) means that projects are compared against an unrealistically low level of future infrastructure capacity. Assuming so little capacity to meet future demand makes the assessment of a project's impact appear larger than it actually will be.

Austroads (2007) defines the road network performance in terms of efficiency (travel speed, variation from posted speed limit), reliability and productivity (speed and throughput). Generally, the road performance is measured by a Level of Service (LOS), where the LOS A represents excellent driving condition and the LOS F represents very poor condition. Austroads considers the LOS D as the limit of stable traffic flow approaching unstable traffic flow. At the LOS D, drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort is poor, and small increases in traffic volume will generally cause a flow breakdown. It would be reasonable to assume road performance that is poorer than LOS E would trigger government intervention. At the minimum, the Base Case performance should not drop to a level worse than LOS F in Table 4.

Table 4: Road capacity at the LOS D and traffic flow at the LOS F

Flow type	Road segment	Indicative capacity (pv/km/ln)	Traffic performance at the LOS F
Uninterrupted flow	Freeway (using free-flow speed of 110 km/h) as an example	2,100	Maximum density > 28 pc/km/ln) Average speed < 83 km/h Maximum volume capacity ratio >1 Maximum service flow rate > 2350 pc/h/ln
	Multi-lane highway (using free-flow speed of 90 km/h) as an example	1,800	Maximum density > 26 pc/km/ln) Average speed < 80 km/h Maximum volume capacity ratio >1 Maximum service flow rate > 2100 pc/h/ln
	Two lane highway (Class I)	1,600	Average travel speed <60 km/h) Percent time spent following >80%
	Ramp merge and diverge segments		Density > 22 pc/km/ln. Demand exceeds capacity
	Weaving segments		Density > 25 pc/km/ln. Demand exceeds capacity
Interrupted flow	Urban road mid-block	Divided: 1000 Undivided: 900 Kerb lane: 600 -	VCR > 1 Speed < 1/4 Free Flow Speed

Flow type	Road segment	Indicative capacity (pv/km/ln)	Traffic performance at the LOS F
		900	
	Two-way stop-controlled intersection		Average control delay > 50 s/veh
	Roundabout		Average control delay > 70 s/veh
Active transport	Signalised intersection		Average control delay > 80 s/veh
	Pedestrian		Walkway: Pedestrian space <0.75 M2/p. Walking speed is severely restricted Queuing area: Pedestrian space <0.2 M2/p. Direct physical contact each other

Source: Austroads (2007), Austroads (2017), Transportation Research Board (2000)

Secondly, the Base Case adjustment should consider potential driver behavioural changes when facing a congested road network. The impacts of new infrastructure are based on today's projections of where people will live and work in the future. This includes maintenance and remedial work designed to maintain road performance to an acceptable standard. Terrill et al. (2018) has shown that cities and the people in them constantly adapt to traffic congestion. Table 5 lists some potential behavioural changes in short-term and long-term.

Table 5: Behavioural change

Short term	Long term
Use public transport Cycling Walking Use a different route Travel in off-peak hours Work from home / teleworking Voluntary cancel unessential trips Use Uber and car-pooling	Reduced car ownership Live in a different location Work at a different location Move to another city Technology change: Autonomous vehicle can potentially take less space and reduce congestion

Recommended Base Case adjustment

In an economic appraisal, if the modelled Base Case is too pessimistic due to unrealistically high demand and low capacity – economic benefits tend to be overestimated. The Base Case should be adjusted based on short and long-term behaviour changes. A Minimum Base Case specification can be used to adjust economic benefits as shown in Table 6.

- If the Base Case is a two lane regional highway (to be upgraded to 4-lanes in the Project Case), the Minimum Base Case is assumed at the LOS F and the speed of 25 km/h. That is, the vehicle speed for economic appraisal is limited to 25 km/h even if the modelled speed is slower. This floor speed, based on Austroads guide on LOS F traffic performance (Austroads, 2017, p.43), will moderate the incremental difference between the Base Case and Project Case, therefore reducing the BCR of the project.
- If the Base Case is an urban arterial road (divided or undivided) with a speed limit of 70 km/h, the Minimum Base Case is assumed at the LOS F and the

speed of 15-16 km/h. This floor speed is based on Austroads guide on LOS F traffic performance (Austroads, 2017, p.60).

- If the Base Case is an urban sub-arterial road (divided or undivided) with a speed limit of 60 km/h, the Minimum Base Case is assumed at the LOS F and the speed of 11 km/h. This floor speed is based on Austroads guide on LOS F traffic performance (Austroads, 2017, p.60).

Table 6: Minimum Base Case

Base case road type	Indicative capacity (veh/h/ln)	Assumed speed limit (km/h)	Estimated free-flow speed (km/h)	Minimum Base Case that should be used in economic appraisal
Regional highway - two lane	2000	90	82	LOS F Speed = 25 km/h
Urban arterial road divided	1000	70	53	LOS F Speed = 16 km/h
Urban arterial road undivided	900	70	50	LOS F Speed = 15 km/h
Urban sub-arterial road	800	60	36	LOS F Speed = 11 km/h

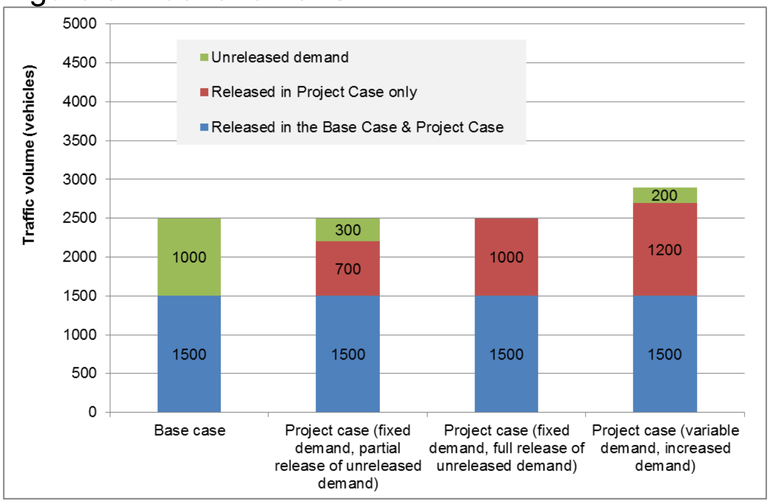
Source: Austroads (2017), ARRB (2009)

4.3 Estimate the economic benefits of UDs

Figure 5 presents a hypothetical project to illustrate scenarios of UD. In the Base Case, the total demand in the peak hour is 2,500 trips. Due to capacity constraints, 1,500 trips have been released and 1,000 trips have not been released. UD represents 40% of the total demand.

In the Project Case, the Total Demand remains unchanged in the fixed trip matrix, the expanded capacity may release part or all UD in the Base Case as shown in two mid columns. The Total Demand can increase if the variable matrix modelling was adopted. In Figure 5 Column 4, the total demand has increased from 2,500 to 2,900 trips including induced and diverted trips.

Figure 5: Illustration of UD



The proposed economic methods include:

- For trips released both in the Base Case and the Project Case, the full benefit per trip should be applied. The benefit per trip is the reduced user cost from the Base Case to the Project Case due to increased speed, reduced Vehicle Operating Cost and reduced environmental externality etc.
- For trips unreleased in the Base Case but released in the Project Case, the 50% of the full benefit should be applied. The Rule of Half (ROH) is an approximate as some users may derive full benefit while others may just get very small benefit to make them change travel behaviour (re-timing, re-routing, re-moding or making more trips).
- For trips unreleased in the Base Case and still unreleased in the Project Case (due to capacity constraint), the economic benefit is considered negligible.

4.4 Analyse the project specific expansion factor and introduce the "benefit expansion factor"

The expansion exercise is typically undertaken in two distinctive stages: (1) from peak hour modelling to a weekday; and (2) from a weekday to a year. Traffic modelling can be undertaken for 1-hr peak, 2-hr peak (i.e. 1-hr AM peak & 1-hr PM peak), 3.5 peak (e.g. 2:30 – 6:00 PM) and 4-hr peak (2-hr AM peak & 2-hr PM peak). This expansion considers time of day traffic patterns, peak hour delays and congestion. A weekday to annual expansion on the other hand considers traffic volumes in weekday, school holiday, weekend and public holiday. Orthongthed et al. (2013) used 2011/12 traffic data of 14 Sydney road sections and 36 NSW regional roads to estimate the expansion factors for traffic volume and road user cost (Table 7, Columns 2 &3).

From the observation of its practical use in 5 years, it has been identified that both volume and cost expansion factors tend to overestimate the economic benefit particularly when the traffic distribution is "peaky". This paper proposes the following revised expansion factor regime:

- The default expansion factors in the TfNSW guidelines (TfNSW 2018) should be replaced by the project specific expansion factors estimated from traffic profiles on roads in the project catchment area.
- The expansion factor should consider directional traffic pattern (AM peak for Eastbound and PM peak for Westbound, Northbound vs Southbound).
- The expansion factors are different for the Base Case and Project Case, as time of day traffic profile and user cost may have changed due to additional capacity. The benefit expansion factor can be used which considers the differences between these two scenarios. Based on the analysis of traffic patterns and user costs in 10 arterial roads in Sydney, we have re-estimated the road user cost expansion factor (see Column 4, Table 7), indicating that the cost expansion factor has been overestimated by around 10% in the 2013 analysis. If further combined with the Base Case and the Project Case effect, the benefit expansion factor (Column 5, Table 7) may have been over estimated by around 40% in an urban congested road network. In analysing the benefit factor, road capacity is a key constraint from providing additional

capacity which should be properly assessed on a project by project basis. In most projects, there is little benefit in night hours and other off-peak hours[2].

Table 7: Volume and user cost expansion factors estimated in 2012

Period **(1)**	Traffic volume expansion factors (2013 Analysis) Source A (2)	Road user cost expansion factors (2013 Analysis) Source A (3)	Road user cost expansion factors (2019 Analysis) Source B (4)
From 1 hr peak to a weekday (highest volume hours, usually 8:00 – 9:00 AM)	14.31	12.45	**10.56**
From 2 hr peak to a weekday (1 hr AM peak + 1 hr PM peak)	7.21	6.29	**6.06**
From 3.5 hr peak to a weekday (6:30 – 10:00 AM)	4.46	4.04	**3.59**
From 4 hr peak to a weekday (2 hr AM peak + 2 hr PM peak)	3.55	3.46	**3.08**

Source A: TfNSW (2018), p.292-294. The factors of 4 hr peak to a weekday are estimated from separate modelling as part of this paper;

Source B: Based on traffic data for ten arterial roads in Sydney;

Caveat: Numbers in column 4 are preliminary. At the project level please consult the Investment Branch for specific expansion factors.

5 Conclusions

The UD phenomenon is a material problem for contemporary CBA used in road network analysis in (typically) highly congested networks. As outlined, there remain a number of specific modelling interventions and adjustments that can be made to assist in ameliorating the UD phenomena. However, the net impact of these adjustments taken in combination is not known with any degree of precision.

The other approach outlined in the paper is based on an orthodox economic framework that seeks to estimate losses to Consumer Surplus and Producer Surplus with the context of a Social Generalised Cost framework. An advantage of this approach is its relative transparency, with the ability to decompose adjustments into their respective components.

Although the focus of this paper is on microsimulation modelling for economic evaluations, the paper acknowledges that the strategic demand model is still a powerful tool for the overall demand analysis and rapid economic appraisal. In most

[2] We have developed a model to estimate the project specific volume and user cost expansion factors. Please email baojin.wang@rms.nsw.gov.au if you need to run a specific factor. Required inputs include hour of day traffic profile, road capacity, posted speed limit or estimated free-flow speed.

cases, the economic benefits estimated from the strategic model are difficult to be allocated to routes or the project catchment areas.

Authors will continue further research on how lessons learnt from economic appraisal and microsimulation modelling can provide useful feedback to strategic model and land use planning.

The economic intervention procedure described in this report has been successfully applied up to 6 RMS projects in 2018. Results show that the new procedure can generate more realistic economic results in the congested urban network. Future empirical data analysis work is likely to test the more complex integral calculus procedure with the simplified geometric procedure, to determine how material the difference between these procedures might be. Furthermore, any difficulties in sourcing information for these procedures can be assessed with a view to including the SWUTA procedure as a standard for adjustment for the network modelling of Unreleased Trips that arise (from strategic, mesoscopic and microscopic models) in transport microeconomic modelling, where the road network is congested.

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