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What are we counting? Getting inputs correct to improve modelling outcomes

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Abstract

A great traffic engineer and modeller once said that every traffic model that is built is wrong because the flow is counted, not the demand. Because the traffic flow is counted, base case models should never be over-saturated. Traffic count balancing required for models such as simulation can amplify this problem. The result of this can be a model that does not reflect observed traffic conditions. If the base case model is not correct, the validity of the forecast models can also be called into question. But how serious is this issue and what are the implications of this for project development and assessment?

This paper will provide practical examples of how counting the flow can produce unrealistic modelling outcomes from a range of modelling packages. It will outline the effects this may have on assessing projects and provide some alternative methods to improve models through better data collection.

1. Introduction

Traffic engineering and traffic modelling relies on quality data being collected and correctly analysed. The use of inappropriate data can result in erroneous results and poor project outcomes.

Traffic Counts for Strategic Transport Model Validation: What Counts? (Hidas and Milthorpe, 2009) outlined how to prepare traffic counts for Strategic Model validation. As strategic modelling outputs are a key input to many other operational models, the strategic data collection is still considered a critical process, however more effort is required by modellers to ensure the detailed data being used is fit for purpose. In particular, traffic counts that measure flow must be converted to demand for accurate traffic modelling.

Other measured traffic data (including queue surveys, travel times, origin-destination surveys) all assist with the calibration and validation of traffic models. While the use of other data is considered critical in the model development process, this paper only discusses issues with traffic volume counts and their application in traffic models. It is noted however that the collection of additional data will assist in determining if observed traffic counts are representing flow or demand.

2. Flow vs Demand

The definition of flow and demand are key to analysing inputs to traffic models.

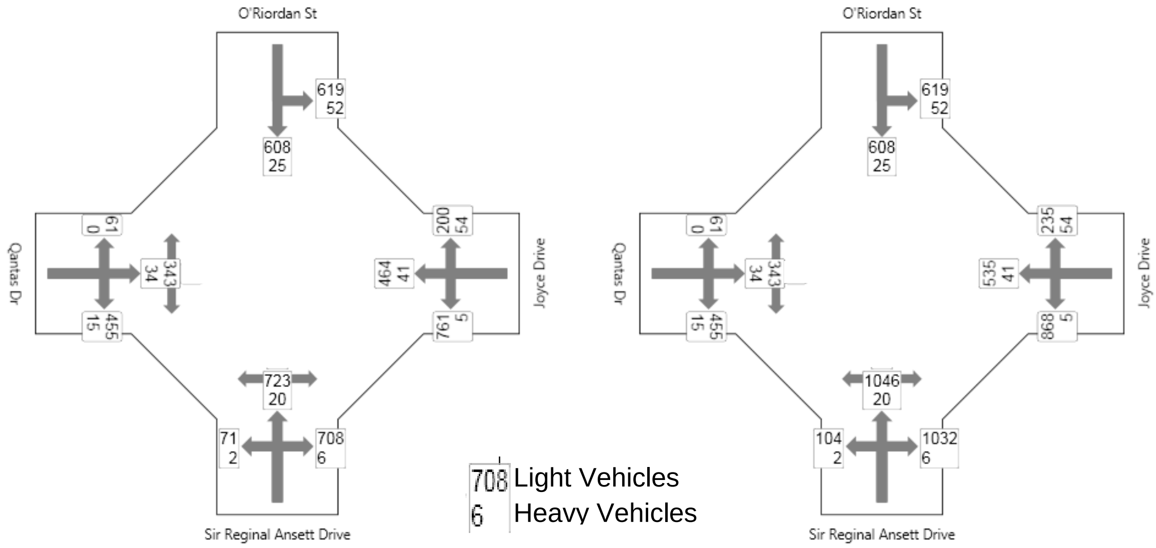
Flow is the amount of traffic passing a particular point on the network, whereas *Demand* is the amount of traffic wanting to pass through a particular point on the network. The distinction may not seem like much, but in a congested environment the difference may be several hundred vehicles per hour.

Traffic models are often referred to as demand models (which allow over-capacity operation), and yet they are calibrated to traffic flows. This disconnect needs to be rectified to ensure project design can cope with forecast demands, not just forecast flows.

Measuring flow is easy and can be undertaken by automatic or manual field measurements. Measuring demand can be more complex and requires a detailed understanding of the site being measured and requires additional counting to ensure the demand is measured.

Figure 1 shows the difference between flow and demand for a key intersection in Sydney.

Figure 1 Demand and Flow at a Single Intersection



Flow Demand

In this case, the demands were estimated by using the exit flows from upstream survey locations. Site observations indicated the presence of queuing on the southern and eastern approaches. This observed queuing persisted throughout the peak period resulting in oversaturated traffic conditions whereby the amount of traffic wanting to pass through the intersection could not be accommodated.

As the demand counts only provided link inflows, the demand growth was applied on a pro-rata basis to all effected turn movements.

2.1 Modelling Flow and Demand

Many traffic models are developed at the intersection level. Traffic counts are undertaken at the intersection to be analysed and input to a modelling program such as SIDRA. The traffic counts from above have been input to SIDRA to examine the impacts on modelling results when using flows or demands. The intersection layout is shown in Figure 2 and the summary results are outlined in Tables 1 and 2.

Figure 2 Intersection Layout

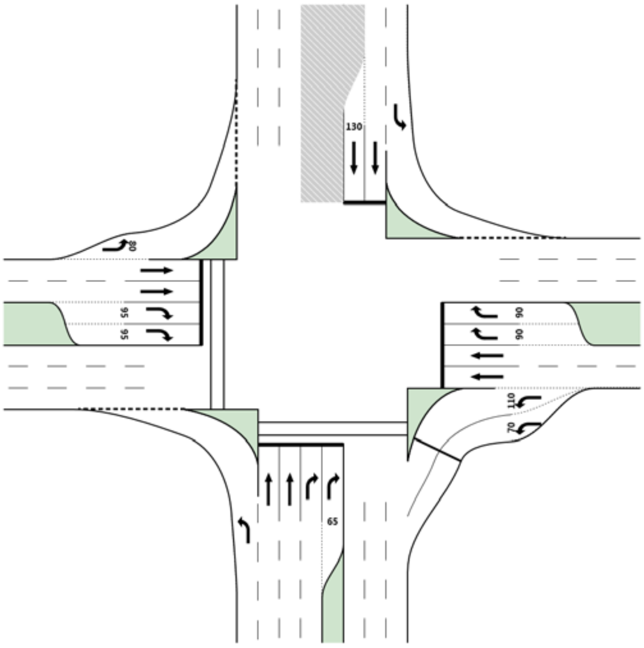


Table 1 SIDRA Intersection Results using flows

Movement Performance – Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
							Vehicles	Distance			
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South											
1	L	73	2.9	0.050	10.3	LOS A	1.5	11.0	0.22	0.64	46.9
2	T	743	2.7	0.346	18.9	LOS B	15.8	113.3	0.59	0.52	38.0
3	R	715	0.9	0.838	63.3	LOS E	35.8	252.2	0.94	0.92	22.1
Approach		1531	1.9	0.838	39.2	LOS C	35.8	252.2	0.74	0.71	28.6
East											
4	L	766	0.7	0.588	21.3	LOS B	13.3	93.3	0.70	0.78	38.1
5	T	505	8.1	0.818	70.7	LOS F	20.0	150.1	1.00	0.94	19.7
6	R	254	21.2	0.562	74.8	LOS F	10.6	87.3	0.98	0.81	19.8
Approach		1525	6.6	0.818	46.5	LOS D	20.0	150.1	0.84	0.84	26.1
North											
7	L	671	7.7	0.730	29.1	LOS C	34.1	254.8	0.82	0.85	33.5
8	T	634	4.0	0.834	68.1	LOS E	24.5	177.5	1.00	0.95	20.2
Approach		1304	5.9	0.833	48.0	LOS D	34.1	254.8	0.91	0.90	25.4
West											
10	L	61	0.0	0.116	11.6	LOS A	1.5	10.8	0.28	0.66	45.6
11	T	377	8.9	0.568	61.0	LOS E	14.2	106.8	0.97	0.80	21.7
12	R	469	3.1	0.843	82.3	LOS F	19.3	138.4	1.00	0.93	18.5
Approach		907	5.3	0.843	68.7	LOS E	19.3	138.4	0.94	0.86	20.6
All Vehicles		5267	4.8	0.843	48.6	LOS D	35.8	254.8	0.84	0.82	25.4

Level of Service (Aver. Int. Delay): LOS D. Based on average delay for all vehicle movements. LOS Method: Delay (RTA NSW).
Level of Service (Worst Movement): LOS F. LOS Method for individual vehicle movements: Delay (RTA NSW).
Approach LOS values are based on average delay for all vehicle movements.

Table 2 SIDRA Intersection Results using demands

Movement Performance – Vehicles												
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South											
1	L	106	2.0	0.073	10.5	LOS A	2.3	16.3	0.23	0.64	46.7
2	T	1066	1.9	0.456	16.9	LOS B	21.6	153.3	0.59	0.53	39.5
3	R	1038	0.6	1.006	112.0	LOS F	87.9	618.5	1.00	1.11	14.9
Approach		2211	1.3	1.007	61.2	LOS E	87.9	618.5	0.76	0.81	22.2
East											
4	L	874	0.6	0.617	18.3	LOS B	13.6	95.8	0.63	0.77	40.1
5	T	576	7.1	1.008	142.5	LOS F	32.9	244.5	1.00	1.41	12.0
6	R	288	18.6	0.733	81.1	LOS F	12.3	100.2	1.00	0.86	18.7
Approach		1738	5.8	1.007	69.9	LOS E	32.9	244.5	0.81	1.00	20.4
North											
7	L	671	7.7	0.916	66.0	LOS E	48.6	362.8	1.00	1.06	21.5
8	T	634	4.0	1.000 [3]	117.7	LOS F	35.2	254.9	1.00	1.25	13.8
Approach		1304	5.9	1.000	91.1	LOS F	48.6	362.8	1.00	1.15	17.0
West											
10	L	61	0.0	0.151	14.0	LOS A	2.0	13.8	0.35	0.68	43.4
11	T	410	8.9	0.727	67.5	LOS E	16.1	121.3	1.00	0.86	20.3
12	R	436	3.1	1.000 [3]	125.1	LOS F	22.4	160.7	1.00	1.12	13.6
Approach		907	5.3	1.000	91.6	LOS F	22.4	160.7	0.96	0.98	16.9
All Vehicles		6160	4.1	1.007	74.5	LOS F	87.9	618.5	0.86	0.96	19.6

Level of Service (Aver. Int. Delay): LOS F. Based on average delay for all vehicle movements. LOS Method: Delay (RTA NSW).
Level of Service (Worst Movement): LOS F. LOS Method for individual vehicle movements: Delay (RTA NSW).
Approach LOS values are based on average delay for all vehicle movements.

The tables show a significant deterioration in intersection performance when the demands are modelled. An intersection that analysis using flows shows may not need an upgrade actually does need capacity improvements when analysed using demands. In this case, the use of incorrect traffic data results in a 55% increase in the average intersection delay.

The reverse can also be true. An existing situation model developed only using flows should never operate poorly (a “bad” Level of Service F, with Degrees of Saturation greater than 1). If the model inputs are flows (which by definition is the amount of traffic passing through the intersection) then the intersection must operate under these flows. Extensive queuing and delays should not occur in an existing situation model developed using flows.

Many intersection models are submitted to road authorities with existing condition models exhibiting a poor level of service and extensive delays. If traffic flows are modelled, the only conclusion that can be drawn is that the model is incorrect. This is a fundamental component of traffic modelling that is often overlooked in the project development process.

The following is an example of an existing situation model, developed using the SIDRA defaults with no regard to adjusting the default parameters to suit existing conditions. The intersection was modelled using existing traffic flows directly from a traffic survey at the subject intersection. Table 3 shows the outputs from this model.

Table 3 SIDRA Intersection Results Existing Model (default Parameters)

Movement Performance – Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South											
1	L	126	5.0	0.070	6.6	LOS A	0.0	0.0	0.00	0.56	35.6
3	R	152	1.4	1.194	260.7	LOS F	24.6	173.9	1.00	2.59	7.2
Approach		278	3.0	1.190	145.2	LOS F	24.6	173.9	0.55	1.67	8.6
East											
4	L	25	8.3	0.021	7.2	LOS A	0.1	0.7	0.15	0.54	34.0
5	T	1332	6.5	0.356	7.1	LOS A	0.0	0.0	0.00	0.59	50.4
Approach		1357	6.5	0.356	7.1	LOS A	0.1	0.7	0.00	0.59	50.2
West											
11	T	1381	5.3	0.366	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
12	R	111	4.8	0.062	7.4	LOS A	0.0	0.0	0.00	0.63	48.8
Approach		1492	5.2	0.366	0.5	LOS A	0.0	0.0	0.00	0.05	59.0
All Vehicles		3126	5.6	1.190	16.3	NA	24.6	173.9	0.05	0.43	40.7

LOS (Aver. Int. Delay): NA. The average intersection delay is not a good LOS measure for two-way sign control due to zero delays associated with major road movements.
Level of Service (Worst Movement): LOS F. LOS Method for individual vehicle movements: Delay (RTA NSW).
Approach LOS values are based on the worst delay for any vehicle movement.

The results show that the southern leg is operating poorly with extensive queuing and delays. The delays are so extensive it is not possible that the observed flows would be able to pass through the intersection during the model period.

There are three options available to the modeller at this point:

1. Accept the results
2. Check the flows to ensure they are accurate flows through the intersection
3. Adjust the model parameters

Accepting the results is the easiest option available to the modeller, however this fails to recognise that the counts are actually the observed flows that traversed the intersection during the model period. Accepting the results is therefore not an appropriate option.

Checking the flows should be the primary check. Incorrect flows could be as simple as a typographic error on entry into the model or a poor traffic count. Flows can be independently verified using signal detector data (where available), re-examining the traffic count video (if one was undertaken) or re-counting the intersection. If the flows are verified, it is the model parameters that require adjustment.

While the default SIDRA parameters are useful in a large number of cases the SIDRA manual does state that parameters should be adjusted where site observations or collected data support such a change.

In the example above, the flows have been verified and subsequent site observations showed the gap acceptance parameters required adjustment. The updated intersection results are shown in Table 4.

Table 4 SIDRA Intersection Results Existing Model (modified Parameters)

Movement Performance – Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
							Vehicles	Distance			
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South											
1	L	126	5.0	0.070	6.6	LOS A	0.0	0.0	0.00	0.56	35.6
3	R	152	1.4	0.394	18.6	LOS B	2.2	15.4	0.80	1.01	35.7
Approach		278	3.0	0.394	13.1	LOS B	2.2	15.4	0.44	0.81	35.7
East											
4	L	25	8.3	0.021	7.2	LOS A	0.1	0.7	0.15	0.54	34.0
5	T	1332	6.5	0.356	7.1	LOS A	0.0	0.0	0.00	0.59	50.4
Approach		1357	6.5	0.356	7.1	LOS A	0.1	0.7	0.00	0.59	50.2
West											
11	T	1381	5.3	0.366	0.0	LOS A	0.0	0.0	0.00	0.00	60.0
12	R	111	4.8	0.062	7.4	LOS A	0.0	0.0	0.00	0.63	48.8
Approach		1492	5.2	0.366	0.5	LOS A	0.0	0.0	0.00	0.05	59.0
All Vehicles		3126	5.6	0.394	4.5	NA	2.2	15.4	0.04	0.35	52.8

LOS (Aver. Int. Delay): NA. The average intersection delay is not a good LOS measure for two-way sign control due to zero delays associated with major road movements.
Level of Service (Worst Movement): LOS B. LOS Method for individual vehicle movements: Delay (RTA NSW).
Approach LOS values are based on the worst delay for any vehicle movement.

With the parameter adjustment the modelled intersection is now satisfying the observed flows.

3. Larger Models

3.1 Corridor Models

Corridor models are usually developed in modelling packages such as LinSig, Transyt or using a microsimulator. The flows input to these models are often developed from a series of traffic counts taken along the corridor. Along the corridor there are often discrepancies between intersections. These discrepancies can be due to a number of factors but are often attributed (correctly or not) to human error.

"Flow Balancing" is often used to provide consistency between adjacent intersections. Flow balancing is a process whereby observed traffic flows at individual intersections are adjusted to ensure consistent traffic flow between adjacent intersections.

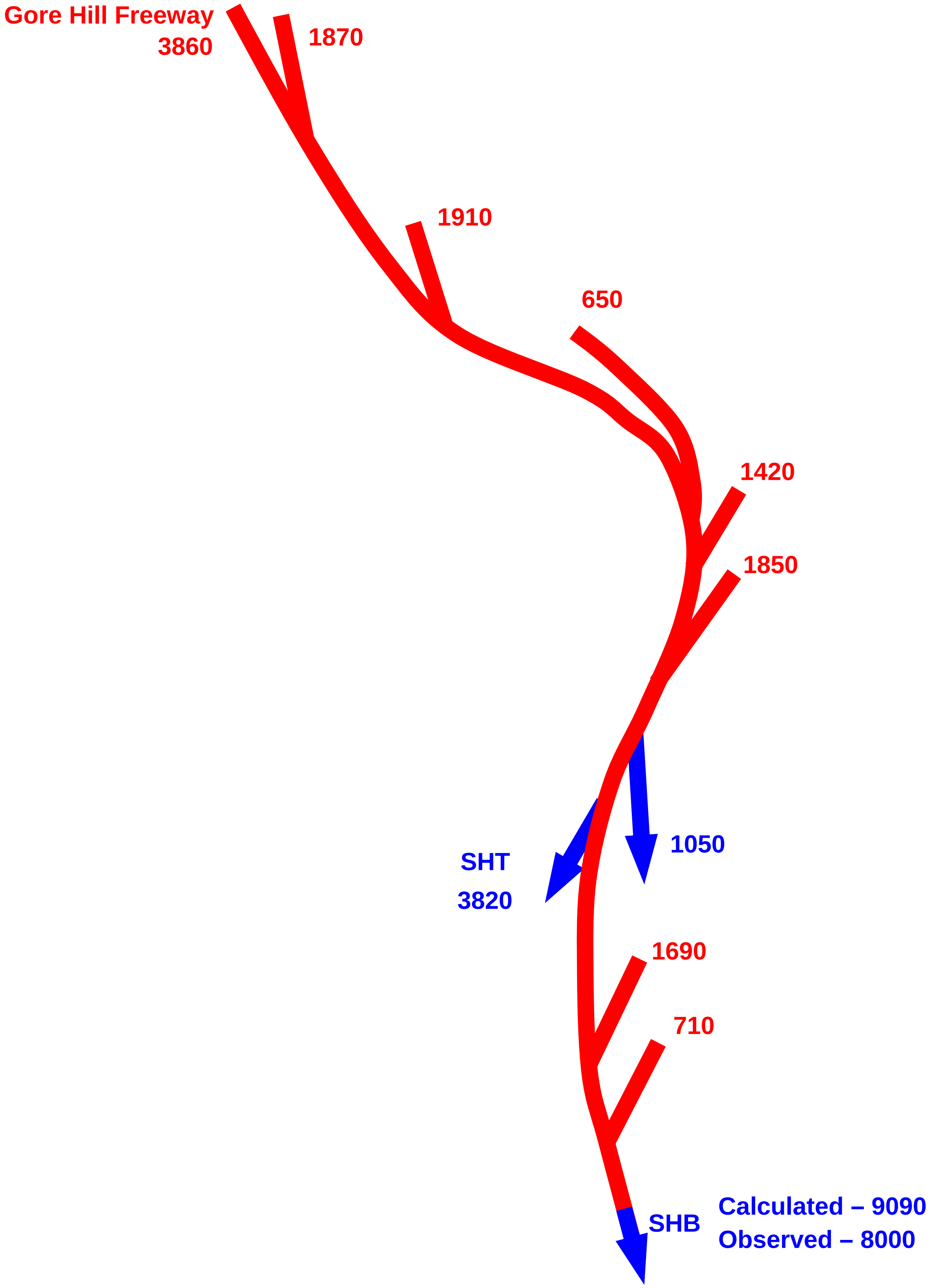
The process of flow balancing can cause its own issues, particularly in a heavily congested corridor. Actual flows are not always balanced over a peak hour, as queues may form between intersections. When undertaking flow balancing modellers must ensure that they are removing the data error components in the observed flows and not actual changes in flow along the road network.

In New South Wales, there are currently no standards for flow balancing and it is up to the modeller to ensure that the method used is valid. Whichever method is used for flow balancing it is critical that the flows are not reduced at any intersection unless there is independent data to support such a reduction. Transport for London recommend that "a general rule is to take the larger flow count from adjacent survey sites as being accurate, as it is more common for errors to result in under-counting than over-counting." (Transport for London 2010, p. 66)

Even with flow balancing, the models are still using flows (and not demands) as inputs are based on counts at the intersections being analysed. Flows at the entrances to the corridor (the ends of the main road and the side roads) may still be under-representing the demand wanting to use the corridor. The effect of this is exactly the same as that described for single intersection models.

An example of the use of flow balancing is the Sydney Harbour Bridge and its approaches. In the morning peak hour the combined inflow from the ramps is greater than the observed flow on the Harbour Bridge. This is not a data error but simply a function of the limited capacity on the Harbour Bridge and the resultant queuing that occurs in the peak hour. If flow balancing was required for a corridor model of this area, the flows should be balanced to the ramp inflows as the demand that wants to cross the Harbour Bridge is greater than the observed flow (hence the reason for the observed queues). Figure 3 shows the observations for the Harbour Bridge approaches.

Figure 3 Sydney Harbour Bridge Approaches



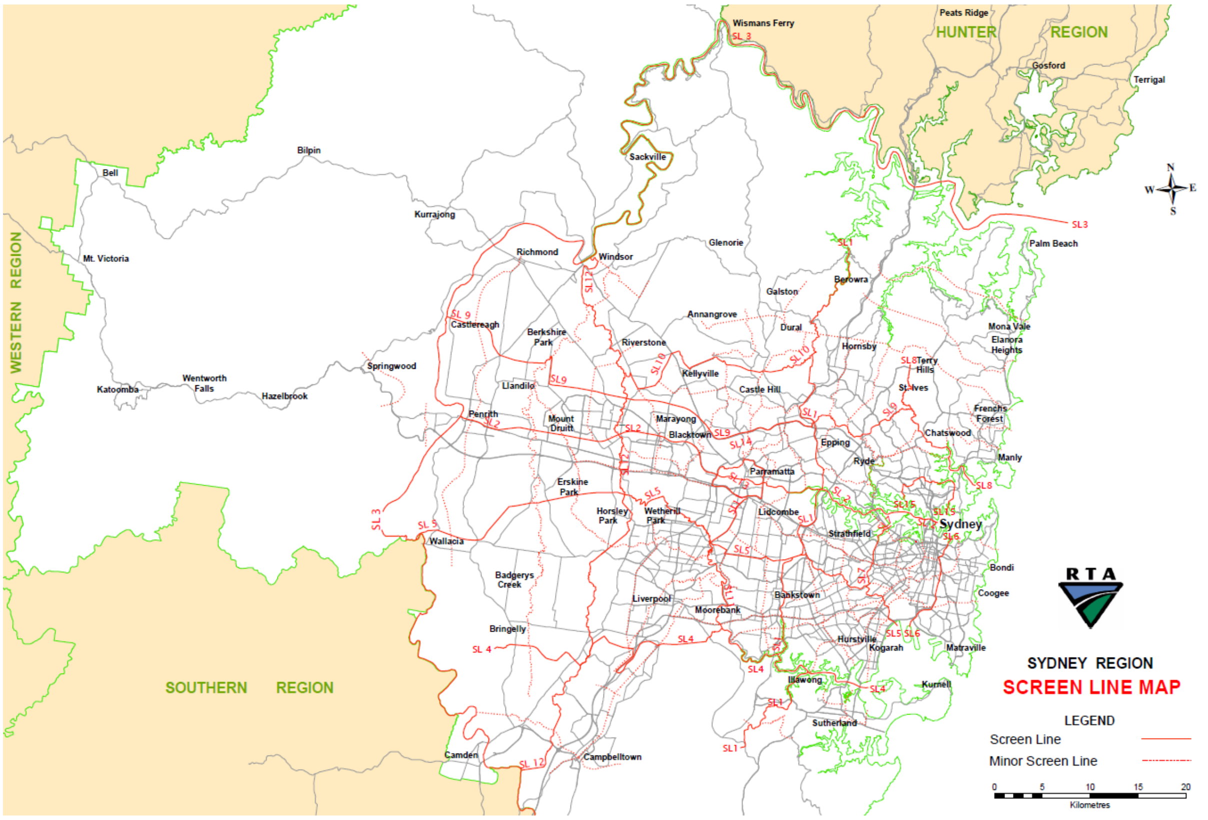
Traffic models used in this level of analysis (generally meso or microscopic simulation models) should be able to adequately model the effects of congestion. Outputs of these models will be link flows (in the same way traffic counts are link flows). To satisfactorily model congestion (eg queues etc), the trip matrices are required to be demand matrices, as flows will not generate expected congestion levels.

3.2 Network Models

When it comes to large scale network models it becomes virtually impossible to undertake flow balancing. It also becomes very difficult to indentify traffic counts that represent flow and traffic counts that represent demand.

In Sydney, the road network demand is calibrated against a number of screenlines throughout the metropolitan area (Figure 4). These screenlines are counted regularly using automated traffic counters.

Figure 4 Sydney Network Screenlines



(Roads and Traffic Authority 2002, p282)

Matrix adjustments using the counts from these screenlines results in the model representing flows and not demands. This is not a major problem in uncongested areas (where flow=demand), but on approach to areas such as the CBD the impact of this could include the skewing of trip lengths.

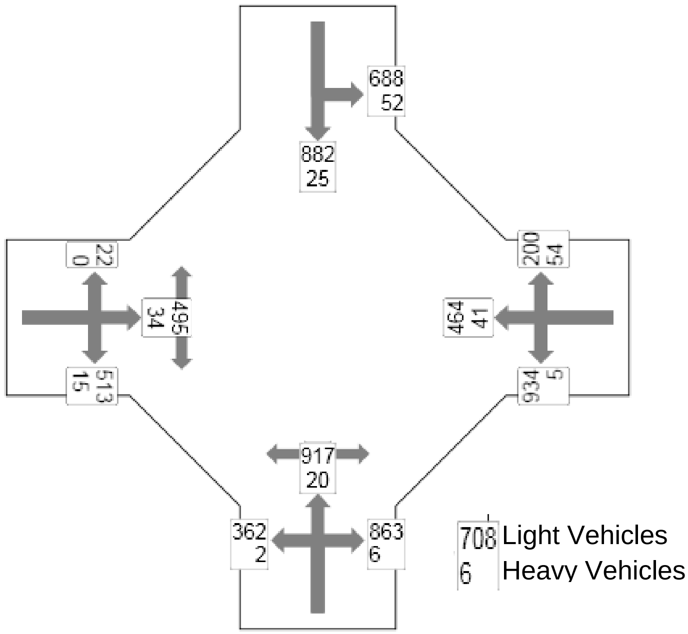
4. Forecasting using Flow or Demand

While the impacts of measuring flow (and not demand) are easily quantifiable for the existing situation, how this effects forecasting is not as well identified.

Base models are often used for forecasting. If a base model with traffic flows has growth applied then the future demands are also under-estimated. This can have serious implications for intersection design.

The effect of this is demonstrated using the example shown in Section 2. Forecast traffic growth has been obtained using absolute growth from a strategic highway assignment model.

Figure 5 Forecast Demand using Traffic Flow Inputs



Using these inputs an intersection design was developed to achieve a level of service D under the forecast traffic flows.

Figure 6 Upgraded intersection Design

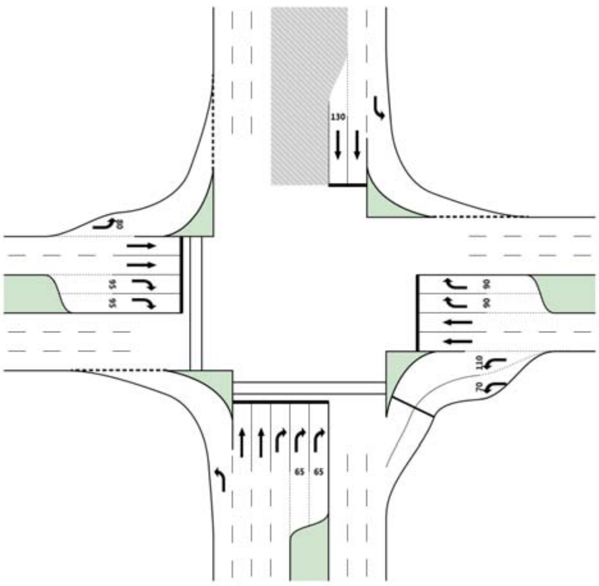


Table 5 SIDRA Intersection Results under Traffic Flow Inputs

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue Vehicles	95% Back of Queue Distance	Prop. Queued	Effective Stop Rate	Average Speed
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South											
1	L	364	0.6	0.247	10.9	LOS A	7.6	53.5	0.27	0.67	46.2
2	T	937	2.1	0.430	19.6	LOS B	20.1	143.5	0.62	0.55	37.5
3	R	869	0.7	0.933	79.3	LOS F	37.8	266.3	0.96	0.95	19.0
Approach		2171	1.3	0.932	42.0	LOS C	37.8	266.3	0.69	0.73	27.6
East:											
4	L	939	0.6	0.856	36.0	LOS C	24.4	171.5	0.86	0.88	30.4
5	T	505	8.1	0.853	74.6	LOS F	20.6	154.6	1.00	0.98	19.1
6	R	254	21.2	0.694	80.9	LOS F	11.0	91.3	1.00	0.84	18.7
Approach		1698	5.9	0.856	54.2	LOS D	24.4	171.5	0.92	0.91	24.0
North											
7	L	740	7.0	0.774	31.5	LOS C	37.3	276.6	0.85	0.90	32.4
8	T	907	2.8	0.934	71.9	LOS F	44.2	316.8	0.99	1.04	19.5
Approach		1647	4.7	0.934	53.8	LOS D	44.2	316.8	0.93	0.97	23.8
West											
10	L	22	0.0	0.049	12.7	LOS A	0.6	4.5	0.31	0.65	44.5
11	T	528	6.4	0.706	60.8	LOS E	19.2	141.9	0.99	0.84	21.7
12	R	527	2.8	0.944	89.3	LOS F	22.4	160.6	1.00	0.96	17.5
Approach		1078	4.5	0.944	73.8	LOS F	22.4	160.6	0.98	0.90	19.6
All Vehicles		6594	3.8	0.944	53.3	LOS D	44.2	316.8	0.86	0.86	24.1

Level of Service (Aver. Int. Delay): LOS D. Based on average delay for all vehicle movements. LOS Method: Delay (RTA NSW).
Level of Service (Worst Movement): LOS F. LOS Method for individual vehicle movements: Delay (RTA NSW).
Approach LOS values are based on average delay for all vehicle movements.

This design was developed using the flow inputs. As discussed in Section 2, the demand for this intersection was higher than the observed flow. The impact of this is shown in the following figures.

Figure 7 Forecast Demand using Traffic Demand Inputs

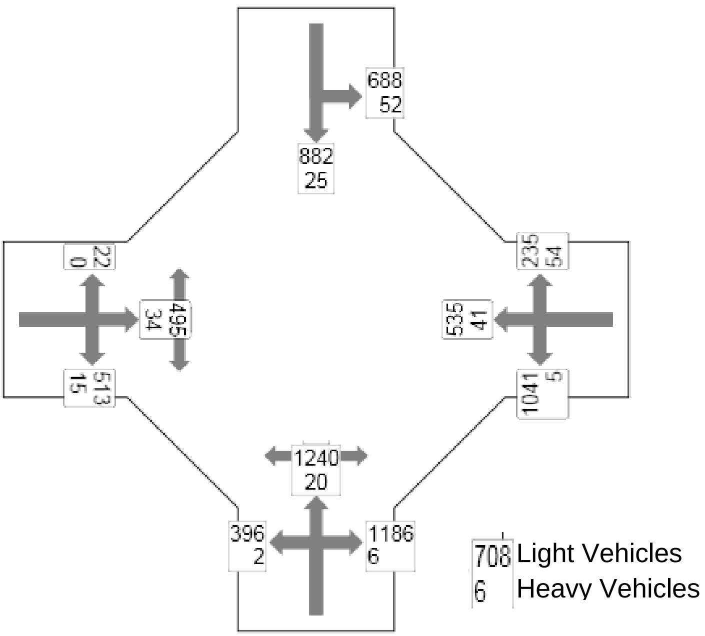


Table 6 Improved intersection Performance under Demand Inputs

Movement Performance - Vehicles											
Mov ID	Turn	Demand Flow	HV	Deg. Satn	Average Delay	Level of Service	95% Back of Queue		Prop. Queued	Effective Stop Rate	Average Speed
							Vehicles	Distance			
		veh/h	%	v/c	sec		veh	m		per veh	km/h
South											
1	L	398	0.5	0.271	11.5	LOS A	8.2	57.8	0.28	0.69	45.7
2	T	1260	1.6	0.532	17.5	LOS B	26.4	187.2	0.62	0.57	38.9
3	R	1193	0.5	1.067	149.9	LOS F	99.1	697.2	1.00	1.19	11.8
Approach		2851	1.0	1.067	72.1	LOS F	99.1	697.2	0.73	0.84	20.0
East											
4	L	1046	0.5	0.874	31.9	LOS C	26.1	183.4	0.77	0.86	32.2
5	T	576	7.1	0.966	105.8	LOS F	28.3	210.4	1.00	1.24	15.0
6	R	288	18.6	0.943	108.0	LOS F	14.5	117.4	1.00	1.09	15.2
Approach		1911	5.2	0.966	65.6	LOS E	28.3	210.4	0.87	1.01	21.3
North											
7	L	740	7.0	0.937	72.2	LOS F	53.0	392.8	1.00	1.13	20.3
8	T	907	2.8	1.069	149.2	LOS F	73.5	526.9	1.00	1.39	11.5
Approach		1647	4.7	1.069	114.7	LOS F	73.5	526.9	1.00	1.27	14.3
West											
10	L	22	0.0	0.063	15.3	LOS B	0.8	5.6	0.37	0.66	42.4
11	T	665	6.4	1.031	170.8	LOS F	42.2	311.4	1.00	1.53	10.3
12	R	391	2.8	1.006	149.1	LOS F	22.4	160.3	1.00	1.28	11.9
Approach		1078	4.5	1.031	159.7	LOS F	42.2	311.4	0.99	1.42	11.0
All Vehicles		7486	3.4	1.069	92.4	LOS F	99.1	697.2	0.86	1.06	16.8

Level of Service (Aver. Int. Delay): LOS F. Based on average delay for all vehicle movements. LOS Method: Delay (RTA NSW).
Level of Service (Worst Movement): LOS F. LOS Method for individual vehicle movements: Delay (RTA NSW).
Approach LOS values are based on average delay for all vehicle movements.

Table 6 shows that the intersection design that was considered acceptable using traditional modelling methods is in fact not acceptable under the forecast demand flows.

The use of flows and not demands can therefore have serious design implications under certain conditions. These need to be understood and considered whenever future intersection design is undertaken in an already congested environment.

5. Modelling Demand

The ways to model demand will vary depending on the scale of the model.

- For a single intersection or corridor, modelling demand may be a simple as measuring the inflows to the model system (ie beyond the back of any approach queuing). Where extensive queuing occurs these infow counts may need to extend back some distance.
- For mid-level meso or microsimulation models (that actually model flow) care needs to be taken that the trip matrices represent the demand, as the modelled link flows should account for congestion.
- For large scale network models identifying demand is far more complex and the most appropriate solution may be to extend the model period to a point where there is no residual queuing between count locations and hence flow will equal demand. In many instances this may mean increasing the model peak period by an additional hour.

In all cases, a thorough understanding of the network and its operation is required by the modeller. Site inspections should whenever possible be undertaken in conjunction with traffic counts to gain an appreciation of the operating conditions at the time of observation. This will also help identify the need for subsequent survey or other data required to accurately represent the demand and not just the flow. Correctly identifying the geographic and temporal scope for data collection and traffic models is the key to ensuring traffic models accurately represent demand.

The modelling of demand (and not flow) will become more critical as our traffic networks become more congested, without the correct inputs infrastructure decisions may be made using inappropriate models.

6. Conclusions

It is very easy to simply put numbers into a modelling package, press a button and report results. The art of traffic modelling is in understanding the input data and in the interpretation of the outputs.

The modelling of flows will continue as traffic counts will always be the primary source of demand data for traffic models. This paper has outlined some ways to improve data collection and get closer to the required demands, this does however come at increased cost.

To improve model outcomes, the correct geographic and temporal scope must be included during the model development. This requires model developers to work with their clients to ensure the full picture of network operations is incorporated into models.

As our roads get more congested, modeller will need to explain the limitations of the inputs to modelling process and how these limitations impact the forecasting ability of the models or preferably update their data collection and modelling techniques to account for the demand.

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