INNOVATIVE TECHNIQUES USED IN TRAFFIC IMPACT ASSESSMENTS OF DEVELOPMENTS IN CONGESTED NETWORKS

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Abstract

For uncongested networks, peak hour trip generation rates are used to generate traffic for a development based on the land use budget. The assumption is made that the trips will be able to move to and from the site during the peak hour, and hence the generated trips are superimposed on the existing peak hour traffic flows, to produce the post development (future) flows. These future flows can be analysed and the impact of the development determined.

However, in congested networks, the current peak hour demand for travel on certain routes within the network, cannot be satisfied. Capacity constraints (bottlenecks) on these routes restrict (meter) flows along these routes. Under these conditions, normal trip generation and superimposition of generated trips onto the existing flows, is unrealistic.

In order to produce realistic future traffic scenarios for analysis purposes it was necessary to develop a method of unconstraining (releasing) the existing traffic flows on the network, by theoretically unlocking the existing bottlenecks in the network. Once unlocked, the development traffic (generated new trips) could be superimposed on the existing unconstrained flows. These future flows could be re-constrained to produce the realistic future traffic flow scenarios, based on predicted future bottleneck capacities.

The analysis of congested networks required innovation in the methods of data survey and interpretation. The paper focusses on the innovative method used to unconstrain and then re-constrain network traffic flows, for the purposes of measuring the traffic impact of developments in congested road networks.

1. Introduction

Traditionally traffic impact assessments are conducted using the four step process of trip generation, trip distribution, mode split and traffic assignment. Trip generation rates have been determined using empirical methods and extensive data collection. However, in congested networks such as those serving the central business districts (CBD's) of cities, peak hour trip generation rates for land uses within the CBD can vary based on the level of congestion into and out of the CBD.

For uncongested networks, peak hour trip rates are applied to the land use budget to determine peak hour trip generation. These generated flows are superimposed on the existing peak hour flows on the road network, based on trip distribution and assignment assumptions. However, in congested networks, this process is an oversimplification in that the peak hour trip generation for the proposed development represents an unconstrained traffic prediction i.e trips are assumed to be accommodated within the peak hour. For congested networks, certain routes to and from the CBD are at capacity (due to existence of bottlenecks on these routes) and hence these routes cannot accommodate any increase in peak hour traffic.

Therefore, if unconstrained generated peak hour trips are superimposed on the existing constrained traffic flows, the impact of the development would be overstated. Furthermore, the future traffic scenario would represent some unrealistic future flow regime that would possibly never occur and hence analysis of this regime would be irrelevant.

In order to predict realistic future traffic scenarios for traffic impact analysis purposes it was necessary to develop a method of unconstraining (releasing) the existing traffic flows on the network, by theoretically unlocking the existing bottlenecks in the network. The unconstained peak hour traffic flows would therefore be a prediction of the peak hour demand for travel on the network. Once unlocked, the development traffic (generated unconstrained new trips) could be superimposed on the existing unconstrained flows. These future unconstrained flows could be re-constrained to produce the realistic future traffic flow scenarios, based on predicted future bottleneck capacities.

The above methodology was developed for the Traffic Impact Assessment of the Cape Town International Convention Centre (1) and adjacent developments (2). These developments are situated in the Cape Town CBD, which is served by various commuter routes. The two major commuter routes into the CBD are the National Route 1 (N1) and National Route 2 (N2). Both of the abovementioned two routes are urban freeways.

2. Constrained vs Unconstrained Commuter Traffic Profiles

The N1 and N2 routes operate under congested conditions in the peak direction of travel, during commuter peak periods i.e these routes operate at capacity for approximately 2 hours during both the weekday AM and PM peak periods. A typical weekday AM peak period traffic flow profile for the N1 route is indicated in Figure 1.

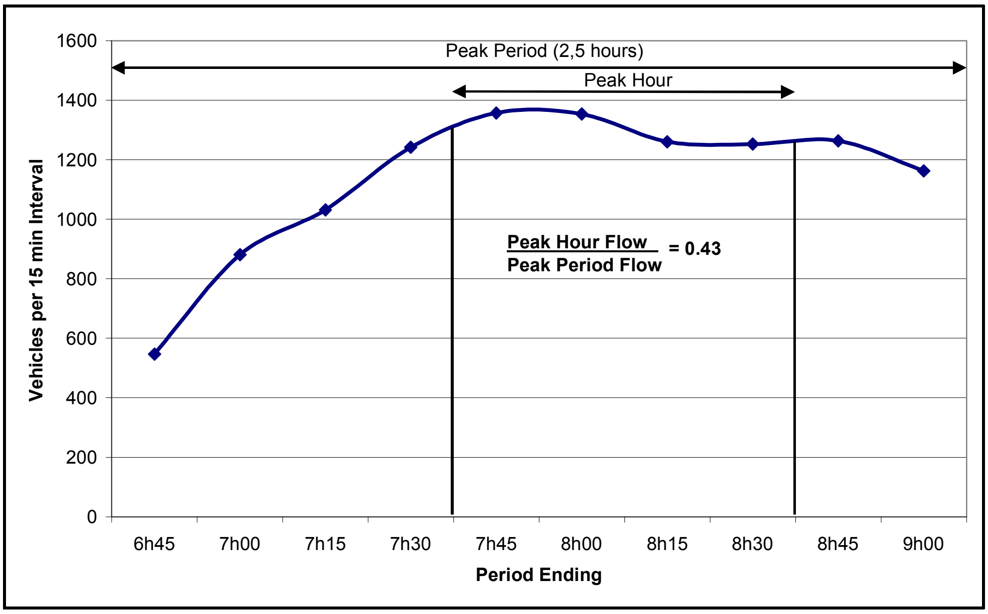

FIGURE 1: TRAFFIC FLOW PROFILE FOR A CONSTRAINED ROUTE (NI ROUTE): AM PEAK PERIOD

A peak period of 2,5 hours was used in this assessment as it encompassed the congested period. The peak period (2,5 hour) flow on the route also provided an estimate of the peak period demand for travel on the route, whereas the peak hour flow provided an estimate of peak hour supply.

The relationship between the peak hour and the peak period flows was used as an estimate of the intensity of congestion on the route. A route that was congested for the entire peak period would render a ratio of peak hour to peak period flow of 0.40, thus setting a lower limit for the chosen peak period duration.

A typical traffic flow profile of an uncongested route was used to determine the upper limit for the ratio of peak hour to peak period flow (Refer to Figure 2). As indicated in Figure 2, the upper limit of the ratio of peak hour to peak period flow was 0.52, for the chosen peak period duration. The ratio of 0.43 measured on the N1 route fell within this range (0.40 to 0.52).

Therefore, an estimate of the unconstrained peak hour flow on the N1 could be determined by multiplying the peak period (2.5 hour) flow by 0.52 i.e. effectively fitting the N1 peak period flow to the unconstrained traffic flow profile. The above estimate of the unconstrained peak hour flow on the route gave an indication of the peak hour demand for travel on the route.

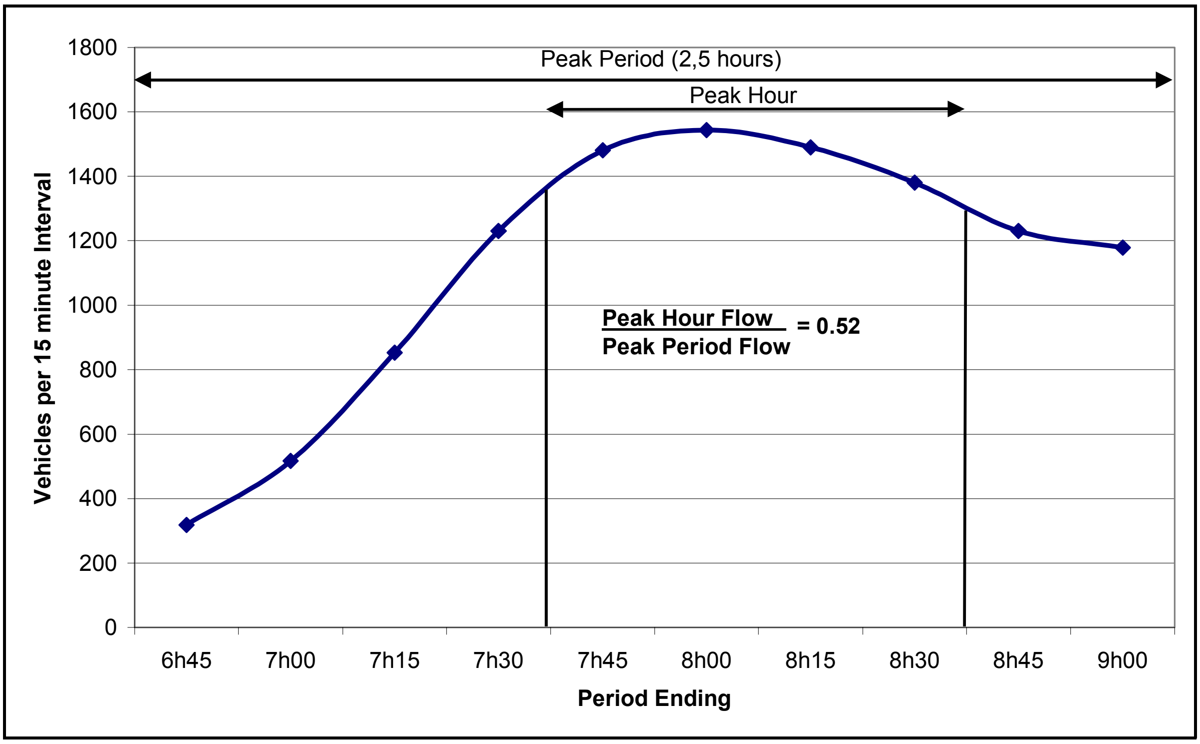

FIGURE 2: TRAFFIC FLOW PROFILE FOR AN UNCONSTRAINED ROUTE: AM PEAK PERIOD

3. Data Collection for Congested Networks

Peak period (2.5 hour) intersection turning movement counts were conducted at each of the intersections included in the study area. From the above counts, the peak hour for the study area road network could be determined. As indicated in Figures 1 & 2, the peak hour for the network was between 07h30 and 08h30. Using the above counts, peak period and peak hour origin destination (O-D) matrices were established for the study area road network.

4. Origin Destination Matrices from Traffic Counts

Classical approaches to deriving O-D matrices from traffic counts involve entropy maximisation and information minimisation. Transportation modelling software packages have been developed to derive O-D matrices from traffic counts. These programmes require detailed input involving O-D path assumptions and some prior O-D matrix. The resultant O-D matrix provided by the programme is the most likely O-D matrix that will render the traffic counts provided. For small networks, the most likely O-D matrix can also be estimated manually from the traffic counts.

The resultant O-D matrix can be calibrated by assigning the O-D matrix to the road network using a transport network modelling package. The modelled turning movement flows at each intersection within the network are then compared to the measured flows. Adjustments to the O-D matrix can be made to improve the correlation between modelled and measured turning movement flows.

As discussed previously, O-D matrices were determined for both the peak hour and peak period (2.5 hour) traffic flows, using the above manual estimation technique. Partial peak period and peak hour O-D matrices for the two congested commuter routes in Cape Town (the N1 and N2) are indicated in Tables 1 and 2 respectively, for illustration purposes.

TABLE 1: EXISTING AM PEAK PERIOD O-D MATRIX FOR THE N1 AND N2 ROUTES

Vehicle Trips (vehicles per 2.5 hours)										
	To (Zones)									
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**	**Total**
N1	2406	1682	1406	1052	500	1452	3289	1282	1318	14386
N2	1301	910	49	2580	216	667	333	693	411	7160

TABLE 2: EXISTING CONSTRAINED AM PEAK HOUR O-D MATRIX FOR THE N1 AND N2 ROUTES

Vehicle Trips (vehicles per hour)										
	To (Zones)									
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**	**Total**
N1	986	697	577	469	239	606	1426	533	673	6206
N2	534	377	29	1234	109	288	121	289	190	3171

5. Manipulation of O-D Matrices

By dividing each O-D pair of the peak hour matrix by the corresponding O-D pair of the peak period matrix, a matrix of ratios of constrained peak hour to peak period flows was obtained (Refer to Table 3).

TABLE 3: MATRIX OF RATIOS FOR CONSTRAINED PEAK HOUR TO PEAK PERIOD FLOWS

Ratio of Constrained Peak Hour to Peak Period Flows										
	To (Zones)									
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**	**Total**
N1	0.41	0.41	0.41	0.45	0.48	0.42	0.43	0.42	0.51	0.43
N2	0.41	0.41	0.59	0.48	0.51	0.43	0.36	0.42	0.46	0.44

The majority of the above ratios fall into the range described in section 2, namely between 0.4 and 0.52, thereby confirming that the route was operating at capacity during the peak hour . A prediction of the ratios of unconstrained peak hour to peak period flows was determined by replacing all cells (in Table 3) with ratios less than the unconstrained ratio of 0.52, with the ratio of 0.52 (Refer to Table 4).

TABLE 4: MATRIX OF RATIOS FOR UNCONSTRAINED PEAK HOUR TO PEAK PERIOD FLOWS

Ratio of Unconstrained Peak Hour to Peak Period Flows									
	To (Zones)								
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**
N1	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*
N2	*0.52*	*0.52*	0.59	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*	*0.52*

Note: Adjusted ratios have been indicated in italics

By multiplying the peak period O-D matrix (Table 1) by the matrix of ratios of the unconstrained peak hour to peak period flows (Table 4), an estimate of the unconstrained peak hour O-D matrix was calculated (Refer to Table 5).

TABLE 5: EXISTING UNCONSTRAINED AM PEAK HOUR O-D MATRIX FOR THE N1 AND N2 ROUTES

Vehicle Trips (vehicles per hour)										
	To (Zones)									
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**	**Total**
N1	1251	875	731	547	260	755	1710	667	685	7481
N2	677	473	29	1342	112	347	173	360	214	3727

By assigning the unconstrained peak hour matrix to the study area road network, it was possible to undertake a demand versus capacity assessment of the road network.

6. Trip Generation

Peak hour trip generation rates applicable to CBD developments were used to determine the unconstrained peak hour trip generation for the proposed developments. For the purposes of illustration, the developments have been concentrated into one zone, namely the zone DEV. The trips attracted to the development zone, from both the N1 and N2 routes, during the AM peak hour were estimated to be approximately 1 690 and 1 330 vehicle trips per hour respectively. The revised unconstrained peak hour O-D matrix for the post development scenario is indicated in Table 6.

TABLE 6: FUTURE UNCONSTRAINED AM PEAK HOUR O-D MATRIX FOR THE N1 AND N2 ROUTES

Vehicle Trips (vehicles per 2.5 hours)										
	To (Zones)									
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**	**DEV**	**Total**
N1	1251	875	731	547	260	755	1710	667	685	1690	9171
N2	677	473	29	1342	112	347	173	360	214	1330	5057

7. Re-constraining of Unconstrained Future O-D Matrices

Currently the practical capacity (in the peak direction of flow) of the N1 route is approximately 6400 vehicles per hour due to the metering effects of upstream bottlenecks. Similarly, the practical capacity of the N2 route is approximately 3200 vehicles per hour. The future unconstrained peak hour demand for travel was therefore approximately 48% in excess of the N1's capacity and approximately 58% in excess of the N2's capacity.

To accommodate the increased demand for travel it was necessary to identify capacity improvements on these routes. Improvements to both routes were identified that would increase the practical capacities of the N1 and N2 to 8 200 and 4 000 vehicles per hour respectively. The above increased capacities were however, still less than the peak hour demand for travel on these routes. Using the above new capacity constraints, the future unconstrained O-D matrix was re-constrained (factored down) to satisfy the future practical capacities of the routes i.e. the N1 O-D pairs were factored by 0.894 or (8200/9171) and the N2 O-D pairs by 0.791 or (4000/5057). The resultant re-constrained future peak hour matrix is indicated in Table 7.

The implications of the above adjustments to the future unconstrained O-D matrix were that on the N1 and N2 routes, only 80% to 90% of the peak hour demand could be accommodated in the peak hour, based on the proposed route improvements. Using the above methodology, the constrained peak hour trip generation for the development could be determined.

TABLE 7: FUTURE RE-CONSTRAINED AM PEAK HOUR O-D MATRIX FOR THE N1 AND N2 ROUTES

Vehicle Trips (vehicles per hour)											
	To (Zones)										
From	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Other**	**DEV**	**Total**
N1	1119	782	653	489	233	675	1529	596	613	1511	8200
N2	535	374	23	1061	89	275	137	285	169	1052	4000

The future re-constrained peak hour O-D matrix was assigned to the upgraded road network and realistic future flows were predicted. Realistic traffic implications on links and intersections within the study area network could be determined.

8. Estimation of Duration of Congested Periods

The duration of congestion (period during which the route operates at capacity) could also be estimated. Firstly, the peak period flow was broken down into 15 minute flows as per the unconstrained flow profile. These 15 minute flows were then compared to the capacity per 15 minute interval (quarter of hourly capacity) of the route. By redistributing the excess traffic from 15 minute intervals were demand exceeded the capacity, to adjacent intervals where capacity exceeded demand, an estimate of the number of consecutive 15 minute intervals at which the route operated at demand to capacity ratios of 1, was made. The estimated congested period durations for the existing and future scenarios are indicated in Table 8.

TABLE 8: ESTIMATION OF THE EXISTING AND FUTURE DURATION OF THE CONGESTED PERIOD

Route	Scenario	Unconstrained Peak Hour Demand (veh/hr)	Peak Period Demand (veh/2.5 hrs)	Peak Hour Capacity (veh/hr)	Duration of Congested Period
N1	Existing Future	7828 9171	14386 17636[1]	6400 8200	2 hrs 8 minutes 2 hrs 0 minutes
N2	Existing Future	3869 5057	7160 9725[1]	3200 4000	2 hrs 8 minutes 2 hrs 25 minutes

Notes: 1. Unconstrained peak hour demand divided by 0.52 i.e. ratio of unconstrained peak hour flow to peak period flow.

The above technique was used to quantify the impact of the proposed developments on the duration of congestion on the commuter routes, based on the proposed route improvements.

9. Conclusions

The methodology described in this paper has been demonstrated using a study conducted in the Cape Town CBD. Whereas the levels of congestion may vary between cities and commuter routes, the principles contained within this methodology should be transferable to other cities and their congested routes. The methodology provides a tool for the realistic estimation of future peak hour trip generation for developments within congested networks. The realistic constrained future peak hour O-D matrix, once assigned to the future road network, provides realistic future flows on the network for analysis purposes. Finally, the methodology also provides a tool to estimate the duration of congestion on the congested commuter routes.

References

1. *"Transport Impact Assessment of the Cape Town International Convention Centre"* Prepared for the Cape Town International Convention Centre Company (Pty) Ltd by the Convenco Transportation Engineers incorporating Hawkins Hawkins and Osborn Consulting South (Pty) Ltd, Cape Town, February 2001.

2. *"Traffic Impact Assessment for the Roggebaai Canal Precinct"* Prepared for Sun West International (Pty) Ltd by Hawkins Hawkins and Osborn Consulting South (Pty) Ltd, Cape Town, South Africa, June 2000.

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During 1996 he was awarded the International Road Federation Fellowship and received his Master of Science degree in Civil Engineering from Texas A&M University in December 1997. During his post graduate studies, Andre was employed by the Texas Transportation Institute. Andre rejoined the Cape Town office of Hawkins Hawkins and Osborn where he is now a Director. He is a member of the Institute of Transportation Engineers and an Associate member of the South African Institute of Civil Engineers.