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# A Micro-simulation Approach to Quantifying Clearway Benefits

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## Abstract

Providing clearways on arterial roads needs a strong justification due to impacts on the community. This paper explores the use of micro-simulation modelling to quantify the benefits of clearway conditions.

The proposed micro-simulation approach looks at two aspects of clearway benefits which are the generic road-section travel time savings and the entire route travel time savings, which includes converting total roadway capacity gains into travel time savings. A simplified arterial road micro-simulation model with carefully designed traffic demand was constructed first to produce a general and well controlled urban arterial road environment. A quantified generic benefit for clearways was estimated by simulating two scenarios, one allowing kerbside parking and the other with no parking "clearway conditions".

A calibrated real word model of a key arterial road in Adelaide was then used to simulate the two scenarios. The true peak hour demand was used in this case to capture the entire route benefits relating to clearway operations. The modelling results showed the generic part of clearway benefits obtained from the two models were consistent. Meanwhile, the real model highlighted where the major roadway capacity gains were obtained through clearway operation and how large the latent benefits would contribute to the entire route travel time savings. Other issues associated with the simplified modelling approach were also identified in this study.

## 1. Introduction

The road network is vital for the economic and social development of Australia. However, we are now facing challenges relating to strong travel demand and a growing population. The 2006 Council of Australian Governments (COAG) report into urban congestion (COAG 2006) highlights the need to maximise the use of existing transport infrastructure to ease traffic congestion in Australia's cities. Otherwise, social costs of congestion would rise strongly to an estimated $20.4 billion by 2020. Clearway operation is one measure that has been emphasised as having the potential to reduce traffic congestion levels.

A clearway is a length of carriageway defined by clearway signs at each end where parking and standing of vehicles is prohibited. The primary benefit of clearway operation on an arterial road is to provide extra capacity by removing kerb-side parking (Austroads 2009a). This provides additional capacity for peak period traffic volumes.

In addition, clearways may help to contain the peak hour spreading problems concerning traffic operation in major Australian cities due to the additional capacity being made available in the arterial road network.

Figure 1 shows a typical example of peak hour spreading on an arterial road in Adelaide (Zhang et al 2009). The shaded area on the graph indicates the current clearway times applied to that road being 7:30 am to 9:00am and 4:30pm to 6:30pm. The red line indicates the trigger volume used by Austroads to justify clearways (Austroads 2009b). Note that each data point in Figure 1 represents the volume of traffic at 30 minute intervals.

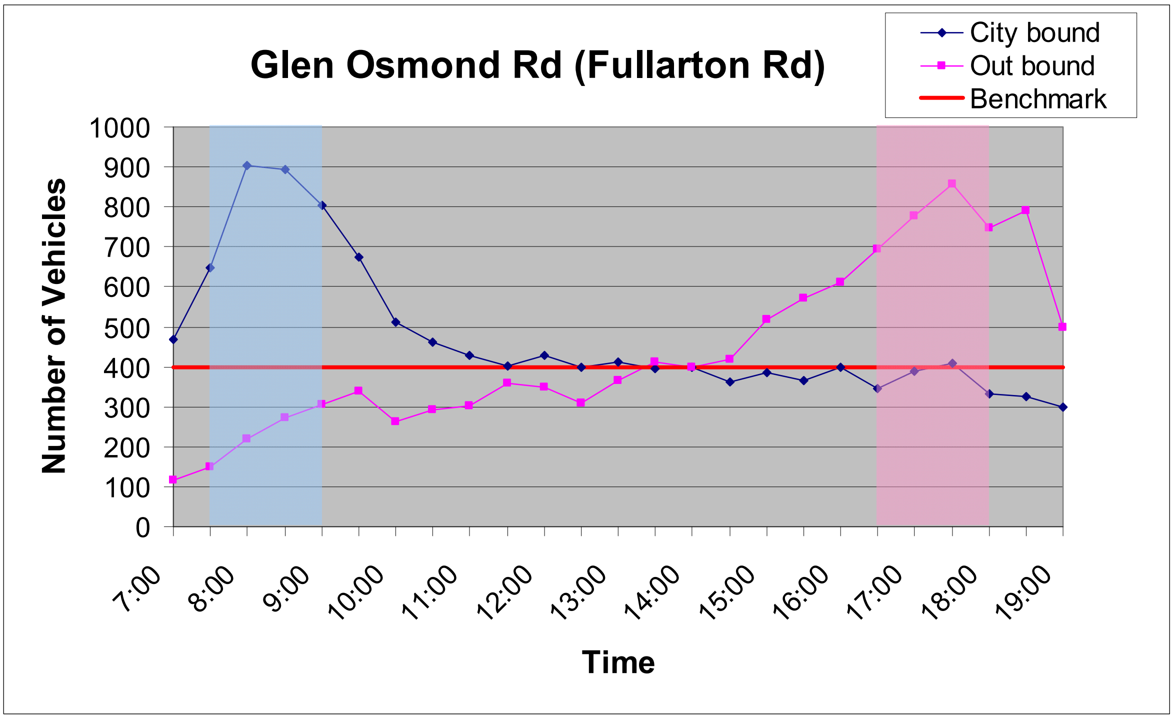


**Figure 1 - Traffic volume profile – Glen Osmond Road (two lanes in each direction)**

Clearways provide for smoother and safer traffic flow by:

- The need to weave around parked vehicles is eliminated improving traffic flow particularly for buses, freight and cycling.
- A safer environment is created by reducing the chance of rear-end crashes, side swipes or hitting parked vehicles.
- An even distribution of vehicles over the traffic lanes as there is less lane changing allowing consistent speeds along a route leading to reduce green house gas emissions.
- Route capacity and average travel speeds are improved with the SCATS linking and intersection ‘green bands’ being adjusted for faster progression as vehicle platoons are not as elongated.
- Improved access to the arterial road system from local roads and safer pedestrian crossing, as sight distances will be improved and the traffic platoons will be more compact which may produce gaps in the traffic flow.

## 1.1 Research problem

Clearways are relatively inexpensive and technically straightforward to implement, however there is often strong public resistance, particularly from adjacent businesses and property owners. The adverse effects that clearway may have on the community may include:

- Possible loss of business that rely on passing trade during the operation of clearway times,
- inconvenience to residential property owners, as on-street parking will be prohibited for certain periods of the day

To justify clearway implementation, it is most important to inform the community affected by clearways that the network benefits will outweigh the local impact on the surrounding community. A quantified measure of clearway benefits is essential.

### 1.2 A key measure of clearway benefits

For the general public, travel time savings is a straight forward and understandable measure. Due to the random nature of kerbside parking (similar to lane-blocking incidents), it would be hard to collect travel time on a specific road section, at certain time period and under desired traffic conditions. It is not feasible to specifically generate multiple lane-blocking incidents on a targeted road under heavy traffic conditions for the purpose of travel time sample collection. Even if it could be physically done, to achieve a reasonable size of travel time samples would be an issue. The current advance in traffic modelling and simulation techniques makes it possible to conduct a well controlled experiment to establish the travel time benefits resulting from clearway conditions on heavily traffic arterial roads.

## 2. Traffic Modelling and Micro-simulation

Traffic modelling techniques are tools that help transport planners and traffic engineers to examine the existing traffic performance and outcomes of proposed traffic changes. In general, modelling techniques can be broadly categorised as Analytical Modelling and Simulation (Austroads 2009c). Each category has two levels: macroscopic and microscopic.

Analytical Modelling uses equations derived from theoretical assumptions of traffic behaviour or from formulas calibrated using field observations. SIDRA is a micro-analytical modelling tool which is used to predict/estimate performance indicators of an isolated site based on traffic flow theories (SIDRA Solution 2007). Since the primary objective of clearway is to address mid-block capacity issues, SIDRA is not an ideal tool to undertake mid-block / corridor traffic analysis.

Simulation is a technique wherein vehicle / pedestrian movements through the traffic system are replicated by computer software. The state of the traffic system is then estimated from the aggregated performance of all simulated vehicles / pedestrians.

Both LINSIG (JCT 2009) and TRANSYT (TRL 2010) are macro-simulation packages where vehicles are represented as a traffic stream or platoon. The model outputs are deterministic (i.e. for a given set of average conditions the same results are produced), which makes it ideal for traffic signal coordination and optimisation. Both packages can capture link delays and intersection delays which are based on macro speed-flow relationship and signal operation at intersections. Kerbside parking can be emulated by the package in the forms of buses stopping at bus stops for certain durations, however the detailed car-following and lane changing / merging behaviour of individual vehicles when they negotiate around parked vehicles is not captured. These vehicle dynamics are very important for travel time analysis.

AIMSUN (TSS 2010) is a microscopic traffic simulator which has been design to test traffic control systems and management policies including Intelligent Transport Systems (ITS). It provides highly detailed modelling of the traffic network, it distinguishes between different types of vehicles and drivers, and it can model incidents, conflicting manoeuvres, which make it an ideal modelling tool for the analysis of clearway operations. In an AIMSUN model, individual vehicle units are traced through the network and detailed vehicle-to-vehicle interactions are modelled. Since micro-simulation is a stochastic technique, it requires several simulation runs to derive average values.

## 3. Research Methodology

### 3.1 Key measure of travel time savings

As discussed in Section 1, travel time savings is the key measure of clearway benefits. This measure was chosen in the clearway study because it is objective, understandable and can be converted to a dollar value for use in benefit-cost analysis.

In the analysis, three different travel time parameters were used. These are free flow travel time ($t_{\_f}$), normal travel time ($t_{\_c}$, under clearway conditions) and extended travel time ($t_{\_p}$, vehicles parked at kerbside lane). For a road section with a posted speed limit and fixed signal control, free flow travel time experienced on the road is fixed. Normal travel time varies according to changing traffic demand levels. Extended travel time responds to both traffic demand level and kerbside parking including the location and duration of the parked vehicles.

The travel time difference ($\Delta t$) between $t_{\_p}$ and $t_{\_c}$ measures absolute travel time savings due to clearway operation. It is based on the assumption that there would be vehicles parking on kerbside lane if clearways were not implemented. The ratio of $\Delta t$ to free flow travel time ($\Delta t$ / $t_{\_f}$) represents relative travel time savings.

There is another way to represent relative trave time savings being the ratio of $\Delta t$ to normal travel time ($\Delta t$ / $t_{\_c}$). This measure seems more meaningful for travellers, as it highlights how significant the travel time savings is comparing to non-freeway traffic conditions. However, the ratio distorts the true benefit of clearway because of the fact that $t_{\_c}$ (normal travel time) varies with the level of traffic demand and the localised travel behaviours. In other words, a floating reference point is unintentionally introduced to assess travel time savings for a specific road. Meanwhile, it makes it difficult to compare the results from different models which were carried out in this study.

### 3.2 Two aspects of travel time savings

It is acknowledged that the pure travel time gain in the mid-block sections of the road does not always translate into the real travel time savings, especially when a trip is relative long which covers a number of signalised intersections and mid-block sections in between. Hence the travel time of a road section between two signalised intersections, which is used in this study, consists of two components, the cruise time taken by a vehicle to travel between the two intersections, and the control delay encountered at the downstream intersection. In this study this is referred as generic section travel time.

It is also known that a vehicle parked on the kerbside lane between two signalised intersections would have different impacts. The longer the distance between intersections the smaller the impact is. However this impact changes again depending on how close the car is parked to the intersection. Hence, the travel time analysis should happen on a relatively long road which consists of multiple intersections – road / corridor travel time analysis.

### 3.3 Well-controlled traffic environment

As discussed in Section 2, one major advantage of using a micro-simulation model to quantify clearway benefits is that a well-controlled traffic environment for experiments can be created. The key parameters of this environment are the:

- Number of signalised intersection of the road,
- Number of lanes and section length of each road section,
- Traffic signal control at intersections and signal coordination,
- Level of traffic demand.

With these parameters, it is possible to create a 'generalised' corridor model to capture 'general' benefits of clearways by comparing modelling results of the two scenarios, one allowing kerbside parking and the other with no parking "clearway conditions".

To gain an increase level of confidence of the modelling results, it is important to use a calibrated real road corridor model to test the two scenarios and check the consistency of both models, even if there is limited control over the parameters of the real corridor model.

## 4. A Generalised Corridor Model

### 4.1 Key features of the 'generalised' model

The proposed micro-simulation approach tried to look at two aspects of clearway benefits being the generic road section travel time savings and total travel time savings of the road. The later one takes into account roadway capacity gains (if any).

To capture the generic road section travel time savings, a simple and representative mid-block scenario was created where the average travel time on the mid-block section included both cruise time and delays caused by intersection signal operations. The leftover vehicles at the end of each simulation run due to the bottle neck effect (if any) would not affect total travel time estimate of the road because they did not form a part of the travel time samples.

Figure 2 shows the modelled road section which consists of three signalised intersections (TS1 ~ TS3). The total length of the modelled road is 1.5 km.

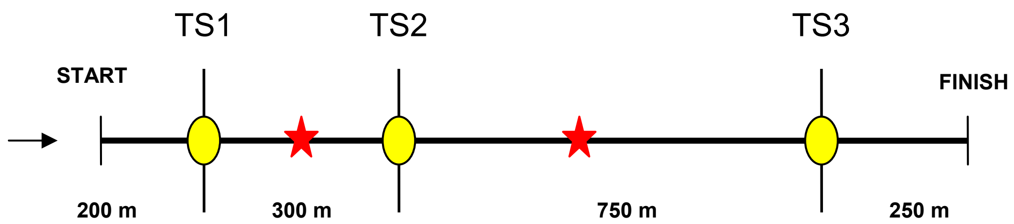


**Figure 2 The modelled two-lane one-way arterial road**

The focus of the modelling was on the two-lane carriageway configuration because the majority of Adelaide arterial roads are of this type. A typical section of this type of arterial roads is shown in Figure 3.

**Figure 3 A typical section of four-lane two-way arterial road in Adelaide**

At signalised intersections, green time allocation for major road movements was 60% of the total cycle length (i.e. 120 second, which is widely used in Adelaide during peak periods). Traffic signals were coordinated along these three intersections to facilitate platoon progression along the main road.

Three levels of traffic flow (i.e. 800 veh/h, 1200 veh/h and 1600 veh/h) were generated to reflect different traffic demands. The 800 veh/h is the Austroads (Austroads 2009b) suggested trigger volume for clearway conditions. In Adelaide, the recent traffic counts suggested the peak hour traffic volumes for major arterial roads were generally around 1200 ~ 1600 veh/h (two-lane roads).

A quantified generic benefit of clearway was estimated by simulating two scenarios one allowing kerbside parking and the other with no parking "clearway conditions". Incidents that occupied kerbside lane for a certain period of times were generated to emulate kerbside parking. Two incidents (i.e. red stars in Figure 2) were generated at two locations during a one hour simulation period. These locations are on the mid-block section between TS1 and TS2, and between TS2 and TS3. The extreme scenario where the incident location is very close to the intersection was not modelled. The duration of each incident was 30 minutes and the two incidents happened sequentially to make sure only one incident happened within the 1.5 km road section at any time during the simulation.

## 4.2 Modelling results

Ten simulation runs were produced for each scenario (using three different traffic demands). The modelling results of the two scenarios are shown in Table 1.

In general, parking on the kerbside lane disrupted normal traffic flow and resulted in increased travel time and delays, which were indicated by the average section travel time (t_p) and its associated standard deviation figure.

There is a positive correlation between traffic demand level and travel time savings ($\Delta t$ ) for the incident affected sections and the entire road. Meanwhile, the short section of the road was more sensitive to kerbside parking than the long section in terms of travel time variation. It suggested more benefit would be gained from clearway implementation on shorter sections.

When considering the normal peak hour traffic demand (i.e. 1200~1600 veh/h), the extra delay of 34% ~ 112% of the free flow travel time $t\_{f}$ would be expected if the kerbside lane was occupied at random locations along the road. Since the length of the road (1.5 km) and the free flow travel time $t\_{f}$ (98 second) was available, the 34% ~ 112% peak hour travel time savings could be converted to 22 ~ 73 ***sec/veh/km/h*** – a unit benefit gain by implementing clearways.

**Table 1 Travel time comparison – generalised corridor model**

| Road Section | Start - TS1 | TS1- TS2 | TS2- TS3 | TS3 - Finish | Entire route |
|---|---|---|---|---|---|
| Distance (m) | 200 | 300 | 750 | 250 | 1500 |
| | | | | | |
| Free flow travel time $t_f$ (second) | 15 | 20 | 48 | 15 | 98 |
| **800 veh/h** | | | | | |
| Mean section travel time / Standard deviation (second) | | | | | |
| - Clearway $t_c$ | 30 / **18** | 22 / **6** | 55 / **14** | 16 / **1** | 124 / **23** |
| - Parking $t_p$ | 30 / **18** | 28 / **14** | 61 / **20** | 16 / **1** | 136 / **24** |
| Difference - Clearway vs Parking $\Delta t$ (second) | 0 | 6 | 6 | 0 | 12 |
| % difference $\Delta t / t_f$ | 0% | 30% | 13% | 0% | 12% |
| | | | | | |
| **1200 veh/h** | | | | | |
| Mean section travel time / Standard deviation (second) | | | | | |
| - Clearway $t_c$ | 32 / **18** | 23 / **7** | 57 / **14** | 17 / **1** | 129 / **21** |
| - Parking $t_p$ | 33 / **18** | 40 / **27** | 72 / **29** | 17 / **1** | 162 / **26** |
| Difference - Clearway vs Parking $\Delta t$ (second) | 1 | 17 | 15 | 0 | 33 |
| % difference $\Delta t / t_f$ | 7% | 85% | 31% | 0% | 34% |
| | | | | | |
| **1600 veh/h** | | | | | |
| Mean section travel time / Standard deviation (second) | | | | | |
| - Clearway $t_c$ | 36 / **18** | 24 / **7** | 61 / **18** | 18 / **1** | 139 / **20** |
| - Parking $t_p$ | 53 / **28** | 71 / **35** | 109 / **58** | 18 / **1** | 249 / **52** |
| Difference - Clearway vs Parking $\Delta t$ (second) | 17 | 47 | 48 | 0 | 110 |
| % difference $\Delta t / t_f$ | 113% | 235% | 100% | 0% | 112% |

For any proposed clearway expansion projects, it is possible to quantify clearway benefits in terms of total travel time savings by using the above unit benefit, when the clearway coverage, the operating hours and the existing traffic demand of the targeted roads are available. The lower bound of the clearway benefits can be estimated by using the trigger volumes (i.e. 800vph for two-lanes one-way) if the detailed existing traffic demand (like Figure 1) is not available.

If traffic composition information is available during clearway hours (e.g. the percentage of commercial vehicles in the traffic stream, the number of buses, etc.), the detailed benefit-cost analysis for clearway operations may be carried out by converting vehicle-travel time savings to person-travel time savings.

## 4.3 Issues

The key issue concerning the above modelling and travel time analysis was the ***distance zone parameter*** settings in the AIMSUN model. Distance zone 1 & 2 settings of a road section had a significant impact on vehicles' lane selection and lane changing behaviour, especially when incidents happened at low volume conditions. Even though efforts had been made to strike a balance between relatively even lane utilisation and the natural tendency of drivers (with good level of awareness) to choose the centre lane in advance in order to avoid incidents, the initial confidence put on the model results was not high. It is essential to use a well calibrated real world model to check and confirm the initial findings.

# 5. A Real Arterial Road Model

## 5.1 North East Road Model

A real world model of a key commuter corridor in Adelaide (North East Road between Innes Road, Windsor Gardens and Galway Avenue, Collingswood) was used to simulate the similar two scenarios – one allowing kerbside parking and the other with no parking "clearway conditions" (See Figure 4). The modelled road segment is four kilometres from Adelaide CBD. The section of North East Road has four major intersections and is a four-lane two-way configuration except for the section between Ascot Avenue and Galway Avenue which is six-lane two-way configuration. The total length of the modelled road segment is approximately four kilometres long.

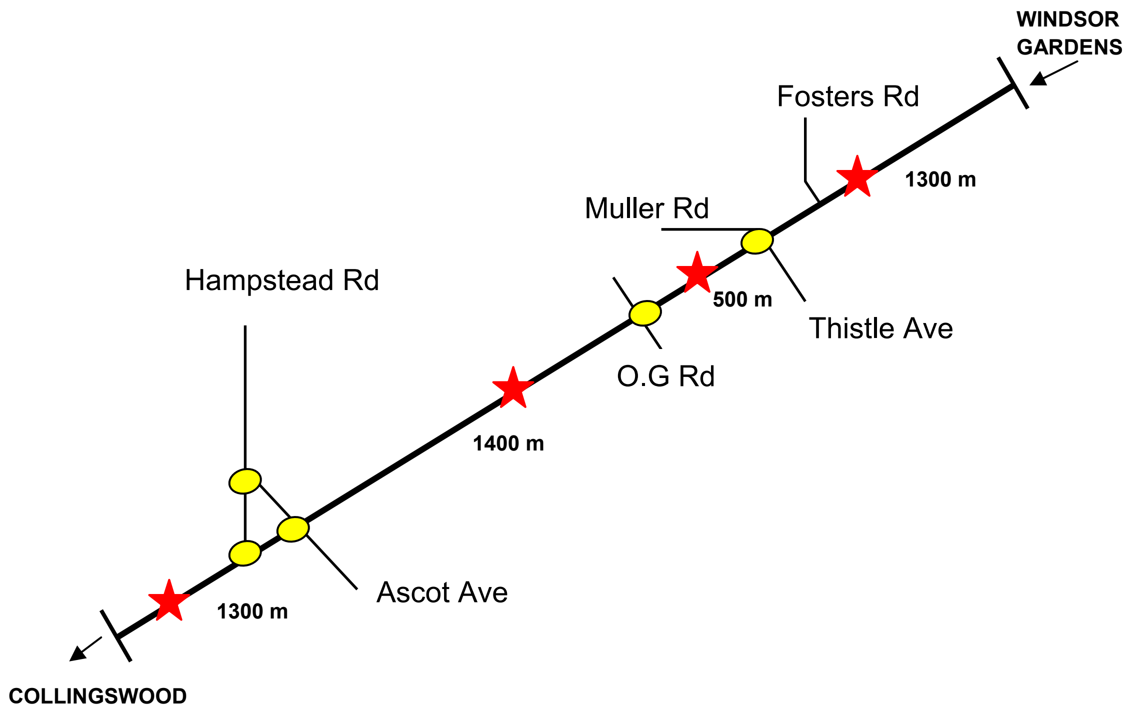


**Figure 4 North East Road corridor**

For this study the AM peak period was chosen. The peak hour traffic flow reached 2700 veh/h. The most current SCATS signal control plans were implemented in the model. Signals coordination was set up between OG Road and Muller Road intersections, and three intersections at North East Road, Hampstead Road and Ascot Avenue which form a triangle. During the peak hour, the side road phases were skipped every second cycle at Muller Road and OG Road intersections. In average, more than 80% of effective green time was allocated to North East Road in every cycle (cycle length is 120 second) to cater for the heavy city bound traffic. Despite the above arrangement, the first section of the road (between Innes Road and Muller Road) was still over saturated. Clearway conditions were applied to the road during peak hours.

During a one hour simulation run, four mid-block incidents were generated with the same duration of 15 minutes. There was always one incident occupying the kerbside lane along the four kilometre stretch of the road during simulation. Meanwhile, the location of the incident changed with time to capture the random nature of incidents (i.e. parking). The extreme scenario where the incident is located very close to intersection was not modelled.

## 5.2. Modelling Results

Table 2 shows the results of the simulation of the two scenarios one allowing kerbside parking and the other with no parking "clearway conditions". Ten simulation runs were carried out for each of the two scenarios.

**Table 2 Travel time comparison – North East Road model**

| Road Section | Section 1 Innes Rd to Muller Rd | Section 2 Muller Rd to O.G Rd | Section 3 O.G. Rd to Ascot Ave | Section 4 Ascot Ave to Galway Ave | Section 0 Entire route |
|---|---|---|---|---|---|
| Distance (m) | 1300 | 500 | 1400 | 800 | 4000 |
| | | | | | |
| Free flow travel time $t_f$ (second) | 87 | 33 | 88 | 48 | 256 |
| **2700 veh/h** | | | | | |
| Mean section travel time / Standard deviation (second) | | | | | |
| - clearway $t_c$ | 236 / **42** | 73 / **30** | 129 / **25** | 58 / **10** | 486 / **58** |
| - parking $t_p$ | 322 / **85** | 87 / **39** | 149 / **40** | 65 / **24** | 612 / **133** |
| Difference - Clearway vs Parking $\Delta t$ (second) | 86 | 14 | 20 | 7 | 126 |
| % difference $\Delta t / t_f$ | 99% | 42% | 23% | 15% | 49% |
| | | | | | |
| Average max virtual queue (vehicle) | | | | | |
| - Clearway | | | | | 243 |
| - Parking | | | | | 630 |
| Difference - Clearway vs Parking $\Delta q$ (vehicle) | | | | | 387 |

The simulation results suggested the real model performed consistently with the generalised corridor model in terms of travel time variation in response to kerbside parking. When an incident happened on a road section, the travel time was almost doubled during the 15 minute incident period.

The model indicated the first section of North East Road (S1) was a bottleneck which produced a much higher percentage gains of travel time savings (i.e. 99%). Meanwhile, the longer sections (S3 and S4) tended to have lower percentage benefits. Note that section 4 (S4) is a three-lane one-way section, and the road section length in the real model is much longer than that of the generalised corridor model.

The overall clearway benefits obtained from the real model operating under peak hour conditions was 49%, which could be translated to a unit benefit of 31 sec/veh/km/h.

### 5.3. Roadway capacity reduction factor

Max Virtual Queue parameter of the first section of North East Road (S1), which is the number of vehicles waiting outside the section to enter the system at the end of each simulation run, is a good measure of the roadway capacity shortage. The difference of Max virtual queue of S1 between two scenarios ($\Delta$q) is 387 vehicles.

The increase of Max virtual queue due to parked cars (see Table 2) highlights another issue when quantifying clearway benefits - how to convert capacity loss due to kerbside parking into extra average travel delay (t_g) for the road during the peak hours.

The following two steps were developed:

Step 1 - working out the extra time ($t_{\_upper}$) taken to clear the extra max virtual queue ($\Delta$q) under reduced corridor capacity ($q_{\_p}$), which is the upper bound of the extra delay. The lower bound of the extra time ($t_{\_lower}$) required to clear $\Delta$q is the time difference between the arrival of the first vehicle of the bunch ($\Delta$q) under clearway capacity ($q_{\_c}$) condition and the end of peak hour.

Equation (1) shows how the extra time required to clear $\Delta$q is estimated. The assumption used for the estimation is that no clearway operation will occur in the following hour and kerbside parking will happen in a similar fashion.

$$t_{\_upper} = \frac{\Delta q}{q_{\_p}} * 3600, \quad t_{\_lower} = \frac{\Delta q}{q_{\_c}} * 3600 \qquad (1)$$

Step 2 – working out the extra average travel delay ($t_{\_g}$) for the road during the peak hour. If the lower bound of the extra delay ($t_{\_lower}$) is chosen, then the conservative estimate of the extra average delay is

$$t_{\_g} = \frac{\Delta q^2}{q_{\_c}^2} * 3600 \qquad (2)$$

The actual average travel time taken to clear the previous peak hour traffic q_c (2457 veh/h, peak hour demand – max virtual queue) under kerbside parking conditions was 701 seconds (t_p + t_g). In this case, t_g  was 89 seconds - another 35% travel time increase based on the free flow travel time.

The result of the above estimation is the actual total travel time saving of the entire road during the peak hour was 84%, which is close to the figure presented in Table 1 for the 1600 veh/h demand level scenario. As mentioned before, phase skipping is used along North East Road, which increased the capacity of the corridor significantly. Therefore, the traffic demand level on North East Road is comparable with the 1600 veh/h traffic demand level in the generalised corridor model.

The modelling results clearly indicated if a road corridor is under capacity, then the clearway benefits will be huge, especially when the road capacity reduction factor is taken into account.

## 6. Conclusion and Future Work

This paper investigated a micro-simulation modelling approach to quantifying clearway benefits. Road section travel time, which consists of both cruise time between two signalised intersections and control delay at the downstream intersection was used as a quantitative measure to compare the traffic performances of two different scenarios. The scenarios are clearway operation and vehicle parking on kerbside lane for a certain period of time. Two traffic models, a generalised corridor model with a well controlled traffic environment and a real world arterial model under peak hour traffic conditions, were constructed to demonstrate how the approach can be implemented.

The traffic modelling revealed that parking on the kerbside lane disrupts normal traffic flow and resulted in increased travel time and delays. There is a positive correlation between traffic demand level and travel time savings for both the parking affected sections and the entire road. Under normal peak hour traffic conditions, more than 30% extra travel delay per vehicle (which is based on free flow travel time of the road) is expected if the kerbside lane is occupied by parked vehicles at random locations. If the road is already at capacity, then clearways deliver more than 80% travel time savings, especially when the roadway capacity reduction due to parked vehicles is taken into account.

The proposed modelling approach provides a mean to translate the percentage travel time savings to an absolute unit benefit in the form of sec/veh/km/h. This unit benefit obtained from the generalised corridor model can be used to carry out cost-benefit analysis for any clearway expansion projects, if traffic composition information is available on the targeted roads during the proposed clearway hours. However, a micro-simulation model for the specific road may be required to work out exactly where and how much the benefits could be achieved from clearway operations.

This paper focuses on the travel time aspect of clearway benefits. Given the detailed level of traffic modelling/simulation, other quantified measures such as fuel consumption and emission could be explored in the future, and the full benefits of clearways could be better captured.

## Acknowledgments

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