Appendix D

Warringah Freeway traffic modelling report
Executive Summary

GHD has undertaken micro simulation traffic modelling to forecast the potential impact of options to upgrade the Sydney Harbour Bridge southern toll plaza precinct. This model examines changes to the ramp arrangements for general traffic access to the northern Sydney CBD and city centre, operation of a separated bus lane facility on the existing eastern ramp and a reconfigured intersection of Grosvenor Street and York Street.

This micro simulation traffic modelling has been undertaken using the RMS Warringah Freeway model (developed using the Paramics micro simulation modelling package), and has been used to forecast the traffic impacts of three options:

- **Option 1**: Base Case assumes no change to the corridor.
- **Option 2**: Removal of the toll booths and realignment of the toll plaza with no changes to the access routes to the northern Sydney CBD and city centre.
- **Option 3**: Realignment of the lanes through the toll plaza (as per option 2) with changes to the access routes to the northern Sydney CBD and city centre. The eastern ramp would be reconfigured to provide additional bus priority from the Sydney Harbour Bridge to the northern Sydney CBD.

The key findings from the model when compared to the base case for southbound traffic in the morning peak period from the Gore Hill Freeway to the southern toll plaza precinct are as follows:

**Option 2**
- General traffic travel times are forecast to increase by up to four minutes.
- Bus travel times are forecast to decrease by up to two minutes.
- The variability of bus travel times are forecast to decrease.

**Option 3**
- General traffic travel times are forecast to decrease by up to two minutes.
- Bus travel times are forecast to decrease by up to four minutes.
- The variability of bus travel times is forecast to decrease.
- All options provide sufficient ramp capacity such that 95th percentile general traffic queues are not forecast to exceed the ramp storage capacity and block flow to the Western Distributor. Traffic signals will require re-optimisation as part of the reconfiguration of the ramp approaches.

The key conclusions from the modelling are that option 3 performs the best for the following reasons:

- A forecast decrease in general traffic travel times in the morning peak.
- A forecast decrease in bus travel times in the morning peak.
- Forecast improved bus reliability in the morning peak.
- Negligible change to bus travel times are likely to occur as a result of the proposed options in the evening peak.
- Satisfactory level of service for the proposed reconfiguration of the intersection of Grosvenor Street and York Street.
This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.3 and the assumptions and qualifications contained throughout the Report.
Table of contents

1. Introduction ............................................................................................................................... 1
   1.1 Overview.......................................................................................................................... 1
   1.2 Purpose of This Report.................................................................................................... 1
   1.3 Scope Limitations and Assumptions .............................................................................. 1
   1.4 Report Structure ............................................................................................................ 2
2. Base Model Development ......................................................................................................... 3
   2.1 Introduction ..................................................................................................................... 3
   2.2 Traffic Data ..................................................................................................................... 3
   2.3 Model Calibration ............................................................................................................ 6
   2.4 Model Validation .............................................................................................................. 7
3. Southern Toll Plaza Precinct Option Test .................................................................................. 9
   3.1 Overview ......................................................................................................................... 9
   3.2 Proposed Network Changes ............................................................................................ 9
   3.3 Intersection Modelling .................................................................................................. 10
   3.4 Changes to Model Operation ......................................................................................... 10
4. Model Results ........................................................................................................................ 11
   4.1 Zone-to-Zone General Traffic Travel Times ................................................................... 11
   4.2 Bus Travel Times ............................................................................................................ 13
   4.3 Intersection Level of Service.......................................................................................... 13
   4.4 Traffic Volumes ............................................................................................................. 14
   4.5 Ramp Queues ............................................................................................................... 15
   4.6 Queuing and Congestion Observations .......................................................................... 15
   4.7 Option Assessment ....................................................................................................... 15
5. Summary and Conclusions ...................................................................................................... 16
   5.1 Overview ....................................................................................................................... 16
   5.2 Key Findings ................................................................................................................. 16
   5.3 Key Conclusions ............................................................................................................ 16

Table index

Table 1 - Morning Peak Hourly Flow Comparison ........................................................................... 6
Table 2 - Evening Peak Hourly Flow Comparison ........................................................................... 6
Table 3 - Observed and Modelled Bus Travel Times ........................................................................ 8
Table 4 - Morning Peak General Traffic Travel Times .................................................................... 12
Table 5 - Evening Peak General Traffic Travel Times .................................................................... 12
Table 6 - Bus Travel Times from Gore Hill Freeway to York Street .............................................. 13
Table 7 - Intersection Level of Service .................................................................................................. 14
Table 8 - Peak Period Traffic Flows (3-Hour Flows) ............................................................................. 14

Figure index

Figure 1 - Observed Average Hourly Traffic Flows ............................................................................... 4
Figure 2 - Modelled Average Hourly Traffic Flows .............................................................................. 5

Appendices

Appendix A – Proposal Concept Sketch
Appendix B – Proposed Signal Phasing
1. Introduction

1.1 Overview

GHD has been commissioned by the Roads and Maritime Services (RMS) to undertake micro simulation traffic modelling to assess the potential impact of the proposed upgrade of the Sydney Harbour Bridge southern toll plaza precinct, located at the southern end of the Sydney Harbour Bridge in The Rocks.

Since being converted to electronic tolling operation, the toll booths within the Sydney Harbour Bridge toll plaza precinct, previously used for the collection of cash tolls, are no longer required, providing an opportunity to realign and resurface the traffic lanes on the Bradfield Highway, on the southern approaches to the Sydney Harbour Bridge.

1.2 Purpose of This Report

RMS maintains a micro simulation model of the Sydney Harbour Bridge and Sydney Harbour Tunnel as well as the Warringah Freeway and Bradfield Highway to the north and south of these facilities, known as the Warringah Freeway Micro Simulation Model. The purpose of this report is to outline the calibration, validation and option testing that was undertaken using this model to determine the potential traffic impacts of the proposed new configuration of the southern toll plaza precinct. The report also examines the potential impacts of reconfiguring this plaza on the operation of the Sydney Harbour Bridge and the Warringah Freeway.

1.3 Scope Limitations and Assumptions

GHD has prepared this report on the basis of information provided by RMS and others including Government authorities, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Traffic modelling of the Warringah Freeway and Sydney Harbour Bridge southern toll plaza precinct has been based on a number or assumptions and is subject to the following assumptions:

- Traffic demand estimation has been undertaken on the basis of a number of different sets of traffic count data supplied by RMS from 2009-2012;
- Calibration of the models has been undertaken on the basis of intersection turning movement counts undertaken in 2011 supplied by RMS;
- Bus dwell time data at bus stops on York Street is based on data collected for a previous version of the model, and has been adjusted to match bus queuing observations made in 2011 and 2012;
- Volumes for taxis and hire cars merging from the lane 7 of the SHB to the Western Distributor are based on surveyed flows taken by RMS;
- Validation of the 2012 Warringah Freeway model has been limited to qualitative analysis of queuing and congestion and travel time data for southbound buses;
- Bus travel times were extracted from the Public Transport Information and Priority System (PTIPS), and provided for a number of southbound routes along the Warringah Freeway from 2004. Many of these routes were incomplete and have been supplemented by similar PTIPS data where available; and
Bus travel time data supplied by RMS was not of sufficient quality for use in the validation of bus travel times beyond an “order of magnitude” assessment. The analysis of bus travel time benefits has been undertaken on the basis of comparative analysis of bus travel times and reliability between the base and the option test models.

Traffic impact analysis has been undertaken on the basis of existing condition traffic flows. No growth forecasts have been included as a part of this impact assessment. This is considered reasonable as the the peak hour traffic flow is constrained by the northern approaches to the Sydney Harbour Bridge and this area is unlikely to experience significant growth in general traffic during the peak periods.

Bus services that have been assumed as a part of this traffic impact assessment reflect current bus operations and do not take into account proposed changes to bus services in the future. If and when these bus services are changed, these traffic impact of the proposal may need to be reassessed.

Due to the data available for calibration and validation of the Warringah Freeway Micro Simulation Model, the following limitations apply to the modelling outcomes summarised in this report:

- Bus services on the Warringah Freeway and York Street are limited to the timetabled services available on Transport for NSW website (www.131500.com) and bus volume data provided by RMS;
- Bus fleet arrangements are limited to count data for various bus types and supplemented by site observations; and
- Taxi counts were provided on the Sydney Harbour Bridge for taxis using the lane 7 of the SHB to access the Western Distributor is limited to an analysis of traffic flow by deduction from a number of sources including permanent count data and intersection turning movement counts.

1.4 Report Structure

This report is comprised of the following sections:

- Base Model Development – Outlines the scope and methodology used in the development of the base models (Section 2);
- Toll Plaza Options – Outlines the proposed toll plaza reconfigurations tested as a part of this assessment (Section 3);
- Model Results – Outlines the results of option testing (Section 4); and
- Summary and Conclusions – Outlines the conclusions of the option testing and assessment process (Section 5).
2. **Base Model Development**

2.1 **Introduction**

This section outlines the process undertaking in developing and updating the Warringah Freeway Micro Simulation Traffic Model supplied by RMS for the purposes of assessing the proposed scheme.

2.2 **Traffic Data**

The Warringah Freeway model was originally developed by Halcrow for RMS to assess the impacts of electronic tolling in the corridor. This model was developed in 2002 using the Paramics micro simulation modelling package and has been continuously updated and recalibrated as conditions in the corridor have changed.

The southern toll plaza upgrade modelling was undertaken using the Warringah Freeway model, which was calibrated to hourly counts on the Sydney Harbour Bridge, Ernest Street and Falcon Street in late 2010.

In addition to this data, other traffic data was also provided by RMS, including:

- Turning movement counts at the following intersections in the northern Sydney CBD in June 2011:
  - York Street and Grosvenor Street; and
  - Grosvenor Street, Bridge Street and George Street.
- Permanent count station data for the Sydney Harbour Bridge (lanes 1 to 6) and lanes 7 and 8 (diverging to the Cahill Expressway) for the year 2011 (truncated to June 2011 to match turning movement counts).
- Bus counts for southbound buses on York Street from 2011.
- Bus fleet data for southbound buses on York Street from 2011.
- Surveys of taxi volumes using the lane 7 of the SHB to access the Western Distributor.
- Operational records of lane-changing on the Sydney Harbour Bridge for the period of a month.
- Intersection diagnostic monitor (IDM) signal timings for the following intersections:
  - York Street and Grosvenor Street;
  - Grosvenor Street and Lang Street;
  - Grosvenor Street, Bridge Street and George Street; and
  - York Street, Land Street and Jamison Street.

A plot of the observed traffic volumes through the northern Sydney CBD intersections is shown in Figure 1. A plot of modelled flows through the northern Sydney CBD intersections is shown in Figure 2.
Figure 1 - Observed Average Hourly Traffic Flows

Source: Roads and Maritime Services
Figure 2 - Modelled Average Hourly Traffic Flows

Source: 2012 Warringah Freeway Micro Simulation Traffic Model
2.3 Model Calibration

A summary of the base model flows across the Sydney Harbour Bridge for the morning and evening peak periods is shown below in Table 1 and Table 2. It should be noted that the permanent count station data for the northbound flow across the Sydney Harbour Bridge in the morning peak were not available, as the data records for the period of June 2011 were corrupted in the permanent count station output. For this reason, northbound flows in the morning peak period have been omitted. For these tables, lanes 1 to 6 are referred to as SHB and lanes 7 and 8 are referred to as Cahill Expressway.

Table 1 - Morning Peak Hourly Flow Comparison

<table>
<thead>
<tr>
<th>Location</th>
<th>Hour Beginning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0700</td>
</tr>
<tr>
<td>SHB Northbound (Observed)</td>
<td>N/A</td>
</tr>
<tr>
<td>SHB Northbound (Modelled)</td>
<td>5236</td>
</tr>
<tr>
<td>Difference</td>
<td>N/A</td>
</tr>
<tr>
<td>SHB Southbound (Observed)</td>
<td>5174</td>
</tr>
<tr>
<td>SHB Southbound (Modelled)</td>
<td>5069</td>
</tr>
<tr>
<td>Difference</td>
<td>-2%</td>
</tr>
<tr>
<td>Cahill Southbound (Observed)</td>
<td>2585</td>
</tr>
<tr>
<td>Cahill Southbound (Modelled)</td>
<td>2552</td>
</tr>
<tr>
<td>Difference</td>
<td>-1%</td>
</tr>
</tbody>
</table>

Table 2 - Evening Peak Hourly Flow Comparison

<table>
<thead>
<tr>
<th>Location</th>
<th>Hour Beginning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1600</td>
</tr>
<tr>
<td>SHB Northbound (Observed)</td>
<td>6255</td>
</tr>
<tr>
<td>SHB Northbound (Modelled)</td>
<td>6241</td>
</tr>
<tr>
<td>Difference</td>
<td>+0.5%</td>
</tr>
<tr>
<td>SHB Southbound (Observed)</td>
<td>2764</td>
</tr>
<tr>
<td>SHB Southbound (Modelled)</td>
<td>2864</td>
</tr>
<tr>
<td>Difference</td>
<td>+3.5%</td>
</tr>
<tr>
<td>Cahill Southbound (Observed)</td>
<td>2009</td>
</tr>
<tr>
<td>Cahill Southbound (Modelled)</td>
<td>1973</td>
</tr>
<tr>
<td>Difference</td>
<td>-2%</td>
</tr>
</tbody>
</table>
Inspection of the modelled and observed flows for the 2011 base model shows the model is adequately calibrated to observed southbound flows on the Sydney Harbour Bridge. For the purposes of this study, as the primary changes to the southern toll plaza and intersection of York Street and Grosvenor Street involve southbound traffic only, this direction only is being modelled.

2.4 Model Validation

Limited data was made available for the validation of the model. Due to the variable operation of the Sydney Harbour Bridge, where lane arrangements are changed dynamically in response to variable traffic demand or incidents, it is difficult to make “typical” observations of traffic congestion and queuing in the corridor, as the operation of the facility changes in response to delays and congestion.

2.4.1 Queuing and Congestion Observations

In terms of qualitative validation, the following queuing and congestion observations were made during the morning peak period:

- Dwell time delays at Wynyard for buses travelling from the lane 7 of the SHB typically cause queues on the SHB (as far back as the North Pylon of the Sydney Harbour Bridge) which interfere with the general traffic entering the Grosvenor Street ramp from the Harbour Bridge main deck, particularly from 0800 to 0900;
- Northbound traffic on the Sydney Harbour Bridge and Western Distributor is typically queued to the south of the southern toll plaza for the morning peak period, due to the merge arrangements for the Cahill Expressway, Western Distributor and Clarence Street.
- Southbound traffic flow on the Sydney Harbour Bridge is constrained by lane changing and merging at a number of key locations, causing shockwaves and congestion as vehicles merge or weave to their target lanes. These locations include:
  - Approach to the southern toll plaza, traffic heading to the northern Sydney CBD merge left to use the Grosvenor Street Ramp or the right to use the York Street Ramp.
  - Mount Street ramp and reversible carriageway merge where traffic from these carriageways merges with southbound traffic on the Bradfield Highway.

Similarly, the following observations of queuing and congestion were made in the evening peak period:

- Southbound traffic on the Sydney Harbour Bridge travels slower in the evening peak than in the morning peak, due to narrow lanes and higher volume of opposed northbound traffic.
- Dwell time delays at York Street in the evening peak do not result in southbound queues on the lane 7 of the Sydney Harbour Bridge as they do in the morning.
- Like in the morning peak period, southbound traffic flow on the Sydney Harbour Bridge is constrained by lane changing at key locations in the evening peak, albeit at fewer locations, with southbound traffic frequently observed queuing as far north as High Street.

2.4.2 Bus Travel Time Comparison

A comparison of bus travel times for the morning and evening peak period was also made based on average speeds derived from the PTIPS system in 2004. These travel times are presented below in Table 3. The observed travel times were calculated from average speeds of Castle Hill to the City bus routes travelling along the Gore Hill Freeway. It is noted that the PTIPS observation for southbound buses in the evening peak period was incomplete and only
extended as far as the Milsons Point toll plaza. Average speeds for the remaining southbound section of this route were supplemented from an average of other southbound routes from High Street and Falcon Street.

**Table 3 - Observed and Modelled Bus Travel Times**

<table>
<thead>
<tr>
<th>Route</th>
<th>PTIPS 2004 (mm:ss)</th>
<th>Modelled 2011 (mm:ss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willoughby Road to York Street Southbound Morning</td>
<td>8:56</td>
<td>14:15</td>
</tr>
<tr>
<td>Willoughby Road to York Street Southbound Evening</td>
<td>8:34</td>
<td>8:43</td>
</tr>
</tbody>
</table>

As both Sydney Harbour Bridge operations and bus services have changed significantly since 2004, these travel times are only useful for an “order-of-magnitude” comparison. Since 2004, bus services from the Warringah Freeway to York Street has increased, with some routes increasing timetabled services and new routes being introduced, in particular the MetroBus services. In addition to this change in services, the operation of the southern toll plaza has also changed, such that flow through this plaza is no longer interrupted by toll collection, making it more difficult for buses to pass through gaps in traffic from the Sydney Harbour Bridge main deck.

In the evening peak, however, there has been little change is bus services, as southbound is the off-peak direction in the evening and buses have historically not been capacity constrained in the evening when entering York Street. On the basis of operational changes that have occurred in the evening peak since 2004, it is not expected that travel time will have significantly changed for southbound buses during this peak period.

Based on the qualitative assessment of changes in bus services since 2004, it is expected that bus travels times would have increased in the morning peak period, but remained similar for the evening peak period. The modelled bus travel times support this, indicating that bus travel times are well validated to the degree that this is possible with the limited data available.

### 2.4.3 Eastern Ramp

During the morning peak period, high volumes of bus lane traffic travelling from lane 7 to York Street crosses high volumes of general traffic travelling to Grosvenor Street along the eastern offload ramp. Buses enter this ramp from the left side of the carriageway and exit on the right side, while general traffic from the main deck of the Sydney Harbour Bridge enter the ramp on the right side of the ramp, and exit on the left side.

In the field, this results in a weave arrangement that restricts the flow of buses and general traffic on this ramp. Due to the short distance available to cross over (approximately 50 m) and the high volume of traffic travelling through this section, it is difficult to model vehicle behaviour accurately through this section of road. In order to achieve the same capacity in the model as is observed in the field, the following modifications to the model were undertaken:

- Vehicles slow down and increase their target headway when approaching the existing toll plaza;
- Bus lane users that merge left-to-right from the lane 7 of the SHB will give way to vehicles merging right to left, particularly in the period when buses queue beyond the ramp onto the Sydney Harbour Bridge;
- General traffic heading to Grosvenor Street to turn left into Harrington Street or George Street tend to merge left earlier than that heading to Grosvenor Street to turn right at Lang Street or George Street; and
In the absence of available gaps, buses will occasionally be unable to merge right until much further down the Grosvenor Street ramp, occasionally blocking vehicles heading to Grosvenor Street.

Due to the limitations of discrete-lane modelling, it is difficult to model the precise behaviour that is observed in this section; however the model accurately reflects the capacity through this section under high flows.

3. Southern Toll Plaza Precinct Option Test

3.1 Overview

RMS has proposed a modified layout for the Sydney Harbour Bridge southern toll plaza precinct to remove the existing toll booths and realign southbound traffic heading to the Western Distributor. In order to facilitate this, a number of options have been considered to best make use of the available road space created within the corridor as a result of the removal of the toll booths. Three options were modelled as a part of this assessment:

- Option 1: Base Case assumes no change to the corridor.
- Option 2: Removal of the toll booths and realignment of the toll plaza with no changes to the access routes to the northern Sydney CBD and city centre.
- Option 3: Realignment of the lanes through the toll plaza (as per option 2) with changes to the access routes to the northern Sydney CBD and city centre. The eastern ramp would be reconfigured to provide additional bus priority from the Sydney Harbour Bridge to the northern Sydney CBD.

Under option 3, two alternative operational configurations were modelled for the morning peak period:

- Option 3 split ramps configuration: Reversal of the eastern and western ramps to direct York Street traffic to the eastern ramp and Grosvenor Street traffic to the western ramp, as well as providing two bus lanes and bus readiness bays on the eastern ramp. This would require reconfiguration (and changes to signal and phasing arrangements) of the intersection of York Street and Grosvenor Street.
- Option 3 western ramps configuration: Dedication of the eastern ramp for bus lane lane users and all city-bound traffic diverted to the western ramp. This would require the same intersection reconfiguration as the split ramps configuration.

Plans of the proposal are presented in detail in Appendix A.

3.2 Proposed Network Changes

The proposed changes to the network relate generally to:

- Changes to the operation of the southern toll plaza precinct; and
- Changes to ingress arrangements to the northern Sydney CBD.

These changes are detailed below.

3.2.1 Southern Toll Plaza Precinct Changes

The primary changes to the operation of the southern toll plaza precinct as a result of the proposal include:
• Removal of the existing toll booths and extension of the SHB variable speed zone to a limit of 70 km/hr.
• Rationalisation of the northbound feed from the Western Distributor, Clarence Street, Kent Street, Grosvenor and Cahill Expressway.
• Reconfiguration of the existing medians from lane 7 of the Sydney Harbour Bridge to retain access for traffic from lane 7 to the Western Distributor over a distance of approximately 150 m under existing time of day and user restrictions.
• Provision of bus readiness bays with the provision of a 24 hour bus lane providing access to York Street.
• Provision of an AM and PM peak bus lane (allowing buses, taxis, hire cars and motorcycles) on the eastern ramp.
• An option for the eastern ramp to run exclusively for buses, taxis, hire cars and motorcycles (in the morning peak only).
• Realignment of the existing lanes through the Sydney Harbour Bridge southern toll plaza precinct.
• Ramp destinations to remain fixed throughout the day (no change to ramp destinations by time of day).
• No left turn allowed from the eastern ramp into Grosvenor Street for general traffic, which must access Grosvenor Street via the western ramp at all times.

3.2.2 Northern Sydney CBD Changes
The primary changes to the ingress arrangement to the northern Sydney CBD from the Sydney Harbour Bridge under option 3 as a result of the proposal are as follows:
• Reconfiguration of the intersection of York Street and Grosvenor Street to direct Grosvenor Street traffic to use the western ramp and York Street traffic to use either ramp, depending on how RMS chooses to configure the access.
• Realignment of the existing pedestrian crossings at the intersection of York Street and Grosvenor Street.
• Construction of a new signalised pedestrian crossing on the loop road connecting Clarence Street to York Street from the cyclist and pedestrian path linked to Kent Street.

3.3 Intersection Modelling
Intersection modelling was undertaken using the SIDRA modelling package for the intersection of York Street and Grosvenor Street. This modelling was undertaken on the basis of observed peak hourly counts for the morning and evening peak period. It should be noted that SIDRA models the operation of intersections in isolation, and does not take into account the effects of upstream or downstream queuing which may affect the flow of traffic to the intersection. The SIDRA model has been modified for option 3 and its alternative configurations to run a modified phasing arrangement that minimises queuing, gives pedestrians the same opportunity as they currently have to cross once every cycle and minimises the impacts on buses and general traffic. This phasing arrangement is shown in Appendix B.

3.4 Changes to Model Operation
Optimisation of traffic signal operations is required to minimise the extent of queuing at the intersection of York Street and Grosvenor Street. The existing two-phase arrangement was retained, with the phase times adjusted to optimise throughput, based on initial timings from the
SIDRA intersection modelling package. The signal offset was also adjusted to minimise queuing on the western ramp and favour the progression of buses to York Street, whilst still allowing for pedestrian phases to be called every cycle. Further development of the signal phasing at this intersection was undertaken in SIDRA, and is detailed in Section 3.3.

4. **Model Results**

The proposed reconfiguration of the Sydney Harbour Bridge southbound toll plaza has been evaluated on the basis of the following network performance measures:

- Zone-to-zone travel times for general traffic travelling from the Gore Hill Freeway to the Western Distributor, York Street and Grosvenor Street;
- Bus travel times and travel time reliability for buses travelling from the Gore Hill Freeway to York Street;
- Peak period traffic volumes over the Sydney Harbour Bridge;
- Intersection average delays and levels of service;
- Qualitative assessment of queues on city-bound ramps; and
- General observations of queuing and congestion in the corridor.

Due to the variable nature of the Warringah Freeway Micro Simulation Traffic Model, all model performance measures presented in this report represent average values from a series of 5 seed runs. Sensitivity testing was undertaken to determine if there was any benefit to running additional seed values. This testing showed that increasing the number of seed runs to 10 had negligible impact on the results.

These performance measures are presented in further detail below.

4.1 **Zone-to-Zone General Traffic Travel Times**

Zone-to-zone travel times for general vehicles are shown in Table 4 and Table 5 for the following trips:

- Gore Hill Freeway to Western Distributor; and
- Gore Hill Freeway to the northern Sydney CBD.
### Table 4 - Morning Peak General Traffic Travel Times

<table>
<thead>
<tr>
<th>Option</th>
<th>0700 – 0800</th>
<th>0800 – 0900</th>
<th>0900 - 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gore Hill Freeway to Western Distributor (Southbound)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>06:51</td>
<td>10:07</td>
<td>06:14</td>
</tr>
<tr>
<td>Option 2</td>
<td>05:45</td>
<td>12:39</td>
<td>10:36</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>05:57</td>
<td>09:12</td>
<td>06:05</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td>06:40</td>
<td>09:43</td>
<td>06:01</td>
</tr>
<tr>
<td><strong>Gore Hill Freeway to northern Sydney CBD (Southbound)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>07:10</td>
<td>10:05</td>
<td>06:45</td>
</tr>
<tr>
<td>Option 2</td>
<td>06:41</td>
<td>12:02</td>
<td>08:38</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>06:54</td>
<td>08:27</td>
<td>06:30</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 5 - Evening Peak General Traffic Travel Times

<table>
<thead>
<tr>
<th>Option</th>
<th>1600 – 1700</th>
<th>1700 – 1800</th>
<th>1800 - 1900</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gore Hill Freeway to Western Distributor (Southbound)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>06:40</td>
<td>10:34</td>
<td>10:13</td>
</tr>
<tr>
<td>Option 2</td>
<td>06:34</td>
<td>10:27</td>
<td>12:12</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>06:07</td>
<td>09:36</td>
<td>10:08</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Gore Hill Freeway to northern Sydney CBD (Southbound)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>07:26</td>
<td>11:07</td>
<td>11:15</td>
</tr>
<tr>
<td>Option 2</td>
<td>07:23</td>
<td>11:21</td>
<td>13:22</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>06:51</td>
<td>10:16</td>
<td>11:13</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Inspection of modelled general traffic travel times shows that southbound travel times are forecast to increase by up to four minutes under option 2 and decrease by up to two minutes under option 3. This is due to the following:

- Modification of the southern toll plaza precinct with the existing ramp arrangements under option 2 leads to additional delay for vehicles heading to Grosvenor Street, as these vehicles must now merge left past buses merging right without the benefit of the gaps in traffic flows that are created by the existing toll plaza. This change to the crossover of traffic, as well as changes to travel behaviour to the Western Distributor and York Street increases travel times for southbound traffic in the morning and evening peak.
• Swapping of the ramp configurations, or moving all city-bound traffic to the western ramp under option 3 removes the existing conflict between buses and general traffic on the eastern ramp.

• Phase times at the intersection of York Street and Grosvenor Street have been configured to provide priority for buses heading south on York Street. This results in higher delays for traffic heading into the northern Sydney CBD, particularly under the western ramps configuration.

4.2 Bus Travel Times

Average travel times for southbound buses from the Gore Hill Freeway are shown below in Table 6.

Table 6 - Bus Travel Times from Gore Hill Freeway to York Street

<table>
<thead>
<tr>
<th>Option</th>
<th>Morning Average</th>
<th>Morning Std. Deviation</th>
<th>Evening Average</th>
<th>Evening Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>14:15</td>
<td>05:30</td>
<td>08:43</td>
<td>00:40</td>
</tr>
<tr>
<td>Option 2</td>
<td>12:18</td>
<td>03:51</td>
<td>08:47</td>
<td>01:07</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>10:19</td>
<td>02:48</td>
<td>08:26</td>
<td>00:55</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td>10:54</td>
<td>02:41</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Inspection of the modelled bus travel times show that average travel times and travel time variability for buses is likely to decrease by up to four minutes in the morning peak period as a result of the proposed upgrade of the Sydney Harbour Bridge southbound toll plaza precinct. No significant change in bus travel times is likely in the evening peak period. Option 3 provides significantly lower travel times for buses than other options. This is a reflection of the additional bus priority for city-bound buses that is provided as a part of this option.

It should be noted that the changes to the merge arrangement for lane 7 vehicles heading to the Western Distributor effectively allows buses to queue through the extended merge area and without the existing toll plazas to moderate this merging behaviour (effectively creating gaps), this decrease in bus travel times comes at the cost of increases in general traffic travel times (as identified in Section 4.1)

4.3 Intersection Level of Service

Average delays and intersection levels of service from SIDRA for the intersection of York Street and Grosvenor Street are shown below in Table 7.
### Table 7 - Intersection Level of Service

<table>
<thead>
<tr>
<th>Option</th>
<th>Morning Peak</th>
<th></th>
<th>Evening Peak</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Av Delay (s)</td>
<td>LoS</td>
<td>Av Delay (s)</td>
<td>LoS</td>
</tr>
<tr>
<td>Option 1</td>
<td>17</td>
<td>B</td>
<td>27</td>
<td>B</td>
</tr>
<tr>
<td>Option 2</td>
<td>17</td>
<td>B</td>
<td>27</td>
<td>B</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>32</td>
<td>C</td>
<td>27</td>
<td>B</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td>35</td>
<td>C</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Inspection of average delay and intersection level of service for the intersection of York Street and Grosvenor Street shows that increases in delays are expected at this intersection in the morning peak period and this accounted for in the overall travel times forecast in the model. This is attributable to the change in signal and ramp operation, which prioritises bus movements, and in the case of option 3 western ramps option redirects all city-bound traffic onto the western ramp.

The intersection of York Street and Grosvenor Street performs adequately under the proposed options, even under the western ramps operation. Queue length forecasts for the eastern and western ramps were also taken from the SIDRA models. These are discussed in further detail in Section 4.5.

### 4.4 Traffic Volumes

Three-hour peak period traffic flows for the Sydney Harbour Bridge northbound and southbound and the Cahill Expressway are shown below in Table 8.

### Table 8 - Peak Period Traffic Flows (3-Hour Flows)

<table>
<thead>
<tr>
<th>Option</th>
<th>Sydney Harbour Bridge (NB)</th>
<th>Sydney Harbour Bridge (SB)</th>
<th>Cahill Expressway (SB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Morning Peak</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>16,093</td>
<td>14,471</td>
<td>6,991</td>
</tr>
<tr>
<td>Option 2</td>
<td>16,163</td>
<td>14,659</td>
<td>7,143</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>16,301</td>
<td>14,301</td>
<td>7,061</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td>16,291</td>
<td>14,224</td>
<td>7,050</td>
</tr>
<tr>
<td><strong>Evening Peak</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>20,428</td>
<td>8,438</td>
<td>6,457</td>
</tr>
<tr>
<td>Option 2</td>
<td>20,139</td>
<td>8,551</td>
<td>6,283</td>
</tr>
<tr>
<td>Option 3 (Split Ramps)</td>
<td>20,262</td>
<td>8,449</td>
<td>6,344</td>
</tr>
<tr>
<td>Option 3 (Western Ramps)</td>
<td>Morning Only</td>
<td>Morning Only</td>
<td>Morning Only</td>
</tr>
</tbody>
</table>

Inspection of the modelled three-hour peak period traffic flows over the Sydney Harbour Bridge shows that no significant changes in traffic flows on the Sydney Harbour Bridge are likely to result from the proposed southern toll plaza precinct upgrade.
4.5 **Ramp Queues**

Qualitative examination of 95th percentile queue lengths was undertaken to determine whether any of the proposed changes to the ramp arrangements or intersection configurations would result in queues that would exceed the storage space of existing ramps and impede traffic flows to the Western Distributor. Queue lengths were extracted from both the micro simulation model and the SIDRA intersection model.

Under both cases, the ramps were shown to be long enough to contain the 95th percentile general traffic queue, however under option 3, a reconfiguration of the signal operation was developed to minimise the likelihood that queues would interfere with general traffic travelling to the Western Distributor.

Under option 2, buses are expected to queue through the merge area at the northern end of the existing eastern ramp; however this is consistent with existing queuing at this location.

4.6 **Queuing and Congestion Observations**

Observation of the operation of the models under the three options showed the following:

- Due to the reconfiguration of the intersection of York Street and Grosvenor Street under option 3 signal operations including phase optimisation and signal coordination will require updating to ensure suitable operation. Signal timings at the intersection of York Street and Grosvenor St could also be optimised to maximise priority for buses heading south on York Street, without causing queues on either ramp that would interfere with traffic heading to the Western Distributor.

4.7 **Option Assessment**

Modelling and analysis of the proposed reconfiguration to the southbound toll plaza on the Sydney Harbour Bridge and the associated operational options has shown the following:

- Option 2 is likely to result in higher general traffic travel times (by up to four minutes) in the morning and evening peak periods.
- Option 2 is likely to result in a decrease in bus travel times of up to two minutes in the morning peak period and reductions in bus travel time variability.
- Option 3 is likely to result in lower general traffic travel times (by up to two minutes) in the morning and evening peak periods.
- Option 3 is likely to result in a decrease in bus travel times of up to four minutes in the morning peak period and reductions in bus travel time variability.
- None of the options are likely to have any impact on southbound bus travel times in the evening peak period.
- Option 2 would increase the merge distance for vehicles crossing from lane 7 of the Sydney Harbour Bridge to the Western Distributor, but this would also increase queuing space for buses and removal of the southern toll plaza would eliminate the regulation of this movement. Consequently, option 2 would result in an increase in general traffic travel times through the corridor.
- The reconfiguration of the intersection of York Street and Grosvenor Street would provide sufficient capacity to allow for both bus-priority operational options to allow the intersection to run at an acceptable level of service.
The proposed ramp configurations at Grosvenor Street and York Street have adequate storage capacity to hold the modelled 95th percentile queues without impacting on southbound traffic to the Western Distributor. Overall, option 3 would provide the greatest benefits in general traffic travel times and bus travel times and reliability, whilst improving the flexibility to provide alternative bus and general vehicle management options.

5. Summary and Conclusions

5.1 Overview

Micro simulation traffic modelling of the Warringah Freeway and Sydney Harbour Bridge has been undertaken using the RMS Warringah Freeway model, and has been used to determine the traffic impacts of the proposed options.

GHD have used the existing micro simulation traffic models supplied by RMS to model the proposed upgrade of the Sydney Harbour Bridge southern toll plaza precinct and associated ramps and intersections. This proposal includes changes to the ramp arrangements (for general traffic access to the northern Sydney CBD and city centre), provision of additional bus capacity on the eastern ramp and reconfiguration of the intersection of Grosvenor Street and York Street.

5.2 Key Findings

The key findings from the modelling of the reconfiguration of the Sydney Harbour Bridge southbound toll plaza are as follows:

Option 2
- General traffic travel times are forecast to increase by up to four minutes.
- Bus travel times are forecast to decrease by up to two minutes.
- The variability of bus travel times is forecast to decrease.

Option 3
- General traffic travel times are forecast to decrease by up to two minutes.
- Bus travel times are forecast to decrease by up to four minutes.
- The variability of bus travel times is forecast to decrease.
- All options provide sufficient ramp capacity such that 95th percentile general traffic queues will not exceed the ramps and block flow to the Western Distributor, provided the appropriate signal phase design is adopted at the intersection of York Street and Grosvenor Street.

5.3 Key Conclusions

The key conclusions from the modelling of the Sydney Harbour Bridge Southbound Toll Plaza are as follows:
- A forecast decrease in general traffic travel times in the morning peak.
- A forecast decrease in bus travel times in the morning peak.
- Forecast improved bus reliability in the morning peak.
- Negligible change to bus travel times are likely to occur as a result of the proposed options in the evening peak.
• Satisfactory level of service for the proposed reconfiguration of the intersection of Grosvenor Street and York Street.
Appendix B – Proposed Signal Phasing
<table>
<thead>
<tr>
<th>Phase Timing Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase</td>
</tr>
<tr>
<td>Green Time (sec)</td>
</tr>
<tr>
<td>Yellow Time (sec)</td>
</tr>
<tr>
<td>All-Red Time (sec)</td>
</tr>
<tr>
<td>Phase Time (sec)</td>
</tr>
<tr>
<td>Phase Split</td>
</tr>
</tbody>
</table>

**Phase A**

**Phase C**

**Phase D**

**Phase B**
GHD
133 Castlereagh St  Sydney NSW 2000
-  
T: 2 9239 7100   F: 2 9239 7199   E: sydmail@ghd.com.au

© GHD 2012

This document is and shall remain the property of GHD. The document may only be used for the purpose for which it was commissioned and in accordance with the Terms of Engagement for the commission. Unauthorised use of this document in any form whatsoever is prohibited.
G:\21\21626\WP\183121.docx

Document Status

<table>
<thead>
<tr>
<th>Rev No.</th>
<th>Author</th>
<th>Reviewer</th>
<th>Approved for Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name</td>
<td>Signature</td>
<td>Name</td>
</tr>
<tr>
<td>1</td>
<td>I Smith</td>
<td>S Konstas</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>I Smith</td>
<td>S Konstas</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>I Smith</td>
<td>S Konstas</td>
<td></td>
</tr>
</tbody>
</table>