Departure Side Platforms as a Measure to Mitigate Level Crossing Road Closures: An Investigative Study Using Simulation Modelling

A thesis submitted in fulfilment of the requirements for the degree Doctor of Philosophy

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or part, to qualify for any other academic award; the content of this thesis is the result work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

William M. Guzman
23 December 2014
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Departure Side Platforms as a Measure to Mitigate Level Crossing Road Closures: An Investigative Study Using Simulation Modelling

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<thead>
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<th>Full Form</th>
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<tbody>
<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
</tr>
<tr>
<td>ACT</td>
<td>Australian Capital Territory</td>
</tr>
<tr>
<td>AECOM</td>
<td>AECOM Australia and New Zealand</td>
</tr>
<tr>
<td>ALCAM</td>
<td>Australian Level Crossing Assessment Model</td>
</tr>
<tr>
<td>ANI</td>
<td>VISSIM Animation File</td>
</tr>
<tr>
<td>ARA</td>
<td>Australasian Railway Association</td>
</tr>
<tr>
<td>ARTC</td>
<td>Australian Rail Track Corporation</td>
</tr>
<tr>
<td>AS</td>
<td>Australian Standards</td>
</tr>
<tr>
<td>ASP</td>
<td>Arrival Side Platform</td>
</tr>
<tr>
<td>ATIS</td>
<td>Advanced Travel Information Services</td>
</tr>
<tr>
<td>ATSB</td>
<td>Australian Transport Safety Bureau</td>
</tr>
<tr>
<td>AVI</td>
<td>Audio Video Interleave</td>
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<tr>
<td>BTRE</td>
<td>Bureau of Infrastructure, Transport and Regional Economics</td>
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<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CfM</td>
<td>Committee for Melbourne</td>
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<tr>
<td>CIE</td>
<td>Centre for International Economics</td>
</tr>
<tr>
<td>COAG</td>
<td>Council of Australian Governments</td>
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<tr>
<td>CONNEX</td>
<td>Connex Melbourne trains</td>
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<tr>
<td>DCC</td>
<td>Department of Climate Change, Australia</td>
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<tr>
<td>DDA</td>
<td>Disability Discrimination Act</td>
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<tr>
<td>DEVS</td>
<td>Discrete Event Simulation</td>
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<tr>
<td>DoI</td>
<td>Department of Infrastructure, Victoria</td>
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<tr>
<td>DoT</td>
<td>Department of Transport, Victoria</td>
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<tr>
<td>DOT</td>
<td>US Department of Transport</td>
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<tr>
<td>DSP</td>
<td>Departure Side Platform</td>
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<tr>
<td>DSP ASP</td>
<td>Departure and Arrival Side Platforms combination</td>
</tr>
<tr>
<td>DSP DSP</td>
<td>Departure and Departure Side Platforms combination</td>
</tr>
<tr>
<td>DTEI</td>
<td>Department of Planning, Transport and Infrastructure, SA</td>
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<tr>
<td>DWL</td>
<td>Deadweight Loss</td>
</tr>
<tr>
<td>ECMT</td>
<td>European Conference of Ministers of Transport</td>
</tr>
<tr>
<td>EIU</td>
<td>The Economist Intelligence Unit</td>
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<tr>
<td>ENVICT</td>
<td>Environment Victoria</td>
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<tr>
<td>ESCAP/UN</td>
<td>United Nations Economic and Social Commission Asia/Pacific</td>
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<tr>
<td>EWS</td>
<td>Early Warning Systems</td>
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<tr>
<td>FHWA</td>
<td>US Federal Highway Administration</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>G Theory</td>
<td>Theoretical Generalisability theory</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GPS</td>
<td>Global Positioning Systems</td>
</tr>
<tr>
<td>HDR</td>
<td>Higher Degree by Research</td>
</tr>
<tr>
<td>HOV</td>
<td>High Occupancy Vehicle</td>
</tr>
<tr>
<td>IRSE</td>
<td>Institution of Railway Signal Engineers, US</td>
</tr>
<tr>
<td>ISA</td>
<td>Intelligent Speed Adaptation</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transport Systems</td>
</tr>
<tr>
<td>ITSR</td>
<td>Independent Transport Safety Regulator, NSW</td>
</tr>
<tr>
<td>ITSRR</td>
<td>Independent Transport Safety and Reliability Regulator, NSW</td>
</tr>
<tr>
<td>JIT</td>
<td>Just In Time</td>
</tr>
<tr>
<td>LCSC</td>
<td>Level Crossing Strategy Council of NSW</td>
</tr>
<tr>
<td>LXM</td>
<td>Level Crossing Management database</td>
</tr>
<tr>
<td>Macro</td>
<td>Macroscopic Simulation</td>
</tr>
<tr>
<td>Meso</td>
<td>Mesoscopic Simulation</td>
</tr>
<tr>
<td>MetLink</td>
<td>Public Transport Victoria</td>
</tr>
<tr>
<td>METRO</td>
<td>Metro Trains Melbourne</td>
</tr>
<tr>
<td>Micro</td>
<td>Microscopic Simulation</td>
</tr>
<tr>
<td>NAC</td>
<td>National ALCAM Committee</td>
</tr>
<tr>
<td>NCHRP</td>
<td>National Cooperative Highway Research Program</td>
</tr>
<tr>
<td>NGT</td>
<td>Next generation trains</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>NSW</td>
<td>State of New South Wales</td>
</tr>
<tr>
<td>NT</td>
<td>Northern Territory</td>
</tr>
<tr>
<td>OCI</td>
<td>Office of the Chief Investigator, Department of Transport, Victoria</td>
</tr>
<tr>
<td>OD</td>
<td>Origin/Destination</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PCR</td>
<td>Public Crossing Register</td>
</tr>
<tr>
<td>PJPL</td>
<td>Port Jackson Partners Limited</td>
</tr>
<tr>
<td>PoMC</td>
<td>Port of Melbourne Corporation</td>
</tr>
<tr>
<td>PTS</td>
<td>Public Transport Stop</td>
</tr>
<tr>
<td>PTV</td>
<td>Public Transport Victoria</td>
</tr>
<tr>
<td>PTV AG</td>
<td>PTV Planung Transport Verkehr AG (VISSIM developer)</td>
</tr>
<tr>
<td>QLD</td>
<td>State of Queensland</td>
</tr>
<tr>
<td>RISSB</td>
<td>Rail Industry Safety and Standards Board</td>
</tr>
</tbody>
</table>
### Departure Side Platforms as a Measure to Mitigate Level Crossing Road Closures: An Investigative Study Using Simulation Modelling

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>RLX</td>
<td>Railway Level Crossing (or at-grade railroad crossing)</td>
</tr>
<tr>
<td>RSC</td>
<td>Road Safety Committee, Parliament of Victoria</td>
</tr>
<tr>
<td>RSSB</td>
<td>Rail Safety and Standards Board, UK</td>
</tr>
<tr>
<td>RTA</td>
<td>Roads and Traffic Authority, NSW</td>
</tr>
<tr>
<td>SA</td>
<td>State of South Australia</td>
</tr>
<tr>
<td>SKM</td>
<td>Sinclair Knight Merz</td>
</tr>
<tr>
<td>STAYSAFE</td>
<td>Joint Standing Committee on Road Safety, Parliament of NSW</td>
</tr>
<tr>
<td>SUV</td>
<td>Sport Utility Vehicle</td>
</tr>
<tr>
<td>TAS</td>
<td>State of Tasmania</td>
</tr>
<tr>
<td>TDM</td>
<td>Travel Demand Management</td>
</tr>
<tr>
<td>TOS</td>
<td>Traffic Operational Strategies</td>
</tr>
<tr>
<td>TSV</td>
<td>Transport Safety Victoria</td>
</tr>
<tr>
<td>V/LINE</td>
<td>V/Line regional line</td>
</tr>
<tr>
<td>V3DM</td>
<td>VISSIM 3D Modeler</td>
</tr>
<tr>
<td>VAGO</td>
<td>Victorian Auditor-General Office</td>
</tr>
<tr>
<td>VAP</td>
<td>Vehicle Actuated Programming</td>
</tr>
<tr>
<td>VCEC</td>
<td>Victorian Competition and Efficiency Commission</td>
</tr>
<tr>
<td>VIC</td>
<td>State of Victoria</td>
</tr>
<tr>
<td>VicGov</td>
<td>State Government of Victoria</td>
</tr>
<tr>
<td>VicRoads</td>
<td>Roads Corporation of Victoria</td>
</tr>
<tr>
<td>VicTrack</td>
<td>Victorian Rail Track Corporation</td>
</tr>
<tr>
<td>Vissig</td>
<td>Signal Optimisation in VISSIM</td>
</tr>
<tr>
<td>VISSIM</td>
<td>Verkehr In Städten – SIIMulationsmodell</td>
</tr>
<tr>
<td>VisVap</td>
<td>Visual VAP – Flow Chart Editor for VAP</td>
</tr>
<tr>
<td>VKT</td>
<td>Vehicle Kilometres Travelled</td>
</tr>
<tr>
<td>VMT</td>
<td>Vehicular Travel Activities</td>
</tr>
<tr>
<td>VRIOG</td>
<td>Victorian Rail Industry Operators Group</td>
</tr>
<tr>
<td>WA</td>
<td>State of Westerns Australia</td>
</tr>
<tr>
<td>ZO</td>
<td>Zonal Operations</td>
</tr>
</tbody>
</table>

William M. Guzman
Intellectual Property (IP) from Thesis

Patent type: Innovation Patent

Patent number: 2010100570

Patent title: Departure Side Platforms as a Measure to Minimise Level Crossing Boom Gates Closure

Patent date: 6 June 2010

Granted to: William Manuel Guzman

Invented by: Guzman, William Manuel
Publications from Thesis

Peer Reviewed Work

*Departure Side Platforms: a Measure to Mitigate Road Congestion*, International Symposium on Logistics (ISL 2014) conference in Ho Chi Minh City, Vietnam (Guzman, Young & Peszynski 2014).

*Zonal Operations: a method to rationalise operations*, Computers in Railways XIV (CompRail 2014) conference in Rome, Italy (Guzman, Peszynski & Young 2014b).

*Departure Side Platforms: a road congestion mitigation measure*, Australian Institutes of Transport Research Conference (CAITR 2015), Melbourne, Australia, February 2015 (Guzman, Young & Peszynski 2015). The paper was conferred the conference’s best paper and presented with the SIDRA SOLUTIONS Students Award.

The paper was also acknowledged with the presentation of an Excellence Award at the RMIT Business Research Showcase 2015, for the Best Conference Paper by an HDR candidate.

Book chapter


Non-peer reviewed work

*Compounding the problem*, Sunday Age, 8 August 2010 (Guzman 2010)

*Trains come at a price*, The Age, 31 December 2011 (Guzman 2011)

*Extra hour spent waiting – A Reply*, The Age, 30 May 2012 (Guzman 2012).
Abstract

This thesis investigates the impact of level crossings closures on traffic congestion at level crossings adjacent to or in the close proximity of railway stations, proposing that making alterations to the infrastructure of the station can derive a reduction of intersection closure periods at these locations. These infrastructure alterations relate to the platform arrangements at stations, and present an opportunity to mitigate the time of roads closure periods at level crossing, thus alleviating road traffic congestion.

To test this proposition, a case is used in the city of Melbourne, in Victoria, Australia. The station environment at one station on the Melbourne rail network is simulated using traffic simulation software that allows the user total control of the environment and the transport network emulated, including vehicles types, traffic composition, intersection controls and the general environment. The simulation process is conducted in two phases, one to emulate the current environment and the other to emulate the proposed environment; the results from each of the simulation processes are then compared to ascertain the differences achieved.

Simulation results testing single, two-train and multiple-train arrivals and departures at the current and proposed environment, confirmed the proposition that the platform repositioning approach can be used to mitigate road traffic congestion at level crossings railway stations precinct. This has led to the development of the theory of Departure Side Platforms (DSP). Further, results confirm, using three different road traffic volume levels, that the theory works when both single and multiple train arrivals and departures are in operation at the level crossing. The simulation results also confirmed that under the proposed platform environment, continual level crossing closures of more than two trains would no longer occur.
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1. INTRODUCTION

There is no single, broadly accepted definition of traffic congestion. One of the principal reasons for this lack of consensus is that congestion is both:

- A physical phenomenon relating to the manner in which vehicles impede each others’ progression as demand for limited road space approaches full capacity
- A relative phenomenon relating to user expectations vis-à-vis road system performance.¹

This thesis investigates road traffic congestion at railway level crossings adjacent to or in the close proximity of railway stations. In doing so, it reviews solutions and alternatives currently used to deal with railway level crossings problems and develop the theory of Departure Side Platforms (DSP). This theory of Departure Side Platforms is further explored using an illustrative case, a level crossing in Melbourne, Victoria, Australia.

The thesis proposes that mitigation of the road intersection closures and the length of closures at train station railway level crossings can be derived or achieved by making alterations to the infrastructure of the railway station. The infrastructure alterations relate to the position of platforms at railway stations; its implementation results in alleviating road traffic congestion at railway station level crossings. A railway level crossing is an intersection where two different modes of transport, rail and road, cross each other’s path at ground or street level, where both modes compete for that same ground space (VicRoads 2011b). Level crossing are an area of conflict between all types of road traffic, which includes motor vehicles, trams, cyclist and pedestrians, and rail traffic (Taylor, J & Crawford 2010).

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Having intersections open for longer periods allows the flow of traffic through intersections to pass with less interruption, thus generating less traffic congestion, less pollution and provide a safer and a more amenable environment at railway stations precincts for commuters, residents and traders alike.

1.1. Road Congestion and Congestion Cost

There is no consensus on what constitutes a standard, generally acceptable definition of road traffic congestion (Boarnet, Kim & Parkany 1998). Congestion is not a new phenomenon and occurs in all types of environments; congestion is not inclusive of roads networks; it also occurs in rail networks, high rise buildings lifts, supermarket checkouts, and many others situations. The focus of the thesis is the mitigation of road traffic congestion at level crossings intersections next to or in the vicinity of railway stations.

Road traffic congestion occurs when pressure demands for road resources, above the available capacity, are placed upon networks; congestion also occurs due to inefficiencies on the networks (Blunden 1983). Blunden presents two types of traffic congestion: congestion due to pressure of demand, and congestion due to inefficiency. Congestion due to pressure of demand is an ally that must be welcome, as it is a product and a sign of vibrant economic activity. Congestion due to inefficiency is an enemy that must be combated and prevented at all cost (Blunden 1983). Taylor and Crawford (2010) further suggest congestion due to inefficiencies are a ‘barrier to the efficient performance of the transport network’ (Taylor, J & Crawford 2010, p. 1). This thesis investigates road congestion at level crossings next to or in close proximity of railway stations.

Vehicular traffic congestion is increasing in most urban areas (OECD/ECMT 2007; SKM, Maunsell & Evans & Peck 2008; Taylor, J & Crawford 2010; VicGov 2013) and in locations where populations and city
Chapter 1: Introduction

Economies are growing and it is likely to continue to increase (COAG 2006; OECD/ECMT 2007; Taylor, B 2002; VicGov 2012).

There are a large number of level crossings in Australia and the state of Victoria has the largest number of level crossings of any other state or territory in the country; the Greater Melbourne area has the largest number of level crossings than any metropolitan areas in Australia. This thesis investigates road traffic congestion using a railway a level crossings location in metropolitan Melbourne as an illustrative case.

1.2. Road Congestion and Level Crossings: A Case in Melbourne, Australia

Estimates indicate that all capital cities in Australia are afflicted by the road congestion phenomenon (BTRE 2007). This phenomena, termed as the 'avoidable costs of traffic congestion' (BTRE 2007, p. 15), if not addressed, presents severe economic consequences for Australia, currently costing the country about 2% of GDP (PJPL 2005). Estimates are indicative that the current annual cost of congestion in Australia is $9.4 billion and forward estimates the figure will reach $20.0 billion per year or more by 2020 (BTRE 2007; COAG 2006). Three independent estimates concur that traffic congestion will continue rising, but differ on by how much would increase and over what period of time the increases will occur (BTRE 2007; PJPL 2005; VCEC 2006a). There is also evidence that congestion is causing serious problems and cost impositions to many business (CIE 2006).

Road congestion and traffic pollution also have other more detrimental implications; it causes serious health effects, including low birth weight and gestation pregnancies, respiratory diseases in children, and lung cancer and cardiovascular disease in adults (Irving 2014).

One area where vehicular traffic congestion is prevalent in most Australian capital cities, is at railway level crossings (Hall & Somers 2012; Lucas 2010; Taylor, J & Crawford 2010; VicGov 2009; Webb & Gaymer 2009). There is evidence that vehicular traffic congestion at metropolitan level
crossings is getting worse and the future prospect of additional train services to cope with growth demand, are obstacles to effective operations of the road transport networks (Lucas 2010; Taylor, J & Crawford 2010).

Taylor and Crawford (2010) indicate that by 2021, some rail lines would carry almost 40 trains per hour during peak periods, close to double the present volume levels. One problem facing transport authorities is that additional train traffic exacerbates traffic congestion at most level crossing locations (Guzman 2011, 2012; Guzman, Peszynski & Young 2014b; Guzman, Young & Peszynski 2014).

In preparation, transport authorities are looking for solutions and alternatives, but the main focus is on grade separation projects by way of tunnels or bridges (Pallas 2010; RACV 2009); plans are under way for several grade separation projects (Andrews 2014; Callick 2014; Carey 2015a; Dowling 2014; Johnston & Campbell 2014; PTV 2013d; VicRoads 2013).

1.3. Area of the Research

Dynamic, affordable, liveable and attractive urban regions will never be free of congestion. Road transport policies, however, should seek to manage congestion on a cost-effective basis with the aim of reducing the burden that excessive congestion imposes upon travellers and urban dwellers throughout the urban road network.2

According to figures presented in Table 1.1, there are 7943 level crossings in Australia, but this figure varies depending on the reporting organisation and the method used for inclusion (i.e. type of level crossing being: road, pedestrian, maintenance, public, private, protected, unprotected, open, etc.) (Henley & Harrison 2009; RISSB 2009; Wallace 2008). Also according to Table 1.1, Victoria has the largest number of public level crossings, 1872 level crossings, more than any other state or territory in Australia (ITSRR 2008; PTV 2013e). The Greater Melbourne area has the

largest number of level crossings in metropolitan areas in Australia, 182 level crossings (Hall & Somers 2012; PTV 2013e; Taylor, J & Crawford 2010); the Melbourne metropolitan area is home to 172 level crossings (PTV 2013e). Table 1.1 indicates population figures and level crossings numbers for each Australian jurisdiction.

Table 1.1: Australian Population and Level Crossings Data – 2012

<table>
<thead>
<tr>
<th>Australian Data</th>
<th>QLD</th>
<th>NT</th>
<th>SA</th>
<th>WA</th>
<th>VIC</th>
<th>TAS</th>
<th>ACT</th>
<th>NSW</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (in 000)</td>
<td>4,538</td>
<td>233</td>
<td>1,651</td>
<td>2,411</td>
<td>5,603</td>
<td>512</td>
<td>373</td>
<td>7,273</td>
<td>22,597</td>
</tr>
<tr>
<td>Percentage of Population</td>
<td>20.1%</td>
<td>1.0%</td>
<td>7.3%</td>
<td>10.7%</td>
<td>24.8%</td>
<td>2.3%</td>
<td>1.7%</td>
<td>32.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Number of Level Crossings</td>
<td>1785</td>
<td>58</td>
<td>1145</td>
<td>1254</td>
<td>1872</td>
<td>370</td>
<td>N/A</td>
<td>1459</td>
<td>7943</td>
</tr>
<tr>
<td>Percentage Level Crossings</td>
<td>22.5%</td>
<td>0.7%</td>
<td>14.4%</td>
<td>15.8%</td>
<td>23.6%</td>
<td>4.7%</td>
<td>18.4%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Deaths at Level Crossings 2002-2012</td>
<td>47</td>
<td>4</td>
<td>26</td>
<td>21</td>
<td>139</td>
<td>3</td>
<td>N/A</td>
<td>110</td>
<td>350</td>
</tr>
<tr>
<td>Percentage of Deaths at Level Crossings 2002-2012</td>
<td>13.4%</td>
<td>1.1%</td>
<td>7.4%</td>
<td>6.0%</td>
<td>39.7%</td>
<td>0.9%</td>
<td>31.4%</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

Source: Population figures: 3101.0 – Australian Demographic Statistics, Mar 2012 (ABS 2012); Level Crossings Data: Australian Rail Safety Occurrence Data 1 July 2002 to 30 June 2012 (ATSB 2012)

The figures presented indicate a similarity between the population of Victoria, 24.8% of the country population and 23.6% of all level crossings in the country. Both figures are close to one quarter of the total corresponding numbers. Yet a disparity is evident in the number of deaths at level crossings in the State of Victoria: one hundred and thirty nine (139) deaths resulting from accidents at level crossings involving a train and motor vehicle(s); these represent 39.7% of all accidental deaths at...
level crossings in Australia, much greater in comparison to the State’s population and level crossing numbers.

The figures are despite the fact that all suburban level crossings in metropolitan Melbourne are equipped with safety equipment, with boom barriers installed across the intersecting roads and supplemented with flashing lights and warning bells (PTV 2013e). The equipment is automatic and activates the closing and opening of the road to all traffic, as trains in either direction approach or departs from the crossings. Trains have right-of-way at level crossings and crossings must be closed to all traffic when a train is in its proximity. More than one hundred (102) of these suburban level crossings are next to or in the close proximity of a railway station. A figure showing station level crossing locations in Melbourne rail network is included in Appendix A.

Accidents at level crossings resulting in death and injury of commuters and pedestrians are currently the main reason for resolving level crossing problems and a topic of much research (Taylor, J & Crawford 2010; Uber 1990; VAGO 2010; VicGov 2009; Wallace 2008; Wigglesworth 1978). Safety at level crossing and road traffic congestion at these locations are also the focus of some research (Hall & Somers 2012; Roberts 2005; Tydlacka 2004). However, road traffic congestion is by no means a motivator in resolving level crossing problems, but benefits from its resolution (Cho 2003; Taylor, J & Crawford 2010).

Between the years of 2000 and 2009 there were 73 fatalities in Victoria due to accidents at level crossing, an average of eight per year, indicating a decline from previous years (VAGO 2010). The decline in accidents is despite increases in both train and motor vehicular traffic; it is attributed to improved safety at level crossings and the introduction of boom barriers at many rural locations in the state (VAGO 2010; Wigglesworth 2007). Currently there are three alternatives to deal with level crossing problems, these are: complete closure of the level crossing; grade separation of the level crossing by way of tunnel or bridge; installation or upgrades of boom
barriers; and ensuring the warning systems of the level crossing are adequate and comply with safety legislation and prescribed standards.

Given the large number of level crossings in Victoria, the focus of this research is metropolitan level crossings next to or in close proximity of railway stations, where the closure of roads for any length of time, creates road traffic congestion, which is specifically worse during peak-hour periods.

Metro Trains Melbourne, the current operator of the Melbourne urban rail network, proposed to introduce a system of no timetables for Metro train’s services, better frequency of arrival/departures with services instead running every ten minutes (Gough 2010); these changes have the potential to increase train traffic along rail network corridors resulting in additional motor vehicle traffic congestion at all urban level crossings. This would present a problem though; as population grows, traffic grows accordingly, creating additional demand for both rail and road transport. Additional train traffic creates a ‘catch 22’ situation; it activates more intersection closures at level crossings on roads that are carrying more motor vehicular traffic, exacerbating the problem further. As of thesis submission, Melbourne Metro trains have not switched to the better frequency of arrival/departures method suggested.

1.4. Research Motivation
The original research interest with railway station intersection closure periods was simply altruistic and motivated by frustration, experienced on a daily basis, when facing delays of ten minutes or longer just to cross a target level crossing, during peak hour periods, from north to south or vice versa. The original investigation was to understand the reason of road closure periods that resulted in vehicular congestion at the level crossing locations (Guzman 2008). That research resulted in identifying deficiencies in the operation of level crossings located at railway stations (Guzman 2008). The deficiencies were found to be due to stations platforms layout (Guzman, Young & Peszynski 2014, 2015); these
research indicated potential benefits could be derived from infrastructure alterations to station platforms location.

Further, there had been several announcements, by the Victorian Government, of a number of programs aiming towards alleviating train patronage overcrowding and some of the motor vehicles traffic congestion, particularly in the Melbourne metropolitan area (DoT/Dol 2006; Eddington 2008; PTV 2013b, 2013c). The introduction of these programs would see increases of train traffic along the urban rail network that would have a negative impact on Melbourne’s road network, aggravating motor vehicle traffic congestion at all metropolitan level crossings. None of these programs include funding for resolving or appeasing road congestion at level crossings locations.

Noticeable, most research conducted on the topic of level crossings has been motivated by injuries and fatalities resulting from accidents at level crossings involving a road vehicle and a train, road traffic congestion and preemption at level crossings (Delmonte & Tong 2008; Pulugurtha & Desai 2007). Delmonte and Tong (2008) in their literature review observed ‘the literature tended to be safety-oriented; very little was found relating directly to road traffic delays at level crossings’ (Delmonte & Tong 2008, p. 3), finding limited evidence of published material on the subject when investigating the same heavy rail topic. Pulugurtha and Desai (2007) indicate ‘literature documents limited research on modelling railroad crossings’ (Pulugurtha & Desai 2007, p. 1). Further, there is no evidence of available literature on the subject of level crossings traffic congestion caused by the railway stations platform positions per se. Therefore, part of the material presented is derived from government reports, news and newspaper articles, archives and local knowledge.

There is, however, some material in the literature in regards to light rail stops platform positions. For instance, a new rail line (light rail) in Los Angeles Expo Line (Expo Line 2012) uses a combination of station stops positions to control speed of light rail vehicles at level crossings. In some
cases, the platform combinations are used to force the rail vehicles to stop before crossing an intersection near a School. The varied platforms position could reflect the differences of building rail infrastructure in 21st century as against the 19th century.

1.5. Research Methodology

In the process of answering the problem addressed in this study, a search was conducted for possible theories as the basis of this research. Queuing theory was initially explored, as queuing theory and its probabilistic methods are a widely utilised theory that mathematically explores waiting lines, congestion or queues (Breuer & Baum 2005; Laval & Leclercq 2010; Mounce 2006; Sztrik 2012). Other road transport theories, techniques and strategies, for instance Travel Demand Management (TDM) (Rouphail 2008), Traffic Operational Strategies (TOS) (Rouphail 2008) and traffic simulation modelling (Pulugurtha & Desai 2007), both deterministic and stochastic, were also explored.

However, there appears to be no theories, strategies or method that addresses the position of railway station platform positions and the subsequent road congestion resulting from such infrastructure settings. The conclusion of the search for a theory indicated no appropriate theory or framework appears to exist in this case; consequently, the challenge for this study was to evaluate a proposition and build a theory using computer traffic simulation techniques.

This research uses computer simulation as the methodology for the process of understanding and evaluating the interaction of rail and road traffic interaction at railroad level crossings. In this research, the process of testing the proposition is conducted using computer simulation and visualisation techniques to develop a theory that addresses the position of railway station platform positions.

Computer simulation is said to be one of the most powerful tools available, as it allows and simplifies the methods used to study, analyse and evaluate conditions that could not be studied under normal circumstances.
Chapter 1: Introduction

(Ingalls 2008; Shannon 1998). Computer simulation aims at understanding and finding solutions to complex phenomena (Winsberg 1999) and in that process, satisfy the three tenets of qualitative research: describing, understanding and explaining (Law 2008; Law & McComsa 1991; Tellis 1997; Yin 2003).

Computer simulation methodology was appropriate for this research because it investigates a particular case and a situation not yet investigated using any other research methods. In addition, the complexities of the components of traffic and network systems are not prescribed under current analytical models (Rosca et al. 2013). Furthermore, according to Quinn (2000), computer simulation contributes in the development of theoretical knowledge in three ways: by generating new theory; by testing existing theory logical consistency; and by conducting empirical case simulations (Quinn 2000).

Computer simulation models were needed, not only to assess the benefits brought about by the proposed changes, but also to help in generating situations, optimising controls, and in predicting network behaviour at the operational level (Boxill and Yu, 2000), and to provide a graphical view of the simulated environment.

For extant transport problems, it is commonly impossible to find straightforward equations or algorithms to express models in search of solutions (Li 2013). In railways networks, delays and conflicts at railroad level crossings can be analysed using models; the complexity of these junctions make it difficult for the development of analytical models to study these problems (Dessouky & Leachman 1995). Using computer simulation, both types of networks are emulated to study the behaviour and activities of rail and road traffic at level crossings, gaining an understanding of the operations of level crossings and of road closure of level crossings, events that cause road motor vehicular traffic congestion.
1.6. Research Objectives

The purpose of this research is to test and explore a proposition and develop a theory that deals with the problem of intersection level crossings closures in the vicinity of railway station precincts. This new theory is complimentary to the three options currently available to deal with level crossing problems and it is not proposed to replace the current options, but to be treated as an additional, either permanent or temporary solution for the process of treatment of railway station level crossings problems.

The research thesis question is: How does modifying platform configuration at railway stations mitigate level crossings road closures times?

This proposition and theory addresses the legacy of railway level crossings and specifically its links to the position of platforms at railway stations. This research is believed to be the first to explore the issue of platform positioning at railway stations level crossings (Guzman, Young & Peszynski 2014, 2015; ISL Reviewer 2014), where two modes of land transport, rail and road, cross each other’s path at the same grade or level.

This research is not aimed towards resolving safety issues at level crossings, or reducing accidents at level crossings. As a by-product, the implementation of the proposed theory could help in resolving safety issues and mitigate level crossings accidents by default. For example, seventy nine per cent (79%) of all accidents at level crossings in Victoria, occur at level crossings protected with boom barriers, lights and bells (TSV 2013).

In addition, this research investigates platforms positions at railway stations and the impact of platforms positions in relation to road congestion at level crossings intersections. This research does not intend to delve into the cost of building infrastructure, the financing of these projects, or in the cost benefit analysis of such infrastructure.
developments, as these issues are considered outside the scope of this research.

This research concentrates its efforts in modelling a station level crossing location within the Melbourne metropolitan area in detail as a case study, because Melbourne metropolitan area is home a very large number of level crossings. The simulation model simulates the operation of the level crossing, the closure of the main arterial roads to motor vehicle traffic, activated by both single and multiple train arrivals and departures. Further complexity was then added to the simulation, requiring it to support and operate multiple trains within a single intersection level crossing closure.

In the simulation model of the proposed environment, a new platform is built about 200 metres further away from the current position but immediately after the intersection level crossing (refer Figure 1.1). The proposed station platform structure and operation of the new station platform arrangement, is simulated and tested accordingly against the simulation the results of the current environment.

It is intended that the results and findings of this study could be used to identify and bring insight to the more than 100 railway stations level crossings in the network, with the same or similar characteristics as the modelled station level crossing. This could provide a ‘theoretical generalisability’ or ‘G’ theory (Bryman & Bell 2007) to these railway stations level crossings considered to be the potential recipients of the remediation process presented in this research.

1.7. Research Significance

The main contribution of this research is through the proposition that mitigation of traffic congestion in the vicinity of railway stations level crossings can be derived by the theory developed as part of this study. Notwithstanding that research has been conducted in Australia and overseas regarding level crossings safety, accidents, as well as to traffic control devices, early warning systems (EWS) and signal preemption, all of these have explored the mitigation of the symptoms of level crossing...
problems and none has explored treating the causes of the level crossings problems. This study is the first of its type to concentrate on addressing the issue of platform positioning at railway stations level crossings, where two modes of land transport, rail and road, cross each other’s path at the same ground level or grade.

The primary contribution of this research is that it addresses the causes of road traffic congestion problems at railway station level crossings, the positioning of platforms at railway stations adjacent to intersecting roads (Guzman, Young & Peszynski 2014). The road traffic congestion in the vicinity of station level crossings is caused by the level crossing intersection remaining closed for long intervals, where trains remain stationary through the process of unloading and loading of passengers from train carriages (Guzman 2008, 2011, 2012; Guzman, Young & Peszynski 2014, 2015). This proposed theory addresses the position of platforms at railway stations.

In addition, this research also contributes to the body of knowledge by enhancing the realm of practice, computer simulation and public awareness of railway level crossings traffic congestion, including the re-positioning of platforms at railway stations next to or in the vicinity of railroad level crossings. Other researchers could benefit from the approach taken in this research, where two simulations, one of the current environment and one of the proposed environments, were developed and provided for the comparison of the results of both simulations.

The target railway station current environment consists of the station infrastructure supporting one Departure Side Platforms (DSP) and an Arrival Side Platform (ASP). Under the proposed environment, the station infrastructure would support two Departure Side Platforms (DSP) infrastructures. The different types of station platform classifications are described in Section 2.3.2. Figure 1.1 illustrates the proposed railway station infrastructure.
Figure 1.1: Proposed DSP – DSP Station Platforms

Figure 1.1 illustrates the proposed station infrastructure comprising of dual Departure Side Platforms (DSP) and the decommissioned Arrival Side Platform (ASP). The proposed station infrastructure environment details, including the two Departure Side Platform (DSP – DSP) platforms arrangement, are described in Section 6.10.

1.8. Thesis Structure

The aim of this study is to examine the causes of road traffic congestion problems at level crossings and presents an alternative solution to the current list of solutions available to transport authorities to resolve level crossing problems. It also differs from previous level crossings research that has been aimed and motivated by accidental death and injuries derived from motor vehicles crashes with trains at level crossings; it is motivated with the aim of providing a new alternative in dealing with station platform infrastructure, said to be causing unintended motor vehicle traffic congestion at these locations.
Chapter 1: Introduction

Chapter Two: Reviews the availability of evidence in relation to motor vehicle traffic congestion in general and its consequences. The topics covered include: motor vehicular traffic congestion in general; level crossings; road traffic congestion and traffic congestion at level crossings; rail networks at large but of more particularly, the Melbourne urban rail network. Most of the documentation encountered and reviewed was related to road traffic congestion in general, safety at level crossings, level crossings accidents, closures of level crossings, preemption and preemption trap issues at level crossings, and the separation of rail/road crossings via tunnel or bridge and related to level crossings issues.

Chapter Three: Reviews and examines level crossings in a general context with an emphasis on the current problems experienced at level crossings and the solutions available to authorities in dealing with problems at level crossings. Reviews are conducted encompassing Melbourne road transport networks, rail networks, railway stations and level crossings in general.

Chapter Four: Explores and discusses the use of computer simulation as a tool to address a complex problem. Discusses and analysis available computer simulation software; reviews the criteria for using simulation software; investigates the available simulation software, including the benefits, advantages and disadvantages when using simulation software as a modelling tool; examines different simulation techniques; expand on the criteria to be used for the selection of the simulation software; investigates and discusses the different design methods and the methodology used when using simulation software modelling; and defines the simulation and research design to be used in the development of the simulation models for this study.

Chapter Five: Summarises current level current crossing operations, including level crossing standards and safety mechanisms, the level crossing train operation activities, entailing the operation of single and multiple train intersection closure activations, rail safety mechanisms,
Chapter 1: Introduction

including train predictors and axle counters and trains headway separation and dwell time, and the primary data the collection process conducted. It discusses trains volumes, derived from timetables and physical observations and road traffic volumes obtained the Victorian roads authority. It also discusses estimated current and future road traffic volumes; these are presented in tables in preparation for its use on the development of the level crossing computer simulation modelling process.

Chapter Six: Presents the simulation modelling development and the building two separate simulation models, one that simulated the current station level crossing intersection environment and another that simulated the proposed station level crossing intersection environment. The aim of these models was to test the effect of platform arrangements on level crossing closures and its impact on motor vehicle traffic congestion at this location. The simulation processes resulted in forty two different combinations of simulation intersection closures performed; visual outputs from the simulations were made available in 3D graphical animation presentation format.

Chapter Seven: The simulation processes and the results from the forty two different combination of simulation performed the results of the simulation processes were analysed, compared, summarised, documented and reported in this chapter. These results, involving different road vehicles traffic flow volumes, all indicate that road traffic congestion mitigation would be derived from the implementation of Departure Side Platforms (DSP). In addition, simulations movies of both the current and proposed environment, captured using 3D graphical animation presentations in video animation format are documented.

Chapter Eight: Concludes the thesis by summarising the study and the new level crossing alternative that has driven this research in the context of level crossings road traffic congestion problems and Departure Sides Platforms (DSP), as an alternative solution. Contributions, implications, benefits and limitations of the proposed alternative are summarised and
Chapter 1: Introduction

presents recommendations for additional research in this area are discussed.
2. LITERATURE REVIEW

An overview of land transport in Australia, from colonial to federation and present times, is conducted to gain an appreciation and understanding of rail and road transport, the networks and how these came into existence and cohabitation. This is followed by a review of some of the legacies resulting from the introduction of these two different transport modals (rail and road).

In addition, a review of railway stations and facilities was conducted that included stations infrastructure, the changes that have occurred over the one and half century since inception of rail and road networks, and how much rail and road traffic has changed overtime, in order to provide context to the research problem.

A review of level crossings was conducted that included research into level crossings around the world, in Australia, in Victoria and in Melbourne. These reviews were related to issues other than accidents and human behaviour at level crossing locations. Melbourne is the focus of the research, because the Greater Melbourne area is home to the largest number of level crossings than any metropolitan areas in Australia.

The issue of level crossing safety and protection, including the types of protection used since the introduction of motor vehicles, were reviewed. Level crossings protection issues, more specifically the introduction and operations of boom barriers at level crossings locations, were also researched in detail. Also, the implications and consequences of the introduction of these safety measures, and the resulting traffic congestions at level crossings, are also explored. An analysis of the research problem will be discussed in the next chapter.

2.1. From Early Colonial to Modern Times

Melbourne, in 1854, was the first of the colonies to introduce a rail system (Cosgrove 2011; Dol 2010). That first rail line, of 3.6 kilometres of tracks, was to carry passenger and transfer cargo to and from ships anchored at
the new Sandridge Pier at Port Melbourne. The event of Melbourne opening the first railway line was followed over the next 35 years by all colonial settlements opening rail lines. From its humble beginnings, the railway system became the dominant transportation mode of the island continent (DoI 2010). Picture 2.1 shows the original Sandridge Pier at Port Melbourne.

**Picture 2.1: Original Sandridge Pier Renamed Station Pier**

![Original Sandridge Pier Renamed Station Pier](source: Sailing ships and steam train at Sandridge Pier, Port Melbourne (RailVic circa 1880))

The Victorian network grew fast, and by the end of the century it had more than 5,000 kilometres of tracks. The individual development infrastructure tactics and efforts used by each of the colonial governments were to have enormous implications into the future. The motives for each colonial government building rail networks, was to connect their own hinterland with the own main city and ports for their own trading purposes (DoI 2010, 2011). Little regard or planning for standards or connectivity was made in each colony; this resulted in a disparity of standard of gauges and rolling
stock in all colonies (DoI 2010). These disparities resulted in problems that would surface later on and would remain a source of problems for many decades to come.

Some of the decisions made by the colonial powers during the second part of the 19th century would impact on transport infrastructure from the time of Federation (in 1901) and well into the future (Wigglesworth 2007). The negative legacies from the introduction of the rail systems of note have been multiple gauge track sizes that have caused problems for intercontinental rail travel, the intersection of railroad level crossings, both of which have caused problems in the island continent all through the 20th century (Railways Museum 2011; Wigglesworth 2008), and the positioning of the platforms at railway stations and its impact on the operation at level crossing intersections (David 2009; Guzman 2008; Guzman, Young & Peszynski 2014; Higgs 2009a, 2009b). These legacies have impacted and affected rail and road transport modal in the past and continue to do so in present times.

2.2. Legacies from the Past
A number of negative legacies resulted from the introduction of the rail networks: having multiple gauge track sizes; having rail-road intersection level crossings; and the issue of platform positioning at stations with level crossings in its vicinity. These colonial legacies, resulting from the introduction of the rail networks, the building of intersecting roads, and the proliferation of the motor vehicle as a mode of transport, have caused problems in Australia through the 20th century and some will continue to do so well into the 21st century and beyond.

2.2.1. Multiple Gauges Track Sizes
In rail transport, the track gauge is the spacing of the rail on the railway tracks, measured between the inner faces of the parallel rails. There are many different sizes of gauges classified into four categories: minimum gauge, narrow gauge, standard gauge and broad gauge. Different gauges were used in developing all the rail networks in the colonies. This lack of
gauge uniformity made rail services in the new colonies difficult or impossible to operate within and across borders.

The problem of the lack of gauge uniformity started to be addressed during WW II; the standardisation of gauges was fully implemented across Australia in 1995. These days, Australia has more than 41,000 kilometres of tracks, with 3,000 kilometres or about 7% of these electrified; intercontinental rail travel is finally a normal affair.

2.2.2. Intersection Level Crossings

The introduction of both modes of land transport, rail and road, particularly when the modes cross each other’s path at the same grade or level, continue to present challenges. The legacy of a large number of level crossings has had detrimental impact on road transport networks, more so in capital cities urban areas, such as Melbourne, contributing to accidents resulting in deaths and injuries, as well as road traffic congestion (COAG 2006; Edquist et al. 2009; Fitzgerald 1950; Lucas 2010; Maslen 2010). The Melbourne metropolitan rail network is home to 182 level crossings, earning the city’s less than attractive title of ‘Melbourne – The City of Level Crossings’ (McNamara & Cox 1979, p. 1).

In stark contrast, another city in Australia, Sydney, has only a handful of level crossings in its urban rail network (Fitzgerald 1950; Guthrie 2011; Lucas 2010). Authorities in Sydney started to address level crossing problems towards the middle of last century by way of grade separation, the process of replacing the level crossing with a bridge, an underpass or a tunnel, separating the railway track from the road (Lucas 2010; Millar & Moynihan 2006; STAYSAFE 2004).

At that time, Melbourne was home to 232 level crossings and there were calls for ‘these dangerous old relics from the past age’ (Fitzgerald 1950, p. 2) to be removed. However, unlike in Sydney, the level crossings problem in metropolitan Melbourne remains and it is not to be resolved in the near future. At the time when authorities in Sydney decided to grade separate all level crossings, authorities in Melbourne decided to start a program of
equipping and upgrading metropolitan level crossings with safety devices such as boom gates or boom barriers, a much cheaper option (Fitzgerald 1950; Tey, Ferreira & Dia 2009; Wigglesworth & Uber 1991). Fitzgerald (1950) was critical of the level crossings legacy, indicating ‘Victoria has been cursed from the beginning by parsimonious Governments. It has more level crossings on its railways than any other State, and compared with other capitals, Melbourne is a most dangerous city for road travellers.’ (Fitzgerald 1950, p. 2).

The boom barriers program in Melbourne was initiated due to a high mortality rate of accidents at level crossings equipped with flashing lights (Wigglesworth 2001; Wigglesworth & Uber 1991). The program, over time, replaced safety equipment installed at many locations, including flashing lights, Wig-Wags (pendulum-like motion signal), give-way and stop sign devices. The program was slow to start and only eight level crossings had replacements installed between 1971 and 1978 and a further 64 crossing replacements were completed between 1983 and 1989 (Wigglesworth 2001).

Nowadays, all 172 level crossings in the Melbourne metropolitan area are fully protected with boom barrier systems (PTV 2013e). The replacement program strategy was considered highly successful (Wigglesworth 2001). However, the success of the program in achieving its goal, that of reducing the accidents mortality rate at level crossings, did not reduce the number of level crossings or pacified road traffic congestion at level crossing intersections in metropolitan Melbourne. Therefore, the issues concerning railroad level crossing closures remain unresolved.

2.2.3. Platform Positioning
The issue of platform positioning has only come to light recently and its implications have not been fully researched or understood (Guzman 2011; Guzman, Young & Peszynski 2014, 2015). The concern of platform positioning is considered to be exacerbating motor vehicle traffic congestion at level crossings adjacent or in the vicinity of railway stations.
(David 2009; Guzman 2008, 2012; Guzman, Peszynski & Young 2014b; Guzman, Young & Peszynski 2015; Higgs 2009b). In addition, the motor vehicle traffic congestion at level crossings worsens during peak hour periods, creating further disruption for road commuters (ENVICT 2005; Guzman, Young & Peszynski 2014, 2015; VAGO 2012). The platform positioning issue was not evident in the past; however, the issue is evident and of concern now by the long periods of closures being experienced at level crossing intersections (Cooper 2012; Guzman 2011, 2012; Guzman, Young & Peszynski 2014, 2015; Hall & Somers 2012).

2.3. Railway Station and Platforms Infrastructure

Since the inception of rail networks and until recent times, train stations have been built with similar configurations. In many cases, the building included housing quarters for the Station Master, with a combination of different platforms, and cantilever veranda to protect patrons from the weather. The main building incorporated a booking hall, ticket office, waiting and rest rooms on the ‘city-bound’ train platform, the up-line side platform. The opposite platform, ‘from the city’ trains platform, the down-line side platform, incorporated a smaller ticket office, perhaps a parcel office or storeroom, and passenger shelter.

Originally, station platforms were designed to elevate passengers and goods to an appropriate height for accessing trains and at the time, the standard specifications were specifically in regards to the height and length of the platform (VRIOG 2006a, 2006b).

Over time, the changes to network operator’s rolling stocks length, safety, efficiency and disability laws, have required changes to platform designs. As such, the most basic components of the specification, being the platform length and height, evolved alongside the dimension of the rolling stock utilised in the network. Despite changes to platform standards, the stations’ configuration and positions of the platforms within stations have remained unchanged since inception, during the second part of the 19th
century. Descriptions and images of stations during mid to late 19th century and early 20th century periods are included in Appendix A.

As demand on the rail network increased, platform design altered considerably due to the realisation that it was the key to improving the safety, efficiency and ambience of the railway station (VRIOG 2006a, 2006b). Safety and DDA Standards\(^3\) have become the prime influences on platform design and as such, the bulk of these standards are driven by legislation. The remainder of the specifications are related to the movement of passengers along and between the platforms and to also ensure that the environment is aesthetically pleasing. These standards include the three platforms dimensions: platform length, platform height and platform width.

The length of a platform is defined as the actual platform edge distance running parallel to the track from one Platform End Barrier to the corresponding opposite Platform End Barrier. The minimum length of platforms is specified as 160 metres; no maximum length of platforms are specified (VRIOG 2006a, 2006b). Nonetheless, there are a number of exemptions.

In the Melbourne metropolitan network, the minimum length of stations platforms allows for a full train set\(^4\) (two three-carriage trains coupled together) to completely fit into the platform area, unless the line is a single line track, supporting single three-carriage trains.

The platform height is defined as the vertical distance separating the rail head plane and the platform edge or coping. The height of platforms is approximately 1080 mm (accepted post construction accuracy is within +0, -10 mm) (VRIOG 2006a, 2006b).

\(^3\) DDA Standards = Disability Discrimination Act Standards (Disability Standards for Accessible Public Transport 2002 [Cwlth]).

\(^4\) There are 4 different types of trains sets used in the Melbourne’s network fleet: Hitachi (143.4 metres), Comeng (144 metres), X'Trapolis (143.34 metres) and Siemens (144 metres) trains.
Chapter 2: Literature Review

The platform width is defined as the horizontal distance, square to the track, separating the platform edge and the nearest face of any permanent structure situated on the platform (VRIOG 2006a, 2006b). The position of platforms in relation to railway stations has served well since the introduction of the rail system and has only become a problem in recent times, specifically with the continual proliferation of the motor vehicle as a mode of transport.

It is noted that station platform length could change in the future, as transport authorities in Melbourne prepare for delivery of next generation trains (NGT) (Carey 2012b, 2014a, 2015b; VicGov 2013). The NGT trains comprise of nine carriages and a length of 215 meters as against the current fleet of six carriages and a length of less than 145 meters (Carey 2012b; VicGov 2013).

2.3.1. Station Classification

Stations are classified depending on the type of platforms and the relative position of the platforms within the station infrastructure. A station can have a single platform, opposite or facing platforms or isle platform, or a combination of an isle platform with a single platform, opposite or facing platforms or isle platform.

There are 210 train stations in the Melbourne urban rail network and the platforms were built in the different configurations stated in the following two tables. Table 2.1 describes the representation of platform combinations in the Melbourne rail network.

<table>
<thead>
<tr>
<th>Platform Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single platform station</td>
<td>One platform servicing a single-track</td>
</tr>
<tr>
<td>Opposite or facing platforms station</td>
<td>Two platforms servicing double-tracks</td>
</tr>
<tr>
<td>Isle platform station</td>
<td>One platform servicing double-tracks</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Platform Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination of single platform and isle platforms station</td>
<td>Two platforms servicing one double-tracks and one single track</td>
</tr>
<tr>
<td>Multiple isle platforms station or any other combination</td>
<td>Multiple platforms servicing double-tracks or combination of double-track and single tracks</td>
</tr>
</tbody>
</table>

Source: The definitions are based on visual observations by the researcher, using Google Earth facilities, of the Melbourne urban rail network.

Of these configurations, opposite or facing platform stations, are the most common configuration used in the Melbourne network, representing sixty six per cent (65.9%) of all stations. Table 2.2 indicates the different platform combinations by numbers and representation percentages in the Melbourne urban rail network.

**Table 2.2: Station Platform Configuration, Type and Representation**

<table>
<thead>
<tr>
<th>Station Platform Type</th>
<th>Number of Platforms</th>
<th>Number of Tracks</th>
<th>Number %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Platform</td>
<td>1</td>
<td>Single-Track</td>
<td>3.3%</td>
</tr>
<tr>
<td>Opposite Platforms</td>
<td>2</td>
<td>Double-Tracks</td>
<td>65.9%</td>
</tr>
<tr>
<td>Isle Platform</td>
<td>1</td>
<td>Double-Tracks</td>
<td>17.6%</td>
</tr>
<tr>
<td>Combination – Single and Isle Platforms</td>
<td>2</td>
<td>Single Track &amp; Double-Tracks or Double-Tracks</td>
<td>12.1%</td>
</tr>
<tr>
<td>Multiple Platforms</td>
<td>2+</td>
<td>Double-Tracks or Double-Tracks &amp; Single Track</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Source: The definitions presented on this table is based on visual observations, using Google Earth facilities, of the 210 station that comprises the Melbourne urban rail network.

Images of some of the Melbourne rail network different types of station platforms combinations are included in Appendix A. In Addition, the position of platforms of the 102 railway stations located at level crossing intersections in Melbourne were assessed to determine the proximity of
the platforms in relation to the intersecting level crossings. Table 2.3 is indicative of the proximity of platforms to level crossings intersections.

Table 2.3: Stations Platform Proximity to Level Crossing

<table>
<thead>
<tr>
<th>Station Platform Proximity (in metres)</th>
<th>Number of Stations</th>
<th>Percentage of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 10</td>
<td>43</td>
<td>42%</td>
</tr>
<tr>
<td>11 - 20</td>
<td>12</td>
<td>11%</td>
</tr>
<tr>
<td>21 - 30</td>
<td>6</td>
<td>6%</td>
</tr>
<tr>
<td>31 - 50</td>
<td>7</td>
<td>7%</td>
</tr>
<tr>
<td>51 - 100</td>
<td>17</td>
<td>17%</td>
</tr>
<tr>
<td>101 - 250</td>
<td>16</td>
<td>16%</td>
</tr>
<tr>
<td>=&gt; 251</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Total</td>
<td>102</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: The data presented on this table is based on visual observations, using Google Earth measurement facilities, of 102 stations in the Melbourne urban rail network.

Table 2.3 indicates the different platform proximity to the adjunct level crossing, in numbers and percentages, of stations in the Melbourne urban rail network. An analysis of the data indicates that a total of sixty eight (68) stations or sixty six per cent (66%) of all station’s platforms near level crossings are located within fifty metres (50mts) from the intersection; thirty four (34) stations or thirty three per cent (33%) are located within two hundred and fifty metres (250mts) from the intersection; the remaining one (1) station or one per cent (1%) of the stations, is further than two hundred and fifty metres (250mts) from the intersection. These 102 railway stations, located in the vicinity of level crossings, with similar platforms positioning infrastructure characteristics, are considered to be the potential recipients of the remediation process presented in this research.
2.3.2. Platform Classification – DSP and ASP

The industry common terminology used to depict the platforms location at railway stations is either the *up-line* platform or *down-line* platform; this terminology is related to the direction of the train travel, and to a degree its origin and destination, where the *up-line* always refers to a city-bound train and the *down-line* always refers to a train from the city. This terminology, though, is not indicative of the position of platforms in relation to the level crossing.

In this research, the platforms at a station are classified as either a Departure Side Platform (DSP) or an Arrival Side Platform (ASP). This classification depends upon the relative position of the platform in relation to the adjunct level crossing intersection; this terminology (i.e. DSP and ASP) was nominated by the researcher and not necessarily industry common practice. This terminology is indicative of the position of platforms in relation to the level crossing, but it does not indicate the direction of the train travel. The configuration of the railway station focus of this research is an opposite site platform configuration; the Departure Side Platform (DSP) is the *down-line* from the city train; the Arrival Side Platform (ASP) is the *up-line* to the city train. Table 2.4 describes the two processes or operations of these types of platforms.

**Table 2.4: Current Station Platform Operation Classification**

<table>
<thead>
<tr>
<th>Platform Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departure Side Platform (DSP)</td>
<td>In this platform, the arriving train crosses the intersecting level crossing and then stops at the platform to unload and load passengers and then continues its journey</td>
</tr>
<tr>
<td>Arrival Side Platform (ASP)</td>
<td>In this platform, the arriving train stops at the platform to unload and load passengers and then crosses the intersecting level crossing and then continues its journey</td>
</tr>
</tbody>
</table>

Source: The details presented are based on visual observations by the researcher at stations along the Melbourne urban rail network.
Table 2.4 indicates the activities of trains at both types of platforms. A train visiting or passing a station initiates a number of operations and these can be described as follows. As a train in either direction approaches the station, the level crossing system automatically locks down the intersection; the actual detection of the train activates the closure of the intersection, closing the intersection to all other traffic, motorised and/or pedestrian. Subsequently, two different operations occur depending on the direction of the train activating the closure:

- At the Departure Side Platform (DSP), the train clears the level crossing, automatically opening the intersection to all road traffic. The train then stops at the platform to unload and load passengers. After completing the unloading and loading process, the train departs the platform, continuing its journey.

- At the Arrival Side Platform (ASP), the train stops at the platform to unload and load passengers before it clears the level crossing intersection. The intersection remains closed during the unloading and loading of passengers. The train then departs the platform area, continuing its journey. The train clears the level crossing, automatically opening the intersection to all road traffic. This last operation, where the intersection remains closed for an extended period of time during the loading and unloading of passengers, is said to exacerbate road traffic congestion (David 2009; Gordon 2015; Guzman 2008; Guzman, Young & Peszynski 2014, 2015; Higgs 2009a, 2009b).

The major difference between both platforms operation is that at a DSP platform, the intersection is closed for a short period of time, as the train passes the level crossing, and opens immediately after the train clears the crossing. The ASP platform operation is different and the intersection remains closed during the loading and unloading of passengers. For as long as the train remains at the station precinct, the intersection remains closed to all other traffic.
These operations are further complicated when multiple trains arrive at the station in close succession. This event occurs more frequently during peak periods, when several trains (up to seven trains were counted during observations) visit the station platforms before the intersection finally re-opens. Consequently, the disruption of road traffic flow caused by the closure of the intersection, as part of the operation and activities of the level crossing train safety process, creates road traffic congestion. The road traffic congestion is exacerbated during peak hour periods, when demand for road availability intensifies.

These extended periods of intersection closures are considered to be causing worsening motor vehicle traffic congestion at level crossings, particularly for crossings that are situated adjacent or in the vicinity of railway stations (Gordon 2015; Guzman 2008, 2010, 2011, 2012; Guzman, Young & Peszynski 2014, 2015).

The platform positioning issue was not considered a problem or evident when Melbourne rail patronage was low, because the frequency of train services was also low. As train services increased to accommodate the unexpected patronage demand and overcrowding issues, and vehicular road traffic congestion at level crossings increased accordingly, further intensified from additional intersection closure activity at level crossings (Gordon 2015; Guzman 2010, 2011, 2012; Guzman, Peszynski & Young 2014b; Guzman, Young & Peszynski 2014, 2015).

Sample images of some of the Melbourne rail network different ASP and DSP station platform combinations are included in Appendix A.

2.4. Increases in Rail and Road Traffic

During the last decade and as a measure to counteract the large patronage demand, rail authorities in Melbourne initially provided more than 635 extra weekly train services (Metro 2011b; VAGO 2010). Further, between 2011 and 2012, more than 1,000 new weekly train services were added to the system (Baillieu 2012; Carey 2014a). These extra services combined, average about 15 additional train services per day in both
directions, for most of the 16 lines in the Melbourne network. In addition, the volume and type of road vehicular traffic also increased over the same period. The effect of the transport mode changes can be exemplified by the way Melbournians have travelled to work over the last three and half decades. Figure 2.1 is indicative of the changes in rail, road and other modes of transport to work between 1976 and 2011.

**Figure 2.1: Journey to Work in Melbourne 1976–2011**

![Journey to Work in Melbourne 1976–2011](image)

Source: Data compiled from Travel to work in Australian capital cities 1976-2011 (Mees & Groenhart 2012)

Figure 2.1 reflects the modes of transport to work changes over the last 35 years. The use of the private motor vehicle increased steadily, peaked in 1996 and then slowly declined to 2011. Public transport as a mode of transport declined steadily from 1976 to 1996; steadily increasing since 2011. Walking, cycling and other modes of transport to work fluctuated little over the 35 years period.

The additional rail traffic created by new services, combined with the additional road traffic, has had a negative impact on road congestion in general, but specifically at level crossing locations (Guzman 2011, 2012; Guzman, Young & Peszynski 2014, 2015). This is indicative in research
conducted in 2008 at a level crossing along the Dandenong line in Melbourne’s South East. At that time, the rail line traffic was 228 train services per day (Connex 2008; Guzman 2008; V/Line 2008a, 2008b). Daily, between the hours of 7:00 am and 7:00 pm, activity at the level crossing kept the intersection open to road traffic for nine hours and closed for three hours (Guzman 2008, 2010).

Research conducted along a selected line location at the end of 2011 and 2012, counted 272 and 273 services per day respectively (Guzman 2012; Metro 2011a; V/Line 2011a, 2011b). That research indicated that between the hours of 7:00 am and 7:00 pm, the activity at the level crossing kept the intersection open for eight hours and closed for four hours (Guzman 2012). The increased train traffic, an additional 44 trains events per day, impacted on this and the 28 other level crossing intersections of this corridor (Guzman, Peszynski & Young 2014b), closing all arterial and intersecting roads, during the twelve hour period, for between three and four hours every working week day (Guzman 2012).

As large increases in services were introduced on all railway lines in the Melbourne metropolitan area; thus, it is most likely that similar level crossing intersection closure activities are being experienced at all level crossings intersections along the Melbourne’s rail network.

Further, site analysis were conducted at seventeen level crossing locations in metropolitan Melbourne to investigate morning peak-time (7:00am to 9:00am) road level crossing closure periods (Gordon 2015). The results of that analysis indicated level crossing intersection closure periods ranging from eighty seven minutes (87min) or seventy two per cent (72%) of the time to thirty minutes (30min) or twenty five per cent (25%) of the time during the two-hour period (Gordon 2015). That analysis indicates that the target station level crossing of this research, the Clayton Station level crossing, was closed to road traffic for eighty two minutes (82min) or sixty eight per cent (68%) of the time during the two-hour morning peak-time period (Gordon 2015).
It is noted that different stakeholders view the term 'peak-time period' differently. Road transport stakeholders consider peak-time period a two-hour period: the morning peak period is between 7:00AM and 9:00AM; the afternoon peak period is between 4:00PM and 6:00PM. Railway timetables, however, consider peak-time period as a one and a half hour period with the morning peak period classified as between 7:30AM and 9:00AM and the afternoon peak period as classified between 4:30PM and 6:00PM.

2.5. Level Crossings
A railroad level crossing is an intersection where two modes of transport, rail and roads, cross each other’s path at ground level (DTEI 2006; Taylor, J & Crawford 2010; Tey & Ferreira 2010; VicRoads 2011b; Wallace 2008), where both compete for the same ground space. Level crossings are not unique to railroad crossings; level crossings occur at intersections of most, if not all types of vehicles or fast moving equipment. On land, in addition to railroad crossings, there are also highway/road, road/road and rail/rail crossings; at sea there are shipping crossings in navigational channels; in the air there are navigation controlled airspace areas.

Railroad level crossings are unique as the only type of crossing of two different infrastructures, infrastructures that are under different responsibilities, and used by vehicles with considerable different performance, power, capacity and dimensions (ESCAP/UN 2000). Of all the transportation modes, air, sea and land, railroad level crossings are some of the most complex control systems from a safety point of view (Tey, Ferreira & Wallace 2011).

One of the main concerns for authorities in regards to railroad level crossings is related to the high risk and level crossing safety at these locations, along with the prevention of loss of life, injury and material damage arising from collisions. Accidents at railroad level crossings are infrequent, but when accidents occur, these can be with detrimental
consequences, thus making safety a high priority with authorities (Rudin-Brown et al. 2011).

2.5.1. **Level Crossings around the World**

Level crossings are found on rail networks all around the world. They exist in developed countries, in developing countries, as well as in underdeveloped countries; they exist in large countries and small countries alike. For example, in the United States there are 155,000 at-grade crossings, the local term to refer to level crossings (IRSE 2009). Table 2.5 is indicative of some level crossings around different countries.

**Table 2.5: Sample List of Level Crossings around the World**

<table>
<thead>
<tr>
<th>Country</th>
<th>Level Crossings</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>155,000</td>
</tr>
<tr>
<td>India</td>
<td>40,445</td>
</tr>
<tr>
<td>Japan</td>
<td>35,612</td>
</tr>
<tr>
<td>France</td>
<td>19,000</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>13,581</td>
</tr>
<tr>
<td>China</td>
<td>12,000</td>
</tr>
<tr>
<td>Great Britain</td>
<td>8,000</td>
</tr>
<tr>
<td>Australia</td>
<td>7,943</td>
</tr>
<tr>
<td>Sweden</td>
<td>7,600</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1,393</td>
</tr>
</tbody>
</table>

Source: US (Noyce & Fambro 1998); India (ESCAP/UN 2000); Japan (IRSE 2009); France (RSSB 2006); Russia (ESCAP/UN 2000); China (SELCAT, 2007); UK (RSSB 2006); Australia (ITSRR 2008); Sweden (RSSB 2006); New Zealand (RISSB 2009)

2.5.2. **Level Crossings in Australia**

There are 7,943 public level crossings, termed in this research as level crossings, in Australia; this figure does not include other types of level crossings such as private, pedestrian, maintenance and sugar cane level
crossings, which total 14,130 crossings, giving a grand total of 23,532 crossings of all level crossing types across the country (RISSB 2009). Another commonly used figure is the existence of 9,400 public level crossings in the country (RISSB 2009; Tey & Ferreira 2010). Australia’s population in 2012 was 22,597 million people (ABS 2012), giving a level crossing/population ratio in the country of one level crossing per every 2,485 people. Table 1.1 is indicative of the level crossings, population and accidents mortality statistics for each State and Territory in Australia.

2.5.3. Level Crossings in Victoria
Victoria has the largest number of level crossings than any other state or territory in Australia, with 1,872 level crossings or twenty three point six per cent (23.6%) of all the level crossings in the country (ITSRR 2008; PTV 2013e; RSC 2008b). Victoria is home to 5,603 million people or twenty four point eight per cent (24.8%) of the Australian population (ABS 2012). The level crossing/ population ratio in the state is one level crossing every 2,993 people; this figure is 20% higher than the average crossing/ population ratio in the country. Victoria also accounts for the highest mortality rate resulting from accidents at level crossings than any other state or territory in Australia; almost forty per cent (40%) of all deaths (refer to Table 1.1) resulting from accidents involving rail and road vehicles between 2002 and 2012, occurred in Victoria (ATSB 2012).

2.5.4. Level Crossings in Melbourne
Melbourne, with a population of 4.248 million people (ABS 2012), is home to 182 public level crossings, more than any other capital city in the country (Lucas 2010; PTV 2013e). The Greater Melbourne area is home to 182 level crossings and the Melbourne metropolitan area is home to 172 level crossings. In comparison, Sydney metropolitan area, is home to only five level crossings in its urban rail network (Fitzgerald 1950; Williams & Creber 2005).
2.6. Level Crossings Safety

Due to the high risk and safety concerns regarding rail operations, which include level crossings operations, strict regulations exist for the permitted train approximation distances, termed headway, and for the operation of level crossings. More specific detailed aspects of the operations of level crossings safety devices are presented in Section 3.5.

2.6.1. Train Headway Separation and Dwell Time

In conventional urban rail systems, two-minute headways or 30 trains per hour per track line are regarded as the norm (Mees 2008; Vuchic 2007). In Victoria, the Department of Transport contends that three minute headways, or 20 trains per hour, is the limit standard. SKM et al. (2008) expand on the reason that a higher practical capacity is not considered possible in Melbourne was because ‘of the long dwell times at the city loop stations, which are up to 50 seconds, and also the irregular arrival of trains from different lines at the loop portals’ (SKM, Maunsell & Evans & Peck 2008, p. 27).

As a safety measure, trains travelling in the same direction/time are not permitted to get in close proximity of each other; this is termed headway (VRIOG 2009a). Thus, there are inbuilt track electromechanical devices and signals to ensure headway is maintained between trains. These devices are called axle counters and ensure that a train does not enter a track section occupied by another train. If a train does enter a section that is not free from the train ahead, a ‘dead man’ switch on the track comes in contact with the offending train braking system, activating the train emergency braking system, forcing the train to come to a halt. According to VRIOG, an axle counting system is a failsafe system that detects the absence or presence of a train within given track sections (VRIOG 2009c). After it is activated, the train driver has the option to override the failsafe mechanism. Further, axle counters are discussed in more details in Section 5.1.
2.6.2. **Level Crossings Operation Standards**

There are strict Australian standards for the activation and operation of level crossings safety equipment; these standards come under Australian Standard: *Railway Crossings – Active Control Treatments* (AS1742.7 2007). The standards specify that the flashing signals shall commence activation a minimum of 20 seconds prior to the arrival of a train at a single track crossing, but some railway organisations may require longer times. Greater periods may be required at multiple track crossing (AS1742.7 2007). In addition, different jurisdictions sanction different standards. For example, the Office of Rail Regulations (ORR) in the UK specifies that a minimum of a 27 second warning of a train arrival at level crossings must be maintained at all level crossings (ORR 2010).

In Victoria level crossing operations, the operating system must provide sensitivity capable of assuring a warning time of 25 seconds (minimum) for constant train speeds of 2 mph or greater (VRIOG 2009b). This period ensures that the immediate crossing area can be cleared of road and pedestrian traffic (first 5 seconds), the boom barriers are lowered and the road and pathway are closed to traffic before the train arrival (remaining 20 seconds) (VRIOG 2009b). Further, level crossing safety operations are discussed in more details in Section 5.3.

2.6.3. **Level Crossings Safety and Accidents**

As indicated in Section 2.5, railroad level crossings are intersections where two modes of transport, rail and road, cross each other’s path at the same level, where both compete for the same ground space. These areas are considered high risk, as trains, which have priority at all intersections, cannot stop quickly in emergencies, requiring a long distance to come to a halt. The type of risk at these locations is considered low in frequency but with high consequences, where injury and fatality levels are predominantly high (RSC 2008b).

No research appears to have been conducted specifically that addresses the cause of the railway stations level crossing problem, the position of
platforms at railway stations in the vicinity of level crossings. Instead, research has been conducted focusing on the symptoms of the problem. Previous research conducted regarding level crossings, were primarily concerned with level crossing safety, accidents and mortality at level crossing, preemption and preemption trap issues at level crossings, road congestion in general at level crossings or to understand driver behaviour at level crossing locations. Section 3.5 elaborates on previous research conducted on the topic.

In addition to the abovementioned reviewed issues, other relevant matters were also investigated as part of this research. These included topics regarding level crossing safety protection issues such as: level crossings accidents in Australia; responsibility for level crossings protection; level crossings protection counts; active and passive level crossing protection; and level crossing safety devices, including the operation boom barrier system.

The primary purpose of this research is to investigate the impact of railway station platform positions on road traffic congestion at railway stations level crossing locations; this research is not oriented towards addressing or resolving safety or other issues at level crossings. Accordingly, these issues were reviewed and are acknowledged, but it was determined these were not applicable to this research.

2.7. Road Traffic Congestion
When the term congestion is used, the immediate connotation is one of negativity, that congestion is bad for us. According to Blunden, this is not necessarily so, this is a misconception (Blunden 1983). Blunden presents the idea that there are two kinds of congestion. One is due to inefficiencies and is an enemy that must be combated; it has negative impact by slowing down or stopping activities. The other is due to pressures of demand, the need for more; this one must be welcome, as it is a sign of vibrant and healthy economic activity. Others propose similar ideas, adding that congestion is a sign of success, of a successful city (Taylor, 2002; ECMT,
2004). Downs (2004) further indicates traffic congestion reflects economic prosperity is here to stay, and that nothing can eliminate traffic congestion from large metropolitan regions around the world; only serious recessions can forestall its increasing (Downs 2004). Yet others indicated that road congestion and the cost congestion is used to ‘justify vast expenditure on road infrastructure’ (Low & Odgers 2012, p. 2).

Melbourne, like many metropolises around the world, is suffering from the effects of traffic congestion, delays and bottlenecks (BTRE 2007; VicGov 2013). These are caused by a number of factors including: network limitations (DoT 2008); a severe underinvestment in transport infrastructure during the decades of the 1980s and 1990s (Stanley & Barrett 2010); restrictions and capacity constraints within the road and transport networks (VicGov 2007); inability for increases on public transport services after long periods of low patronage (Dol 2007); and from the ever increasing demand for more capacity derived from population growth and from the increasing dependence on the motor vehicle as a mode of transport (Cervero 1998; Dol 2007; DoT/Dol 2006; Mees & Groenhart 2012; VAGO 2012); all of which exacerbate road traffic congestion problem further.

2.7.1. Congestion at Level Crossings

Traffic congestion at level crossings, as the phenomena, occurs at level crossings in other countries as well (ESCAP/UN 2000; OECD/ECMT 2007). For example, traffic delays at Great Britain’s 7,000 public level crossings are of concern, not only due to the traffic congestion derived from them, but also the additional issue of vehicle emission, safety and economic costs caused by delays at level crossings (Delmonte & Tong 2008).

Delmonte and Tong (2008) investigated opportunities for improving level crossing operations in view of increasing effectiveness and reducing delays on both rail and road networks. Some of the findings of that report are: there are numerous different types of level crossings in operation and
the manually operated (with or without CCTV) cause the most congestion; ‘serious delays’ has different meanings to stakeholders and authorities; there is no standard procedure to deal with traffic delays; most aim at reducing risk; level crossings are made scapegoats for all traffic malice’s in towns, mainly caused by roundabouts and other intersections; there is no national funding for the closure of level crossings; and there is a need for interaction between road, rail and town planning authorities (Delmonte & Tong 2008).

2.7.2. Traffic Congestion and Level Crossing

Trains have right-of-way at level crossings and crossings must be closed to all traffic when a train is in its proximity. The introduction of safety devices at level crossings combined with increases in rail and road traffic, has had unintended consequences at these locations. Additional train services introduced to deal with growth in patronage and overcrowding issues, resulted in further road traffic congestion at level crossing locations (Carey 2012a; Guzman 2011; Guzman, Peszynski & Young 2014b) and are ‘a barrier to the efficient performance of the transport network’ (Taylor, J & Crawford 2010, p. 1); these could be classed as the types of inefficiencies and enemy to be combated as referred to by Blunden (1983).

Over time, motor vehicular traffic has grown and the closure of roads for any length of time, as a direct result of additional train traffic, intensifies motor vehicles traffic congestion, congestion that is specifically worse during peak-hour periods (Lucas 2010; VicRoads 2010). Nowadays, suburban train lines carrying 200 or more train services per day are the norm and not the exception (Metro 2011a), as are intersecting major arterial roads carrying 25,000 or more motor vehicles per day (VicRoads 2008b). Level crossing intersections, located at railway stations precincts, are areas where the traffic congestion from closure of roads, are affecting motor vehicle commuters, shopping centres customers, retailers, the neighbourhoods and the population in general (Lucas 2010). Future trends
indicate that the problem will be exacerbated by increases in train volumes; by 2021, some rail lines, during peak period, will carry almost 40 train per hour, increasing level crossings closure activity (Taylor, J & Crawford 2010). A recent Federal Government infrastructure audit report indicates that demand for public transport in Melbourne will increase 89% by 2031 (Infrastructure Australia 2015).

2.8. The Costs of Congestion

The cost of congestion is said to be the difference between the total cost of travel and the benefits resulting from such travel (VCEC 2006b). It is suggested that the more appropriate name for the road congestion phenomenon is ‘the avoidable cost of congestion’ (BTRE 2007, p. 108), as it is indeed a cost that can be avoided, when suitable measures are taken. Road traffic congestion is expensive in resources and there are indications of at least four external costs associated with traffic congestion: extra travel time costs, environmental pollution costs, traffic accident costs, fuel consumption costs and there are also the additional costs of wear-and-tear to vehicles for the running and travel (Luo et al. 2007). Other effects from traffic congestion include increased fuel usage, higher vehicle maintenance cost, idle time of commuters including public transport and emergency services, lost productivity, longer delivery times, undelivered goods, delays and supply chain disruption (Coyle et al. 2010; Gargett & Gafney 2005).

Studies indicate urban road congestion already costs Australia about 2% of GDP (PJPL 2005), and there are reports that indicate the current yearly cost of congestion to be $9.4 billion (BTRE 2007; COAG 2006). In Victoria, VCEC estimates the current economic cost of congestion in Melbourne is in the range of $1.3 billion to $2.6 billion per year (VCEC 2006a). Table 2.6 indicates the cost of congestion for Australian capital cities during 2005 and the expected cost for 2020.
### Table 2.6: Costs of Congestion in Capital Cities 2005–2020

<table>
<thead>
<tr>
<th>Australian Capital Cities /Period</th>
<th>2005 in $Million per Year</th>
<th>2020 Estimate in $Million per Year</th>
<th>2005–2020 Growth Estimate %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>$3,500</td>
<td>$7,800</td>
<td>223%</td>
</tr>
<tr>
<td>Melbourne</td>
<td>$3,000</td>
<td>$6,100</td>
<td>203%</td>
</tr>
<tr>
<td>Brisbane</td>
<td>$1,200</td>
<td>$3,000</td>
<td>250%</td>
</tr>
<tr>
<td>Perth</td>
<td>$900</td>
<td>$2,100</td>
<td>233%</td>
</tr>
<tr>
<td>Adelaide</td>
<td>$600</td>
<td>$1,100</td>
<td>183%</td>
</tr>
<tr>
<td>Canberra</td>
<td>$110</td>
<td>$200</td>
<td>182%</td>
</tr>
<tr>
<td>Hobart</td>
<td>$50</td>
<td>$70</td>
<td>140%</td>
</tr>
<tr>
<td>Darwin</td>
<td>$18</td>
<td>$35</td>
<td>194%</td>
</tr>
<tr>
<td><strong>Total Congestion Cost</strong></td>
<td><strong>$9,400</strong></td>
<td><strong>$20,400</strong></td>
<td><strong>217%</strong></td>
</tr>
</tbody>
</table>

Source: (BTRE 2007; COAG 2006)

Others disagree with these figures and propose that the figures are conservative, approximating that the total congestion cost in Australia would reach $29.7 billion by 2015 (PJPL 2005), much higher and much earlier than other estimates (BTRE 2007; VCEC 2006a). These separate estimates have something in common: the concurrence that traffic congestion will continue rising; they differ by how much and over what period congestion increases will occur (BTRE 2007; PJPL 2005; VCEC 2006a).

But not everyone agrees with the concept and figures presented, with Low and Odgers (2012) indicating that these are 'exaggerated claims made by politicians and infrastructure advocates', and the real economic cost of congestion is much lower and predominately caused by private car traffic (Low & Odgers 2012).

The congestion cost and increases in greenhouse gas emissions are of concern (BTRE 2005) and the amount of road traffic is not going to abate.
in the future (Guzman, Peszynski & Young 2014b; Infrastructure Australia 2015); as populations expand, travel demand will continue to growth (ABS 2009). With the increase in demand for both rail and road, congestion in general and specifically road congestion at level crossings will swell to new levels (Infrastructure Australia 2015; Taylor, J & Crawford 2010). A recent Federal Government infrastructure audit report indicates that the congestion cost in Australia will grow to $53 billion per year by 2031 (Infrastructure Australia 2015). According to that report, Melbourne congestion will surge to more than $9 billion during the same period billion (Infrastructure Australia 2015).

Private transport, or more specifically, motor vehicle traffic and congestion are responsible for a significant use of energy (i.e. fossil fuels) and greenhouse gas emissions (DCC 2013; Lindsey et al. 2010). Commuter’s travel behaviour and public transport operations will both need to be altered considerably to change this and to be able to gain the full potential benefit of less pollution (Wilkenfeld, Hamilton & Saddler 2007). Implementing changes to limit private vehicle ownership is one solution that could reduce energy (fuel) and emissions (greenhouse gas) as well as congestion in large cities in various continents (Poudenx 2008).

However, it is believed that there are reasons why these measures are not working, and these include convenience, comfort and standard of living; commuters prefer to use their own transport (Wilkenfeld, Hamilton & Saddler 2007). Commuters prefer the flexibility of driving themselves instead of using public transport, if one is available, and are prepared to pay the price in costs, time and risk, for the privilege. Wilkenfeld et al. (2007) suggest that in addition to the issues of privacy, convenience, comfort and standard of living, the problems are partly due to the way our cities have developed and the distances between suburbs.

This research agrees with the suggestions from Wilkenfeld et al. (2007) regarding commuters preferring private to public transport and the problems caused by the way Melbourne, as a city, evolved. This research
further suggests that the problems currently faced at all level crossings locations in relation to road congestion, are a direct result of both of these issues; the way Melbourne developed into large areas covering many suburbs, and the private mode of transport currently in used due to the absence of an extended and reliable public transport network. In addition, the lack of investment to update or replace 19th century infrastructure at rail-road intersections level crossings has had and will continue to have, a negative impact on Melbourne’s economy and population wellbeing. It has been suggested that if commuter’s road travel time in Sydney, for instance, were to reduced their travel by five minutes per each trip, the result would be benefits amounting to $3.6 billion per year (Gittins 2014).

2.9. Summary
This chapter discussed the topics of level crossings, level crossings operations and safety, current problems at level crossings, road traffic congestion, road traffic congestion at level crossings and available methods and solutions to address level crossings problems. It delves into Australia’s land transport, from early colonial to present times, and how these transport modes came into existence and cohabitation. It also discusses the legacies resulting from the introduction of the two different transport modals, rail and road; road traffic congestion in general and the cost of congestion are also discussed. It further examines railway stations and infrastructure, level crossings abroad, in Australia, in Victoria and in Melbourne; the issues of platform position at railway stations, including the types of platforms, Departure Side Platforms (DSP) and Arrival Side Platforms (ASP), are explored in detail. Issues pertaining to level crossing locations, including safety measures and traffic congestion at railway station level crossing locations, were also discussed.

The road traffic congestion at railway station level crossing locations topic was impaired by the limited published local evidence on the subject; most of the documented evidence was obtained from government reports, newspapers articles, archives and local knowledge. A full analysis of the
problem with level crossings in general and current solutions available to transport authorities for the treatment of level crossings problems, are presented in Chapter 3.

Further, a number of colonial legacies resulting from the introduction of the rail networks were revealed during the literature review process. These included the problems associated with multiple gauge track sizes, having rail-road intersection level crossings and the positioning of platform at railway stations with level crossings in its vicinity. These legacies are an unintended result from the introduction of the rail networks, the building of intersecting roads, and the proliferation of the motor vehicle as a mode of transport. These legacies have caused problems in Australia all through the 20th century and some will continue to do so well into the 21st century and beyond.

The rail tracks gauge legacy is no longer the problem that once was; intercontinental rail travel in Australia become a reality when the gauge uniformity problem was finally completed in 1995, when the standardisation of gauges was fully implemented connecting all Australian capitals cities.

The intersection level crossings legacy remains and the problem is aggravated by the additional road and rail traffic increases, and it would not be resolved for many years to come; the result is that level crossing road congestion will remain and will be exacerbated by increases in both rail and road traffic caused by population growth demand. In 1950, Fitzgerald indicated the existence of 232 level crossings in Melbourne (Fitzgerald 1950); today, the Greater Melbourne area is still home to 182 level crossings, in what Fitzgerald (1950) refers to as the curse of parsimonious Governments actions.

The platform positioning legacy problem was not evident in the past, when demand for rail transport was slow or in decline, and road traffic was on the increase. However, the issue is obvious and of concern now, manifesting in long periods of intersection closures experienced at level
crossings. The station platforms positioning is considered to be causing exacerbating motor vehicle traffic congestion at level crossings adjacent or in the vicinity of railway stations. The platforms positioning at railway station in the vicinity of level crossings issue has only come to light recently and its implications have not been fully researched or understood. Therefore, the platform positioning arrangements at railway station near level crossings is the **main focus of this research**.
Chapter 3: Analysis of the Problem and Current Solutions

3. ANALYSIS OF THE PROBLEMS AND CURRENT SOLUTIONS

3.1. Introduction

The emphasis of this chapter is on reviewing the legacy of level crossings, the problems experienced at level crossings with increases in both rail and road traffic, and the current alternatives available to transport authorities in dealing with the legacy of level crossings. The concept of the platforms positioning problem at railway station in the vicinity of level crossings is introduced; this is the focus of this research. This new concept deals with level crossings railway station problems and it is termed in this research as Departure Side Platforms (DSP). Further, another concept that could help to deal with level crossings problems, Zonal Operations (ZO), is also introduced.

The main concerns about level crossings have been issues related to safety at level crossing locations, along with the prevention of life losses, injury and material damage arising from collisions at these intersections (Lee, Nam & Park 2005; Taylor, J & Crawford 2010). Taylor and Crawford suggest that another issue of concern with level crossings, though not of primary concern in most jurisdictions, is related to vehicular traffic congestion in the vicinity of the level crossings. This should be the case in Melbourne, because the large number of level crossing in the metropolitan area are causing road congestion, making it a primordial case for the grade separations of all level crossings in the metropolitan area (Taylor, J & Crawford 2010). Level crossings in Melbourne are aggravating road traffic congestion and are also a contributing factor to the inefficient operations of transport networks (Carey 2011, 2015c; Fitzgerald 1950; Gordon 2015; Guzman, Peszynski & Young 2014b; Lucas 2009a, 2010; VCEC 2006a).

Fitzgerald indicated in 1950 that ‘the prospect of getting on with the job of abolishing Victoria’s level crossings look worse now than they did before the war.’ (Fitzgerald 1950). Fitzgerald was right and was making reference
to WWII; more than sixty five years after he made the remarks, the level crossing legacy in Melbourne remains unresolved.

3.2. Melbourne Rail Infrastructure
Melbourne’s rail network and station infrastructure, including platform positioning, were developed during the second part of the 19th century; only one of the sixteen lines of the Melbourne metropolitan rail network, the Glen Waverly line, was completed early during the 20th century. The introduction of motor vehicles as a mode of transport early in the 20th century led to the building of paved roads and necessitated the introduction of safety devices, such as boom gates and boom barriers at railroad crossings, to separate both modes of transport from each other’s path. Over time, due to population growth and travel demand, as well as increases in travel distances, both transport infrastructure modes expanded in length, enlarged in volumes and augmented in travelling speeds.

Furthermore, station infrastructure and platforms positioning at railway stations have not changed since inception of the rail networks; the position of a station platforms in relation to level crossings intersection, forces the intersection to remain closed to road traffic for extended periods of time, unintentionally creating additional traffic congestion on roads in the vicinity or in close proximity of station level crossings.

3.3. What is the Problem?
Nineteenth century station infrastructure platform positions are causing longer than necessary road closures. The position of platforms in relation to level crossings intersection, combined with increases in train traffic along rail corridors, creates additional and longer intersection road closures; these road closures exacerbate road traffic congestion in the vicinity of railway stations level crossings, congestion which is not conducive to the efficient running of 21st century transport networks.
Chapter 3: Analysis of the Problem and Current Solutions

Research by Taylor and Crawford (2010) indicated that the average single train intersection closure times were well in excess of one minute (60s). The problem stands with level crossing intersection closure periods that differ in time depending on the direction of train activating the closure. Under observed conditions carried out and recorded by this research, closure times for a single train average forty six seconds (46s) in one direction and average one minute and forty one seconds (101s) in the opposite direction, (Guzman 2008, 2011, 2012).

Level crossing intersection closures are further complicated when multiple trains arrive at a station within a short space of time; this results on the intersection remaining closed for long periods, with Lucas (2010) reporting level crossings experiencing four-train closures of seven minutes or more at a time (Lucas 2010). Under observed conditions carried out at a level crossing by this research, the average longest continues closure for a six-train closure, was in excess of ten minutes (600s) (Guzman 2008, 2011, 2012). Specific to the case study in Melbourne, a recent site analysis conducted by Gordon (2015) at seventeen level crossing locations in metropolitan Melbourne, investigating closure periods during the two-hour morning peak-time period, indicated level crossing intersection closure ranging from eighty seven minutes or 72% of the time to thirty minutes or 25% of the time during the two-hour morning peak-time period (Gordon 2015).

The road traffic congestion in the vicinity of station level crossings is caused by the level crossing intersection remaining closed for long intervals; the position of one of the station platforms and its relative position to the level crossing area, forces the intersection to remain closed during the unloading and loading of passengers from train carriages (Guzman 2008, 2011, 2012; Guzman, Young & Peszynski 2014, 2015).

In addition, in 2011 Metro introduced new timetables throughout the network that provided 635 new weekly services (Metro 2011b); this amounted to about five additional services for each of the sixteen lines of
Chapter 3: Analysis of the Problem and Current Solutions

the network each day. In 2013, the Transport Minister indicated that the
government has introduced 1078 new services per week (Carey 2014a);
this amounted to about nine additional services for each of the sixteen
lines of the network each day. There are more services available and
these are a welcome relief to train commuters.

However, the introduction of additional train services to the Melbourne
urban network, increased train traffic along all rail corridors; the much
needed train services traffic generated additional intersection closures at
level crossings, leading to further road traffic congestion at level crossings
intersections (Carey 2011; Guzman 2010; Guzman, Peszynski & Young
2014b; Guzman, Young & Peszynski 2014, 2015; Taylor, J & Crawford
2010).

Traffic congestion at level crossings is expected to worsen in the future.
The need for public transport in Melbourne, particularly the train network,
will increase during the next twenty years to new heights (Infrastructure
Australia 2015; Lucas 2015). According to a Federal Government new
audit report of Melbourne’s future transport needs, demand for public
transport will increase by 89% by 2031 (Infrastructure Australia 2015;
Lucas 2015).

3.4. What Research Has Been Done?
An exhaustive review of the literature found no studies related to railway
station platform positioning or similar topics related to railway stations
infrastructure in the vicinity of level crossings. Research concerning level
crossings, has so far mainly addressed issues of level crossing safety
(DoT 2009; VAGO 2010; Wigglesworth 1978, 2007; Yohe & Urbanik II
2007), level crossing accidents (Berry & Harrison 2008; CARRS-Q 2009;
Davey et al. 2007, 2008), deaths resulting from accidents at level
crossings (Clarke et al. 2010; Dmytryshchak 2012; Loumiet & Jungbauer
2006; OCI 2009; VAGO 2010), drivers and pedestrian’s behaviour at level
crossings locations (Davey, Ibrahim & Wallace 2006; Wallace 2008).
Signals preemption and preemption trap issues (Brennan Jr. Thomas M.

The issue of road traffic congestion in general has been explored (CfM 2011b; ENVICT 2005; FHWA 2005; Infrastructure Australia 2015; PoMC 2005; Taylor, B 2002), but little or no attention has been given, other than in relation to signals preemption and congestion, preemption trap and clearing vehicles from the intersection level crossing (Brennan Jr. Thomas M. et al. 2009; Cho 2003; DeeAngela 2004; Goldblatt & Horn 1999; Hall & Somers 2012; Jacobson 1997; Roberts 2005; Yohe & Urbanik II 2007), to the implications of stations platform positioning in relations to level crossings road traffic congestion.

There has been no research conducted regarding platform position at railway stations, for instance, in comparison to accidents at level crossings, human behaviour at level crossings, into rail and road signal improvements, signal preemption at railroad level crossings and road congestion in general at level crossings. Most of these have been driven from either a safety perspective and to ensure the clearance of motor vehicles from the railroad crossing shared area and from the path of incoming trains or by road congestion at level crossing locations. However, the focus of these has concentrated on road issues and not rail.

There has been much research conducted overseas regarding level crossings road congestion in general. For example, one of these is from Arizona in the US that investigates both safety and road congestion problems at level crossings (Roberts 2005). Another is in the UK that investigated road traffic congestion (of about 20 vehicles) at a rural setting with low rail traffic (Delmonte & Tong 2008).

Concerning Australia, Crawford and Taylor conducted research into level crossings grade separation priorities, indicating that in Melbourne, road traffic congestion is the main motivator for level crossing remediation work (Taylor, J & Crawford 2010). Hall and Somers conducted research into rail and road signal improvements and one of their hypotheses was that a
strong indicator that road users perception of road congestion conditions is ‘influenced by their worst journey’ (Hall & Somers 2012, p. 3).

Overall, research in Australia into the treatment options for the resolution of level crossings problems is limited (VicGov 2009); there is a need for additional research into other approaches for the treatment of level crossing problems (Lee, Nam & Park 2005). Wallace (2008) indicates the problem in this area to be ‘plagued by the rail/road interface and the separation of responsibilities between rail and road authorities reflecting the social and political context in which they are contained’ (Wallace 2008, p. ii), where in the past level crossing problems have not been given the attention, priority, or funding required to address those problems (CfM 2011a; Colebatch 2012; Dunkley 2012; Gough 2011; RSC 2008b).

3.5. Dealing with Level Crossings and Congestion

Many countries do have rules and active programs for level crossing remediation. For instance, the US has Federal guidelines for closure of level crossings (Anonymous 2004; FHWA 2011; Ogden 2007). The potential closures are dependent on a combination of train speed, the area, the average daily vehicles traffic, the distance to the next crossing and the increase on trip length (Anonymous 2004; FHWA 2011; Ogden 2007). It is noted that one of the US Federal Highway Administration (FHWA) guidelines for permanent closure of level crossings is measured by train traffic; it indicates that 75 passenger train movements per day in an urban area as the rule to either closure or grade separation of the level crossing (Anonymous 2004; Ogden 2007).

In comparison, most if not all, Melbourne metropolitan lines carry more than double or triple that amount of train traffic per day. For instance, the Dandenong/Pakenham line currently carries more than 270 train movements per day every weekday (Guzman, Peszynski & Young 2014b; Metro 2013a; V/Line 2013), almost four times the US FHWA guidelines; the Frankston line carries approximately 220 train movements per day (Guzman, Peszynski & Young 2014b; Metro 2013b), almost three times
the US FHWA guidelines. Under those US guidelines, all level crossings in metropolitan Melbourne should had been either closed or grade separated long time ago. Further, there are no available reports or figures that specifically address the cost of congestion at level crossing locations.

In Victoria, since 2001, level crossings are no longer permitted to be built; the Victorian Parliament passed legislation that prohibits the building of new level crossings (Planning & Environment Act 1987 VC71-2001; DoT 2009; PTSV 2009; RSSB 2006). All new tracks or new roads require grade separation between rail and road at these locations incorporated into the design and development plans (DoT 2009; PTSV 2009). An enquiry into safety at level crossings (RSC 2008a), presented to the Government, included 44 recommendations to be followed up. These included a grade separation program; a level crossing closure program; and implementation of new and developing technologies, including Intelligent Transport Systems (ITS), Global Positioning Systems (GPS) and Intelligent Speed Adaptation (ISA), among others (RSC 2008b).

But the cost associated with separating rail and road projects is high, requiring on average more than $160 million on each project. This is based on details from the last three projects of this nature completed or partly completed in metropolitan Melbourne, and from details of the proposed nine grade separations currently either under development or planning phases in metropolitan Melbourne (Freemantle 2011). Examples of these projects are: the Springvale Rd, Nunawading, costing $160 million and completed in 2010 (DoT 2011); and the Springvale Rd, Springvale, costing $160 million and yet to be completed (Carey 2014b).

Thus, resolving the level crossing problems are a lengthy and costly exercise, requiring financial commitment and development projects with long lead times. As Melbourne is home to one hundred and seventy two (172) level crossings, it would cost more than $28 billion (NPV) and at the current pace of grade separation projects completion rate, it could take
many years, if ever (RSC 2008b), for the level crossings problem to be fully resolved.

Melbourne transport authorities continue to deal with the level crossing problem within the fiscal constraints imposed; two grade separations projects, encompassing three level crossings, are currently under way in Melbourne East (VicRoads 2013). Work commenced on the projects during 2013 and the Springvale Road, Springvale grade separation is expected to be completed by early 2015 (VicRoads 2013). The Mitcham – Rooks Roads grade separation, designated as a single project due to the proximity of the two crossings, is progressing as planned, with the Mitcham Road level crossing removed on 25 January 2014 and the Rooks Road level crossings to be removed in the near future; the Mitcham Station facilities are also to be completed in the near future (VicRoads 2014).

Current transport plans are for the removal, by grade separation, of several level crossings from the metropolitan area (Carey 2015a; Freemantle 2011; VicRoads 2011a). Plans announced during March and April 2014, indicate a further five grade separations to be conducted over the next ten years (Carey & Millar 2014; Dowling 2014; Johnston & Campbell 2014; Zielinski 2014). These latest plans for grade separations are welcomed by the Public Transport Users Association (PTUA), but PTUA is wary of election-year promises (Dowling 2014), as elections are due in Victoria during November 2014. During the election campaign, the incoming Government promised to remove 50 level crossings from metropolitan Melbourne over the next ten years (Andrews 2014; Callick 2014; Carey 2015a).

Recent announcements by transport authorities indicate several additional grade separation projects will be conducted over the next 10 years (Dowling 2014; Johnston & Campbell 2014). Contracts for four grade separations projects, costing $524 million, were signed during May 2015, with completion dates due in 2018 (Carey 2015a). These include the
removal of level crossings at Bourke Road in Glen Iris, Centre Road in Bentleigh, McKinnon Road in McKinnon and North Road in Ormond (Carey 2015a), all level crossings are along the Frankston Line.

But the level crossing legacy will remain; after removal of these level crossings is completed, Melbourne metropolitan area will still be home to about one hundred and sixty (168) level crossings; about one hundred (100) of these are station level crossings.

3.5.1. Level Crossings Risk Assessment and Prioritisation

Historically, there is only one alternative to resolve the issues relating to level crossings in metropolitan or urban areas: the removal of the level crossing by way of grade separation. As there are many level crossings, this brings out the issue of which level crossing to treat first. To be able to decide how to treat each level crossing, rural or urban, or to be able to decide which crossing to be treated before another, a priority list of each level crossing was created using a methodology of algorithms to determine priority risks. The system is called *The Australian Level Crossing Assessment Model (ALCAM)* (NAC 2008; PTSV 2009; Spicer 2007).

The Victorian Government completed the ALCAM model analysis of all level crossings in the state and published the list in mid-2008 (Mitchell 2008; VicGov 2008). For audit purposes and before population of the ALCAM database was completed, field survey data from all level crossings was cross referenced against the Australia Standard 1742.7 (PTSV 2009). Victoria now has a priority list database of all level crossings to be able to prioritise work on upgraded via either grade separation or closure of all 1872 level crossings in the state (NAC 2010; RSC 2008a; VicGov 2008). Further details of the ALCAM model analysis program are included in Appendix B.

3.5.2. Level Crossing Remediation Alternatives

The first option in addressing the level crossing problem should always be the closure of the crossing (NCHRP 1999; RSC 2008b). Crossing closures
can be achieved by either closing the crossing to road traffic, closing the
crossing to rail traffic through relocation or abandonment of the rail line, or
by grade separation (Glennon 2005; Wallace, McCusker & Hirsch 2008).
Grade separation is the name given to the process of separating both
traffic modes, by way of building a tunnel or a bridge. Grade separation
eliminates the problem all together; it separates both modes of transport,
rail and road, from each other’s path (McNamara & Cox 1979; VicGov
2009). Although topical research is limited (Pulugurtha & Desai 2007;
VicGov 2009), grade separation of level crossing is the main option of
remediation used in urban areas in Victoria, said to be perhaps the only
secure and safe solution to alleviate the level crossing problem (ARA
2009; RSC 2008b).
The elimination of level crossing ‘is the only way to truly address
catastrophic risk’ (VicGov 2009, p. 6). Addressing and remediating level
crossing problems can be achieved by a number of engineering solutions.
These include the closure of the rail tracks all together, the closure of the
road intersecting the rail tracks, and the grade separation of the level
crossing by way of tunnel or bridge. Conversely, the elimination of level
crossings by way of grade separation is an efficient solution (Lee, Nam &
Park 2005).

3.5.2.1. Level Crossing Closure
Closures of level crossings, by closing the track or the road, is suggested
to be the most effective measure of improving safety and reducing the risk
of collision at these locations (LCSC 2013; Wigglesworth 2008). Different
methods of closure are available depending on the location of the level
crossing, being at a rural or urban setting.

Rural Level Crossing Closures
Level crossing closures are possible in rural areas, where both the volume
of rail and vehicular traffic is lower than in urban areas, where the closure
does not have a negative impact on the community and the vehicular
traffic from the closed crossing can be redirected and absorbed by another
crossing in its vicinity (Ogden 2007; PTSV 2009). Transport authorities encourage and provide financial incentives for the closure of level crossings (Spicer 2006; TC 2013).

In Victoria, the government encourages regional road authorities (local Shires/Councils) to close remote and low traffic level crossings by providing an encouragement; this encouragement is by way of a ‘Bounty’ cash incentive bonus of $25,000 for each level crossing closures (DoI 2005; RSSB 2006).

Urban Level Crossing Closures

Closure of level crossings is impractical in urban areas because most, if not all level crossings in Metropolitan areas, are on main rail lines and at arterial or major road intersections. Closing one of these would have the effect of closing part of the rail network and/or closing an arterial or major road and transferring the traffic problem somewhere else in the road network.

In urban or metropolitan areas, grade separation is generally accepted as the most practical and only closure alternative to treat level crossing problems; it would be difficult or near impossible task to close a main road to road traffic or to permanently close a rail track to train traffic, or attempting reducing road and/or train traffic.

3.5.2.2. Level Crossing Grade Separation

Grade separation of level crossings creates safer and more reliable travel for commuters, vehicular traffic, walking public and the community in general. Grade separation, in most cases, is the Victorian Government preferred solution to resolve level crossing problems; but while grade separation is the most effective alternative, it is also an extremely costly solution (CfM 2011a; VicGov 2009). For example, the cost of removing all level crossings in Victoria, while an unrealistic proposition, has been calculated would cost between $60 billion and $80 billion (NPV) (Lucas 2009b).
Level crossings remediation process can be achieved by one of the following engineering solutions:

- lowering the rail line by tunnelling under the road;
- lowering the road by tunnelling under the rail line;
- building a road bridge over rail line; or
- building a rail bridge over road.


The fourth alternative, in most cases, is not considered a viable alternative due to technical and cost issues (Taylor, J & Crawford 2010). In addition, level crossing grade separations are not unique to rail/road crossings. There are also road/road crossings as well as rail/rail crossings that require grade separations. An example of the latter is the Sandgate grade separation project in the New South Wales Hunter Valley region.

**Lowering the Rail Line**

This option is the most expensive to developed, costing on average $160 million for each grade separation project (Freemantle 2011), and creates most of the disruption to the rail network, its commuters and the community, causing little or no disruption to vehicular traffic.

Lowering the rail line is the preferred option currently being used by transport authorities in Melbourne. The last three completed grade separation projects, the Middleborough Road, Blackburn, completed in 2007 (DoT 2006), Springvale Road, Nunawading, completed during early 2010 (VicGov 2010), and the Springvale Road, Springvale, currently in completion, are an example of this option in this type of grade separation work. In all these cases, the railway line was lowered and tunnelled under the road. This option does not present technical problems in having to replace or redirect existing infrastructure or acquiring land, as the lowering of the rail line, in most cases, is on land owned by VicTrack and already reserved for rail infrastructure upgrade purposes. In addition, all planned grade separation will use this option of grade separation work.
Chapter 3: Analysis of the Problem and Current Solutions

As in the previous grade separation of the Middleborough Road, Blackburn railway station, at both the Springvale Road grade separation projects, the railway line was lowered eight metres and moved twelve metres sideways tunnelled under the road, and a new station built. Further details of the Springvale Road Nunawading grade separation project are included in Appendix B.

**Lowering the Road**

Lowering the road is a much cheaper option than lowering the rail line (NewAustralia 2010). Digging and tunnelling under the current tracks achieves lowering the road. With this option there are several technical issues to deal with; these are in relation to existing utilities infrastructure in operation, including sewerage, gas, water, drainage, telephony, internet, cable TV, among others. This method would require disconnection and permanent repositioning of all utilities during construction work, causing disruption of the utility supplies to all consumers in the affected area. This option could also present the problem of having to cater for issues related to flooding and provision for permanent water pumping mechanisms. This option also creates much disruption to vehicular traffic, the rail network and the community for lengthy periods. This option is not viable in some cases as the topography and other technical complications, like water basement, could prevent its implementation.

**Building a Road Bridge**

Building a road bridge is a cheaper option than both previous solutions (NewAustralia 2010), but is the one that causes the most disruption to road users and the community in the vicinity of the building area, as all the utilities, including gas, water, electricity, sewerage, drainage, telephony, internet and cable TV, are built on the road. The road must face closures for long periods of time during construction. If the arterial or major road is of multiple lines in each direction, then this will necessitate building two bridges and closures of the road in either/both directions at times. This alternative could be further complicated if, as in most cases in Melbourne,
the arterial road is also intersected by other road(s) and there is a necessity to provide for entry or exit ramps to the bridge for these side roads. However, this option could benefit from making use of pre-fabricated lane bridges, providing minimal disruption to the rail network during construction and implementation.

An example of this option is the Collins Street Extension in Melbourne's CBD that cost $38 million (NewAustralia 2010). It comprises of building a bridge at a 'T' intersection, thus extending Collins Street into a new area, Docklands. The four-lanes and two-tram-track bridge was built over twelve railway tracks at Southern Cross Station and a four lane highway, Wurundjeri Way (NewAustralia 2010). Further details of the Collins Street Extension project are included in Appendix B.

Building a Rail Bridge

Building a rail bridge is an expensive option and one that causes the most disruption to rail users and the community in the vicinity of the building area. The rail must face closures for periods of time during construction; these types of projects present many technical engineering challenges and costing issues.

An example of this is the Sandgate Grade Separation project in the NSW Hunter Valley region, which separated and relieved rail/rail congestion on the Hunter Valley coal delivery chain, commenced in 2005 and complete in 2007, at a cost of $85 million (ARTC 2008). Details of the Sandgate Grade Separation project are included in Appendix B.

3.5.3. Current and Future Remediation Plans

Of all the alternatives available to remediate level crossing problems, the most common one in use in Melbourne is grade separation by lowering the rail, by tunnelling under the road. This option is, in most cases, the most expensive of the alternatives and the one that causes the most interruptions to rail operations and rail commuters; substitute transport must be used by commuters, for long periods, to commute between stations, bypassing the affected station. Yet this alternative causes the
least amount of interruption to road commuters and the community surrounding the grade separation station area. All the proposed grade separation projects currently under way in Melbourne use this method of grade separation. However, grade separation as a solution attacks the symptom of the problem, instead of the cause of the problem, and are heavy on resources and costly (Lee, Nam & Park 2005). In metropolitan Melbourne urban rail network, in the past twenty years, only five railway stations grade separation projects have been completed. Further details of proposed grade separation projects are included in Appendix B.

3.6. Alternative Calming Solution

Another alternative that could mitigate level crossings road congestion is Zonal Operations (ZO), a transit operation method used in many places around the world but not in the Melbourne rail network (Guzman, Peszynski & Young 2014b; Mees 2007a; Symons 2009; Vuchic 2005). ZO is specifically designed to improve railway line operations, increase service capacity and reduce commuters overcrowding (Mees 2007a; Vuchic 2005, 2007); ZO are not designed to reduce closure activity at level crossings, but it can do so by streamlining rail services. ZO makes use of available infrastructure to better manage the available resources (rolling stocks, station platforms, turnbacks, etc.). In ZO, a rail line service is divided into two or more sectors called zones; each zone is serviced by its own set of trains and its own set of timetables (Guzman, Peszynski & Young 2014a; Mees 2007b; Vuchic 2005).

Initial research identified that, if implemented, ZO has the potential, in addition to abovementioned benefits, to also mitigate road traffic congestion at level crossings by, in most cases, reducing rail traffic along rail corridors; this would mitigate intersections closure activity and allow less encumbered road traffic flow along arterial roads (Guzman, Peszynski & Young 2014b). The ZO concept is not used in the Melbourne rail network, yet international best practices rail operation modal established in North America and Europe, and already in use in Australia in rail lines.
such as Perth’s Northern Suburbs, recommend the use of the ZO method of operation (Guzman, Peszynski & Young 2014b; Mees 2007a).

As an example, the implementation of zonal operations on the Caulfield Group of lines would alleviate the current capacity and overcrowding problems facing the corridors, allow for expected increases on train patronage, and help towards resolving capacity problems with the City Loop, as well as mitigating road traffic congestion along the corridors fifty seven (57) level crossings (Guzman, Peszynski & Young 2014b).

3.7. Proposed Level Crossings Remediation Solution
This research is about introducing and presenting an alternative that has not been investigated or implemented in the past. This proposition has been termed Departure Side Platforms (DSP). This alternative proposes treating the cause of the level crossings problem and not the symptoms of the level crossing problems, like all the current available alternatives. It is alleged in this research that road congestion at station level crossings is not caused by the level crossing closure operation, rather by the trains prolonged stay at the Arrival Side Platform (ASP), forcing the intersection to remain closed for long intervals. The proposed alternative is to focus on developing Departure Side Platforms (DSP). Figure 1.1 illustrates the proposed station infrastructure comprising of dual Departure Side Platforms (DSP).

3.8. Thesis Research Question
This thesis introduces and tests the proposition that mitigation of road closures at level crossings next to a railway station can be achieved by building a new station platform, a Departure Side Platform (DSP). This new Departure Side Platform (DSP) replaces an existing Arrival Side Platform (ASP) at stations. The consequence of lessening intersection closure periods at the station road intersection, have the effect of calming road traffic congestion at stations precinct.
Chapter 3: Analysis of the Problem and Current Solutions

The proposition is considered to be a new option for the treatment of railway station level crossings problems. The research question that is addressed is: How does modifying platform configuration at railway stations mitigate level crossings roads closure times?

The proposition leads to a theory that addresses the legacy of railway level crossings and specifically its links to the position of platforms at railway stations. This study is the first of its type to concentrate on addressing the issue of platform positioning at railway stations level crossings, where these two modes of land transport, rail and road, cross each other’s path at the same ground level or grade.

3.9. Discussion

This chapter summarises the problems experienced at level crossings and how they are currently being addressed through level crossing closure and the grade separation. However, the cost associated with the only alternative currently used in Melbourne, grade separation, prohibits the treatment of more than a few level crossing every ten years or so. At that rate of remediation, it would take a long time for Melbourne to be free of the level crossing hazards. Therefore, this Chapter presented the concept of Departure Side Platforms (DSP) as a method to mitigate road traffic congestion, which has the potential to alleviate road closure periods, lessening the road congestion at the station precinct.

The methodology and the computer simulation approach used in the process of testing and confirming the effects of platform re-arrangements, are fully detailed and discussed in Chapter 4.
4. RESEARCH METHODOLOGY – COMPUTER SIMULATION

4.1. Introduction

This chapter focuses on the use of computer simulation as a tool to address a complex problem, the railway station intersection level crossing problem, with the emphasis in replicating the conditions of the actual problem, considering the events and operation of the actual system, providing visual interface between the perceived problem and the proposed alternative leading to the research question. An analysis of computer simulation software and the methodology used when using simulation software is provided. These include a review of available traffic simulation software, complimented by an examination of previous research conducted using traffic simulation.

The process for the selection of the traffic simulation software is documented. This is followed by a definition and methodologies used by other researchers when using computer simulations for their research. In addition, a simulation design methodology review was conducted and is presented as part of the design model used for the simulation process.

The chapter introduces the methodology used to evaluate and analyse the proposition of Departure Side Platforms (DSP) to deal with railway station intersection level crossing problems, in the context of the Melbourne case study. The theories currently used to analyse road traffic congestion were investigated and indicated most road transport theories and strategies were made to address road transport problems created by road transport conditions. However, this research investigates platform position infrastructure at railway stations and the implications of the position of the platforms in relation to the intersection closure periods and the resulting road traffic congestion. The complexities of the combined components of both the rail network and road network systems are not prescribed under current analytical models. Therefore, a new design model was developed,
allowing for these complexities, to accommodate the specific requirement of this research.

4.2. Transport Theories and Strategies

Current road transport theories and strategies, including Queuing Theory, Travel Demand Management (TDM) and Traffic Operational Strategies (TOS) were initially explored and considered. Other transport strategies and approaches were considered as well, including congestion charging, alternatives modes of transport, restriction from central or congested urban areas, managed lanes, smart corridor analysis, traffic signal preemption and traffic assignments (BAH 2006; MacGregor, Burris & Goodin 2010; NAO 2004; Westell 2008).

However, some of these transport theories, models and strategies, are designed to address road transport traveller’s activities and transport conditions. This research investigates platform position infrastructure at railway stations and the implications of the position of the platforms in relations to the intersection closure periods; closure periods that result in road congestion at the level crossing intersection. In addition, this research addresses the cause of level crossing congestion problem and not the symptom of the problem. The complexities of the combined components of both the rail network and road network systems are not specifically prescribed under current analytical models, tools or strategies (Guzman, Young & Peszynski 2014, 2015).

Further, traditional theories and models use a cumulative representation of traffic is of vehicles flow per hour and all vehicles perform under the same single rule (Wang & Prevedouros 1996). Using traffic simulation modelling techniques, the behaviour of each individual vehicle on the network, both rail and road, can be modelled using the pre-set algorithms and rules (PTV AG 2012b).
4.2.1. Queuing theory

Queuing theories are probabilistic methods and stochastic modelling tools widely utilised theory that mathematically explores waiting lines, congestion or queues (Breuer & Baum 2005; Laval & Leclercq 2010; Mounce 2006; Sztrik 2012). According to Breuer and Baum (2005), these stochastic concepts are used when deterministic laws cannot be framed (Breuer & Baum 2005). According to Sztrik (2012), queues are common in many fields and not specific to road transport. In queuing theory, a model is constructed so that queue lengths and waiting times can be predicted, where the characteristics of the queuing system identify the probabilistic properties of the incoming flow (Sztrik 2012). Sztrik (2012) further indicates the aim of all investigations in queuing theory is to get the main performance measures of the system probabilistic properties, and therefore this does not align with the focus of this research.

4.2.2. Travel Demand Management

Travel Demand Management (TDM) presents a number of strategies focusing at modifying travel activity before the actual trip is made (Rouphail 2008). The proliferation of mobile telephony, the internet and other applications, has provided the ground for new alternative strategies (Buliung et al. 2010).

TDM strategies aim at modifying travel demand patterns to achieve specific objectives, including vehicular travel activity, changing travel demand to both less congested and less polluting transport modes (Rouphail 2008). Further, to promote efficient use of network systems, Hensher and Puckett (2007) suggest TDM initiatives should be linked to congestion pricing strategies (Hensher & Puckett 2007), thus again, this is not align with the focus of this research.

4.2.3. Traffic Operational Strategies

Traffic Operational Strategies (TOS) presents both freeway and non-freeway strategies, including Freeway Operational Strategies and Surface Street Operational Strategies (Horowitz 1992; Rouphail 2008).
TOS strategies have a tendency to aim at prevailing traffic conditions. In addition, TOS strategies tend to increase and not decrease travel demand; the strategies can be defined by the type of facilities targeted, namely freeways or surface roads (Rouphail 2008), and not in a railway context, which is the focus of this research.

4.2.4. Traffic Simulation Modelling

The use of traffic simulation modelling techniques have developed over the last decades and play a vital role in providing solutions to transit problems (Pulugurtha & Desai 2007). Wang and Prevedouros (1996) indicate that simulation model can be dynamic and stochastic, or dynamic and deterministic in nature. Barceló et al. (2005), suggest the use of macro, meso or micro modelling techniques (see Table 4.2) could be considered as an appropriate methodological framework (Barceló et al. 2005). In addition, simulation software modelling offers the ability to model transit and public transport stops, provide vehicle detecting capabilities and signal systems; the stochastic nature of vehicles speeds and arrivals, both rail and road, can be incorporated into simulation models. Pulugurtha and Desai (2007) indicated there was limited research available on modelling railroad crossings (Pulugurtha & Desai 2007).

4.2.5. Investigation Strategy

The focus of this investigation, the railway station platform position problem and the resulting road traffic congestion that the research specifically addresses, is not a road transport problem created by road transport conditions. It is a road and a rail transport problem created by the cohabitation or ground sharing conditions of both transport networks combined, but more specifically as the result from the location of the railway station platforms position. No specific theories, strategies or methods were identified addressing this issue. Accordingly, this research used computer simulation modelling techniques to analyse, test, and evaluate the proposition presented in Section 3.7.
4.3. Computer Simulation

Computer simulation methodology is most appropriate for this research because it investigates a particular case and a situation not yet investigated. In addition, it would be physically difficult and expensive, if not impossible, to recreate the networks specifically for the purpose of evaluating the proposition; in this research, it would require building costly infrastructure. Using computer simulation, both types of networks, rail and road, can be emulated to study the behaviour and activities of rail and road traffic at level crossings, gaining an understanding of the operations of level crossings and of road closures at level crossing intersections, events that causes road traffic congestion.

Using traffic computer simulation modelling techniques, the behaviour of each individual vehicle on the network, both rail and road, as well as the networks performance, can be modelled using the pre-set algorithms and rules (Wang & Prevedouros 1996). The implementation of new techniques to improve transport modes service deliveries that requires rigorous testing, can be accomplished by testing and evaluation using computer simulation modelling (Papageorgiou et al. 2009).

Simulation models describe the temporal, spatial activities and interactions of vehicles in transport networks (Rosca et al. 2013). Operations of traffic systems have always been subjected to intensive investigation using modelling and simulation (Fotherby 2002). According to Quinn (2000), computer simulation contributes to the development of theoretical knowledge in one of three ways:

- by generating new theory;
- by testing existing theory logical consistency; and
- by implementing empirical case simulations

(Quinn 2000).

Pursula (1999) believes there are five driving forces behind the increases use of simulation technology in transportation:
• development and advances in traffic theory;
• advances in computer hardware technology;
• advancement in programming tools;
• the development of the general information infrastructure; and
• society's demand for more detailed analysis of the consequences of traffic measures and plans.

Computer simulations have proven to be an essential addition to the traditional traffic engineering analysis methods to understand the complex dynamics of traffic networks (Clark & Daigle 1997). Clark and Daigle (1997) indicate that simulation tools play an important role in the development and evaluation of new ideas, algorithms and traffic control systems. Simulation models are confirmed to be compelling tools, not only for the innovative analysis and design of systems, but also to make possible the visualisation of proposed systems.

The use of computer simulation software for traffic modelling is a process nowadays widely used by researchers to help and facilitate traffic modelling, planning and the actual development of traffic networks and systems (Kotusevski & Hawick 2009). The process of modelling vehicular traffic is a complex problem, as it must reproduce or emulate realistic traffic dynamics and spatial vehicular interaction within intricate transport networks (Boel & Mihaylova 2006; Lu, Mahmassani & Zhou 2008).

4.3.1. The Use of Computer Simulation

Computer simulation allows and simplifies the methods used to study, analyse and evaluate conditions that could not be studied under normal circumstances (Ingalls 2008; Shannon 1998). Simulation modelling has been compared with working on a real world problem replicated in an artificial world that could be controlled and manipulated by the researcher (Peck 2004). Shannon (1998 p. 1) defines simulation as:
Chapter 4: Research Methodology – Computer Simulation

The process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and/or evaluating various strategies for the operation of the system.5

Shannon (1998) emphasises that the model must be designed to mimic not only the conditions of the actual system but also the events that eventuate in the actual system. A list of Carson’s (2005) prescription on when and why it is appropriate to use computer simulation is included in Appendix C.

This research encompasses, to a certain degree, most if not all, of the circumstances prescribed by Carson (2005). For instance, there are no analytical models to analyse behaviour and activities of both rail and road traffic at level crossings; both rail and road networks systems are well bedded, having been in place for more than a century; both rail and road are complex networks, with interactions and dependencies between components of both systems; major changes to current infrastructure are difficult, costly in both resources and time; it would be difficult and expensive to physically recreate the networks infrastructure specifically for the purpose of testing the proposed modifications; and the simulation and visualisation tools available could be used extensively to present and demonstrate the outcomes.

Further, computer simulation has a number of advantages and disadvantages over other methods of analysis (Law 2007; Shannon 1998). Table 4.1 lists some of the advantages and disadvantages as suggested by Shannon (1998) and Law (2007).

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5 Introduction to the Art and Science of Simulation (Shannon 1998)
Table 4.1: Simulation Advantages and Disadvantages Comparison

<table>
<thead>
<tr>
<th>Simulation Advantages and Disadvantages – Shannon</th>
<th>Simulation Advantages and Disadvantages – Law</th>
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<tbody>
<tr>
<td><strong>Simulation Advantages</strong></td>
<td><strong>Simulation Advantages</strong></td>
</tr>
<tr>
<td>• Easy to explain and understand, thus easy to justify to customers and management alike</td>
<td>• Often the only type of investigation possible when more complex systems cannot be accurately described by other methods</td>
</tr>
<tr>
<td>• More credible as it relies on mimicking real systems and requires lesser assumptions to portray the real environment situation</td>
<td>• Allows the estimation of the performance of an existing system under a controlled environment than otherwise would not be possible</td>
</tr>
<tr>
<td>• Allows the testing new plans, designs or systems devoid of development and implementation cost</td>
<td>• Alternatives can be compared using the actual simulation to evaluate outcomes</td>
</tr>
<tr>
<td>• Allows for the identification of problem areas and for the testing of an hypotheses</td>
<td>• Can be used to have a better control over trial conditions than otherwise would not be possible</td>
</tr>
<tr>
<td>• Allows to study systems over prolonged periods of observation, to gain knowledge of it operations and to answer ‘what if’ situations or conditions</td>
<td>• Allows for the study of a systems over a long period, either in compressed time mode or in a detailed expanded mode</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simulation Disadvantages</th>
<th>Simulation Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>• Requires skills and abilities to produce the actual model</td>
<td>• Each test run of a simulation only generates estimates of characteristics according to input data</td>
</tr>
<tr>
<td>• Gathering of data for the simulation process takes times and the quality of the data must be reliable, as the concept of ‘garbage in – garbage out’ applies</td>
<td>• Simulation models require time and are expensive to develop</td>
</tr>
<tr>
<td>• Does not provide optimal solutions, as it's a tool to analyse a system behaviour under certain conditions</td>
<td>• Generate large amount of figures and animation that at times can create tendency of overconfidence than it is justifiable</td>
</tr>
</tbody>
</table>

Source: (Shannon 1998)  
Source: (Law 2007)

In addition, it is suggested that there are a number of pitfalls that can be avoided when conducting simulation modelling work (Law 2007). A list of pitfalls prescribed by Law (2007), are detailed in Appendix C.

It is further suggested that an appropriate commercial simulation package model should be used to develop models, using one of the many general purpose and/or specialised purpose software packages available (Carson II 2005). It is also recommended and emphasised the need to be cautious.
and prudent, and to give strong due consideration to the selection of the simulation package to use (Law 2007), so the appropriate software is selected. Law indicates that the selection of the software to use by the analyst, researcher, or modeller is one of the most, if not the most important decisions to be made during a project life cycle. Therefore, the simulation software selection criteria used in this study is described in Section 4.4.2.

To address the problem of the positioning of platforms at railway stations without building the necessary infrastructure of tracks, station, platforms and roads, computer simulation was used specifically to address this theory. But in this process, there were a number of questions, including:

- what is computer simulation?
- how and when is computer simulation used to resolve problems?
- what computer simulation software to use?

4.4. The Computer Simulation Software and Selection Process

A literature review of the availability of traffic and transport system simulation packages highlighted different types of simulations and simulation modelling techniques was conducted. Work by other researchers indicates simulation models are typically classified according to the level of detail and the type of techniques used to represent a model, specifically in transport simulation (Ratrout & Rahman 2009). These different models of simulation software can be classified as:

- microscopic simulation or microsimulation;
- macroscopic simulation;
- mesoscopic simulation; and
- hybrid simulation.

These four different simulation techniques and terminology currently used and prescribed by Ratrout and Rahman (2009), are describe in Table 4.2.
Table 4.2: Different Simulation Techniques

<table>
<thead>
<tr>
<th>Simulation Technique</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microscopic or microsimulation</td>
<td>In this process, the modelling aim at simulating individual vehicle movements within a transport network system; it refers to facilities used to develop signal control plans and to test them with real flow values from traffic counts.</td>
</tr>
<tr>
<td>Macroscopic</td>
<td>In this process, models simulate traffic flow taking into consideration cumulative traffic stream characteristics and the relationships to each other; the model focuses on a section-by-section of the network, rather than by tracking individual vehicles.</td>
</tr>
<tr>
<td>Mesoscopic</td>
<td>These models combine the properties of both microscopic and macroscopic simulation models and it is used to model dynamic aspects of very large networks. These models are somewhat less consistent than microsimulation tools, but are superior to some other traffic analysis techniques.</td>
</tr>
<tr>
<td>Hybrid</td>
<td>These models exhibits both continuous and DEVS (discrete events simulation) behaviour, and make use of continuous time multi-state model (CTM) making use of both microscopic and macroscopic simulation techniques.</td>
</tr>
</tbody>
</table>

Source: (Ratrout & Rahman 2009)

From the details of this review and using common knowledge of the problem of level crossing road intersections, it is determined that macroscopic, mesoscopic and hybrid do not provide the level of detail required in this case. All these methods share some common concepts but are based on different types of network representations (Barceló et al. 2005). Macroscopic, mesoscopic and hybrid model large parts or many intersections of the network; microscopic or microsimulation models detailed definition of an intersection or smaller area of a network. Microscopic simulation provides the level of detail needed to develop and simulate the target level crossing intersections as required, and thus has been used in this research. Figure 4.1 illustrates the different computer simulation modelling technique types.
Figure 4.1 illustrates the different computer simulation modelling techniques and the relationship to each other, as used in this research. The macroscopic model encompasses the whole of the Melbourne rail network; the mesoscopic model represents two of the Caulfield group of lines; the microscopic model represents the Clayton Station intersection level crossing area and the focus of this research.

4.4.1. Traffic Computer Simulation Software

Currently, there are a number of traffic computer simulation software packages purposely made for addressing the issue of road transport and traffic assignments, and fit within the microscopic resolution required. According to the literature review and research conducted in this area, the most commonly used and preferred packages are:

- AIMSUN—developed at the Department of Statistics and Operational Research, Universitat Politecnica de Catalunya, embedded in
GETRAM, a simulation environment using the TEDI traffic network editor;

- CORSIM—developed by the University of Florida and widely used by the US FHWA (Federal Highways Administration) and many US states transport administration bodies;

- PARAMICS—developed by the Scottish company Quadstone Limited—software developed to model urban and rural networks, including freeways, to replicate movement and behaviour of traffic and individual vehicles on these networks; and

- VISSIM—from PTV in Germany—software specifically made for simulation and visualisation of traffic conditions, conditions which include motor vehicles and public transport, including trains, trams and buses, incorporating a powerful 3-D visualisation tool.

PARAMICS, unlike all the other packages reviewed, is based on the UNIX platform and not on the Microsoft platform (Choa, Milam & Stanek 2003). This is a constraint for this research, as the RMIT University network environment is based on a Microsoft platform. A table of different software available and their characteristics, as well as their main features and capabilities, is included in Appendix C.

In addition, due to the large variety and availability of simulation software, this research concentrates its efforts specifically on transport simulation software. Instead of conducting a full review of all available simulation software, efforts were concentrated on topical research previously conducted by other researchers in reviewing transport simulation software; the reviewers’ commentaries are detailed in Appendix C.

The table presented therein indicates that there are differences between the types of software used previously in research to conducted transport simulation studies. These show some have stronger point and preferences above other types, their usability and differences in the cost of acquiring the software. These also indicated some require particular calibration of
parameters to derive to acceptable results, use similar car-following algorithms and vehicle behaviour under road congested conditions. This information provided an initial filtering of available traffic simulation software relevant to this research problem.

### 4.4.2. Research Software Selection Criteria

Using the understanding of the research purpose, perceived problem and alternative solution, as road and rail oriented research, as well as the detailed information derived from the simulation software literature, a number of minimum requirement criterion were created for the selection process. Table 4.3 presents the selection criteria details.

**Table 4.3: Simulation Software Selection Criteria**

<table>
<thead>
<tr>
<th>Simulation Software Selection Criteria</th>
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<tr>
<td>- Ability to run under an existing MS Windows XP or latest computer environment in the University.</td>
</tr>
<tr>
<td>- Software to be a microscopic simulation, for traffic flow, vehicle transport (public and private) simulation attributes, as opposed to discrete event simulation attributes (DEVS).</td>
</tr>
<tr>
<td>- Be able to simulate multi-modal traffic situations, different vehicles types, including: car, trucks, bikes, buses, trams, trains (heavy rail), etc. An added bonus well be to be able to represent pedestrians as well.</td>
</tr>
<tr>
<td>- Allow the operation of traffic signals with three different types of controls including:</td>
</tr>
<tr>
<td>(a) pre-timed signal control</td>
</tr>
<tr>
<td>(b) NEMA Standard Signal Control Emulator</td>
</tr>
<tr>
<td>(c) vehicle actuated signal control (VAP).</td>
</tr>
<tr>
<td>- Ability to process, simulate and analyse railroad level crossing using these multiple signal processing.</td>
</tr>
<tr>
<td>- Traffic simulation output to be 3D, with the added bonus of movie output presentation.</td>
</tr>
</tbody>
</table>

Source: Research internal requirement

Some of the basic points used for the selection criteria were obvious from the outset of the research, including the need to micro simulate a railway station, heavy rail (as opposed as light rail), roads and road intersections, signals, road and rail signals interaction, as well as the ability to program these signals; thus, the criteria for the selection of the simulation software was established. Once the criterion was defined, it became a matter of
reviewing each of the selected software packages and comparing these with the set of selection criteria.

Time had been spent exploring MATLAB and ARENA, as these two simulation software packages were readily accessible in the University and thus worthwhile examining. MATLAB and ARENA are not specific traffic simulation software packages and do not meet the criteria. Yet, both packages had been part of the research since the early stages; for completeness, the two were included in the selection process with CORSIM, AIMSUN and VISSIM, the three software packages classified as transport simulation software (refer to Table C-3 in Appendix C). PARAMICS, also a transport simulation software tool, was excluded as it does not run on the MS Windows operating environment, which is the only platform available in the University. Five software packages were assessed for final selection. The list included VISSIM, AIMSUN, CORSIM, MATLAB and ARENA.

- AIMSUN, ‘Advanced Interactive Microscopic Simulator for Urban and Non-urban Networks’, is a microscopic simulation model based in car-following, lane changing and gap acceptance algorithms; is the one of the most popular traffic simulator in Europe. Using its mesoscopic option, large model covering many intersections or corridors, can be less restrictive in terms of modelling and calibration. AIMSUN provides only light rail simulation capabilities and limited or no level crossings signal capabilities;

- ARENA is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system, and employs an object-oriented design for entirely graphical model development. ARENA is a general purpose simulation software tool and not a traffic simulation software packages; it does not provide simulation capabilities for any type of rail environment. Hence, it does not meet the criteria requirements;
Chapter 4: Research Methodology – Computer Simulation

- CORSIM, ‘CORridor SIMulation’, is one of the most regularly used micro-simulation programs in the USA for modelling vehicle traffic operations. CORSIM specialises in simulation of freeways and highways vehicular traffic issues and provides limited signal capabilities and no rail simulation capabilities;

- MATLAB, ‘MATrix LABoratory’, is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. MATLAB is predominately used for engineering simulations and not a traffic simulation software packages; thus, it does not meet the criteria requirements; and

- VISSIM is a multi-modal microscopic traffic flow simulation software purposely developed by Planung Transport Verkehr AG (PTV AG) in Karlsruhe, Germany and the named VISSIM resulting from the German ‘Verkehr In Städten – SIMulationsmodell’ or ‘Traffic in cities – simulation model’ in English (Choa, Milam & Stanek 2003).

Using a selection criteria matrix, VISSIM was selected and deemed the most appropriate of the packages available, as it met all of the selection criteria, as it is made for the type of research that encompasses a combination of road and rail traffic. VISSIM offers much more flexibility than the other contenders because of its ability to model unusual sites, for example railroad crossings, as well as providing powerful 3-D and movie capture (Fontaine 2012).

Using the selection matrix it was determined that VISSIM was the simulation software that met all but one of the selection criteria requirements. Specifically this is the only software available able to simulate heavy rail, a must for this research. AIMSUN was close second, addressing many of the requirements, but providing limited level crossings signal capabilities and provides only light rail and no heavy rail simulation capabilities. CORSIM came third, with a number of limitations. The simulation software selection matrix is presented in detail in Appendix C.
4.4.3. **VISSIM Simulation Software**

Multi-modal simulation is a term used in the simulation modelling process to describe the ability to simulate more than one type of traffic mode and vehicle type that can interact with each other in a simulation. VISSIM allows the following type of traffic entities to be simulated:

- motor vehicles (cars, buses, and trucks);
- public transport vehicles including heavy rail (trains), light rail (off road articulated trams), trams and buses;
- emergency vehicles including fire, police, ambulance and emergency services in general; and
- other road users including cyclists, pedestrians and rickshaws among others.

VISSIM consists of two main components, the actual simulator and a signal generator controller component. The simulator role is to generate the traffic and the actual graphical representation of the network, using imported photographic aerial images of the required segments of the network. The network is ‘planted’ or digitised on top of the photo with the attributes collected from data collection being applied, including road widths, traffic directions, speeds and speed zones, detector locations, etc., to the graphical representation, which then becomes the test bed for the simulation.

The signal generator module sits outside the simulator and is where all signal logic is defined, and where each intersection controlling the logic is loaded into the Vehicle Actuated Programming (VAP) file. The characteristics of intersection signals are represented, including phase sequences and other parameters including: minimum green times, actuated forced-off, and gap out of times; these are the sequences controlling the intersection signals.

The VISSIM model construction consists of defining a number of tasks including:
• identification of the geometry features of the environment;
• analysis of the data;
• data collection and data processing;
• coding of the VISSIM environment model; and
• calibration of the model.

(Gomes, May & Horowitz 2004)

4.5. Simulation Design
The literature on computer simulation modelling indicates that simulation practitioners have different views and approaches to the process of defining, designing and developing computer simulation models. They also have different views as to the number of steps the simulation modelling process should take. For some, this is a twelve-step process (Shannon 1998), a nine-step process (Ulgen, Gunal & Shore 1996), a seven-step process (Law 2008; Law 2014; Law, Kelton & Kelton 1991), a five-step process (Carson II 2005), or even a four-step process (Raychaudhuri 2008). A summary of five recommended design methods is presented in a table in Appendix C.

Of all five design methods examined, Law (2008) was considered the most simple and appropriate design method to use. No design method examined presented a construct design incorporating two simulation model processes as proposed to be developed by this research. Law’s design method was used as the basis to develop the research design model, taking into the consideration of the design and the proposed method of simulation using VISSIM as the simulation software modelling tool.

4.6. Research Design
As mentioned above, the research methodology was developed using Law’s model and expanded to fit the requirements of this research, ensuring that the new design model incorporated into its design, the
validity, reliability, and replicability features from Law’s method. In addition, this new design model also incorporated the design of two simulation processes, one simulating the current environment and the other simulating the proposed environment. This method of creating two simulation processes incorporated into one design model is a new concept and a model design not mentioned on the reviewed literature. Law’s model design was modified for this research to specifically incorporate two simulation processes, to evaluate the proposition set out in this study and assisted in generating the theory. The research model design methodology is presented below as Figure 4.2.
Figure 4.2: Model Design Methodology

Source: Law’s (2008) design model modified to the research requirements
The methodology was specifically constructed for the model design to use the data collected during the data collection process and develop the traffic computer simulation model to simulate the current operations of the level crossing. The simulation model is tested as many times as required, in the process termed as calibration, ensuring:

- the operation validity; and
- replicability of a simulation design model created.

Once a valid and operational model of the current operations is achieved, a new model is created by the repositioning of the infrastructure of the station, modifying the station to the new platform specifications. The new model is a replica of the current model, ensuring the validity and replicability of a simulation design of the new model.

The results from both simulation models, the current operation and the proposed operation, are then compared to ascertain the differences between the two simulation processes outcomes.

4.7. Simulation Model Design

Computer simulation techniques are used to test and evaluate the proposition that the implementation of Departure Side Platforms (DSP) at a railway station, result in mitigating road traffic congestion in the vicinity of the railway station. To evaluate this claim, the current operation of a level crossing was first modelled, simulated and tested using VISSIM traffic simulation techniques; this ensured the operation validity and replicability of a simulation design model created.

Once a validated and operational model of the current operations was achieved, a new model was created, using the operational model of the current operation as base model, by the repositioning of the infrastructure of the station, modifying the station to the new platform specifications. The new model is a replica of the current simulation model, ensuring the replicability of the simulation design was incorporated into the new model.

The results from both simulation models, the current operation and the
proposed operation, were then compared to evaluate the proposition of this study.

A number of steps are required to build an accurate simulation model, including:

- confirmation of the accuracy of the model, that it represents the actual phenomenon;
- analysis of the full aspect of subject matter; and
- analysis of model using both uncertainty and sensitivity methods to understand the models behaviour.

(Peck 2004)

According to Winsberg (2003), for the simulation to work and to produce reliable results, it requires a lengthy period of trial, error and comparisons of the simulated theory and actual results of physical experiments; this process is termed as calibration of the model. This process allows for approximations, idealisation, falsification and additional information during the model development process (Winsberg 2003). Further, Quinn (2000) postulates that simulation is a *model* of reality (Quinn 2000). In addition, Hellinga (1998) indicates there are few standards by which the level of calibration, validation and verification of a model can be measured (Hellinga 1998).

Simulation models contain multiple independent parameters to express traffic control operations, traffic flow characteristics, and behaviour of drivers (Park & Schneeberger 2003). Park and Schneeberger (2003) further indicate that simulation software models contain many default values, allowing the modeller access for modification of variables and parameters; they suggest that changes to set parameters during calibration should be justified and defensible by the modeller (Park & Schneeberger 2003).
4.8. Summary

This chapter presented the topic of computer simulation, how and why computer simulation is used for traffic assignments; it discusses when the use computer simulation is appropriate, introduces the simulation selection process and describes the different traffic simulation software packages available, describing the actual computer simulation selected for this research.

In general, traffic computer simulation models are used to explore alternative methods, without the need to modify or interrupt current activity, in a less costly and safer way. In the case of this study, there are no analytical models to analyse the behaviour and activities of both rail and road traffic at level crossings. Instead, computer simulation models are used in this research to address the problem of the positioning of platforms at railway stations without the need to build tracks, station, platforms and roads.

VISSIM was selected as the most appropriate software package available encompassing a combination of road and rail traffic; it was the only software available able to simulate heavy rail, a must for this research. The simulation and visualisation tools available in VISSIM could be used extensively to present and demonstrate the outcomes of the study.

Further, the methodologies used when using computer simulation techniques were presented. The development of the research design methodology and the simulation model design to be followed were also discussed and presented. The next chapters present the data collection processes, the actual computer simulation processes followed, and the presentation of the results of the simulation efforts.
5. MELBOURNE CASE STUDY: LEVEL CROSSINGS OPERATIONS AND DATA COLLECTION PROCESSES

This chapter presents the processes conducted prior to and in preparation of the computer simulation development process, in the context of the Melbourne case study. It discusses the Melbourne rail network, level crossing operations, including level crossing standards, safety mechanisms, level crossing predictor’s, rail track axle counters technology, train headway separation and dwell time. The data collection processes carried out to obtain the primary research data, the sources and type of secondary data collected, as well as the preparation and analysis of both the primary and secondary data used, are also discussed in detail.

5.1. Level Crossing Operations

There are a number of safety standards and devices related to the operations of level crossings and some of these have been discussed in Section 2.6. To be able to understand the level crossing operations and the simulation process that follows, it is necessary for a number of these safety standards, including level crossings train predictors and axle counters, to be described in detail. Level crossing train predictors activate and control the closure and subsequent opening of the level crossing intersection. Axle counters insure that a certain degree of separation or headway exists between trains travelling on the same track and in the same direction. Other issues for consideration, regarding stations dwell time and rail tracks practical train capacity, are also discussed.

The level crossings train predictors and axle counter, more specifically the headway between trains, do have implications into the building of the simulation model and to the final outcomes presented; these are discussed in Section 6.7.4.
5.1.1. Level Crossing Safety Mechanisms and Standards

Safety implications of level crossing operations require a strict set of guidelines to be in place; these guidelines or standards are organised and maintained by Australian Standards: these govern the safety operation of level crossings (AS1742.7 2007). The standards dictate that the level crossings closure operation shall commence activation for a period prior to the arrival of a train at a single track crossing and also indicates that greater periods may be required for multiple track crossings. Further, these Federal standards indicate that some States and Territory laws may require longer activation times, as is the case with level crossing standards in the State of Victoria.

The Australian regulations require train warning systems to provide a minimum warning of the train arrival, as specified in Australian Standard (AS1742.7 2007). That minimum warning time is specified as seventeen seconds (17s) plus two point two seconds (2.2s), and rounded to twenty seconds (20s) of warning time. This statutory safety requirement is to ensure that the warning device, called a train predictor or actuator, is activated by a train travelling at approximately 100 km/hour (kilometres per hour) within limits of safety, providing sufficient time to clear the crossing of motor vehicle and pedestrian traffic, and for the timely and safe closure of the level crossing intersection. Therefore, the train predictors or actuators, must be located at a minimum distance of about 550 metres (556m) away from the level crossing, allowing for a train travelling at 100 km/hour or 27.8 m/sec (metres per second) to activate the level crossing warning system within the prescribed period of time.

Victorian standards for level crossing train predictor operations differ from the Australian Standard, prescribing that the operating system provides sensitivity capable of assuring a warning time of twenty five seconds (25s) minimum for constant train speeds of 2 mph (miles per hour) or greater (VRIOG 2009b). Therefore in Victoria, the train predictor or actuator must be located at a minimum distance of about 700 metres (694.5m) away from the level crossing, allowing for a train travelling at 100 km/hour or
27.8 m/sec, to activate the level crossing warning system within that prescribed period.

5.1.2. Level Crossing Train Predictors
As discussed in Section 2.6, active protected level crossings are installed with electronic equipment that is activated at the detection of an approaching train (Wigglesworth 2001). The electronic equipment directs all traffic at the level crossing, interacting in one direction only with road traffic signal equipment, passing data of the impending train arrival to, and departure from, the level crossing area of operation. As a train approaches or exits the level crossing, the level crossing equipment automatically locks down or opens up the intersection to road and pedestrian traffic.

The detection of the train by the level crossing train predictor activates the closing the intersection by sending messages to the road signals system, closing the intersection to all other traffic, motorised and/or pedestrian, and opening the intersection to rail traffic. As train exit movement from the station area is detected by the level crossing train predictor, the opening of the intersection is activated sending messages to the road signals system, opening the intersection to all traffic, motorised and/or pedestrian, and closing the intersection to all train traffic.

In addition, the train predictors comprise of two different activation operating settings, which is dependent on the speed of the arriving train. For a fast approaching train, for instance a non-stopping train or a train travelling at a constant train speed of 2 mph or greater, the train predictor closes the intersection as soon as the train is detected, to allow for the twenty five seconds (25s) safety rule. For slow approaching trains or a train travelling at constant train speed of less than 2 mph, the train predictor closes the intersection at the latest possible moment after the train is detected, as the train is a considered by the train predictor system as a slow stopping train.

The predictors operations determine the timing of both the level crossing closure activation and the level crossing opening activation and are
triggered by the presence of train(s). The position of the station platforms in relations to the level crossings intersection or to the detectors has no bearings on the activation of the intersection level crossing closure and opening operations. That is, train movements and the length of train stopping period along the station precinct, including at the station platform areas, determine the intersection level crossing closure and opening operations.

5.1.3. Rail Tracks Axle Counters

Axle counter is the name given to the mechanism that insures the existence of certain degrees of separation or headway between trains travelling on the same track and in the same direction. The system is a failsafe system that detects the presence or absence, of a train within a given track section (VRIOG 2009c), that negates access to a sector of the track section if the track is occupied by another train.

The axle counter works in the following manner: when a train passes a detection head point, a count of the number of wheels passing the head is recorded; this count is compared to the count of the detection head point at the end of the section; if the two counts are not the same (count in unequals count out), the section is indicated as occupied; when the counts are the same (count in equals count out) the section is indicated as vacant (VRIOG 2009c); the mechanism ensures that no trains do come in close proximity, maintaining the relative prescribed headway. Details and images of the operations of the Axle counter mechanism are included in Appendix D.

5.1.4. Headway Separation and Dwell Time

In addition to the axle counter technology in place, and as a further safety measure, the Victorian Department of Transport, as discussed in Section 2.6, contends that three minute headways or separation between trains travelling on the same track and in the same direction must be maintained; these give, as the standard limit for Victoria’s rail network, a practical maximum capacity of 20 trains per hour per single track (60min / train
separation of three min = max 20 trains per hour). According to SKM et al. (2008), the reason that a higher practical capacity is not considered possible in Melbourne, is because of long dwell times and irregular arrival patterns at certain stations (i.e. City Loop stations) (SKM, Maunsell & Evans & Peck 2008).

5.2. The Melbourne Rail Network

The Melbourne urban rail network consists of 16 radial lines divided into five separate groups currently servicing more than 210 stations (PTV 2013e). Figure 5.1 illustrates the Melbourne Rail Network Groups.

![Figure 5.1: Melbourne Rail Network Groups](source: SKM, Maunsell & Evans & Peck 2008)

The Melbourne urban rail network is used by a number of operators. The urban train network is operated by Metro Trains. V/Line operates rural and
regional services, sharing some tracks with the urban network; freight operators have limited use of some lines.

5.2.1. The Caulfield Group of Lines

Two of the busiest lines in the network services the south-eastern part of the metropolitan area and belong to the Caulfield Group of lines. The group consists of four corridors: Sandringham, Frankston, Pakenham and Cranbourne lines (the Dandenong line is serviced by both the Pakenham and Cranbourne lines); the group lines are presented in Figure 5.1 in blue colour. The lines share six tracks from the City to South Yarra where the Sandringham line separates, taking two tracks. At Caulfield, the remaining lines separate, with the Frankston line taking two tracks and the Dandenong lines (the Pakenham and Cranbourne lines) taking the remaining two tracks. Further, the group of lines is also home to a total of 68 level crossings. Of these, 36 are level crossings located away from railway stations; 32 are level crossings located at, or in the proximity of, railway stations; the target level crossing of these research is one of these railway stations level crossing. Figure 5.2 illustrates the Dandenong and Frankston rail corridors lines.
5.3. **Level Crossing Current Operations**

The Melbourne metropolitan area is home to more than one hundred intersection railway station level crossing of similar rail and road infrastructure. As indicated in Section 2.3, two different operations occur at station level crossings, depending on the direction of the approaching train. The different operations relate to a train arriving in the direction of the Departure Side Platform (DSP) and a train arriving in the direction of the Arrival Side Platform (ASP). As mentioned therein, the process of unloading and loading passengers at an Arrival Side Platform (ASP) platform while the intersection level crossing remains locked down for
extended periods of time, forces roads at the level crossing intersection to remain closed for longer periods, creating road traffic congestion. This problem is exacerbated when multiple trains pass through the intersection in close proximity, prolonging the intersection closure period. The operation of both Departure Side Platform (DSP) and Arrival Side Platform (ASP) are analysed in detail in Section 2.3.2.

The target and the data collection process of this research was the intersection railway station level crossing at Clayton Railway Station in Clayton, in the state of Victoria. The level crossing had been the focus of attention of the Research Project component of a Master of Business (Logistic Management) during 2008 (Guzman 2008). Because of this, the accumulated knowledge and data collected for the previous research, the intersection level crossing also became the focus of attention of this thesis. Picture 5.1 illustrates the target Clayton Railway Station precinct and the adjacent level crossing intersection.
Picture 5.1: Clayton Railway Station and Level Crossing Intersection

Source: superimposed GoogleEarth images of the target area

Picture 5.1 illustrates the general level crossing intersection area, with the enlarged area illustrating the Clayton Station precinct. The general details indicate the station platforms location and length; the arrows indicate the physical location of the train detectors or actuators (Section 5.1.1). In addition, Figure 5.3 provides a more detailed diagram of the target intersection roads, lanes per road, roads width and road signals locations.
Figure 5.3: Target Intersection Diagram

Source: Research generated diagram

Figure 5.3 depicts the target railway station area and the level crossing intersection, showing details of road width, numbers of lanes per road, road and rail signals locations and boom gate barrier locations. Detailed road traffic data volumes are discussed in Section 5.6.2.1; a detailed traffic flow diagram is provided in Figure 5.5. Further, Picture 5.2 shows the Clayton Railway Station platforms environment.
Picture 5.2: Clayton Station Platforms View

Source: Clayton Station Eastbound view in Feb 2006 (www.answers.com)

Picture 5.2 illustrates the station platform infrastructures facing eastward from the edge of road intersection; it shows the platforms positions in relation to the level crossing intersection; the platforms are located ten metres from the level crossing area.

5.3.1. Level Crossing Intersection Closure Operations

The current level crossings operation process accommodates single train in either directions activating intersection closures, two-train activating intersection closures, and multiple trains activating intersection closures, defined as combinations of more than two trains. In this research, each of these events is treated as a different operation and accordingly, these events are discussed and simulated as seven separate operations; one for each of the seven activating intersection closures processes.

Single train operations, irrespective of the train’s direction, are considered two different operations, as each activate a single closure operation; these
are simulated as two separate operations, each modelling the train travelling direction. Two trains operation, one in each direction, activate a single closure operation, are considered a single operation and simulated as one operation. Multiple trains are considered each to be different operations, activating a single closure operation; these can encompass three trains, four trains, five trains and six trains; thus, each is simulated as a separate operations; this is because multiple train operations consist of a number of trains travelling on the same track and in the same direction and are required to, for safety reasons, maintain a certain degree of separation or headway, a process enforced by the axle counter system.

5.3.2. Single Train Operation Activation

Single train activation on opposite directions generates level crossing intersection closures of different lengths of time: a train travelling in the direction of the DSP platform generates shorter closures; a train travelling in the direction of the ASP platform generates longer closures. For example, a single stopping train from the city, irrespective of the service type, closed the level crossing on average for forty-six seconds (46s); a single stopping train to the city, irrespective of the service type, closed the level crossing on average for one minute and forty-one seconds (101s), more than twice (2.2 times) as long than a train in the opposite direction. These differences are further discussed in Section 5.5.2.1.

5.3.3. Two Trains Operation Activation

Two trains activated intersection closures, one train in each direction, are also different in timing, depending on the origin/destination (OD) of the closure-activating trains and the timing of the arrival of the second train; the closure of two trains activating the closure simultaneously is shorter than an activation of a train at the platform and another activating in the opposite direction well into the closure period. Overall, the differences are much smaller than the difference between single train activation closures, thus the operation is considered a single operation. These differences are further discussed in Section 5.5.2.1.
5.3.4. Multiple Trains Operation Activation

Multiple train level crossing closures can involve several trains in each direction, with more than one train travelling on the same track and in the same direction of another, but separated in time. These closures, activated by multiple trains, continuously keep level crossing intersections and the adjacent roads closed for extended periods of time; thus, these events are simulated and tested separately as multiple train events. Furthermore, all multiple train activation operations differ depending of the origin/destination (OD) of the closure-activating trains and the number of trains arriving and departing during the closure period. These differences are further discussed in Section 5.5.2.1.

An example of multiple trains level crossing closure, four-train in this case, is showed in Picture 5.3; the pictures illustrates the same vehicles at the level crossing, with four trains passing through the level crossing during that period, two in each direction, keeping the level crossing closed for an extended period of time, about seven minutes (420s) in this example.

Picture 5.3: Multiple Trains Level Crossing Closure

Source: *The Age*, Melbourne, 21 September 2010 (Lucas 2010)

From Picture 5.3 it can be ascertained that the level crossing was closed from about 5:16 pm and open at about 5:23 pm, a seven minutes (420s) period; no road traffic, vehicular or pedestrian, was permissible to transit the level crossing area during the locked down period. These types of
occurrences are frequent at all station level crossings and are worse during the morning and afternoon peak periods.

In the process to understand, describe and explain the level crossing problem, data collection and an analysis of the actual events of the level crossings closure was conducted. Details were obtained, including trains volumes and direction, the time of each closure activation, the origin and destination of the each train, the actual period of each closure, and of each train platform arrival and departure times.

5.4. Data Collection Process

The data collection effort included two separate processes; the primary data collection process and the secondary data collection process. As part of these processes, a number of tasks were completed, including:

- the level crossing site development task;
- a transit development collection data task that included both rail and road traffic, but excluded pedestrian traffic, as this was outside the scope of the research; and
- a signal controller data collection task, a task planned but abandoned after several requests to transport authorities, Public Transport Victoria (PTV), for the provision of level crossing data, failed. Instead, signal data was collected using video recordings of the intersection road signal operations.

The primary data sought included rail and road signal controllers, as well as signals that are actuated from the rail controller to the road controller and was inclusive of data pertaining to activating level crossing closures. This issue was overcome, during the physical observation and data collection periods, by expanding the primary data collection to include the times of intersection closure per each train activation period, as well as observations and, using video recordings equipment, recordings the road signal operations sequences.
Secondary data collection consisted on obtaining vehicular traffic from both the rail track and the roads. The rail line traffic data was documented and analysed from the train timetables for the corridor, as well as from visual observations during the primary data collection effort. Road traffic data was obtained from VicRoads, the roads authority of Victoria and consisted of average week day traffic volumes covering the years from 1995 to 2008.

5.5. **Data Collection Process – Primary Data**

The primary data collection process consisted of manual collection, via visual observation and worksheet recording, of the actual events of the level crossing closures, including:

- the direction of the train activating the closure;
- the time of activation;
- the OD of the train(s) activating the closure;
- the period of the closure; and
- the train platform arrival and departure times.

The visual observation consisted of observation of both networks traffic during the collection periods; road signal system operations were also recorded on-site using video recording equipment; the recordings collected AM and PM peak-hour periods road signals operations.

5.5.1. **Level Crossing Data Collection**

The level crossing data collection efforts for this research were carried out during 2008 (Guzman 2008), 2011 and 2012. Figure 5.4 is an example of a worksheet used and data collected in the primary data collection process.
Figure 5.4: Level Crossing Up and Down Activity Worksheet

![Figure 5.4: Level Crossing Up and Down Activity Worksheet](source.jpg)

Source: Research data collection worksheet

Figure 5.4 shows details of the collected data, including: the date and time of collection; the time of each intersection closure; the number of trains in each direction; the time of each intersection opening; and the elapsed times of each operation.

Each data collection effort was conducted over three days, recording different periods of the day, aiming at covering the twelve hour (12) period between 7:00 am and 7:00 pm, as follows: a) the morning period, ensuring morning data collection included the morning-peak period (7:30 am to 9:00 am); b) the afternoon period, ensuring afternoon data collection included the afternoon-peak period (4:30 pm to 6:00 pm); and c) the period covering between the morning-peak period and the afternoon-peak period (9:00 am and 4:30 pm). Again, the purpose for the collection and
Chapter 5: Level Crossings Operations and Data Collection Processes

observations process was to obtain and document level crossing intersection closure and open data, the frequency of the closing and opening events, as well as the number and direction of trains (stopping and non-stopping) activating the closures.

Data analysis of the collected data was accomplished using MS Excel, and summarised results were produced. An example of the intersection analysis worksheet using the data collected is included in Appendix D.

An analysis and summary of each the data collection period follows, commencing with the data from 2008 effort, followed by 2011 and 2012 periods. The results of the data collection are summarised as group/categories/time period are summarised in Table 5.1, Table 5.2, Table 5.3; a summary of the three data collection periods is presented as Table 5.4.

Table 5.1 illustrates the 2008 data collection summary including train numbers and level crossing ratios.

**Table 5.1: Train Traffic and Level Crossing Data Collection – 2008**

<table>
<thead>
<tr>
<th>Day and Instances – 2008</th>
<th>Boom Barrier Closures</th>
<th>Trains to City</th>
<th>Trains from City</th>
<th>Un-scheduled Trains</th>
<th>Total Trains</th>
<th>Trains Boom Barrier Ratio</th>
<th>Boom Barrier Trains Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 Aug</td>
<td>39</td>
<td>22</td>
<td>28</td>
<td>2</td>
<td>50</td>
<td>1.28</td>
<td>0.78</td>
</tr>
<tr>
<td>14 Aug</td>
<td>56</td>
<td>44</td>
<td>35</td>
<td>6</td>
<td>79</td>
<td>1.41</td>
<td>0.71</td>
</tr>
<tr>
<td>18 Aug</td>
<td>36</td>
<td>22</td>
<td>21</td>
<td>2</td>
<td>43</td>
<td>1.19</td>
<td>0.84</td>
</tr>
<tr>
<td>Totals</td>
<td>131</td>
<td>88</td>
<td>84</td>
<td>10</td>
<td>172</td>
<td>1.31</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Source: Research data collection process

Table 5.2 illustrates the 2011 data collection summary including train numbers and level crossing ratios.
Table 5.2: Train Traffic and Level Crossing Data Collection – 2011

<table>
<thead>
<tr>
<th>Day and Instances – 2011</th>
<th>Boom Barrier Closures</th>
<th>Trains to City</th>
<th>Trains from City</th>
<th>Unscheduled Trains</th>
<th>Total Trains</th>
<th>Trains Boom Barrier Ratio</th>
<th>Boom Barrier Trains Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Dec</td>
<td>39</td>
<td>28</td>
<td>37</td>
<td>12</td>
<td>65</td>
<td>1.66</td>
<td>0.60</td>
</tr>
<tr>
<td>8 Dec</td>
<td>37</td>
<td>32</td>
<td>28</td>
<td>8</td>
<td>60</td>
<td>1.62</td>
<td>0.61</td>
</tr>
<tr>
<td>9 Dec</td>
<td>54</td>
<td>42</td>
<td>40</td>
<td>8</td>
<td>82</td>
<td>1.52</td>
<td>0.66</td>
</tr>
<tr>
<td>Totals</td>
<td>130</td>
<td>102</td>
<td>105</td>
<td>28</td>
<td>207</td>
<td>1.59</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Source: Research data collection process

Table 5.3 illustrates the 2012 data collection summary including trains and level crossing ratios.

Table 5.3: Train Traffic and Level Crossing Data Collection – 2012

<table>
<thead>
<tr>
<th>Day and Instances – 2012</th>
<th>Boom Barrier Closures</th>
<th>Trains to City</th>
<th>Trains from City</th>
<th>Unscheduled Trains</th>
<th>Total Trains</th>
<th>Trains Boom Barrier Ratio</th>
<th>Boom Barrier Trains Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Dec</td>
<td>39</td>
<td>27</td>
<td>27</td>
<td>4</td>
<td>44</td>
<td>1.13</td>
<td>0.89</td>
</tr>
<tr>
<td>10 Dec</td>
<td>65</td>
<td>43</td>
<td>42</td>
<td>14</td>
<td>85</td>
<td>1.31</td>
<td>0.76</td>
</tr>
<tr>
<td>11 Dec</td>
<td>56</td>
<td>42</td>
<td>36</td>
<td>9</td>
<td>78</td>
<td>1.39</td>
<td>0.72</td>
</tr>
<tr>
<td>Totals</td>
<td>160</td>
<td>112</td>
<td>105</td>
<td>27</td>
<td>207</td>
<td>1.29</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Source: Research data collection process

Table 5.4 shows the train traffic and level crossing data collection time summaries including trains and level crossing ratios for the 3 years periods 2008, 2011 and 2012.
Table 5.4: Data Collection – 3 Periods Summary

<table>
<thead>
<tr>
<th>Day and Instance 2008 – 2012</th>
<th>Boom Barrier Closures</th>
<th>Trains to City</th>
<th>Trains from City</th>
<th>Unscheduled Trains</th>
<th>Total Trains</th>
<th>Trains Boom Barrier Ratio</th>
<th>Boom Barrier Trains Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>131</td>
<td>88</td>
<td>84</td>
<td>10</td>
<td>172</td>
<td>1.31</td>
<td>0.76</td>
</tr>
<tr>
<td>2011</td>
<td>130</td>
<td>102</td>
<td>105</td>
<td>28</td>
<td>207</td>
<td>1.59</td>
<td>0.63</td>
</tr>
<tr>
<td>2012</td>
<td>160</td>
<td>112</td>
<td>105</td>
<td>27</td>
<td>207</td>
<td>1.29</td>
<td>0.77</td>
</tr>
<tr>
<td>3 Periods Totals</td>
<td>421</td>
<td>302</td>
<td>294</td>
<td>65</td>
<td>586</td>
<td>1.39</td>
<td>0.72</td>
</tr>
<tr>
<td>3 Periods Average</td>
<td>140</td>
<td>100</td>
<td>98</td>
<td>22</td>
<td>195</td>
<td>1.39</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Source: Research data collection process

The comparison of the data collected on intersection closure activities from the three periods highlight several differences that have taken place over these years. For instance, there is evidence of increased daily train traffic over the twelve hour period between 7:00 am and 7:00 pm; the 2008 indicate 172 train movements during the period. Both the 2011 and 2012 figures indicate 207 train movements during the same period. These increases are corroborated by the analysis of the Public Transport train timetables for the periods (Connex 2008; Metro 2011a, 2013a; V/Line 2008b, 2011b, 2013) and by published reports (Guzman 2011, 2012; Lucas 2010) and summarised in Table 5.11.

5.5.2. Level Crossing Closures Analysis

Further analysis of the data of the three periods indicate changes on the activation of level crossing closures by the number of trains passing through the station and by the number of activated intersection closures. Table 5.5 shows the percentages of intersection closures for the type of train activating the closures.
Table 5.5: Intersection Closures per Train 2008 – 2011 – 2012

<table>
<thead>
<tr>
<th>Train Boom Barrier Period</th>
<th>Single Train to City</th>
<th>Single Train from City</th>
<th>Single Non-Stop Train</th>
<th>Two Trains</th>
<th>Multiple Trains</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 Number</td>
<td>51</td>
<td>45</td>
<td>10</td>
<td>13</td>
<td>14</td>
<td>133</td>
</tr>
<tr>
<td>Percentage</td>
<td>38%</td>
<td>34%</td>
<td>8%</td>
<td>10%</td>
<td>11%</td>
<td>100%</td>
</tr>
<tr>
<td>Combined %</td>
<td>80%</td>
<td>10%</td>
<td>11%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011 Number</td>
<td>25</td>
<td>31</td>
<td>16</td>
<td>51</td>
<td>7</td>
<td>130</td>
</tr>
<tr>
<td>Percentage</td>
<td>19%</td>
<td>24%</td>
<td>12%</td>
<td>39%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td>Combined %</td>
<td>55%</td>
<td>39%</td>
<td>5%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012 Number</td>
<td>52</td>
<td>51</td>
<td>10</td>
<td>44</td>
<td>5</td>
<td>162</td>
</tr>
<tr>
<td>Percentage</td>
<td>32%</td>
<td>31%</td>
<td>6%</td>
<td>27%</td>
<td>3%</td>
<td>100%</td>
</tr>
<tr>
<td>Combined %</td>
<td>70%</td>
<td>27%</td>
<td>3%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Research data collection process

Table 5.5 figures indicate that level crossing closures activation changes occurred during the data collection periods. In 2008, ninety per cent (90%) of all closures were activated by single or two-train events (80% single trains and 10% two-train events); multiple train events, meaning intersection closures activated by more than two train events, accounted for eleven per cent (11%) of all closures.

The trend started to change, as shown from the 2011 data, where ninety four per cent (94%) of all closures were activated by single or two-train events (55% single trains and 39% two-train events); multiple trains events accounted for five per cent (5%) of all closures.

The trend continued changing, as shown from the 2012 data, where ninety seven per cent (97%) of all closures, were activated by single or two-train events (70% single trains and 27% two-train events); multiple trains events accounted only for three per cent (3%) of all closures.
5.5.2.1. Average Level Crossing Activation Closure Times

From the analysis of the data the following patterns of activation of level crossing closures were identified. Different patterns were identified depending on a number of factors, such as number of trains, the OD of the trains and the service type, being Connex/Metro, V/Line, Pacific National cargo and non-stopping. Table 5.6 is a summary of the average intersection closure times activated by different types of train arrival during 2008, 2011 and 2012 and reflected from the data collection effort.

Table 5.6: Level Crossing Closures Times 2008 – 2011 – 2012

<table>
<thead>
<tr>
<th>Train/Closure Type (expressed in seconds)</th>
<th>Average 2008</th>
<th>Average 2011</th>
<th>Average 2012</th>
<th>Three Periods Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortest closure recorded</td>
<td>33</td>
<td>45</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>Single non-stopping train</td>
<td>41</td>
<td>80</td>
<td>58</td>
<td>60</td>
</tr>
<tr>
<td>Single V/Line from City</td>
<td>43</td>
<td>45</td>
<td>51</td>
<td>46</td>
</tr>
<tr>
<td>Single Connex/Metro from City</td>
<td>46</td>
<td>46</td>
<td>47</td>
<td>46</td>
</tr>
<tr>
<td>Single Connex/Metro to City</td>
<td>76</td>
<td>111</td>
<td>118</td>
<td>101</td>
</tr>
<tr>
<td>Single V/Line to City</td>
<td>122</td>
<td>112</td>
<td>70</td>
<td>101</td>
</tr>
<tr>
<td>Two-Train</td>
<td>120</td>
<td>153</td>
<td>108</td>
<td>127</td>
</tr>
<tr>
<td>Three-Train</td>
<td>243</td>
<td>254</td>
<td>231</td>
<td>243</td>
</tr>
<tr>
<td>Four-Train</td>
<td>286</td>
<td>319</td>
<td>348</td>
<td>318</td>
</tr>
<tr>
<td>Five-Train</td>
<td>N/A</td>
<td>527</td>
<td>N/A</td>
<td>527</td>
</tr>
<tr>
<td>Six-Train</td>
<td>N/A</td>
<td>638</td>
<td>N/A</td>
<td>638</td>
</tr>
<tr>
<td>Longest closures recorded</td>
<td>311</td>
<td>638</td>
<td>348</td>
<td></td>
</tr>
</tbody>
</table>

Source: Research data collection process

5.5.2.2. Shortest Closure Activation

The average shortest level crossing closure activation recorded was thirty nine seconds (39s). The actual shortest closure recorded was thirty three seconds (33s) in 2008.
Single-train average pattern of activation of level crossing closures differ depending on the service activating the closure. A single stopping train from the city, irrespective of the service type, closed the level crossing for forty-six seconds (46s). Single non-stopping trains closed the level crossing for sixty seconds (60s). Single stopping trains to the city, irrespective of the service type, closed the level crossing for one minute and forty-one seconds (101s), more than twice (2.2 times) the length of time of closures activated by trains travelling on the opposite direction.

Two-train average pattern of activation of level crossing closures, regardless of the origin or type of trains activating the closures, closed the level crossing for two minutes and seven seconds (127s).

Multiple-train closure activations, meaning more than two-train, regardless of the OD or train service type, arriving at the level crossings in close proximity, closed the level crossing as follows: a) a three-train closure closed the level crossing for four minutes and three seconds (243s); b) a four-train closure closed the level crossing for five minutes and eighteen seconds (318s); c) a five-train closure closed the level crossing for eight minutes and forty-seven seconds (527s); and d) a six-train closure closed the level crossing for ten minutes and thirty-eight seconds (638s). An example of a multiple-train level crossing activation closure, a four-train closure lasting about seven minutes (420s), is shown in Picture 5.3.

Overtime, the closure occurrences have not diminished; during the afternoon peak-period of 29 August 2014, the researcher experienced, as a pedestrian, a seven-train closure at the level crossing lasting for more than twelve minutes (720s).

The longest level crossing closure activation recorded was ten minutes and thirty-eight seconds (638s), recorded for a six-train closure in 2011. It is noted that 2011 was the only data collection year to present more than four-train closures during the data collection periods. This is not representative of actual operations and no conclusions can be drawn from these; six-train and seven-train closures have been experienced by the
researcher during 2013 and 2014. During these late unrecorded closure observations, the level crossing closures extended for periods in excess of ten minutes (600s) in duration.

Further analysis of the data provides details of the total closure time per period of the day for the three different years, including the number of trains per period, the train’s origin/destination, the intersection closure in seconds and the intersection closure in hours, minutes and seconds. Table 5.7 is indicative of the closure time changes experienced per period of the day over the three years period.

**Table 5.7: Train Level Crossing Closure Times 2008 – 2011 – 2012**

<table>
<thead>
<tr>
<th>Year/Period of day</th>
<th>Boom Barriers Trains Periods</th>
<th>Trains to City</th>
<th>Trains from City</th>
<th>Train Totals</th>
<th>Closure Times</th>
<th>Closure Times</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Connex Metro</td>
<td>V/Line</td>
<td>Other</td>
<td>Connex Metro</td>
<td>V/Line</td>
</tr>
<tr>
<td>AM Peak 2008</td>
<td></td>
<td>22</td>
<td>2</td>
<td>0</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>3</td>
<td>0</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>PM Peak 2008</td>
<td></td>
<td>11</td>
<td>1</td>
<td>2</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>2</td>
<td>4</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>3</td>
<td>4</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>12 Hrs 2008</td>
<td></td>
<td>64</td>
<td>11</td>
<td>5</td>
<td>63</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>68</td>
<td>13</td>
<td>13</td>
<td>69</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>71</td>
<td>13</td>
<td>13</td>
<td>70</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: Research data Collection process

In summary, the 2012 period data indicates that during the one and half hour AM peak-hour period, the road was closed to traffic for thirty nine minutes and seven seconds (2,347s) or for forty three per cent of the time; during the one and half hour PM peak-hour period, the road was closed to traffic for thirty nine minutes and twenty six seconds (2,366s) or for 44% of
the time. Overall, during the twelve-hour period between 7:00pm and 7:00pm every working day, the road was closed to traffic for three hours, twelve minutes and 50 seconds (11,570s) or for 26% of the time.

Of note, and from local knowledge only, it can be said that the 2011 large increase in level crossing closure periods resulted from a number of issues, including: a) union enforced train driver bans; b) problems with braking systems on all new trains delivered; and c) summer heatwave causing rail tracks to buckle, thus forcing trains to travel at low speed. Train traffic increased in 2011 and again in 2012. Yet, the 2012 data analysis shows much improvement in level crossing closure periods against the 2011 period data, regardless of train traffic increases experienced.

5.5.2.3. Composition of Train Level Crossing Activation
The composition of the trains activating during the level crossing data collection periods was analysed and indicates differences in the level crossing closure activation per train type, as well as per OD of the train activating the closure. Table 5.8 indicates the actual level crossing closures per train as a percentage of the collection efforts of 2008, 2011 and 2012 processes.

Table 5.8: Closures per Train as Percentage 2008 – 2011 – 2012

<table>
<thead>
<tr>
<th>Train Boom Barrier Period</th>
<th>Single Train to City</th>
<th>Single Train from City</th>
<th>Single Non-Stop Train</th>
<th>Two Trains</th>
<th>Multiple Trains</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 Number</td>
<td>51</td>
<td>45</td>
<td>10</td>
<td>13</td>
<td>14</td>
<td>133</td>
</tr>
<tr>
<td>Percentage</td>
<td>38%</td>
<td>34%</td>
<td>8%</td>
<td>10%</td>
<td>11%</td>
<td>100%</td>
</tr>
<tr>
<td>Combined %</td>
<td>80%</td>
<td></td>
<td>10%</td>
<td>11%</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>2011 Number</td>
<td>25</td>
<td>31</td>
<td>16</td>
<td>51</td>
<td>7</td>
<td>130</td>
</tr>
<tr>
<td>Percentage</td>
<td>19%</td>
<td>24%</td>
<td>12%</td>
<td>39%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td>Combined %</td>
<td>55%</td>
<td></td>
<td>39%</td>
<td>5%</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>
Chapter 5: Level Crossings Operations and Data Collection Processes

<table>
<thead>
<tr>
<th>Train Boom Barrier Period</th>
<th>Single Train to City</th>
<th>Single Train from City</th>
<th>Single Non-Stop Train</th>
<th>Two Trains</th>
<th>Multiple Trains</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 Number</td>
<td>52</td>
<td>51</td>
<td>10</td>
<td>44</td>
<td>5</td>
<td>162</td>
</tr>
<tr>
<td>Percentage</td>
<td>32%</td>
<td>31%</td>
<td>6%</td>
<td>27%</td>
<td>3%</td>
<td>100%</td>
</tr>
<tr>
<td>Combined %</td>
<td>70%</td>
<td></td>
<td>27%</td>
<td>3%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Source: Research data collection process

The intersection closures activated by single trains averaged over the three periods is about sixty eight per cent (68%) of all closures; two-train intersection activated closures average over the three periods is about twenty five per cent (25%) of all closures; multiple trains intersection activated closures average over the three periods is about seven per cent (7%) of all closures. Notwithstanding multiple trains intersection activated closures are a small percentage of all closure, these closure types closed the arterial roads for long periods of time, exacerbating road congestion at the level crossing location.

In addition, road congestion created by multiple trains activated intersection closures, cannot be cleared in time before the next train(s) arrival(s), adding to congestion and delays, as not all vehicles in the queues are cleared before the next closure. These events can overlap multiple sets of train arrivals and intersection closure periods, exacerbating road traffic congestion.

5.5.3. Other Issues and Difference in Intersection Closures

The closures elapsed times are dependent on the speed of the train and the length of the train. In addition, when more than one train are arriving at the station in opposite directions, the intersection closures elapsed time is longer than for a single train. This is then compounded when another train in the opposite direction arrives before the train at the station departs. There were several observations of three or more trains during a single intersection closure period. During each of these periods, intersection
closure elapsed times were, in most cases, for longer than four minutes duration.

This is further complicated when access to trains by disabled people using wheelchairs or motorised scooters, requiring support from the train driver. The train driver needs to: a) vacate train driver’s cabin; b) move to the first door of first carriage to retrieve first and then replace a platform ramp to allow ingress/egress to/from trains by disabled patrons; c) to place and remove, the platform ramp on the ground to the first door of first carriage, allowing access to wheelchairs or motorised scooters; and d) return to the cabin to drive the train. Before leaving the train cabin, the driver must secure the train; when leaving the driver compartment, the driver must ensure the driver cabin is locked and secured, the driver must unlock and relock the platform ramp from a locked cabinet, and the driver must then return to the driver’s cabin, unlocking it to gain access and the relocking again for security reason. A similar operation occurs when the disabled commuter reaches his/her destination, requiring the same train driver intervention.

This operation adds approximately sixty seconds (60s) to the dwell time that a train remains at the station and in the case of a city-bound or to the city train; it forces the intersection to remain closed for longer periods. The operation occurs twice during the disabled commuter trip; once on ingression and once on egression, adding dwell time to the entire trip. During the peak-hour periods, when trains are carrying 800 or more passengers, this action causes delays to all commuters, rail and road. In past times, this operation was performed by station staff; this is no longer the case, as stations are unmanned or staffed by sale and service by staff only, and the responsibility passed on to train drivers. The main problem is that when this operation is at the Arrival Side Platform (ASP), the level crossing remains close during the entire operation, causing delays not only the train commuters, but also to road commuters as well.
In addition, there are a number of differences in train dwell times at stations and are mentioned here as a matter of completion only. Trains dwell time at stations platform were longer when a cancellation occurred just prior to the arriving of a train in the same direction of the cancelled one; there are more passengers to egress and ingress the arriving train. Dwell time at stations when a city-bound or to the city train immediately follows a V/Line train. The headway between the previous suburban service and the arriving suburban service is longer.

5.5.4. Data Collection – Intersection Road Signal Data

As mentioned in Section 5.4, it was the intention of this research to obtain the signal controller data from transport authorities (PTV), a task that was planned but abandoned as no official data was made available for this research. This issue was overcome by expanding the primary data collection, during the visual observation and data collection periods, to include the recording of the road signal operations.

Level crossings rail and road signals were discussed in Section 2.6, indicating that both systems, the rail signals warning control system and the road traffic signals control system are not integrated and work independently of each other. The road controls system manages the smooth operation of the intersection road traffic flow, in a normal cyclical pattern of operation; it is pre-programmed with cycles of green, amber and red signals patterns that control vehicular and pedestrian traffic.

The rail controls system provides advanced warning information (preemption signals) to the road controls system, indicating an imminent train arrival to and/or departing from the level crossing area. The road control system is programmed to receive the signals from the rail control system and acts accordingly to change the road traffic signal cycle to stop all vehicular and pedestrian traffic from the crossing. When the road control system receives the signal from the rail control system that the train has passed, the road control system either resumes the normal cycle operation as before the interruption occurs, or resumes operations from...
the beginning of a new cycle, depending on the road signal control system programming, allowing traffic to return to normal operation.

Road signal system operations were recorded on-site using video recording equipment; the recording collected AM and PM peak-hour periods road signals operations. The AM period recording provided 6.5GB of road intersection data, the equivalent of 5,910 seconds of road signals operations data; the PM period recording provided 6.4GB of road intersection signals operations data, the equivalent of 5,768 seconds of road signals operations data. Table 5.9 provides details of the data collection road signal movies.

Table 5.9: Road Signals System Operations Movies

<table>
<thead>
<tr>
<th>Movie File Name</th>
<th>Recording Date</th>
<th>Start Time hh:mm:ss</th>
<th>Finish Time hh:mm:ss</th>
<th>Length hh:mm:ss</th>
<th>Length MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>File1203</td>
<td>10/12/2012</td>
<td>16:36:50</td>
<td>17:08:12</td>
<td>31:22</td>
<td>2099</td>
</tr>
<tr>
<td>Fi011203</td>
<td>10/12/2012</td>
<td>17:08:13</td>
<td>17:39:37</td>
<td>31:24</td>
<td>2099</td>
</tr>
<tr>
<td>Fi021203</td>
<td>10/12/2012</td>
<td>17:39:38</td>
<td>18:10:01</td>
<td>31:22</td>
<td>2099</td>
</tr>
<tr>
<td>Fi031203</td>
<td>10/12/2012</td>
<td>18:10:02</td>
<td>18:14:14</td>
<td>4:22</td>
<td>215</td>
</tr>
<tr>
<td>File1208</td>
<td>11/12/2012</td>
<td>07:38:40</td>
<td>08:10:05</td>
<td>31:25</td>
<td>2099</td>
</tr>
<tr>
<td>Fi011208</td>
<td>11/12/2012</td>
<td>08:10:06</td>
<td>08:41:30</td>
<td>31:24</td>
<td>2099</td>
</tr>
<tr>
<td>Fi021208</td>
<td>11/12/2012</td>
<td>08:41:31</td>
<td>09:12:55</td>
<td>31:24</td>
<td>2099</td>
</tr>
<tr>
<td>Fi031208</td>
<td>11/12/2012</td>
<td>09:12:56</td>
<td>09:14:51</td>
<td>1:55</td>
<td>129</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td>03:19:38</td>
<td></td>
<td>12938</td>
</tr>
</tbody>
</table>

Source: Research data collection process

Table 5.9 details each signal data collection movie recorded, including: the name of each individual movie made; the date of the movie recording; the start time of the movie, expressed as hh:mm:ss; the finish time of the movie, expressed as hh:mm:ss; the length of each movie, expressed as mm:ss; and the length of each movie, expressed in megabytes recorded. Totals include total recording time, expressed as hh:mm:ss, and total recording, expressed in megabytes recorded.
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The recorded events provided the intersection signal operations data, which were then collected manually using the movies recording timing information display data; the data was transcribed into data collection spreadsheets.

Table 5.10 displays road traffic signal operations data collection spreadsheets.

Table 5.10: Data Collection Road Traffic Signal

| Source: Research data collection process | Departure Side Platforms as a Measure to Mitigate Level Crossing Road Closures: An Investigative Study Using Simulation Modelling | William M. Guzman Page 114 |
Table 5.10 indicates the signal operations data details collected and transferred to the collection spreadsheets from the captured video recordings. The table presents details of the collected data including: the time of day in expressed in hours, minutes and seconds (hh:mm:ss); the signal direction, including all the different signal permutations available (i.e. NB TH Green = north bound through green; NT RT Green = north bound right turn green; NB Amber = north bound amber, etc.); and the signal transition period in minutes and seconds (mm:ss).

The different colours, black and red, are indicative of the intersection level crossing status, being either: black during the intersection level crossing open periods, and red during intersection level crossing closed periods.

These recorded and collected figures formed the base cycle times of the road signal system timings controlling the intersection road traffic operations; the cycles and timing were then used as input data to the simulation model of the traffic signal operations system. Picture 5.4 is a sample image from the recorded road signal movie.

**Picture 5.4 Road Signals Recording Image**
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Source: Research road signal recording process

Picture 5.4 presents an image of the operations of the intersection signal system recording movie dated 10 December 2012 at 16:37:16. The image shows Clayton Road on a green phase of the signal cycle and the intersecting Carinish Road on a red phase of the signal cycle.

5.6. Data Collection Process – Secondary Data

The secondary data collection consisted of collecting, analysing and summarising rail traffic data from rail lines, obtained from rail timetables, and road traffic data, provided by VicRoads.

5.6.1. Data Collection – Rail Timetables

The rail line traffic data was assembled and analysed from the train timetables for the corridor and visual observations during the primary data collection effort. The timetables used consisted of both the urban Metro and rural V/Line trains networks, both users of the rail tracks and having trains passing along the target level crossing. The rail line traffic data was obtained, documented and analysed from the train timetables for the corridor as well as from visual observations during the primary data collection effort.

The trains timetables data consisted of both the urban Metro and rural V/Line trains networks 2011 and 2013 timetables, covering the December 2012 period (Metro 2011b, 2013a; V/Line 2011b, 2013). In addition, 2008 timetables data (Connex 2008; V/Line 2008b), previously documented and analysed, were also used. Table 5.11 is indicative of the weekday daily rail traffic along the target rail corridor over the three periods analysed.
Table 5.11: Target Corridor Timetables Summary 2008 – 2011 – 2012

<table>
<thead>
<tr>
<th>Timetables Year per Day Period</th>
<th>2008</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Morning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connex/Metro</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To City</td>
<td>44</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>From City</td>
<td>29</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>Sub Total</td>
<td>73</td>
<td>79</td>
<td>78</td>
</tr>
<tr>
<td>V/Line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To City</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>From City</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Sub Total</td>
<td>17</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Morning Total Traffic</td>
<td>90</td>
<td>96</td>
<td>95</td>
</tr>
<tr>
<td>Afternoon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connex/Metro</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To City</td>
<td>43</td>
<td>52</td>
<td>53</td>
</tr>
<tr>
<td>From City</td>
<td>60</td>
<td>72</td>
<td>73</td>
</tr>
<tr>
<td>Sub Total</td>
<td>103</td>
<td>124</td>
<td>126</td>
</tr>
<tr>
<td>V/Line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To City</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>From City</td>
<td>14</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Sub Total</td>
<td>25</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Afternoon Total Traffic</td>
<td>128</td>
<td>149</td>
<td>152</td>
</tr>
<tr>
<td>Daily</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Scheduled Traffic</td>
<td>218</td>
<td>245</td>
<td>247</td>
</tr>
<tr>
<td>Daily Unscheduled Traffic</td>
<td>10</td>
<td>28</td>
<td>27</td>
</tr>
<tr>
<td><strong>Total Daily Train Traffic</strong></td>
<td>228</td>
<td>273</td>
<td>274</td>
</tr>
</tbody>
</table>

Source: (Connex 2008; Metro 2011a, 2013a; V/Line 2008b, 2011b, 2013)

The analysis of the combined timetables weekday daily rail traffic for the three periods along the target level crossing, provided insight into the daily combined traffic scheduled, but not necessarily the actual traffic passing the target level crossing per periods of the day. Totals are provided covering different periods of the day, including the morning traffic, the afternoon traffic the total scheduled traffic, the total unscheduled traffic and finally, the total train traffic. It is noted that unscheduled train traffic are actual unscheduled traffic observed during the data collection period; unscheduled train traffic are not included in timetables.

The total daily scheduled traffic in 2008 was two hundred and eighteen (218) scheduled services, increasing in 2011 to two hundred and forty-five (245) scheduled services.
(245) scheduled services, and again increasing in 2012 to two hundred and forty-seven (247) scheduled services.

The actual total daily train traffic in 2008 was two hundred and twenty-eight (228) trains, increasing in 2011 to two hundred and seventy-three (273) trains, and again increasing in 2012 to two hundred and seventy-four (274) trains. The main differences between the scheduled train traffic and actual train traffic along the corridor, was the unscheduled non-stopping train traffic.

The unscheduled non-stopping train traffic consists of two different train traffic types: a) Connex/Metro non-stopping empty trains; and b) freight trains. The total daily unscheduled traffic in 2008 was ten (10) trains per day each weekday, increasing in 2011 to twenty eight (28) trains per day each weekday, and decreasing in 2012 to twenty seven (27) trains per day each weekday. Most of the train traffic consisted of Connex/Metro non-stopping empty trains.

The practice of running empty unscheduled non-stopping trains is the result of the system of timetables used by Connex/Metro and, according to Mees (2007), not conducive to the operation of a rail network using recognised best practice urban rail timetables systems. Research by Mees (2007) and Vuchic (2005) indicates that international best practices should provide, among others, service patterns that are easy to operate reliably, easy understood and to make the most efficient use of infrastructure and rolling stock (Mees 2007a; Vuchic 2005). In this case, the practice of running dozens of empty non-stopping trains, a practice operated daily and used for prepositioning of trains for peak periods of demand, is considered not the most efficient use of infrastructure and rolling stock.

5.6.2. Data Collection – Road Traffic Data

In three opportunities during 2011, 2012 and 2013, the Victorian Department of Transport (DoT) was approached to provide data for this research. Specifically, requests were made for the provision of material compiled during the ALCAM assessment, which included data regarding...
the targeted level crossing and intersecting roads and road signal. The requested material was originally collected by DoT as part of work designated as the ALCAM Field Survey of all Victorian Railway Crossings, a risk assessment/field survey on all road and pedestrian railway crossings in the State of Victoria (DoI 2005; Spicer 2006); the survey was completed in 2008 (ALCAM 2008).

The requested material from the ALCAM Field Survey would have been of much interest and benefit to this research, but the transport authorities did not produced or made available the survey. No explanations were given to this effect. Instead, this research used road traffic data previously provided by VicRoads to derive estimates of the main arterial roads traffic volumes for 2013, and developed its own version of the intersection site sketch.

5.6.2.1. Road Traffic Data
The road traffic data was obtained from VicRoads, the roads authority of Victoria. This data was obtained in 2008 as part of the Research Project component of a Master of Business (Logistic Management). The 2008 supplied data consisted of the average traffic volumes per periods of the day over a fifteen year period, covering from 1995 to 2008 (VicRoads 2008b). The daily average road traffic volumes figures included vehicles movements for:

- morning peak period 7:30-9:00 am
- afternoon peak period 4:30-6:00pm
- off-peak periods 10:00-12:00 am, 1:00-3:00 pm
- twelve hour period 7:00am-7:00 pm; and
- twenty four hour period.

Table 5.12 indicates the main arterial roads traffic volumes of the VicRoads 2008 supplied data main arterial road based on the VicRoads 2008 supplied data.
Table 5.12: VicRoads Main Arterial Roads Traffic Data – 2008

<table>
<thead>
<tr>
<th>Volume Period – Traffic Direction</th>
<th>AM Peak 7:30-9:00</th>
<th>PM Peak 4:30-6:00</th>
<th>4 Hrs Off Peak 10–12 1–3</th>
<th>12 Hrs 7AM 7PM</th>
<th>24 Hrs avg per hour</th>
<th>Peak plus Off Peak</th>
<th>Hours Between Peaks*</th>
</tr>
</thead>
<tbody>
<tr>
<td>South to North</td>
<td>1268</td>
<td>1445</td>
<td>3374</td>
<td>10417</td>
<td>2959</td>
<td>13376</td>
<td>557</td>
</tr>
<tr>
<td>North to South</td>
<td>1320</td>
<td>1415</td>
<td>3497</td>
<td>10576</td>
<td>3005</td>
<td>13581</td>
<td>566</td>
</tr>
<tr>
<td>Combined Traffic</td>
<td>2588</td>
<td>2860</td>
<td>6871</td>
<td>20993</td>
<td>5964</td>
<td>26957</td>
<td>1123</td>
</tr>
</tbody>
</table>

* Hours between peaks or interpeak, are the five hours including 7:00-7:30, 12:00-1:00, 3:00-4:30 and 6:00-7:00

Source: (VicRoads 2008a)

This data, coupled with information and statistical data from the Australian Bureau of Statistics (ABS) statistical motor vehicular data, was then used to derive estimates of the main arterial roads traffic volumes for 2013. The data was used as the basis to derive an estimate of traffic volumes for 2013 using data from the ABS Demographic Statistics and ABS Motor Vehicle Census (ABS 2012, 2013). The ABS data (ABS 2013) indicates that during the period of 2008 and 2013, Victoria officially recorded an eleven point eight per cent (11.8%) increased on the number of road vehicles; the increase was then applied to the 2008 VicRoads provided data to derived to the 2013 estimated figures. Table 5.13 is indicative of the estimated traffic volumes of the main arterial roads.
Table 5.13: Estimated main arterial roads traffic data – 2013

<table>
<thead>
<tr>
<th>Volume Period – Traffic Direction</th>
<th>AM Peak 7:30-9:00</th>
<th>PM Peak 4:30-6:00</th>
<th>4 Hrs Off Peak 10–12</th>
<th>12 Hrs 7AM–7PM</th>
<th>12 Hrs 7PM–7AM</th>
<th>24 Hrs</th>
<th>24 Hrs avg per hour</th>
<th>Peak plus off Peak</th>
<th>Hours Between Peaks*</th>
</tr>
</thead>
<tbody>
<tr>
<td>South to North</td>
<td>1418</td>
<td>1616</td>
<td>3772</td>
<td>11646</td>
<td>3308</td>
<td>14954</td>
<td>623</td>
<td>6805</td>
<td>4841</td>
</tr>
<tr>
<td>North to South</td>
<td>1476</td>
<td>1582</td>
<td>3910</td>
<td>11824</td>
<td>3360</td>
<td>15184</td>
<td>633</td>
<td>6967</td>
<td>4857</td>
</tr>
<tr>
<td>Combined Traffic</td>
<td>2893</td>
<td>3197</td>
<td>7682</td>
<td>23470</td>
<td>6668</td>
<td>30138</td>
<td>1256</td>
<td>13773</td>
<td>9698</td>
</tr>
</tbody>
</table>

* Hours between peaks or interpeak are the hours including 7:00-7:30, 12:00-1:00, 3:00-4:30 and 6:00-7:00

Source: Research data collection process

5.6.2.2. Proposed Road Traffic Volumes

During the simulation modelling process, three levels of road traffic volume data were used, including a low-range road traffic volume, a mid-range road traffic volume and a large-range road traffic volume. As there was no available traffic data other than the VicRoads supplied data from 2008, this research used that data as the basis for the estimation of the three road traffic volumes, to be used during the computer simulation of the current and proposed processes. The reported hourly average data was used as the starting point for the low-range of the data for the main arterial road traffic and used for the simulation process. Table 5.14 indicates the target intersection three different sets traffic flow ranges, from low-range, to mid-range and to large-range that are used during simulation processing.
Table 5.14: Target intersection traffic flow ranges per hour

<table>
<thead>
<tr>
<th>Estimated Road Traffic (vehicles per hour)</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
<th>East-West Traffic</th>
<th>West-East Traffic</th>
<th>West-East Traffic1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Range</td>
<td>1000</td>
<td>1000</td>
<td>300</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>1500</td>
<td>1500</td>
<td>500</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>Large-Range</td>
<td>2000</td>
<td>2000</td>
<td>700</td>
<td>700</td>
<td>400</td>
</tr>
</tbody>
</table>

Source: Generated data – three different ranges

The main arterial roads are depicted as South-North traffic, shown as NB (north-bound) and North-South traffic, shown as SB (south-bound) on Figure 5.5; these arterial roads carry substantial road traffic and are the focus of the traffic congestion analysis, and thus the focus of this research. In addition, intersection roads depicted as East-West traffic, shown as WB (west-bound), West-East, shown as EB (east-bound) and West-East 1, shown as EB1 (east-bound) on Figure 5.5; these intersecting roads carry much less road traffic than the arterial roads and are currently subjected to lesser degrees of road congestion.

The generated data volumes were considered consistent and for as long as both the current and proposed simulation models used the same road traffic volumes data, integrity and validity of the simulations can be maintained, thus allowing for the comparison of the simulation results in equal terms. In addition, no data concerning turning vehicle volumes for right hand turns or left hand turns was available or require for the simulation process; the simulation software, using its own sets of algorithms, generates turning movements from the estimated road traffic volumes provide for main arterial and intersecting roads.

The intersecting roads currently benefit, to a certain degree, from the continual closure of the arterial roads by having, during these closure periods, constant or uninterrupted traffic flow, that only changes when pedestrian request and activate pedestrian crossing signal or by the opening of the closed intersection arterial roads, after train traffic is...
through and cleared the crossing. Figure 5.5 depicts all the target intersection traffic flows.

**Figure 5.5: Target Arterial and Intersecting Traffic Flow Diagram**

Figure 5.5 details the target intersection traffic flows, noting that during intersection closure periods, traffic movement directed by the rail signal system and controlled by the road signal system, permits traffic movements away from the level crossing intersection and not towards the closed rail path (i.e. EB1 RT, EB TH and LT, and WB TH and RT). Figure 5.3 provides details of the intersection road signals locations.
5.7. Summary

This chapter summarises the aspects of the Melbourne context, that need to incorporated in the simulation models. This includes level crossing train operation activities, which entails the operation of single train, two-train and multiple-train intersection closure activations; the data collection process, both primary and secondary data, are also discusses. It describes train volumes, derived from timetables and physical observations, and road traffic volumes obtained from VicRoads. The road signals video recording, collection and transcription process was described; data collection spreadsheets, created using signal operation data from the captured video recordings, were presented and discussed. Estimated current and future road traffic volumes were based on figures provided by VicRoads and adjusted using the latest Australian Bureau of Statistics (ABS) motor vehicular data. All of these are presented in tables in preparation for its use on the development of the level crossing computer simulation modelling process.

The computer simulation modelling development process requires the incorporation of a number of features derived from this chapter. These include level crossings train predictors, separation or headway between trains, rail and road traffic signal, train traffic and timetables, stations dwell time, and road traffic volumes. Axle counter technology will not be incorporated into the design of the simulation model; instead, headways will be imbedded into the train timetables design of the simulation model. Independent communication between the rail and road signal systems will not be simulated. Instead, the communication between rail and road systems will be incorporated into the design of the simulation model in unison.

Level crossings train predictors or actuators, as required by safety standards, will be simulated and located at the required distance before the level crossing, and immediately after the level crossing intersection. Separation or headway between trains, as required by safety standards, will be simulated with headways imbedded into the train timetables,
ensuring a minimum separation. Rail and road traffic signal are separate systems working independently of each other; these will be reflected in the simulation model development.

The communication between the rail signal system and the road signals system one-way warning communication must also be incorporated into the simulation model development. Train traffic and timetables are to be incorporated into the simulation model development, allowing for the headways for minimum separation of trains. Timetables should emulate peak periods (i.e. am peak period) train arrivals that are close in proximity; these will allow simulation approximating actual conditions. Train stations public transport station stops dwell time is to be incorporated into the simulation model development to supplement for non-pedestrian traffic. In addition, it is noted that the position of the station platforms has no significance on the operation of the level crossing safety equipment.

The road signals video recording data collection spreadsheets, were presented in Table 5.10. Road traffic and traffic volumes for the simulation model development were discussed and the proposed road traffic volumes generated were presented on Table 5.14.

Pedestrians and pedestrian traffic will not be incorporated into the design of the simulation model. Instead, train stations public transport station stops dwell time will be incorporated into the simulation model development design. The processes for the design of the computer simulation development, incorporations and inclusions and testing processes are presented in the next chapter.
6. COMPUTER SIMULATION PROCESS

6.1. Introduction
This chapter presents the processes carried out to conduct the computer simulation development and testing processes. The computer simulation was used to evaluate the effect of platform arrangements on level crossing closures and its impact on motor vehicle traffic congestion at railway stations level crossings. The processes used to evaluate the proposition were conducted in two phases, being the simulation of the level crossing current operations and the simulation of the level crossing proposed operations. The computer simulation modelling construct consisted of defining a number of tasks including the identification of the geometry features of the environment, the data analysis and processing, the coding of the computer simulation environment model and the calibration and validation of the model (Gomes, May & Horowitz 2004).

6.2. Computer Simulation Development Process
Three main components are required in the development of a VISSIM traffic simulation modelling application:

- the traffic flow simulator, VISSIM in this case;

- any extra tools required, in this case Vehicle Actuated Programming (VAP) (PTV AG 2012a) and Visual VAP – Flow Chart Editor for VAP (VisVap) (PTV AG 2012c), both used for this simulation model development; and

- specific data pertinent to the simulation application collected and/or developed of the target simulation area.

Details of VISSIM traffic simulator components and of the additional tools required for the simulation process are included in Appendix E.

6.2.1. Simulation Specific Data
The specific data relevant to this simulation application model consists of three main developing processes; infrastructure, controls and traffic
processes details of the target simulation area. Some of the data was available as the result of the data collection process (primary and secondary); other data was sourced from local knowledge and observations of the target area; some of the data was estimated based on previous years actuals and future years predictions; yet other data, like the target area imaging, were captured, for educational purposes, from Google Earth (GoogleEarth 2014).

6.2.2. Validation and Calibration Process

The validity of a simulation model is an important aspect of the process (Ruehr et al. 2004). Both calibration and validation are part of the process of developing a traffic modelling application and can impact simulation model results. These events, calibration and validation, are to ensure that the designed application model reflects an accurate sample of the actual conditions and the behaviour of the traffic movements of the targeted location. These events have been built into the design model methodology as described in Section 4.6.

According to Rakha et al. (1996), calibration can be defined as the method of selecting the best set of model input parameters to address differences between the model’s default assumptions/conditions, and those actually observed locally (Rakha et al. 1996). Park and Schneeberger (2003) further suggest that traffic simulation software contains many default values, allowing the modeller access to modify variables and parameters; the authors prescribed that changes to simulation software set parameters for calibration purposes should be justified and defensible by the modeller, as ‘many of the parameters used in simulation models are difficult to measure in the field, yet they can have a substantial impact on the model’s performance’ (Park & Schneeberger 2003, p. 1).

For example, Park and Schneeberger (2003) suggest some of these set parameters include start-up lost time, queue discharge rate, car-following sensitivity factors, time to complete a lane change, acceptable gaps, and the driver’s familiarity with the network. Further, the model should be
calibrated for local conditions (Hellinga 1998). In addition, Hellinga (1998) indicates there is little uniformity in the definition and conduct of model verification, validation and calibration. That is, no generally accepted standards exist to determine when a model can be considered to be suitably calibrated or validated (Hellinga 1998).

In this research model design, a number of VISSIM set parameters were customised, for calibration purposes, away from default values. These parameters, specific local conditions parameters, were modified to suit Australian rules, regulations and driving behaviour. These included measurement and driving conditions settings. Measurements were specified as metrical (i.e. kilometers per hour, metres per second, etc.); driving rules were changed to left hand drive. Others settings, such as the driver’s driving behaviour, were unchanged to the original Wiedemann model settings, which included free driving, approaching, following and braking assumptions. In addition, validations of actual conditions of the simulation models are dependent on visual observations and changes were made using all of the simulator’s properties and options. These included properties and options such as lane configurations, vehicle compositions, traffic signals and public transport stops, among others.

The validation process ensures the actual traffic conditions of the simulation model are alike to the actual traffic operations and behaviours, helping determine the modelled events are accurately simulated. In this research, simulation design created two models, the simulation of the current environment and the simulation of the proposed environment. The current environment simulation model is built and validated. Once the model of the current environment is validated and fully operational, a copy of the model will be made, with minor modifications, to create the proposed environment simulation model. These modifications changed the ASP platform to a DSP and move a PT Stop location, resulting in the formation of the proposed environment model. No other modifications were made to the design or operation of this new model, including the traffic volumes and signals systems. For as long as both simulation
models design used the same calibration settings and validation, parameters and data, the integrity of the simulation processes will be maintained, allowing for the simulations results of both simulation models to be compared in equal terms.

Fellendorf and Vortisch (2010) suggest that to be able to achieve a detailed and accurately designed model of the subject matter, the simulation model should contain three major building processes; in this case, a fourth process will be required for the generation of the data and results of the simulation model. These combined building processes are: a) an infrastructure process; b) a traffic process; c) a control process; and d) an output process (Fellendorf & Vortisch 2010). Figure 6.1 illustrates the simulation process model designed for this research.

**Figure 6.1: Simulation Design Processes Model**

![Simulation Design Processes Model](source.png)

Source: (Fellendorf & Vortisch 2010) modify to suit this research requirements
The three main process interactions are dependent on each other, working in tandem to generate the simulations required action/s. For example, a vehicle entering the simulation environment (a traffic process) onto roads (an infrastructure process) activates detectors (an infrastructure process), which in turn can activate the signals system (a control process). Meanwhile, the fourth process (the output process), is always active when a simulation is running, collecting data of all the events occurring within the three other processes.

### 6.3. Simulation Development Processes

Specifically designed for this study, the processes model design consists of four independent processes that work in unison with each other; these include:

- an infrastructure process, which contains road and railway infrastructure, public transport stops, sign posts, signal heads and masts, as well as detectors and predictors;

- a traffic process, which contains origin–destination routes, public transport stops, road and rail vehicles and vehicle volumes, and public transport stops;

- a control process, which contains rules such as priority, reduced speed areas and conflict areas, traffic signals, signal settings and actuated control; and

- an output process, which produces the required data and reports resulting from the running of each simulation.

As part of the process of calibration and validation of the developing traffic modelling application, each of the components of these three main processes was developed independently. The validation testing process, whenever possible, was conducted independently of other components previously developed, unless the testing process required multiple component validation testing.
Chapter 6: Computer Simulation Process

Each of the components validation and testing was conducted in an incremental and progressive mode; vehicle traffic was released initially in small numbers per each lane or segment of road being tested, incrementing in number and conditions as the testing process progresses. Each road direction was tested independently from others in the segment, as were the right and left turn, and give way at each intersection. The validation testing events required many, and in some cases hundreds, of simulation runs, until the desired validation results were achieved to meet each development process, stated or required as part of validation testing criteria. The criteria for validating and testing each component of the first three processes, in matching the observed condition and require behaviour of the model, are fully detailed within each of the processes description.

Also, the sequence of the development was not necessarily conducted in the order presented. For example, for road infrastructure, and infrastructure process, to be able to be tested, vehicles traffic, a traffic process, had to be specified, simulated and tested; the same development process apply to all components of the three processes. At times, some of components had to be developed specifically for testing the behaviour and performance of other components on the process of being developed. These processes are detailed below and their development in this simulation model, are fully described in Section 6.10.

The graphical representation of the network and the ability to view and test the simulation in motion, in different visual display representations, were an indispensable tool available for the process of calibration and validation; it made the process simple in use and effective in the visual evaluation of the results of the simulation model testing process, allowing for a test as you go development progression of each of the research four simulation development processes.
6.3.1. Simulation Infrastructure Development Process

The infrastructure development process contains road and railway infrastructure development, parking facilities, public transport stops, signposts, signal heads and masts, road and rail detectors and rail predictors. The infrastructure building process consists of making road links interconnecting, by way of connectors, arterial and intersecting roads; centre lines techniques were used to model actual road curvatures and contours, including pedestrian crossings and walk areas. Rail tracks were built using rail track links interconnected by connectors also using centre lines techniques, to model actual track curvatures and contours. Public transport stops were built with access to pedestrian traffic and flow, allowing for passenger walking and waiting areas.

6.3.2. Simulation Traffic Development Process

The traffic development process contains road and rail vehicle definitions, road vehicle volumes, road vehicle routes, including arterial and intersecting roads vehicles right-turn and left-turn movements, public transport bus lines and rail vehicle definitions, public transport bus lines and rail vehicle lines or routes, including public transport lines and public transport operations, and public transport stops and stations.

6.3.3. Simulation Control Development Process

The control development process contains road rules, comprising of road reduced speed areas, road conflict areas and road priority rules; some of these apply both to vehicular traffic as well as pedestrian traffic. The process also includes traffic signals, both rail and road signals, rail network signals system comprising of train predictors and rail to road signals system, as well as road network and pedestrian signals systems. In addition, the process also contains simulation data collection processes, including data collection points, queue counters and databases, and output generation reports.
6.3.4. Simulation Output Development Process

The output development process ensured that data was collected on all activities within simulation process runs including: data collected from data collection points and queue counters; vehicles inputs and vehicles entering the networks; signals operations; nodes; network performance details; public transport waiting time; travel times; lane changes; queue lengths; link evaluation and delay, among others.

In addition, there are a number of alternatives available to the type and mode of collection, storage and reporting of all data collected from the data collection points and queue counters; this could be online live reports displayed on small screens during the simulation, or in files, using different formats including text, MS Excel and MS Access database files. Data was collected for each individual simulation processing and testing; the simulation output and reporting were also collected individually. Including among these procedures was the generation of video animation recording and storage of simulation movies in a number of formats, including in standard AVI file format and ANI format, an exclusive VISSIM animation format that requires VISSIM operating for viewing the animation file.

6.4. VISSIM Simulation Environment Development

Like most software development tools, VISSIM provides a Windows desktop work environment that contains a menu bar and multiple toolbars that can be placed on the main pane. Access to the pane and toolbars are used to access VISSIM commands that can be selected from and used by, to access and perform all the available facilities within VISSIM desktop environment. As the simulation model develops and expands, the initial empty desktop environment start to get filled in with images and infrastructure of the target simulation environment, with vehicles and traffic controls necessary for the operation of the simulated environment. As this evolution was occurring, the simulated model was tested and recorded to observe the actions, behaviour and/or performance of the added model contents and functions.
6.4.1. Simulation Development Environment – Desktop

The desktop work environment main pane displays in the header area details including the program name, version, version of service pack and the project title, detailing the project file location and name. In addition, menu toolbars are accessed using mouse clicks or keyboard shortcuts to activate or point to pull-out menu or sub menu selections. The toolbar is used to access the editor and simulation functions and scroll bars, both horizontal and vertical are made available if/when the desktop work area needs further work area. A sample image of the VISSIM simulation modelling desktop work environment is included in Appendix E.

6.4.2. Desktop with Target Intersection Images

The first task performed in the creation of the simulation model was building the visual model of the target environment, using images of the application environment, to accurately depict the background real settings. The background settings of the model determine the accuracy of the model, as the simulator process uses the background, to precisely scale the model and all its components. Figure 6.2 shows the simulation desktop work environment.

Figure 6.2: Desktop with Target Intersection Images Background

Source: selected Google Earth images of the target area
Figure 6.2 illustrates the simulation desktop work environment superimposed with selected Google Earth images of the target area over the simulation desktop background that makes of the rail and roads networks of the targeted work area.

The precise scaling of the model is one of the most important tasks in the application development process, as all simulation objects, infrastructure items and timing of the simulation are all reliant on the correct scaling of the model; the simulation model results are dependent on the accuracy of the model development.

6.4.3. VISSIM Simulation Environment Test Process
As part of the process of calibration and validation of the developing traffic modelling, each of the components of the three main processes components, the infrastructure processes, the traffic process and the control process, were developed and tested, wherever possible, as independent tasks. This method of validation, using a test as you go approach, ensured the working of the simulation model replicated all the field observed conditions as well as all requirements set under the stipulated validation testing criteria. In addition, the graphical representation of the developing network and the ability of the simulation to be viewed and tested in motion, both in 2D and 3D representation, made the development and testing processes a simple and effective visual evaluation, permitting results of simulation development and testing of each task, to be performed and scrutinised, simultaneously.

As the development processes of each component expanded, the validation and testing processes changed accordingly. Whenever possible, testing was conducted independently of other components previously developed, unless the testing process required multiple component testing. The criteria for validating and testing each component processes are defined within each of the processes description.
6.5. Simulation Environment Development – Infrastructure Processes

The infrastructure development process contained road and railway infrastructure development, public transport stops, signal heads and masts, road detectors and rail predictors. This development process consisted of arterial and intersecting roads, using centre lines techniques to model actual road curvatures and contours, inclusive of pedestrian crossings and walk areas; rail tracks were built following actual track curvatures and contours.

Public transport stops were built with access to pedestrian traffic and flow, allowing for passenger walk and waiting areas. Pedestrians were excluded from the simulation process, as trains can carry many hundreds of passengers, thus simulation processes were slow when simulating multiple-train events. Instead, for public transport stops dwell time purposes and visual impact, it was necessary to incorporate into the simulation model certain aspects of pedestrian activity areas such as public transport stops, pedestrian walk areas, pedestrian waiting areas, and pedestrian crossings and signals.

6.5.1. Infrastructure Process – Rail and Road Networks

The desktop, with background imaging, was used to develop all the roads and tracks, using infrastructure links and connectors traced over the scaled background, in a process known as network coding. Using this method, all roads and approaches to the target intersection were represented by links and connected to other links or intersections using connectors. Connectors, rather than links, were used to model turning movement at intersections and for road changes, like changes from three lanes to two lanes or to link a turning lane to a road.

Connectors were used when two or more links merge into one or when a link splits into more than one link. Connectors were also used when the characteristics of a segment of a road changed. For example when the
road speed of a segment of road changed or other conditions of the road segment changed. Figure 6.3 shows the target simulation area in 2D.

**Figure 6.3: Target Intersection Rail and Road Network 2D View**

Source: target intersection – road and rail infrastructure in 2D

Figure 6.3 shows the target simulation area in 2D visual display, traced over the background imaging, following the contours of the actual networks, both rail and road; the rail and road networks are in dark grey and pedestrian areas and pedestrian crossings are in white. The ability to view and work with the network, both in 2D and 3D visual representation, made to process of calibration, validation and testing, easier. A sample image of the target simulation area in 3D is included in Appendix E.

### 6.5.2. Infrastructure Process – Links and Centre Lines

As part of the network development process, all the roads and track links were interconnected to other links or other intersecting links. Connectors were used to model turning movement at intersections and to follow contours and road curvatures. To facilitate this task, the simulator provides Centre Lines facilities using different colours lines; these allow the development and changes of links and connectors to be done with ease. A sample image of the centre lines of the target area is included in Appendix E.
6.5.3. Infrastructure Process – Detectors

VISSIM provides signal controls logic for the detection of a number of different situations. It provides for the detection of all road vehicles on roads and intersections, and detectors that can differentiate between vehicle front ends and/or rear ends, depending on the simulation model needs; pedestrian links can detect free or occupied changes; public transport detectors recognise only selected public transport vehicles; public transport vehicles are detected as a normal vehicle by all roads detectors. Each detector within the simulation model can be addressed and its logic coded independently of other like detectors. The activation of road, rail and pedestrian signals, called preemption events, are further discussed under the Control Processes section. Figure 6.4 displays target area road and rail detectors.

Figure 6.4: Rail and Road Networks – Road Detectors

Source: target intersection – road detectors in 2D

Figure 6.4 illustrates some of the target area road and rail detectors defined for the simulation process and are shown in blue and some are pointed by white arrows.

As no pedestrians or pedestrian traffic are simulated into the model, there are no pedestrian crossing detectors coded into the simulation model.
Also, train predictors shown in the above image are only the intersection exit detectors; the intersection entry detectors are placed about seven hundred metres (700m) before the level crossing intersection. The approximate locations of all four train predictors are shown in Picture 5.1 and Figure 6.5.

### 6.5.4. Infrastructure Process – Train Predictors

As indicated, public transport detectors recognise only selected public transport vehicles and public transport vehicles are detected as a normal vehicle by all roads detectors. Trains are treated differently, as although they are defined as public transport vehicles, trains use tracks and not roads. Trains are also different in the type of signals activated by trains; train signals control logic required two types of detections per each train traversing through the network: an entry signal, called a predictor or detector actuation, when the train is first detected arriving at the designated area; and an exit signal, when the train is detected departing from the designated area.

As stated in Section 5.1.1, the distance of the placement of the detectors in Victoria is relative to the twenty five seconds (25s) of warning required for communication to be passed from the rail signal controller to the road signal controller of the impending arrival of a train to the level crossing. Further, as indicated in Section 5.1.2, the position of the station platforms in relations to the level crossings intersection or to the train detectors, has no bearing on the activation of the intersection level crossing closure and opening operations. Train movements and the length of train stopping periods along the station precinct, including at the station platforms area, determine the intersection level crossing closure and opening activation operations. The simulation model activation of rail signals, also referred as railroad preemption, is further discussed under the control processes section. Figure 6.5 shows two sets of rail detectors per track.
Figure 6.5: Rail and Road Networks – Rail Detectors

Figure 6.5 illustrates the two sets of rail detectors per each track built into the model, an entry detector and an exit detector; these are shown and pointed out by the white arrows, corresponding to each of the two rail tracks.

6.5.5. Infrastructure Process – Road Signals System

Road and pedestrian crossing signals were coded into the simulation model in 2D graphics mode, and each signal set was defined and coded separately from other signals in the network and can be modified using signal properties within the simulator. Each signal belongs to a set of signals and each set of signals can be coded and made to operate in sync with a group set. The activation and operations of road and pedestrian signals, called preemption events, are discussed in details under the Control Processes section. Figure 6.6 shows the target area road and pedestrian signal system.
Figure 6.6: Road Signals Definition

Source: target area – road signals in 2D

Figure 6.6 shows the target area road and pedestrian signal in red, with the focus signal having a Signal Head pane open, and road position of the signal shown in bright red.

6.5.6. Infrastructure Process – Public Transport Stops

Public Transport Stops were coded into the model, allowing for passenger walking and waiting areas, designated as simulation construction elements, built into the design. Vehicles designated and recognised as public transport vehicles stop and service these public transport nominated areas at nominated times. In general, public transport stops were designated for all types of public transport vehicles. In this simulation, there are two types of vehicles nominated as public transport vehicles, trains and buses.

Trains operate along the designated train tracks lines and train stops were positioned at the target railway station; pedestrian platforms were built into the model emulating the length and size of the actual platforms and contained both passengers walking and waiting areas; the train public transport stops were designed to accommodate the full length of a train set, about 150 metres.
Buses operate along the designated road routes and stops are at designated areas; bus stops did not required any specific design characteristics if the stops are street stops; lay-by or off-road designed stops required specific design characteristics. Figure 6.7 depicts the target area public transport stops.

**Figure 6.7: Public Transport Stops**

![Public Transport Stops](image)

Source: target area – public transport stops

Figure 6.7 shows four public transport stops, two train stops and two bus stops; details of the development of Stop 4, to the city train stop, are shown in three panels inside the main pane.

### 6.5.7. Infrastructure Process – Testing Criterion

The process for the validation and testing for the infrastructure processes were developed independently for each process. Testing, when possible, was also conducted independently of other previously developed components. Table 6.1 is indicative of the criteria for the infrastructure processes testing.
Table 6.1: Infrastructure Process – Testing Criteria

<table>
<thead>
<tr>
<th>Task</th>
<th>Testing Criterion</th>
<th>Dependent Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Infrastructure – Links, Connectors</td>
<td>Be able to support vehicular traffic</td>
<td>Traffic – Vehicles</td>
</tr>
<tr>
<td>and Centre Lines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail Infrastructure – Links, Connectors</td>
<td>Be able to support train traffic</td>
<td>PTS</td>
</tr>
<tr>
<td>and Centre Lines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Detectors</td>
<td>Be able to detect motor vehicles at detector locations</td>
<td>Roads</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traffic – Vehicles Control – Signals</td>
</tr>
<tr>
<td>Train Predictors</td>
<td>Be able to detect train at predictor locations</td>
<td>Trains</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traffic – PT Lines Control – Signals</td>
</tr>
<tr>
<td>Road Network Signals</td>
<td>Physical location definition only</td>
<td>Roads</td>
</tr>
<tr>
<td>Public Transport Stops (PTS)</td>
<td>Physical location definition only</td>
<td>Roads &amp; Rail</td>
</tr>
</tbody>
</table>

Source: research internal testing criteria

As each component development of the infrastructure processes progressed, the testing processes changed accordingly to specific requirements and to match field observations. The criterion for testing each infrastructure processes and dependant tasks, described in Table 6.1, are specified as:

- the road infrastructure, including links, connectors and centre lines – the task was able to support vehicular traffic movement in all directions, vehicles changing lanes and turning into intersecting roads; the dependant task for this process were the vehicles definition and operations from the road traffic process;

- the rail infrastructure, including links, connectors and centre lines – the task was able to support train traffic in each direction; the dependant task for this process was the availability of public transport stops (PTS) from the road traffic process;
• the road detectors – the task was able to detect motor vehicles at detector locations; the dependant task for this process were the vehicles definition and operations from the roads traffic process traffic and road signals from the control process;

• train predictors – the task was able to detect train traffic at predictor locations; the dependant task were the ability to support train traffic from the road traffic process and rail signals from the control process;

• road network signals – physical and visual observation of the definition of signal infrastructure; the dependant task for this process was the definition of road infrastructure from the road traffic process; and

• public transport stops (PTS) – physical and visual observation of the definition of PTS infrastructure – the dependant task were the ability to support road and rail PT traffic from both the road and rail traffic process.


The traffic modelling process contains road and rail vehicle definitions, road and rail vehicle volumes, road vehicle routes, including arterial and intersecting roads, public transport bus routes, rail vehicle routes, including public transport rail lines and public transport train operations. All of these vehicles transited in the infrastructure network are modelled.

Private transport vehicles including cars, SUVs, vans, trucks, motorcycles, bikes and pedestrians, transited over individual routes; public transport vehicles, on the other hand, follow predetermined routes that include public transport stops; these can be on-road stops, off-road stops or stations stops. In addition, the simulator presented two methods of modelling the definition of vehicles routing information: by direction decisions or by routing decisions; direction decisions are discussed under road vehicles traffic volumes and routing decisions are discussed under road routes.
6.6.1. Road Vehicles Definition

Road vehicles used for the simulation were selected from the VISSIM vehicles library. If a specific vehicle is not provided or included within the VISSIM vehicles library, one can be designed using a software tool called V3DM; the tool is not included with the simulator. Vehicles can be selected from the model individually or a by percentage of vehicles mixture make up, such as ninety per cent (90%) cars, five per cent (5%) trucks, three per cent (3%) buses, two per cent (2%) cent bikes, consisting of one per cent (1%) motorbikes and one per cent (1%) bicycles; this was the mix used in this simulation modelling. Colours and performance of vehicles could also be specified as a per cent of the total make up of simulated vehicles. Figure 6.8 shows the simulation selection pane for a private motor vehicle, a car.

Figure 6.8: Road Vehicle – Car

Source: sample vehicles selected from the VISSIM vehicles library

Vehicles such as the cars, SUVs, vans, utilities, motor bikes and similar vehicles, require single selection from the VISSIM vehicles library, as it was the case in this simulation modelling.
The selection and definition of public transport vehicles, including buses, from the library, differs as against other road vehicles, as public transport vehicles follow predetermined routes that include public transport stops. In addition, these types of vehicles required additional information such as route to follow, timetables and passenger loads, egression and ingress at public transport stops details, and dwell time at transport stops. Individual colours of bus lines were selected or modified when creating the corresponding public transport routes.

Other vehicles, such as trucks, semi, B-doubles, B-triples or articulate trams, required selection from a number of vehicles components, from two, three or even four or more different components necessary to make a complete vehicle set.

6.6.2. Rail Vehicles Definition

Trains differ in operation to other public transport vehicles that use roads, as trains use tracks. Trains also follow these predetermined and dedicated routes or lines not available to other public transport vehicles or other vehicles in general. These routes or lines provide access at nominated public transport stops or Stations. Pedestrian access to stations is provided via pedestrian walk and waiting areas.

Trains were a type of vehicle in this simulation model that required selection of multiple components. Various components were required to be selected to build similar types of train sets as used in the Melbourne metropolitan rail network. The selection of multiple components was necessary to model a complete right length train set for the simulation model. The colour of the train set was selected or modified when creating the corresponding trains public transport route. Figure 6.9 shows the simulation selection pane for a train engine.
A train set was made of a combination of two trains coupled together into a single train set, to be operated by a single train driver, as used in the Melbourne urban rail network. Twenty four different components were necessary to complete the train set to the require specifications of about 145 metres in length.

A train set was made of four engine cabin cars, one in the front and one in the rear of each train, and an additional 16 carriages and other components, eight carriages plus components in-between each engine cabin cars sets, to make the complete train set to be realistically similar and of the approximated length as to the train sets used in the Melbourne urban rail network. Figure 6.10 shows a complete train set assembly incorporating two trains coupled together into a single train set.
6.6.3. Network Development – Road Vehicles Routes

Routes facilitate the modelling of vehicle transit along the network roads and specifically allowed route decisions to be made in the model, for specific vehicles or classes of vehicles. Routing allowed the programming of vehicle classes to precise routes to be followed, thus permitting, for instance, public transport lines to follow routes not specified for other vehicles in general. Routes covering many links and connectors and can be of any length, from a turning movement and single intersection movement, to routes that can cover entire sections of the network. Vehicle movement along routes only affect classes of vehicles assigned to that specific route.

There were several different types of routes available for modelling into a simulation model, but only one type was used within this research simulation model: static routing decisions complimented by static routes. More specifically, five static routing decisions were designated in the model, encompassing nineteen static routes. Actual road vehicles routes...
were traced and displayed in yellow on top of the road link section covered by that route.

In addition to the vehicles input definitions process, vehicle inputs on specific routes were defined in more detail than using vehicle inputs facilities, where vehicles inputs are specified generally in vehicles number per link, regardless of turning movement and entrance from/to other links. Target intersection traffic flow of the arterial and intersecting roads, as depicted in Figure 5.5, supported the development and design of the network routes.

6.6.3.1. Main South-North Arterial Route
Clayton Road is the main South-North arterial route and in the model design is designated as static routing decision number one. The route encompasses four static route traffic flow destination movements. The first static route traffic flow is along Clayton Road north-bound through traffic, and carries the largest proportion of the route traffic. The second static route traffic flow is from Clayton Road north-bound traffic left turn into Haughton Road in a westerly direction, carrying a small proportion of the route traffic. The third static route traffic flow is from Clayton Road north-bound traffic left turn into Carinish Road in a westerly direction, carrying a small proportion of the route traffic. The fourth static route traffic flow is from Clayton Road north-bound traffic right turn into Carinish Road in an easterly direction, also carrying a small proportion of the route traffic.

Figure 6.11 shows the main South-North arterial route with all possible traffic interactions and turns from the route.
Figure 6.11: Road Network – Main South-North Arterial Route

Source: target intersection – main south-north arterial route in 2D

Figure 6.11 illustrates the main traffic flow destination movements available for the south-north arterial route.

6.6.3.2. Main North-South Arterial Route

Clayton Road is the main North-South arterial route and in the model design is designated as static routing decision number two. The route encompasses four static route traffic flow destination movements. The first static route traffic flow is along Clayton Road south-bound through traffic, and carries the largest proportion of the route traffic. The second static route traffic flow is from Clayton Road south-bound traffic left turn into Carinish Road in an easterly direction, carrying a small proportion of the route traffic. The third static route traffic flow is from Clayton Road south-bound traffic left turn into Carinish Road in a westerly direction, carrying a small proportion of the route traffic. The fourth static route traffic flow is from Clayton Road south-bound traffic for pre-positioning for a right turn into Haughton Road in a westerly direction, also carrying a small proportion of the route traffic. Figure 6.12 shows the main North-South arterial route with all possible traffic interactions and turns from the route.
Figure 6.12: Rail and Road Network – Main North-South Arterial Route

Source: target intersection – main north-south arterial route in 2D

Figure 6.12 illustrates the main traffic flow destination movements available for the north-south arterial route. As all other simulated roads are not of prime concerns, routing details of the West-South roads, East-West roads and West-East roads routes are included in Appendix E.

6.6.4. Network Development – Road Vehicles Traffic Volumes

Road vehicles traffic volumes used for the research were estimated and details fully described in Section 5.6.2.2. Three different sets of traffic flow ranges, from low-range, to mid-range and to large-range were defined to be used during simulation processing. The road traffic volumes used for the simulation model were derived from both the actual 2008 road traffic volumes data and the 2013 estimated road traffic volumes. No data regarding the level crossing intersecting roads has been made or are available; the main roads data has been extrapolated at a rate of approximately 30% and 20% in round figures, to derive to the estimated intersecting roads traffic volumes; these figures were ascertained from visual observation during the data collection process, as well as from local knowledge.
These generated data volumes were considered consistent for the simulation process; for as long as both the current and proposed system used the same road traffic volumes data, integrity and validity of the simulation process would be maintained.

Details of the three different sets traffic flow ranges during the simulation process are indicated in Table 5.14. It is emphasised the main arterial road, Clayton Road and both of the road traffic flows individually depicted as South-North and North-South bound traffic, are the focus of the traffic congestion analysis of the research.

6.6.5. Network Development – Public Transport Lines

Public transport lines are used similarly to road vehicles routes, defining the routes origin and destination (OD), with public transport stops along the way, timetables, which indicate the volume of these types of vehicles as well as the time during the simulation when these are generated by the simulator. Other details can include colour and branding of the vehicles, speed distribution, occupancy, which in turn determines dwell time at stops, time offset and slack time at stops, among others. This research simulation model comprises of two types of public transport lines, buses and trains.

6.6.5.1. Public Transport Lines – Buses

Public transport bus lines like all road vehicles transit along the road vehicular network and behave as another motor vehicle in the road. The main difference is that buses can access places that other vehicles cannot, such as lay-by or off-road public transport stops, bus terminus, and have set timetables to keep. Bus volumes are not required to be specified as road vehicles volumes are specified; these are derived from details included in the timetables for that specific line. In addition, specific line routes are not exclusive for a single bus line and many lines can service sections of routes and using common bus stops. Public transport lines, similar to road vehicles, follow routes decision which also contains
public transport stops along the routes. Figure 6.7 illustrates four public transport stops, including two bus stops.

6.6.5.2. Public Transport Lines – Trains

Public transport train lines differ in operation from other public transport vehicles, as trains use tracks instead of roads. Trains also follow predetermined and dedicated routes or lines, not available to other public transport vehicles or other vehicles in general, but can be used by other train lines. In the case of some lines in the Melbourne network, tracks are shared between urban and rural services and freight movements; the public transport stops are shared by both urban and rural rail network services (i.e. Metro and V/Line) only. These routes or lines provide access at nominated public transport stops or Stations, with pedestrian access to stations provided through pedestrian walks and waiting areas. Trains, like any other public transport lines, have set timetables to keep, and train volumes are not required to be specified as road vehicle volumes are specified; these are derived from details included in specified timetables for that specific line. Train station public transport station stop dwell times were incorporated into the simulation model development to supplement non-pedestrian traffic.

Most of the Melbourne network infrastructure is dual track, thus the most common public transport stops at station do exhibit similar platform infrastructure with an ASP Platform Station Stop and a DSP Platform Station Stop. The focus target station of this research is no different and the station infrastructure available is: an up-line or to the city track and ASP platform stop; and a down-line or from the city track and DSP platform stop. The ASP and DSP platform concept was fully discussed in Section 2.3.

6.6.5.3. Trains Up-Line and ASP Station Platform Stop

Train public transport lines, similar to road vehicles routes decisions including buses, were incorporated into the model. Public transport line stops, as with bus lines, were also incorporated into the model. In addition,
pedestrian walking and waiting areas were incorporated as well. As with all public transport lines, the design made use of three panels within the main development pane, providing public transport line details available for input or modification, including timetabling. Figure 6.13 shows the up-line ASP platform public transport line stop.

Figure 6.13: Public Transport Up-Line and ASP Platform Stop

![Source: Clayton Station to-the-city line and ASP platform stop in 2D](image)

Figure 6.13 shows the target area up-line ASP platform public transport line stop, in yellow, the ASP platform stop in red, and the pedestrian walking and waiting areas in white.

6.6.5.4. Train Down-Line and DSP Station Platform Stop

The same attributes described for the up-line and ASP station platform stop description, also applies for the train down-line and DSP station platform stop. Figure 6.14 shows the target area down-line and DSP platform public transport line stop.
Figure 6.14: Public Transport Down-line and DSP Platform Stop

![Figure 6.14](image)

Source: Clayton Station from-the-city line and DSP platform stop in 2D

Figure 6.14 shows the target area down-line and DSP platform public transport line stop, in yellow, the ASP platform stop in red, and the pedestrian walking and waiting areas in white.

6.6.6. Traffic Processes – Testing Criterion

The process for the calibration and validation for the traffic processes were developed independently for each process. The testing process, where possible, was also conducted independently of other previously developed components. Table 6.2 indicates the testing criteria for the traffic processes.
Table 6.2: Traffic Processes – Testing Criteria

<table>
<thead>
<tr>
<th>Task</th>
<th>Testing Criterion</th>
<th>Dependent Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Vehicles Definition</td>
<td>Vehicles behaviour on road – multiple vehicles operations including: cars, SUVs, vans, trucks, motorcycles, bikes and pedestrians</td>
<td>Infrastructure – Roads</td>
</tr>
<tr>
<td>Rail Vehicles Definition</td>
<td>Trains behaviour on tracks</td>
<td>Infrastructure – Tracks</td>
</tr>
<tr>
<td>Road Vehicles Routes</td>
<td>Vehicles follow prescribed routes including intersection through traffic, left and right turns</td>
<td>Infrastructure – Roads Motor Vehicles</td>
</tr>
<tr>
<td>Road Vehicles Traffic Volumes</td>
<td>Traffic defines volumes are consistent</td>
<td>Infrastructure – Roads Motor Vehicles</td>
</tr>
<tr>
<td>Public Transport Lines – Buses</td>
<td>Bus traffic follow prescribed routes, number and timetables are as specified</td>
<td>Infrastructure – Roads Motor Vehicles – Bus PT Lines</td>
</tr>
<tr>
<td>Public Transport Lines – Trains</td>
<td>Trains traffic follow prescribed routes, number and timetables are as specified</td>
<td>Infrastructure – Rail Trains PT Lines</td>
</tr>
</tbody>
</table>

Source: research internal testing criteria

As each component development of the traffic processes progressed, the testing processes changed accordingly to specific requirements and to match field observations. The criterion for testing each traffic processes and dependant tasks, described in Table 6.2, are specified as:

- the definition of road vehicles, including cars, SUVs, vans, trucks, buses motorcycles and bikes – the task tested all vehicles behaviour on road infrastructure; the dependent task for this process was the road infrastructure process;

- the definition of rail vehicles – the task tested trains behaviour on track infrastructure; the dependent task for this process was the rail infrastructure process;
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- the defined road vehicle routes allows vehicles to follow prescribed routes, including intersecting roads through traffic, left turns into intersecting roads and right turns into intersecting roads; the dependent task for this process were roads infrastructure and motor vehicles from the infrastructure processes;

- the defined road vehicle volumes are consistent and transit through both the road infrastructures and the defined motor vehicle routes; the dependent task for this process were roads infrastructure from the infrastructure processes and road vehicle routes from traffic processes;

- the bus public transport lines defined follow the number, timetables and bus routes as specified; the dependent task for this process were motor vehicles from infrastructure processes and bus PT lines from traffic processes and;

- the trains public transport lines defined follow the number, timetables and train routes as specified; the dependent task for this process were trains from infrastructure processes and train PT lines from traffic processes.

6.7. Simulation Environment Development – Control Processes

The control development process is where road rules, encompassing road reduced speed areas, road priority rules and road conflict areas where defined; all of these apply to vehicular traffic and one applies to pedestrian traffic. These rules are specifically designed to complement the development requirements of the target area.

The simulator also contains other road behaviour rules, but these rules have been built into algorithms within the framework of the simulator design and do not require detailed specifications. Some of these rules, considered to be part of the calibration process of the model, include:

- car following model parameters (Wiedemann's 1974 and Wiedemann’s 1999);
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- lane changing manoeuvres parameters (Busch and Leutzbach 1983 and Sparmann 1978);
- vehicles on multi-lane streets and across signalised and non-signalised intersections rules (Hubschneider 1983); and
- social force pedestrian modelling (Helbing and Molnár 1995), among others (Fellendorf & Vortisch 2010).

As these rules are built into the simulation software, there are alternative choices for their usage and selection. For example, driving behaviour parameters for car following rules, the choices presented are Wiedemann 1974, Wiedemann 1999 or no interaction; the first two also provide a range of selection parameters.

The control development process also contains internal simulation data collection processes, including data collection points and queue counters; these are used to populate databases and output files with vehicles and events data as these occur during actual simulations; the data collected is used by the outputs processes for the generation of reports. In addition, the control development process contains traffic signals processes, including: both rail and road signals; rail network signals system included train predictors and rail to road signals system; road network vehicles and pedestrian signals system, that include road vehicles detectors.

6.7.1. Network Development – Road Rules

The process of road rules comprise of directions for reduced speed areas, road priority rules and road conflict areas; some of these apply either to vehicular traffic or to pedestrian traffic, or both; all of these were specifically design to accommodate the requirements of the target area. Other road behaviour rules contained within the simulator, are built into algorithms within the framework of the simulator design, requiring specifications by menu selection only when traffic volume from the standard or benchmark provided by the simulator.
6.7.1.1. Reduced Speed Areas

Within the simulation model, reduced speed areas were defined to make vehicular speed distribution changes, changes that can be permanent or temporary. These changes are required to ensure a reduction of set speed limit in the approach of intersections, near or at pedestrian crossings, when vehicles are entering a major arterial road from a street or intersecting road, or when turning from arterial roads into side roads. The changes can also be in place when changes of circumstances, for instance, when vehicles are reaching conflict areas, like a level crossings, where the speed limits are reduced for safety reasons.

The reduced speed areas in the simulation model of the target area, with some applying for road vehicles, yet others applying to rail vehicles, ensure all vehicles, trains included, reduces speed on approaches to level crossings and station platforms at public transport stops.

6.7.1.2. Priority Rules

Priority rules were built into the simulation model to avoid conflict in movements between vehicles on different links or connectors, or when moving or entering into a main road from an intersecting road, so these vehicles can recognise each other and act accordingly to the set rules, thus avoiding conflict. The rules were also for ensuring pedestrians and vehicles follow certain rules of engagement within conflict areas in the model, for example, at non-signalised pedestrian crossings. Another example of priority rules usage can be to ensure that an area, within the target area, is maintained clear of vehicles under certain circumstances, for vehicles not to block intersections or not to stray across intersections that are blocked with traffic.

6.7.1.3. Conflict Areas

Conflict areas provide the conflict rules, and are an alternative to and a compliment for, priority rules. For example, when turning into a road and having vehicles in the opposite direction, facing the turning vehicle, also arriving at the intersection, the turning vehicle must give way. Another
example of priority rules usage can be to ensure that an area, within the target area, is maintained clear of vehicles under certain circumstances or for vehicles not to stray across intersections that are blocked with traffic. In the simulation model, conflict areas are defined at the actual level crossing, and areas of conflict between two different types of vehicles, rail vehicles and road vehicles. By law, trains have the right of way at intersections above any other vehicle or pedestrian traffic.

6.7.2. **Network Development – Data Collection Points**

As part of the process of evaluating the simulation process and to provide evaluation results, the simulator selectively collects information of vehicles and events; the data is then used to generate output databases, files and reports. The data collected by the process can be made available for display online or, as in the case of this research, in reports available at the completion of the specific simulation run. Data can be collected of many selected events using configuration panels, and can include vehicle inputs, nodes details, network performance, public transport details, travel times, lane changes, queue lengths, link evaluation, delay, vehicle inputs, analyser database and special evaluations. In addition, some of these configurations allow for collecting information on about sixty different parameters. Figure 6.15 illustrates the position of the data collection point positions built into the simulation model.
Figure 6.15: Rail and Road Network – Data Collection Points

Source: target intersection – data collection points in 2D

Figure 6.15 shows the data collection points built into the simulation model of the target area are represented as blue lines and pointed by the arrows. In addition, various different types of data was collected using the data collection point facilities, including queue lengths, vehicles stops within given queues, acceleration, headway, lane changes, occupancy and other similar parameters. However, the emphasis of the data required for collection for this research was specifically related to queue length data and vehicle stops within given queue data. All other data collected was not reported or analysed, as it was deemed that the research primary interest is related to queue length and stops and not acceleration, headway, lane changes, occupancy or similar events.

6.7.3. Network Development – Queue Counters and Vehicle Stops

Within the simulation model of the target area, in addition to data collection points, queue counters were defined for the purpose of measuring the length of queues and the number of stop events vehicles perform within queues in a given simulation run. The measuring process commences from the start of the queue counter position until the last vehicle on the queue or for the length of the road segment. When more than one road
approach is at play (i.e. more than one lane in the road segment), the simulator records all queues and reports on the longest queue. The queues are measured in units and not in numbers of vehicle; in this research, the queue unit measurement is queue length in metres.

The position of queue counters built into the simulation model of the target area are, in addition to the data collection points, located in the same position as the data collection points illustrated in Figure 6.15. Modelled queue counters are depicted within the simulation model of the target area as blue lines, marking the position of the beginning of the process for that segment of the road. Visual representations of queue counter positions are similar to data collection point positions, but are not the same, both requiring being present for data collection, calculation and reporting purposes. The simulator records vehicle events that are presented as queue details, including:

- average queue length is derived from the current queue length at every simulation cycle step and the arithmetical average calculated at every time interval;

- maximum queue length is derived from the current queue length at every simulation cycle step and the maximum calculated at every time interval; and

- the number of vehicle stops within the queue is recorded as the total number of events when a vehicle enters a given queue.

6.7.4. Network Development – Road and Rail Traffic Signals

The control development process includes traffic signal simulation design for the development of traffic signals logic comprised both rail and road signals systems. In reality, both systems, the road traffic signals control system and the rail signal warning control system, are not integrated and work independently of each other. The rail system provides advanced warning information, or preemption signals, to the road system, indicating
an imminent train arrival to and/or departure from, the crossing prescribed area.

The rail signals system consists of train predictors and the rail to road signals system, in a single system. In addition, the actual rail network system also comprises of axle counter and headway separation and dwell time technology that keeps certain degrees of separation or headway between trains travelling on the same track and in the same direction at a different time.

The research simulation process model used no axle counter technology, headway separation and dwell time and reference is made only to acknowledge the use of the technology in the Melbourne rail network; the technology physically enforces a minimum of two and half minutes (150s) headways or separation between trains travelling on the same tracks and in the same direction.

In the simulation model, separation between trains was controlled by having headways imbedded into train timetables. This was achieved by scheduling PT Lines train starting times that maintain the minimum required of two and half minutes (150s) headways or separation. As the simulated rail network is short in length and servicing only one station, there were no delays in train arrivals and departures necessary ingrained into the model. In addition, train station public transport station stops dwell time was incorporated into the simulation model development.

The road network signals system consists of and controls the road intersection signal system, the road vehicle and pedestrian signals system, the vehicles detector system, as well as the system that receives information from the rail to road signals system, are all integrated into one signal control system. The communication between the rail signal warning control system and the road signals system is a one-way communication. The rail signal system passes information to the road signal system, for the road signal system to take the appropriate action. No acknowledgment
communication emanates from the road signal system towards the rail signal system.

6.7.4.1. Combined Signals Operation Design
In the development of the signal simulation logic using VISSIM and the VISSIM tools, the two unintegrated systems, the road signals and rail signals systems, were also recognised as separated systems, but were programmed and coded as one system that recognised both of the systems activation triggers, the train predictors and the road vehicle detectors. The programmed code logic recognised both systems triggers working in unison, emulating the require effect of having two separate systems.

6.7.4.2. Road Signal Intersection Operation
The actual road control system was programmed to receive the signals from the rail control system and act accordingly, changing the traffic signal stage cycle and stop all vehicular and pedestrian traffic from the crossing. When the road control system received the signal that the train had passed, the system either resumed the stage cycle operation as before the interruption occurs or it resumed operations from the beginning of a new stage cycle, depending on the road control system programming, thus allowing traffic to return to normal. From observations at the target area during the data collection process, it was determined that after interruptions, the road control system resumes operation from the beginning of a new stage cycle operation, starting by opening the main arterial roads, by giving the green light, allowing the main arterial road vehicular and pedestrian traffic flow to resume.

The data collection signal recorded figures, collected during the data collection process, have been used to estimate times of the road signal systems controls timings cycles controlling the intersection road traffic operation; the estimated cycles were then used as input to the simulation model as the basis of the model traffic signal operations.
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It is noted that the data collection figures were documented in seconds (a second = 1/60) and the simulation process operated under operating time cycles (cycle = 1/100), a different unit of measurement, requiring adjustments or allowances to be made; thus, the simulation process is an approximation of the actual system. This was not considered an issue, as both the simulation of the current operation and the simulation of the proposed operation, were both synchronised by using the same time measurement, being cycles. In addition, simulation operating speed could be influenced by other factors including PC power and memory availability, number of vehicles in the simulation and more importantly, the number of pedestrian included in the simulation process (PTV AG 2012b). The standard definition of simulation speed under simulation parameters is set at 2.0 Sim. (two simulation cycles per second), further skewing the issue of timing.

6.7.4.3. Signal Controller Processing Task
The signal controller processing task comprised of a rail component and a road component. The rail component data was derived from the data collected from the intersection closure data observation, recorded as part of the data collection process. The data from the road controllers relies on data collected by observations and recorded at the target site during the data collection process. Details of the road signal recording, collection and transcription processes are described in Section 5.5.4.

6.7.5. Network Development – Traffic Signals Development
The signal generator module is not part of the computer simulator itself, but must be used in conjunction with the simulator, as it is used to define and control all traffic signal logic used when the simulation model is in operation. The signal generator module is where intersection controller signal logic is defined and from where the logic is loaded into the Vehicle Actuated Programming (VAP) database or file for interpretation by the simulator during the actual running of simulations. The traffic signal system recognises two main sequence elements within its logic: stages
and interstages. Stages are considered the periods when the traffic signals are constant, either in green signal phase or red signal phase. Interstages are considered the periods when the traffic signals are in transition, for example from green signal phase to amber signal phase and from amber signal phase to red signal phase, or from red signal phase to green signal phase.

6.7.5.1. Network Development – Traffic Signals Stages and Interstages
The characteristics of the intersection signals are pre-defined, including the phase sequences and other parameters such as minimum green signal phase times, actuated forced-off, and gap out of times; these are the basic stage sequences controlling the intersection signals. Figure 6.16 is an example of stages and interstages as described by the VISSIM simulation software.

Figure 6.16: Road Signal Stages and Interstages

![Figure 6.16: Road Signal Stages and Interstages](Source: VISSIM Training material (PTV AG 2012b))

The stages and interstages sample shows two signal stages and an interstage period corresponding to both signal stages. The first signal stage starts from the green signal phase, advancing into the interstages, changing from green signal phase to amber signal phase, and then changing from amber signal phase to red signal phase (PTV AG 2012b). The sample shows the second signal stage starting from the red signal phase, getting into the interstages, and then changing from the red signal phase into the green signal phase (PTV AG 2012b).

The research stage cycles were designed and based on this cyclical method of stage operation using collected timings, recorded during the data collection process; the concept was used during the programming of
the traffic signal logic in VAP and VisVap. In the example, the interstages cycle is shown as starting at sixty point five cycles (60.5c) and finishing at sixty six point five cycles (66.5c), a 6 cycle period; at the start of the interstages changing from one stage on the green cycle to the amber cycle for four cycles (4c), before changing from amber cycle to red cycle, for two cycles (2c) before the completion of the interstage period; the other stage only changes from the red cycle to green cycle only at the end of the interstages and at the beginning of the stage next cycle (PTV AG 2012b).

During the interstages period, both stages have simultaneous red phases for a period of two cycles (2c); this allows some vehicles on the first stage to finish turns and others to come to a complete halt before permitting the second stage vehicles, the new green cycle stage, to commence moving (PTV AG 2012b). The research interstage cycles were designed and based on this cyclical method of interstage operation collected and used during the programming of the traffic signal logic in VAP and VisVAP.

6.7.5.2. Network Development – Traffic Signals Development Tools
Two tools were used for the simulation model development in this research, VISSIM VAP and VISSIM VisVAP Figure 6.17 is indicative of the structure of the simulator signal system framework.
Figure 6.17 illustrates the structure of the VAP, Vissig and VisVAP programming tools, in relation to the VISSIM simulator and indicates how the structure of the VISSIM, VAP, Vissig and VisVAP fit together, identifying and naming all the outputs that are required for the development of the simulation traffic signal controls logic.

### 6.7.5.3. Vissig PUA File Generation

The definition of stages and interstages input file, required for the generation of the simulation traffic signal controls logic, was generated manually. This was achieved using a text editor and based on data generated from the data collection process; the generated file, regardless of the method of development, is known as the .pua file. There were two options for the development of the stages and interstages logic file: using Vissig, a VISSIM simulator tool or creating the logic file manually. Vissig was not used in this research, as the tool complements the phase-based fixed time control of the module, supports node editor/control facility of multiple set intersections, and it is specifically made for signals...
optimisation. Figure 6.18 is part of the target area generated stages timing design parameter .pua file code.

**Figure 6.18: Code VISSIM PUA Stages Timing Design**

![Image of VISSIM PUA Stages Timing Design]

Source: VISSIM target area PUA stages timing design

Figure 6.18 .pua file shows coded details of each individual signal of the target intersection, the individual signal corresponding to each of the three stages, the cycle starting stage, as well as two of the programmed interstages, coded into the .pua file; this was used as input to the traffic signal controls logic process and interpreted by the simulator during the actual running of simulations.

### 6.7.5.4. VisVap Design Flowchart and Parameters Tool

To facilitate the simulation development process, VISSIM provides VisVap, a tool that makes the method of generating VAP programming
code an uncomplicated task for non-programmers. The tool allows the use of flowcharts as the mechanism to create and edit VAP signals logic. An example of the flowchart generated to code the design logic of the signal system of this research, incorporating both the road detectors and train predictors is included in Appendix E.

6.7.5.5. Vehicle Actuated Programming (VAP)
The Vehicle Actuated Programming (VAP) programming language is a VISSIM family tool specifically designed for programming traffic actuated signal controls used by the VISSIM computer simulation models. Signal control logic needs to be described or coded in the VAP language, and during execution of a simulation process, VAP interprets the logic and the current status of variables, such as detectors and predictors, to perform and simulate the desired environment. An example of the target area design code .vap file generated using the VisVAP tool is included in Appendix E.

6.7.6. Rail Signal Intersection Operation
The VISSIM signals generator module sits outside the simulator and is where all signal logic is defined, and where each intersection controlling the logic are loaded into the Vehicle Actuated Programming (VAP) database or file. As indicated in Section 6.7.5.2, in the development of the signal simulation logic using VISSIM and the VISSIM tools, the two unintegrated systems, the road signals and rail signals systems, are recognised as separate systems. The two were programmed and coded as one system that recognised both of the systems activation triggers: the road vehicle detectors and the train predictors. The programmed code logic recognises both systems triggers working in unison, emulating the require effect of two separate systems; the logic for both systems was designed and developed under one system and described in Section 6.7.5.

As identified in Section 5.1.1, level crossing operations system in Victoria must provide sensitivity capable of assuring of twenty five seconds (25s)
minimum warning time before train arrivals. This period ensures that the immediate crossing area can be cleared of road and pedestrian traffic; this is done during the first five seconds (5s) of the warning period. It also allows for the boom barriers to be lowered and the road and pathway are closed to traffic before arrival of the train; this is done during the remaining twenty seconds (20s) of the warning period. The logic for minimum warning time before train arrivals was built into the VisVap and VAP logic by placing train predictors at the require distance in relation to the level crossing area.

Rail systems also differ in the type of signal that trains activate; train signal controls logic required two types of detections per each train traversing through the network and were described in Section 6.5.4. The logic for two types of detections, train arrivals and train departures, were built into the VisVap and VAP logic. The activation of rail signals procedures were discussed in Section 5.1.

6.7.7. Control Processes – Testing Criterion

The logic for the calibration and validation for the control processes were developed independently for each task and to match field observations. The testing, when possible, was conducted independently of other previously developed components. In addition, the testing of the road and rail signals design was much more complex than the testing of each of the components of the entire simulation model. VAP and VisVap are programming languages that provide their own internal vetting, editing and testing; once these task had been completed, the signal systems were tested as the rest of the processes, using the graphical representation of the network, both in 2D and 3D for a more effective and critical observation of the processes, using a predetermined set of testing criteria, to emulate the field observed operation. Table 6.3 indicates the testing criteria for the control processes.
Table 6.3: Control Processes – Testing Criteria

<table>
<thead>
<tr>
<th>Task</th>
<th>Testing Criterion</th>
<th>Dependent Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Rules – Reduced Speed Areas</td>
<td>Road vehicles reduce speed rules at prescribed locations</td>
<td>Infrastructure – Roads Motor Vehicles</td>
</tr>
<tr>
<td>Road Rules – Priority Rules</td>
<td>Road vehicles follow and obey priority rules at prescribed locations</td>
<td>Infrastructure – Roads Motor Vehicles</td>
</tr>
<tr>
<td>Road Rules – Conflict Areas</td>
<td>Road vehicles follow and obey conflict areas rules at prescribed locations</td>
<td>Infrastructure – Roads Motor Vehicles</td>
</tr>
<tr>
<td>Data Collection Points</td>
<td>Data is collected from all prescribed collection locations</td>
<td>All simulation processes</td>
</tr>
<tr>
<td>Queue Counters and Vehicle Stops</td>
<td>Data is been collected from prescribed queue counters locations</td>
<td>Infrastructure – Roads Traffic – Motor Vehicles Road Signal</td>
</tr>
<tr>
<td>Traffic Signals – Road Signals</td>
<td>The road signals system works with the prescribed synchronisation and operates both with detectors</td>
<td>Infrastructure – Roads</td>
</tr>
<tr>
<td>Traffic Signals – Rail Signals</td>
<td>The rail signals system provides predictors signal data to the road signal system logic</td>
<td>Infrastructure – Tracks</td>
</tr>
<tr>
<td>Combined Rail and Road Signals</td>
<td>The rail signals system provides predictors signal data to the road signals system and the road signal operates both with detectors and predictors signal data and logic</td>
<td>Infrastructure – Tracks and Roads</td>
</tr>
</tbody>
</table>

Source: research internal testing criteria

As each component development of the control processes progressed, the testing processes changed accordingly to more specific requirements. The criterion for testing each traffic processes and dependant tasks, described in Table 6.3, are specified as:
for prescribed road reduced speed areas, tested all vehicles to reduce speed at reduced speed specified locations; the dependant task for this process were the road infrastructure and motor vehicles process from the infrastructure processes;

for prescribed road priority rules, tested all vehicles to follow and obey the priority rules at specified locations; the dependant task for this process were the road infrastructure and motor vehicles process from the infrastructure processes;

for prescribed road conflict areas, tested all vehicles to follow and obey the conflict areas rules at specified locations; the dependant task for this process were the road infrastructure and motor vehicles process from the infrastructure processes;

for prescribed data collection points, tested that data was collected of all activity at all specified collection locations; the dependant task for this process were all operational simulation processes;

for prescribed queue counters locations, tested that data was collected of all vehicles queues and stops at all specified collection locations; the dependant task for this process were the roads from road infrastructure processes, motor vehicles and road signals from traffic processes;

for prescribed road traffic signals, tested the signals synchronised operations as well as the support of road and rail detectors signals at all specified locations; the dependant task for this process were the roads and signals from road infrastructure processes, signals from rail infrastructure processes and motor vehicles from the traffic processes; and

for prescribed rail signals, tested the rail signals provided predictor signal data to the road signal system logic; the dependant task for this process were the roads, signals, detectors and predictors from rail infrastructure processes, and train traffic from the traffic processes.

Once the development and testing of each individual component of the three processes was attained and the stipulated testing criteria had been met, when all the component were working in unison, the testing of the complete simulation was conducted to fine tune any problems not encountered during the individual component testing and to ensure the simulation model matched observed field conditions and behaviour. During the testing process and to facilitate the processes, maximum green signal timing were deliberately programmed longer than required; these permitted a better observation of the graphical representation and evaluation of each of the testing subjects. Table 6.4 indicates the testing criteria for the combined processes testing.

Table 6.4: Combined Processes – Testing Criteria

<table>
<thead>
<tr>
<th>Task</th>
<th>Testing Criterion</th>
<th>Dependent Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Rail and Road Signals</td>
<td>The rail signals system provides predictors signal data to the road signals system and the road signal operates both with detectors and predictors signal data and logic</td>
<td>Infrastructure – Tracks and Roads&lt;br&gt;Infrastructure – Signals&lt;br&gt;Infrastructure – Detectors&lt;br&gt;Infrastructure – Predictors Traffic – Trains and Motor Vehicles</td>
</tr>
</tbody>
</table>

Source: research internal testing criteria

As all components processes had been individually tested, the final test was for the all processes to be tested working in unison. The criterion for the final testing of the combined processes and dependant tasks, is described in Table 6.4, indicates that for prescribed road and rail signals, tested the rail signals system provides predictors signal data to the road signals system and the road signal operates both with detectors and predictors signal data and logic; the dependant task for this process were the roads, tracks, signals, detectors and predictors from infrastructure processes, signals from rail infrastructure processes and road vehicles and train traffic from the traffic processes.
No other specific or additional criteria was necessary to be established for final testing, as each and all components of all processed had been fully tested and in working order, ensuring the working of the simulation model matched all observed conditions and all requirements set under the stipulated validation testing criteria.

The process of the validation and testing of the development of the traffic modelling application focusing the target area were deemed to be completed when all the components were:

- working in synchronisation to each other;
- producing the desired result of a fully operational level crossing intersection;
- supporting the transit of the two main traffic flows, road and rail, behaving in orderly manner; and
- following and obeying the road rules, without incidents.

At the completion of the testing, maximum green signals timing that had been programmed longer during the testing phase, were modified to reflect recorded timing, before the commencement of the process of testing and comparison between the current simulation model with the proposed simulation model.

6.9. Simulation Environment Development – Output Processes

The output development process produced outputs from the data collected on all activities within a given simulation process. Reports and video simulation recording of the simulation process comparisons between the current infrastructure simulation models with the proposed infrastructure simulation models were used as the basis for the analysis and preparation of the results presented as part of the simulation modelling process. Included in the process of output reporting, the generation of video simulation recording and storage of simulation movies was made for each individual simulation process.
6.9.1. Output Processes – Reports
The main reports generated for this research were produced in semicolon delimited text format files for easy input into MS applications, including Excel spreadsheets. Data was collected from each individual simulation model processing and the simulation output and reporting were also collected individually. Care was taken with the reporting process during simulations, as in VISSIM, new simulations override previously generated output files and reports. Therefore, for the preservation and integrity of the simulation process, each individual simulation was given an individual identifier, creating a large number of simulation models data files and reports, involving both simulations models of the current environment and simulations models of the proposed environment.

Due to the large amount of reports generated, encompassing twenty one (21) different simulations for each of the two environments simulated, the reports presented represents three simulations reports amalgamated into one report; in this case, the report covered the three traffic volumes ranges for each simulation process for the current DSP-ASP single up-line train simulation results. A sample report and a detailed description of the report contents are prescribed in Section 7.4.1.

6.9.2. Output Processes – Simulation Animation Recording
The generation of simulation model animation recording was made in two different formats, including in standard Audio Video Interleave (AVI) file format and Animation (ANI) format, an exclusive VISSIM animation format that requires VISSIM operating for viewing the animation file. Figure 6.19 displays a frame of a simulation AVI file format video image of the target area.
Figure 6.19: Simulation Video Animation Image Frame

Source: Video image frame of the simulation animation of the target area

Figure 6.19 displays a frame of a simulation AVI file format video animation image of the target area, captured during the simulation process; the frame shows two trains arrivals at Clayton Station, intersection vehicular traffic at Clayton Road level crossing and vehicular transit along Carinish Road. Details of video simulation recording, including a completed list of all video simulation movies generated and presented is provided in Section 7.6.3.

6.10. Level Crossing Intersection Simulation Process

The target area level crossing intersection simulation process was conducted in two stages, one to simulate the current environment, the other to simulate the proposed environment.

The first phase of this process started only when the current environment simulation model had been fully developed, proven to be fully operational and the simulation calibration and validation processes had been
successfully completed. The second phase of the process, the simulation of the proposed environment, started only when the simulation of current environment was fully operational. This method ensured all the processes of the current environment, including the calibration and validation of the original model, were inherited by the simulation of the proposed environment, before changes to the new simulation model station platform infrastructure were made, resulting in a fully operational simulation model of the proposed environment, a mirror copy of the current environment.

6.10.1. Simulation Process – Current Environment Simulation
The simulation model of the current environment consisted of the station infrastructure depicting the current method of operation, supporting a Departure Side Platform (DSP) and an Arrival Side Platform (ASP) station infrastructure. Figure 6.20 illustrates the current station DSP – ASP platforms infrastructure.

**Figure 6.20: Current DSP – ASP Station Platforms**

Source: Target level crossing current DSP – ASP station platforms environment
Figure 6.20 illustrates the current station DSP – ASP platforms infrastructure arrangement with a train departing from each of the station platforms. Both the Departure Side Platform (DSP) and the Arrival Side Platform (ASP) station infrastructure are pointed by arrows. This first phase simulated the current environment and was developed to test, simulate and ensure the simulation was able to affectively reflect the current environment as observed during the data collection process. Section 5.3 describes the current station platforms environment.

The environment initially simulated the operation of the level crossing, the closure of the main arterial roads to motor vehicle traffic, activated by a single train. Complexity was then added to the simulation, by having two-train, an arriving train in one direction when another was at or leaving the platform in the opposite direction. Further complexity was then added to the simulation, requiring it to support and operate multiple trains within a single intersection level crossing closure.

Multiple series of simulation events were performed to emulate the following DSP - ASP train traffic level crossings closures:

- a single down-line train intersection closure;
- a single up-line train intersection closure;
- two trains arriving in close proximity, one in each direction, intersection closure;
- three-train intersection closure;
- four-train intersection closure;
- five-train intersection closure; and
- a six-train intersection closure.

These seven simulations were further modelled using the three levels of vehicle road traffic volumes flow per hour, as shown in Table 5.14. This gave a total of twenty one (21) simulations in all, modelling the target level crossing current DSP – ASP station platforms environment. The
processes were deemed completed when the simulations were able to handle or process all seven separate simulation level crossing road closures performed, using all three different levels of vehicle road traffic volumes flow, replicating the observed field condition.

6.10.2. Simulation Process – Proposed Environment Simulation

The simulation model of the proposed environment consists of the station infrastructure depicting the suggested method of operation, supporting two Departure Side Platforms (DSP) station infrastructures; the current Arrival Side Platform (ASP) was decommissioned. The starting point or base for the simulation model of the proposed environment was a fully operational copy, or mirror image, of the current environment simulation model.

Physical changes were made to the new model for the transition to the proposed new environment, comprising of the decommissioning of the old Arrival Side Platform (ASP) and the commissioning of a new Departure Side Platforms (DSP). No signal logic changes where necessary, as the changes affected only the platform positioning and changes to the infrastructure and pedestrian facilities, including walking and waiting areas, along the new platform.

The relocation of the simulation station platform location were made by changing the actual location of the Public Transport Stop, the pedestrian walking and waiting area, from the Arrival Side Platform (ASP) current location, into a Departure Side Platforms (DSP) at a new location, about 200 metres further along the tracks from the current location, from just before the intersection of Clayton Road to just past the intersection of Clayton Road. Figure 6.21 illustrates the proposed station Departure Side Platforms (DSP) platforms.
Figure 6.21: Proposed DSP – DSP Station Platforms

Source: Target level crossing proposed DSP – DSP station platforms environment

Figure 6.21 illustrates the proposed station infrastructure environment, shown the platforms arrangement; the current Departure Side Platform (DSP), the decommissioned Arrival Side Platform (ASP) platform and the new Departure Side Platform (DSP) are pointed out by arrows. Trains are shown at or departing from each of the stations platforms.

The first task of this phase, after duplicating the simulation model of the current operation, was changing the environment from the station having a Departure Side Platform (DSP) and an Arrival Side Platform (ASP), modifying the station infrastructure to reflect having two Departure Side Platforms (DSP), one in each train traffic direction; the second task was the decommissioning of the old Arrival Side Platform (ASP).

The logical change was achieved by removing from the simulation all code pertinent to the Arrival Side Platform (ASP). The code removed was then replaced with the same code generated under the first phase ASP platform environment, but for the new location.
Under this new simulation model, the environment simulated the same operation of the level crossing as described in Section 6.10.1. Under this new environment, multiple simulations were performed to emulate the following DSP – DSP train traffic level crossings closures. The closures are of the same type and nature as described under the DSP – ASP current environment in Section 6.10.1.

These seven simulations were generated using the three levels of vehicle road traffic volumes flow per hour as shown in Table 5.14. This gave a total of twenty-one (21) simulations in all, modelling the target level crossing proposed DSP – DSP station platforms environment.

It is noted that under the proposed environment, multiple level crossings closures of more than two trains no longer occurred. For comparison reasons, simulations of multiple train closures of more than two-train were simulated, but all these simulations consisted of more than one period of level crossing closure events.

6.10.3. Simulation Modelling – Current and Proposed Environment

The level crossing simulation emulated the seven distinctive intersection closure operations, using low-range volumes of road vehicular traffic. These seven (7) operations were first simulated for the current level crossings operation. When these were finalised, then the seven operations were simulated for the proposed level crossings operation, giving a total of fourteen (14) different environments simulated using low-range volumes of road vehicular traffic.

Further to these fourteen different environments simulated using low-range volumes of road vehicular traffic, simulations using the two additional volumes of road vehicular traffic, covering mid-range and large-range of road vehicular traffic, were performed to provide three different ranges of simulation output results, resulting in forty two (42) simulations in total.
6.11. Summary

The computer simulation modelling development consisted in building two separate simulation models: one to emulate the current station level crossing intersection environment; the other to emulate the proposed station level crossing intersection environment. The aim of these models was to test the effect of platform arrangements on level crossing closures and its impact on motor vehicle traffic congestion at a railway station level crossings intersection.

It is noted that the data collected figures were documented in seconds (second = 1/60) and the simulation process operated under operating time cycles (cycle = 1/100), a different unit of measurement, requiring adjustments or allowances to be made; thus, the simulation process is not be a precise replica of the actual system. This was not considered to be an issue, as both the simulation of the current operation and the simulation of the proposed operation, were both synchronised by using the same time measurement.

In addition, simulation operating speed could be influenced by other factors including PC power and memory availability, number of vehicles in the simulation and more important, the number of pedestrian included in the simulation process. The standard definition of simulation speed under simulation parameters is set at 2.0 Sim. (two cycles per second), further skewing the issue of timing.

Using computer simulation for the first time was not an easy task, but a lengthy and complex one. The learning curve of using VISSIM was enhanced by attending training provided by PTV Asia Pacific. In addition, being aware of the advantages, disadvantages and pitfalls when using simulation modelling, kept the research in good stead.

The development of the simulation model of the current environment was a long process that required much learning and perseverance. The actual results for the effort were only obtained after much testing, calibration and validation of the model, using a trial and error concept, one that Winsberg
(2003) refers to as a process of approximations, idealisation, falsification and additional information of the model development process (Winsberg 2003).

In contrast, the development of the simulation model of the proposed environment was an effortless process, as most, if not all of the testing, calibration and validation of the model, had already been conducted during the development of the model of the current environment.

The ability of the simulation developing model networks to be viewed and tested in motion, both in 2D and 3D representation, was an invaluable development instrument. It made the development and testing processes a simple and effective visual evaluation, permitting results of simulation development and testing of each task, to be performed and scrutinised simultaneously.

The simulation process resulted in forty two (42) different combinations of simulation intersection closures performed; the results of these are too large to present in this chapter. Brief analysis, comparisons and summaries are documented and reported, and the results of the simulation efforts are fully detailed and discussed on the next chapter.
7. COMPUTER SIMULATION ANALYSIS AND RESULTS

7.1. Introduction
This chapter presents the analysis and comparison of the results of the computer simulation development process. Computer simulation modelling techniques were used to test the effect of platform arrangements on level crossing closures and its impact on motor vehicle traffic congestion at a railway station level crossing precinct. The tasks performed to compare the results of both the current and proposed environment are discussed in detail, describing the simulation analysis comparison processes conducted using the results and reports of both computer simulation models. The simulation efforts conducted provided the results of forty two (42) different intersection closures simulated and analysed. The results of both simulation processes were then analysed, compared, reported and presented. The summary results and conclusion to the potential benefits derived from the implementation of the developed theory are also presented. In addition, visual simulation results produced in 3D graphical animation are summarised.

7.2. Computer Simulation Results
The fourteen simulations were replicated, seven each for the current and proposed environments, using the three different volumes of road vehicular traffic, provided a total of forty two different simulated environments. These forty two individual simulations generated large amounts of data to be analysed and compared. Detailed reports of all these simulations are extensive, thus, only summary reports are presented.

Result comparison from selected train closure operations of both the current and proposed environment are presented in a number of tables, covering each of the seven train closure patterns and using three different
road vehicular traffic volumes. The three different road traffic volumes used were discussed in Section 6.6.4.

Two different types of results and reports are provided for the summaries and include:

- summaries of individual simulation process details for both the current and proposed environments, including a comparison analysis summary of both current and proposed simulation process details; and
- computer generated simulation result reports from VISSIM and the computer generated of both current and proposed simulation environments.

The main arterial roads are depicted as South-North traffic, shown as NB (north-bound) and North-South traffic, shown as SB (south-bound) in Figure 5.5. These main arterial roads carry substantial road traffic and are the focus of the traffic congestion analysis.

It is noted that in this case, the VISSIM simulation process functions under operating unit of time cycles (cycle = 1/100), and not in seconds, a different unit of measurement to that of seconds. Refer to Section 6.7.4.1 for further details regarding differences between seconds and simulation cycles.

7.3. Individual Simulation Summaries Details

Details were manually collected by observation of each individual simulation process of seven simulations of the current environment and seven simulations of the proposed environment, using one of the vehicle volume ranges. The simulation details and results of these fourteen simulations did not change when the three different vehicles volumes were used, as the simulation differences applied were related to the difference on the physical environment (DSP – ASP and DSP – DSP) and the number of trains instigating the intersection level crossing closures. Thus, the process details pertaining to simulations using one vehicle volume
range also apply to the other twenty-eight simulations of the other two vehicle volume ranges.

Details for each simulation, recorded in simulation cycles, include:

- individual simulation details as to the platform environment, being DSP – ASP or DSP – DSP;
- intersection closure start period(s), indicating the start of the level crossing closure, expressed in simulation cycles;
- train arrival(s) at each platform, indicating train(s) arrival(s) at platforms, expressed in simulation cycles;
- train departure(s) from each platform, indicating train(s) departure(s) from platforms, expressed in simulation cycles;
- intersection open starts period(s), indicating the end of the level crossing closure, expressed in simulation cycles;
- total simulation period, indicating the duration of the simulation period, expressed in simulation cycles;
- intersection total lockdown period, indicating the level crossing closure period during the simulation event, expressed in simulation cycles; and
- intersection total open period, indicating the level crossing open period during the simulation event, expressed in simulation cycles.

7.3.1. Individual Simulations Process Details – Current Environment
The results of the current environment individual simulation are detailed in Table 7.1, which summarises the simulation details of the seven simulations train activity of the current environment.
### Table 7.1: Individual Simulation Details – Current Environment

<table>
<thead>
<tr>
<th>Trains Level Crossing Closures Current Environment</th>
<th>RLX Closure Starts</th>
<th>Train Arrivals</th>
<th>Train Departs</th>
<th>RLX Opens</th>
<th>Sim Finish</th>
<th>RLX Closure Period</th>
<th>RLX Open Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Train Down-Line Closure</td>
<td>31.2</td>
<td>96.0</td>
<td>124.6</td>
<td>102.0</td>
<td>125.0</td>
<td>70.8</td>
<td>54.2</td>
</tr>
<tr>
<td>Single Train Up-Line Closure</td>
<td>62.0</td>
<td>72.0</td>
<td>130.0</td>
<td>152.8</td>
<td>165.0</td>
<td>90.8</td>
<td>74.2</td>
</tr>
<tr>
<td>Two-Train Down-Up Closure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 1</td>
<td>66.0</td>
<td>109.0</td>
<td>137.6</td>
<td>158.0</td>
<td>170.0</td>
<td>92.0</td>
<td>78.0</td>
</tr>
<tr>
<td>Train 2</td>
<td></td>
<td>109.4</td>
<td>122.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-Train Up-Down Closure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 1</td>
<td>66.0</td>
<td>101.0</td>
<td>131.0</td>
<td>158.0</td>
<td>170.0</td>
<td>92.0</td>
<td>78.0</td>
</tr>
<tr>
<td>Train 2</td>
<td></td>
<td>122.0</td>
<td>137.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-Train Closure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 1</td>
<td>66.0</td>
<td>88.0</td>
<td>107.4</td>
<td>217.0</td>
<td>225.0</td>
<td>151.0</td>
<td>74.0</td>
</tr>
<tr>
<td>Train 2</td>
<td></td>
<td>93.6</td>
<td>116.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 3</td>
<td></td>
<td>214.0</td>
<td>225.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Four-Train Closure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 1</td>
<td>66.0</td>
<td>108.0</td>
<td>136.2</td>
<td>312.0</td>
<td>320.0</td>
<td>246.0</td>
<td>74.0</td>
</tr>
<tr>
<td>Train 2</td>
<td></td>
<td>108.6</td>
<td>122.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 3</td>
<td></td>
<td>214.4</td>
<td>244.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 4</td>
<td></td>
<td>262.6</td>
<td>285.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Five-Train Closure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 1</td>
<td>66.0</td>
<td>108.0</td>
<td>136.2</td>
<td>368.0</td>
<td>385.0</td>
<td>302.0</td>
<td>83.0</td>
</tr>
<tr>
<td>Train 2</td>
<td></td>
<td>108.6</td>
<td>122.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 3</td>
<td></td>
<td>214.0</td>
<td>243.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 4</td>
<td></td>
<td>262.4</td>
<td>285.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 5</td>
<td></td>
<td>358.6</td>
<td>385.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7.1 presents and summarises the simulation details of train activity at both the down-line and the up-line current platform environment. A detailed description of the report follows and summary analyses of the above results are detailed later in Section 7.3.5, comparing the results of the current simulation environment and the proposed simulation environment. It is noted that multiple-train intersection closures were simulated regardless of the train initiating the closure or the mixture of the train’s origin/destination.

7.3.2. Summary of Simulation Details – Current Environment

The simulation details of train activity at both the down-line and the up-line current platform environment intersection closure periods and intersection open periods was summarised as follows: the intersection closed period varied from seventy point eight cycles (70.8c) for a single down-line train to three hundred and seventy four cycles (374.0c) for a six-train intersection closure; the intersection open period varied from fifty four point two cycles (54.2c) for a single down-line train to eighty six cycles (86.0c) for a six-train intersection closure.
Chapter 7: Computer Simulation Analysis and Results

7.3.3. Individual Simulations Process Details – Proposed Environment

The results of the proposed environment individual simulation are detailed in Table 7.2, which summarises the simulation details of the seven simulations train activity of the proposed environment.

Table 7.2: Individual Simulation Details – Proposed Environment

<table>
<thead>
<tr>
<th>Trains Level Crossing Closures</th>
<th>RLX Closure Starts</th>
<th>Train Arrivals</th>
<th>Train Departs</th>
<th>RLX Opens</th>
<th>Sim Finish</th>
<th>RLX Closure Period</th>
<th>RLX Open Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed DSP – DSP Environment (in cycles)</td>
<td>Train 1</td>
<td>Train 2</td>
<td>Train 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Train Down-Line Closure</td>
<td>31.8</td>
<td>98.8</td>
<td>120.0</td>
<td>102.2</td>
<td>125.0</td>
<td>70.4</td>
<td>54.6</td>
</tr>
<tr>
<td>Single Train Up-Line Closure</td>
<td>31.8</td>
<td>85.8</td>
<td>105.8</td>
<td>102.2</td>
<td>125.0</td>
<td>70.4</td>
<td>54.6</td>
</tr>
<tr>
<td>Two-Train Down-Up Closure</td>
<td>Train 1</td>
<td>31.0</td>
<td>93.8</td>
<td>107.2</td>
<td>102.0</td>
<td>125.0</td>
<td>71.0</td>
</tr>
<tr>
<td></td>
<td>Train 2</td>
<td>100.6</td>
<td>120.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-Train Up-Down Closure</td>
<td>Train 1</td>
<td>31.0</td>
<td>90.0</td>
<td>110.4</td>
<td>102.0</td>
<td>125.0</td>
<td>71.0</td>
</tr>
<tr>
<td></td>
<td>Train 2</td>
<td>103.6</td>
<td>117.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-Train Closure</td>
<td>Train 1</td>
<td>36.0</td>
<td>92.0</td>
<td>104.0</td>
<td>100.0</td>
<td>225.0</td>
<td>128.0</td>
</tr>
<tr>
<td></td>
<td>Train 2</td>
<td>96.0</td>
<td>120.0</td>
<td>204.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Train 3</td>
<td>208.0</td>
<td>217.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Four-Train Closure</td>
<td>Train 1</td>
<td>50.0</td>
<td>93.8</td>
<td>107.0</td>
<td>102.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Train 2</td>
<td>100.0</td>
<td>120.4</td>
<td>253.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Train 3</td>
<td>100.0</td>
<td>253.0</td>
<td>265.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Train 4</td>
<td>174.2</td>
<td>223.6</td>
<td>265.0</td>
<td>224.0</td>
<td>244.0</td>
<td>265.0</td>
</tr>
</tbody>
</table>
Table 7.2 presents and summarises simulation details of train activity at both the down-line current platform environment and at the up-line proposed platform environment. A detailed description of the report follows and summary analyses of the above results are detailed in Section 7.3.5, comparing the results of the proposed simulations environment against the current simulations environment. It is noted that multiple-train intersection closures were simulated regardless of the train initiating the closure or the mixture of the trains' origin/destination.

### 7.3.4. Summary of Simulation Details – Proposed Environment

The simulation details of train activity at both the down-line and the up-line proposed platform environment intersection closure periods and intersection open periods was summarised as follows: the intersection closed period varied from seventy point four cycles (70.4c) for a single

<table>
<thead>
<tr>
<th>Trains Level Crossing Closures Proposed DSP – DSP Environment (in cycles)</th>
<th>RLX Closure Starts</th>
<th>Train Arrivals</th>
<th>Train Departs</th>
<th>RLX Opens</th>
<th>Sim Finish</th>
<th>RLX Closure Period</th>
<th>RLX Open Period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Five-Train Closure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 1</td>
<td>50.0</td>
<td>93.8</td>
<td>107.0</td>
<td>102.0</td>
<td>385.0</td>
<td>191.8</td>
<td>193.2</td>
</tr>
<tr>
<td>Train 2</td>
<td>174.2</td>
<td>223.6</td>
<td>253.0</td>
<td>244.0</td>
<td>365.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 3</td>
<td>295.0</td>
<td>358.0</td>
<td>385.0</td>
<td>365.0</td>
<td>385.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Six-Train Closure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 1</td>
<td>50.0</td>
<td>100.0</td>
<td>121.4</td>
<td>122.0</td>
<td>460.0</td>
<td>256.0</td>
<td>204.0</td>
</tr>
<tr>
<td>Train 2</td>
<td>172.4</td>
<td>213.6</td>
<td>243.4</td>
<td>244.0</td>
<td>460.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 3</td>
<td>294.2</td>
<td>358.0</td>
<td>390.0</td>
<td>365.0</td>
<td>460.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train 4</td>
<td>416.6</td>
<td>447.8</td>
<td>460.0</td>
<td>460.0</td>
<td>460.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: research simulation details report
down-line train to two hundred and fifty six cycles (256.0c) for a six-train intersection closure; the intersection open period varied from fifty four point six cycles (54.6c) for a single down-line train to two hundred and four cycles (204.0c) for a six-train intersection closure.

7.3.5. Simulation Results Comparison Summaries

The simulation details comparison summary report compares the simulations results of fourteen different simulations of the current environment and the proposed environment. Details were documented for each individual simulation of the seven simulation processes of the current environment and the seven simulation of the proposed environment.

As indicated, the simulation details of the fourteen simulations of only one of series of simulations performed was analysed and presented. Table 7.3 presents the summary comparison of both the current and proposed environments.

Table 7.3: Simulation Closure Details Comparison Summary

<table>
<thead>
<tr>
<th>Trains Level Crossing Closures (in cycles)</th>
<th>Current DSP – ASP Simulation</th>
<th>Proposed DSP – DSP Simulation</th>
<th>Current vs Proposed Simulations Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycles</td>
<td>RLX Closure Period</td>
<td>RLX Open Period</td>
<td>Cycles</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>--------------------</td>
<td>------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Single Train Down-Line</td>
<td>125.0</td>
<td>70.8</td>
<td>54.2</td>
</tr>
<tr>
<td>Single Train Up-Line</td>
<td>165.0</td>
<td>90.8</td>
<td>74.2</td>
</tr>
<tr>
<td>Two-Train</td>
<td>170.0</td>
<td>92.0</td>
<td>78.0</td>
</tr>
<tr>
<td>Three-Train</td>
<td>225.0</td>
<td>151.0</td>
<td>74.0</td>
</tr>
<tr>
<td>Four-Train</td>
<td>320.0</td>
<td>246.0</td>
<td>74.0</td>
</tr>
<tr>
<td>Five-Train</td>
<td>385.0</td>
<td>302.0</td>
<td>83.0</td>
</tr>
<tr>
<td>Six-Train</td>
<td>460.0</td>
<td>374.0</td>
<td>86.0</td>
</tr>
</tbody>
</table>

Source: research simulation details report
Table 7.3 presents the summary comparison of both the current and proposed environment individual simulation details in relation to train initiated closures of the level crossing area. The report compares the analysis summaries of the simulation results of both environments. It compares the results, providing the differences between the two simulation environments in regards to:

- the simulation periods for each simulation;
- the level crossing intersection closure periods; and
- the level crossing intersection open periods.

In addition, actual changes were experienced in multiple train closures, manifested over the last several years; these changes are indicated in Table 5.5, and show a decline of multiple train closures over all other closures. None the less, for comparison and completeness of the simulation process of the study, proposed environment simulation of more than two-train were generated, but all these simulations consisted of more than one event of level crossing closure periods.

Under the DSP – DSP platform environment changes proposed, continual level crossing closures of more than two trains would no longer occur; the proposed closure periods are for shorter time periods than under the current system. Track trains separation controlled by axle counters technology insure the existence of a certain degree of separation or headway between trains travelling on the same track and in the same direction. As a result, the intersection level crossing would open in between train arrivals, opening the intersection road traffic between train traffic, allowing road and pedestrian traffic passage, which does not and cannot occur under the current DSP – ASP platform environment.

During the DSP – DSP proposed platform environment simulations and during the same simulation period, more than two-train were simulated in the following manner:
• a three-train activated closure was simulated as combined closure of two-train and a single train closure, two closure events;

• a four-train activated closure was simulated as two combined closure of two sets of two-train closures, two closure events;

• a five-train activated closure was simulated as three combined closure of two sets of two-train closures and a single train closure, three closure events; and

• a six-train activated closure was simulated as four combined closure of two sets of two-train closures and two single train closures, four closure events.

7.3.6. Summary – Simulation Results Comparison Analysis
Comparisons were made of each of the seven train modes initiated closure periods using period details measured in simulation cycles. All comparisons train modes initiated closures, with the exception of single train down-line initiated closures, indicates various degrees of improvements; these improvements were measured on the duration of the intersection closure periods and the duration of intersection open periods.

The simulation summary details comparison analysis confirmed overall shorter road intersection closure periods and longer road intersection open periods; these are a direct result from the implementation of the theory presented. The intersection closure period varied from point four cycles (0.4c) for single down-line train to one hundred and eighteen cycle (118.0c) for a six-train intersection closure. The intersection open period varied from of point four cycles (0.4c) for single down-line train to one hundred and eighteen cycle (118.0c) for six-train intersection closure. In addition, the actual simulation periods indicated a difference of forty cycles (40.0c) difference in the simulation processes periods for single down-line train to a difference of fifty five cycle (55.0c) difference in the simulation processes periods for a four-train intersection road closure, with some simulation having no simulation periods difference.
Simulation Result Generated Reports

Simulation result reports of each individual simulation process were generated by VISSIM. The generated reports comprised of individual reports of the seven simulations of the current environment and the seven simulations of the proposed environment, using the three different road traffic volume levels, forty two reports in all. More specifically, the reports included details pertinent to vehicle queue length and the number of vehicle stops within queues. Particulars of queue counters and data collection points technology, and the data collection method used by the simulator, were discussed in Section 6.7.

In addition, as the detailed reports of all computer generated simulation reports are too numerous to present and discuss individually, two reports, one for each the current and proposed environment simulations for single up-line train, are presented as examples of system generated reports. The detailed data of all forty two reports was used to analyse, create, report and compare the findings presented and analysed in Section 7.5.

Computer Generated Simulation Results – Current Environment

Simulation results, as generated by the computer simulation software for a single up-line train, using the three different road traffic volume levels for the current DSP – ASP platform environment, are indicative of the simulation vehicle queue length and number of vehicle stops within each queue. The reports indicate the average and maximum queue length per designated road segment and the number of vehicle stops within a queue, as recorded during the simulation period.

Three simulation reports, covering the three ranges of road traffic volumes for each simulation process for the current DSP-ASP single up-line train simulation results, were amalgamated into one report, encompassing the three road traffic volumes ranges.

In addition to the report name, date and time of the simulations, and the details of each of three simulations, the report also includes the queue
counters number and physical location within the simulation model; the combined report presents the details of the average and maximum of metres of queue per each road segment or links of the road network, as well as the number of stops within each queue. Table 7.4 shows a sample report results of the combined three specific road traffic volumes for the current DSP – ASP single up-line train simulation results.

Table 7.4: Current DSP – ASP Single Up-Line Train simulation result

<table>
<thead>
<tr>
<th>Queue Counter</th>
<th>Link</th>
<th>Queue Length</th>
<th>Queue Counter</th>
<th>Link</th>
<th>Queue Length</th>
<th>Queue Counter</th>
<th>Link</th>
<th>Queue Length</th>
<th>Queue Counter</th>
<th>Link</th>
<th>Queue Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>26</td>
<td>2</td>
<td>49</td>
<td>80</td>
<td>3</td>
<td>56</td>
<td>26</td>
<td>4</td>
<td>49</td>
<td>58</td>
</tr>
<tr>
<td>2</td>
<td>81</td>
<td>22</td>
<td>3</td>
<td>56</td>
<td>60</td>
<td>4</td>
<td>49</td>
<td>75</td>
<td>5</td>
<td>27</td>
<td>58</td>
</tr>
<tr>
<td>3</td>
<td>56</td>
<td>60</td>
<td>4</td>
<td>49</td>
<td>75</td>
<td>5</td>
<td>27</td>
<td>58</td>
<td>5</td>
<td>27</td>
<td>58</td>
</tr>
</tbody>
</table>

Avg.: average queue length [m] within time interval
max: maximum queue length [m] within time interval
Stop: number of stops within queue

In the report example (Table 7.4), the simulation run recorded the following details: the average queue length for link number 1 is reported as 26, indicating the average length of the vehicular queue for link number 1, was 26 metres long; similarly, the maximum queue for link number 1 is reported as 80, or 80 metres long; and the total number of vehicular stops within the queue is reported as 28. The report is presented as an example.
Chapter 7: Computer Simulation Analysis and Results

of the system generated reports for the current environment; the report contents are fully detailed in Section 7.5.

7.4.2. Computer Generated Simulation Results – Proposed Environment

Simulation results, as generated by the computer simulation software for a single up-line train, using the three different road traffic volume levels for the proposed DSP-DSP platform environment, are indicative of the simulation vehicle queue length and number of vehicle stops within each queue. The reports indicate the average and maximum queue length per designated road segment and the number of vehicle stops within a queue, as recorded during the simulation period. Table 7.5 is an example of an amalgamated report for the proposed DSP-DSP single up-line train simulation results.
Table 7.5: Proposed DSP – DSP Single Up-Line Train simulation result

<table>
<thead>
<tr>
<th>Queue Counters</th>
<th>Link</th>
<th>Average Queue Length [m] within time interval</th>
<th>Maximum Queue Length [m] within time interval</th>
<th>Number of Stops within Queue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>33,000</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>81</td>
<td>22,700</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>56</td>
<td>60,899</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
<td>75,656</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>27</td>
<td>58,586</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

Source: Amalgamated computer generated simulation results report

Table 7.5 presents three simulation reports, covering the three ranges of road traffic volumes for each simulation process for the proposed DSP – DSP single up-line train simulation results, were amalgamated into one report, encompassing the three road traffic volumes ranges. In this table example, the simulation run recorded the following details: the average queue for link number 1 is reported as 19, indicating the average length of the vehicular queue for link number 1, was 19 metres long; similarly, the maximum queue for link number 1 is reported as 55, indicating the maximum length of the vehicular queue for link number 1, was 55 metres long; and the total number of vehicular stops within the queue is reported as 21. The report is presented as an example of the system generated reports for the proposed environment; the report contents are detailed in Section 7.5.
7.4.3. **Simulations Results Generated Reports Summary**  
The detailed reports of each simulation were too numerous to present individually in this section. Instead, two simulation reports, one for each the current and proposed environment simulations for single up-line train, are presented; each of these two simulation reports are the amalgamation of three individual simulation generated reports using the different road traffic volume levels. These reports are presented as an example of the system generated reports of the current and proposed environment. The detailed data from all forty two reports was used to analyse, create, compare and develop comparison summary reports. Analysis of the data and the comparison report results are presented in the following section.

7.5. **Simulation Generated Report Comparison Analysis**  
Simulation details comparison summary reports cover the simulations results of fourteen different simulations of the current and proposed environments. Details were collected for each individual simulation process of the seven simulation of the current environment and the seven simulation of the proposed environment, using the three different road traffic volume levels, with a large number of reports generated; these were mentioned in Section 7.4. These computer generated simulation report results required further analysis and comparison at each simulation level, before the results could be used for summary comparison reporting.

The result of the analysis of the reports covering the current DSP – ASP station platform train simulations and the proposed DSP – DSP station platform train simulations, were compiled and analysed to provide comparison details of both operations. The results were further analysed to identify the differences between the operation of both the current and proposed operations.

The traffic queue lengths and the number of stops within queues resulting from the forty two simulations computer generated reports, were used as input data to MS Excel worksheets to analyse the details and differences
between the current and proposed operations. Seven reports were generated and analysed using the MS Excel worksheets, one for every type of train initiated level crossing closure event. The reports are indicative of the degree of differences between both simulated operations.

Summary analysis reports of both environments, one for each of the seven types of train initiated level crossing closure mode simulations, are presented in this section. The main arterial roads are the focus of the traffic congestion analysis; these are depicted in the reports as *South-North Traffic* and *North-South Traffic* and the results boxed and highlighted by heavier borders.

The reports for both the current DSP – ASP operations and proposed DSP – DSP operations indicate the train’s operational mode and the time, in simulation cycles, taken for the simulations. The results of the three different vehicles volumes simulations, are specified under the headings of average queue (*Avg*) and maximum queue (*Max*), both expressed in metres of queue, and number of stops (*Stop*), meaning the number vehicles stops within queues during simulations periods.

The report *Differences DSP – ASP and DSP – DSP* represents the differences between the first and second part of the reports, a comparison between the current system environment and the proposed system environment, indicating the degree and percentage of the differences for the three road traffic volumes, between both the current and proposed environments.

In addition, some of the numbers of stop within queues are reported having increased in the numbers of occurrences under the proposed environment. This is due to the proposed simulation environment for multiple train closures, simulated purposely with more than one intersection closure event within the same simulation period. For example, in a four-train intersection closure, under the current simulation environment, motor vehicles arrive and stop at the queue only once and remain stationary until the intersection opens at the end of the closure.
event. Under the proposed simulation environment, motor vehicles arrive and stop at the queue, but as the intersection opens in between train arrivals and departures during the same simulation event, a second queue develops, thus reporting additional number of stops within queues, but not indicating the number of queue iteration’s, rather reporting the total combined number of stops within queues.

7.5.1. **Single Down-Line Trains Comparison Analysis**

The simulation development process comprised of no changes to the operations of the current DSP environment platform for single down-line train closure. This was reflected by the analysis of both the current and proposed environment simulations for a single down-line train.

The simulation development report for single down-line trains reflected no changes were made to the environment. Under these conditions, both simulations provided the same results and the report analysis indicates NIL differences in the operation of both simulations. This was the expected result, as no changes were made affecting the current DSP platform. The results also confirm both simulations provide the same results when executed independently, further establishing the accuracy of both simulation models. A summarised detailed analysis table comparison report for single down-line train closure is included in Appendix F.

7.5.2. **Single Up-Line Train Comparison Analysis**

The simulation development process comprised of changes to the operations of the current ASP environment platform, converting the environment from an ASP environment platform to a new DSP environment platform. In that process, the current up-line ASP environment platform was decommissioned and rendered non-operational. These changes are reflected by the analysis of the current and proposed environment simulations for a single up-line train, two-train and all multiple train simulations. Under these new conditions, the simulations provided different results and the report analysis indicated the differences in the operations of both of these simulations. A summarised detailed analysis
table comparison report for single up-line train closure is included in Appendix F.

The analysis report indicates the simulation operational time of the current environment and the proposed environment was forty cycle (40.0c) difference and indicates mitigation in most queue lengths and number of stops for the South-North traffic flow, with limited mitigation in queues lengths and number of stops for the North-South traffic flow.

7.5.2.1. South-North Traffic Flow

The South-North traffic flow indicates the following outcomes:

- declines in low-range of the average queue length by twenty seven per cent (-27%), the maximum queue length by thirty one per cent (-31%) and in the number of stops within the queue by twenty five per cent (-25%);

- declines in mid-range per cent of the average queue length by twenty four per cent (-24%), the maximum queue length by thirty one per cent (-31%) and in the number of stops within the queue by sixteen per cent (-16%); and

- declines in large-range per cent of the average queue length by nineteen per cent (-19%), the maximum queue length by twenty five per cent (-25%) and in the number of stops within the queue by twenty three per cent (-23%).

7.5.2.2. North-South Traffic Flow

The North-South traffic flow indicates the following outcomes:

- no difference in low-range per cent of the average queue length, an increase of the maximum queue length by one per cent (1%), and a decline in the number of stops within the queue by eight per cent (-8%);
an increase in mid-range average queue length by nine per cent (9%), and declines in the maximum queue length by five per cent (-5%) and the number of stops within the queue by thirteen per cent (-13%); and

an increase in large-range average queue length by eleven per cent (11%), declines in the maximum queue length by two per cent (-2%) and in the number of stops within the queue by seven per cent (-7%).

The above differences in traffic flows are not inclusive of the forty cycles (40.0c) differences between the simulations operation. If applied, these would reflect further reductions to the average and maximum queue lengths, as well as in the number of vehicle stops within queues.

7.5.3. Two-Train Comparison Analysis

The comparison analysis of the current and proposed environment for the simulation process for two-train indicates the simulations were conducted using two different operating cycles: one hundred and seventy cycles (170.0c) and one hundred and twenty five cycles (125.0c), correspondingly to the DSP – ASP and DSP – DSP platform environments. A summarised detailed analysis table comparison report for a two-train closure is included in Appendix F.

The analysis report indicates the simulation operational time of the current environment and the proposed environment was forty five cycles (45.0c) difference in the operation of both the current and proposed simulations, and indicates mitigation in most queue lengths and number of stops for the South-North traffic flow, with limited mitigation in queues and number of stops to the North-South traffic flow.

7.5.3.1. South-North Traffic Flow

The South-North traffic flow indicates the following outcomes:

- declines in low-range per cent of the average queue length by thirty two per cent (-32%), the maximum queue length by thirty five per cent (-35%) and the number of stops within the queue by thirty per cent (-30);
• declines in Mid-range per cent of the average queue length by twenty nine per cent (-29%), the maximum queue length by thirty five per cent (-35%) and the number of stops within the queue by eighteen per cent (-18%); and

• declines in large-range per cent of the average queue length by sixteen per cent (-16%), the maximum queue length by twenty one per cent (-21%) and the number of stops within the queue by twenty two per cent (-22%).

7.5.3.2. North-South Traffic Flow
The North-South traffic flow indicates the following outcomes:

• an increase in low-range per cent of the average queue length by nine per cent (9%), and decreases in the maximum queue length by four per cent (-4%) and the number of stops within the queue by eight per cent (-8%);

• an increase in mid-range average queue length by three per cent (3%), and decreases in the maximum queue length by four per cent (-4%), as well as the number of stops within the queue by thirteen per cent (-13%); and

• an increase in large-range per cent of the average queue length by fourteen per cent (14%), and decreases in the maximum queue length by ten per cent (-10%), as well as the number of stops within the queue by two per cent (-2%).

The above differences in traffic flows are not inclusive of the forty five cycle (45.0c) differences between the simulations operation. If applied, these would reflect further reductions to the average and maximum queue lengths, as well as in the number of vehicle stops within queues.

7.5.4. Three-Train Comparison Analysis
The comparison analysis of the current and proposed environment for the simulation process for three-train closure indicates the simulations were conducted using the same operating cycles of two hundred and twenty five
cycles (225.0c). In addition, the DSP-DSP three-train closure was simulated as one set of two-train and a single train with two intersection closure between train sets. A summarised detailed analysis tables comparison report for a three-train closure is included in Appendix F.

The analysis report indicates the simulations operational time for both the current and the proposed environment was the same and indicates mitigation in most queue lengths and increases in number of stops for the South-North traffic flow, with limited mitigation in queues and increases in number of stops to the North-South traffic flow.

7.5.4.1. South-North Traffic Flow
The South-North traffic flow indicates the following outcomes:

- declines in low-range per cent of the average queue length by thirty five per cent (-35%), the maximum queue length by thirty nine per cent (-39%), as well as the number of stops within the queue by five per cent (-5%);

- declines in mid-range per cent for the average queue length by eight per cent (-8%) and in the maximum queue length by eighteen per cent (-18%), and an increase in the number of stops within the queue by twenty one per cent (21%); and

- declines in large-range per cent for the average queue length by two per cent (-2%) and in the maximum queue length by eighteen per cent (-18%), and an increase in the number of stops within the queue by thirty three per cent (33%).

7.5.4.2. North-South Traffic Flow
The North-South traffic flow indicates the following outcomes:

- declines in low-range per cent for the average queue length by thirty five per cent (-35%) and in the maximum queue length by thirty one per cent (-31%), and an increase in number of stops within the queue by twenty three per cent (23%);
• declines in mid-range per cent for the average queue length by thirty seven per cent (-37%) and in the maximum queue length by thirty eight per cent (-38%), and an increase in the number of stops within the queue by seventeen per cent (17%); and

• declines in large-range per cent of the average queue length by thirteen per cent (-13%) and in the maximum queue length by eight per cent (-8%), and an increase in the number of stops within the queue by twenty three per cent (23%).

As indicated, three-train activated closure were simulated as a combined closure of two-train and a single train closure, with two separate intersection closures during the same simulation period, comprising of two warning (2) closure processes requiring twenty five seconds (25s) of preemption each. If applied, these would reflect further reductions to the average and maximum queue lengths, as well as in the number of vehicle stops within queues.

7.5.5. Four-Train Comparison Analysis

The comparison analysis of the current and proposed environment for the simulation process for four-train closure indicates the simulations were conducted using two different operating cycles: three hundred and twenty cycles (320.0c) and two hundred and sixty five cycles (265.0c), correspondingly to the DSP – ASP and DSP – DSP platform environments. In addition, the DSP-DSP four-train closure simulation consists of two sets of two-train with an intersection closure between train sets. A summarised detailed analysis table comparison report for a four-train closure is included in Appendix F.

The analysis report indicates the simulation operational time of the current environment and the proposed environment was fifty five cycles (55.0c) difference in the operation of both the current and proposed simulations, and indicates mitigation in most queue lengths and number of stops for the South-North traffic flow, large mitigation in queues and in numbers of stops to the North-South traffic flow.
7.5.5.1. South-North Traffic Flow
The South-North traffic flow indicates the following outcomes:

- declines in low-range per cent for the average queue length by sixty eight per cent (-68%), the maximum queue length by sixty nine per cent (-69%) and in the number of stops within the queue by twenty eight per cent (-28%);  
- declines in mid-range per cent for the average queue length by fifty seven per cent (-57%), in the maximum queue length by fifty five per cent (-55%) and in the number of stops within the queue by eleven per cent (-11%); and  
- declines in large-range per cent for the average queue length by forty one per cent (-41%) and in the maximum queue length by forty three per cent (-43%), and an increase in the number of stops within the queue by eighteen per cent (18%).

7.5.5.2. North-South Traffic Flow
The North-South traffic flow indicates the following outcomes:

- declines in low-range per cent for the average queue length by sixty seven per cent (-67%) and in the maximum queue length by thirty one per cent (-31%), and an increase in number of stops within the queue by thirteen per cent (13%);  
- declines in mid-range per cent for the average queue length by seventy eight per cent (-78%), in the maximum queue length by seventy three per cent (-73%) and in the number of stops within the queue by forty six per cent (-46%); and  
- declines in large-range per cent of the average queue length by seventy per cent (-70%), in the maximum queue length by sixty five per cent (-65%) and in the number of stops within the queue by thirty three per cent (-33%).

As indicated, four-train activated closure were simulated as a combined closure of two sets of two-train closures, with two separate intersection
closures during the same simulation period, comprising of two warning (2) closure processes requiring twenty five seconds (25s) of preemption each. In addition to the above differences, the results are not inclusive of the fifty five cycle (55.0c) differences between the operations of both simulations. If applied, these would reflect further reductions to the average and maximum queue lengths, as well as in the number of vehicle stops within queues.

7.5.6. Five-Train Comparison Analysis

The comparison analysis of the current and proposed environment for the simulation process for five-train indicates the simulations were conducted using the same operating cycles of three hundred and eighty five cycles (385.0c). In addition, the DSP-DSP five-train closure simulation consists of two sets of two-train plus one single train with three intersection closures between train sets. A summarised detailed analysis table comparison report for a five-train closure is included in Appendix F.

The analysis report indicates the simulations operational time for both the current and the proposed environment was the same and indicates mitigation in all queue lengths and decreases in most number of stops for the South-North traffic flow, with mitigation in queues and decreases in most number of stops to the North-South traffic flow.

7.5.6.1. South-North Traffic Flow

The South-North traffic flow indicates the following outcomes:

- declines in low-range per cent for the average queue length by seventy six per cent (-76%), the maximum queue length by seventy two per cent (-72%) and in the number of stops within the queue by twenty per cent (-20%);

- declines in mid-range per cent for the average queue length by sixty nine per cent (-69%), in the maximum queue length by sixty one per cent (-61%) and in the number of stops within the queue by three per cent (-3%); and
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- declines in large-range per cent for the average queue length by forty three per cent (43%), maximum queue length by forty six per cent (46%), and an increase in the number of stops within the queue by forty nine per cent (49%).

7.5.6.2. North-South Traffic Flow

The North-South traffic flow indicates the following outcomes:

- declines in low-range per cent for the average queue length by seventy four per cent (74%) and in the maximum queue length by seventy five per cent (75%), and an increase in number of stops within the queue by thirty three per cent (33%);

- declines in mid-range per cent for the average queue length by eighty four per cent (84%), in the maximum queue length by seventy eight per cent (78%) and in the number of stops within the queue by forty one per cent (41%); and

- declines in large-range per cent of the average queue length by seventy two per cent (72%), in the maximum queue length by fifty six per cent (56%) and in the number of stops within the queue by twelve per cent (12%).

As indicated, five-train activated closure were simulated as a combined closure of two sets of two-train plus a single train closures, with three separate intersection closures during the same simulation period; thus, the proposed simulation environment comprises of three (3) warning closure processes requiring twenty five seconds (25s) of preemption each. If applied, these would reflect further reductions to the average and maximum queue lengths, as well as in the number of vehicle stops within queues.

7.5.7. Six-Train Comparison Analysis

The comparison analysis of the current and proposed environment for the simulation process for six-train indicates the simulations were conducted using the same operating cycles of four hundred and sixty cycles (460.0c).
In addition, the DSP-DSP six-train closure consists of two sets of two-train plus two single trains with four intersection closures between train sets. A summarised detailed analysis table comparison report for a six-train closure is included in Appendix F.

The analysis report indicates the simulations operational time for both the current and the proposed environment was the same and indicates mitigation in most queue lengths and decreases in most number of stops for the South-North traffic flow, with mitigation in all queues lengths and increases in all number of stops to the North-South traffic flow.

7.5.7.1. South-North Traffic Flow
The South-North traffic flow indicates the following outcomes:

- declines in low-range per cent for the average queue length by eighty two per cent (-82%), the maximum queue length by seventy seven per cent (-77%) and in the number of stops within the queue by twenty per cent (-20%);
- declines in mid-range per cent for the average queue length by seventy six per cent (-76%), in the maximum queue length by sixty eight per cent (-68%) and in the number of stops within the queue by eight per cent (-8%); and
- declines in large-range per cent for the average queue length by forty two per cent (-42%) and in the maximum queue length by twenty three per cent (-23%), and an increase in the number of stops within the queue by ninety six per cent (96%).

7.5.7.2. North-South Traffic Flow
The North-South traffic flow indicates the following outcomes:

- declines in low-range per cent for the average queue length by seventy eight per cent (-78%) and in the maximum queue length by eighty three per cent (-83%), and an increase in number of stops within the queue by sixty per cent (60%);
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- declines in mid-range per cent for the average queue length by sixty nine per cent (-69%), in the maximum queue length by seventy nine per cent (-79%) and in the number of stops within the queue by one hundred and thirteen per cent (113%); and

- declines in large-range per cent of the average queue length by seventy six per cent (-76%), in the maximum queue length by fifty four per cent (-54%) and in the number of stops within the queue by fifteen per cent (15%).

As indicated, six-train activated closure were simulated as a combined closure of two sets of two-train plus two single train closures, with four separate intersection closures during the same simulation period; thus, the proposed simulation environment comprises of four (4) warning closure processes requiring twenty five seconds (25s) of preemption each. If applied, these would reflect further reductions to the average and maximum queue lengths, as well as in the number of vehicle stops within queues.

7.6. Computer Generated Simulation Results Summaries

Seven operations were simulated for each the current and proposed level crossing operations using fixed road vehicular traffic. These fourteen simulated environments were replicated using the three different volumes of road vehicular traffic, giving the total of forty two different simulated environments created, tested, analysed and reported. Each of these produced results that were analysed and compared separately, depending on the road traffic volume used, the low-range, the mid-range and large-range of road vehicular traffic volumes; the forty two different simulated environments were all reported separately using the corresponding road vehicular traffic volumes to produce two distinct reports, one each for the main arterial road, Clayton Road South-North road traffic flow and Clayton Road North-South road traffic flow.
The results indicate average and maximum vehicle queues lengths reduce under the proposed system. The number of vehicles stops within queues at the intersection, in many cases, also reduced under the proposed system. Summaries of these results are presented in Table 7.6 and Table 7.7.

In addition, North-South vehicular traffic flow comparison indicated differences in the results in contrast to the South-North vehicular traffic flow results. The differences manifested in increased occurrences of some average, maximum vehicle queues lengths and in number of vehicles stops within queues at the intersection. The differences are most likely related to the positioning of an active on-street public transport bus stop in close proximity to the North-South level crossing intersection location, affecting vehicles flow on that road segment. Figure 7.1 shows a bus at the bus stop just before the intersection.

**Figure 7.1: Clayton Rd South-Bound Bus Stop**

![Bus Stop Image](image-url)

Source: Google Earth image of the target area

Figure 7.1 shows a bus, pointed by the arrow, in the process of loading and unloading passengers at the south-bound inner lane bus stop at the corner of Clayton and Carinish Roads; no cars are stationary between the
intersection and the bus at the bus stop. The public transport stop impacted on the proposed simulation environment more, as the intersection is open for vehicles traffic more often than under the current simulation environment; under the current simulation environment, vehicles traffic is at a standstill for longer periods of time. Refer to Section 6.5.6 for public transport stops locations and other details.

It is also noted that single down-line train operations did not change under the proposed station modifications, thus the results of all simulations of single down train operations reflect this by showing zero per cent differences in all queues. These results confirm the integrity of both simulations: the two different simulations produced exactly the same result.

7.6.1. South-North Road Vehicular Traffic Simulation Summary

The results for the South-North vehicular traffic comparison indicate most average and maximum vehicle queues lengths reduced by considerable amounts under the proposed system. The number of vehicles stops within queues at the intersection also reduced by substantial amounts under the proposed system. Table 7.6 summarises the difference of the three South-North road vehicular traffic volumes used.

<table>
<thead>
<tr>
<th>South – North Traffic/ Road Traffic Volumes</th>
<th>Low-Range Road Traffic</th>
<th>Mid-Range Road Traffic</th>
<th>Large-Range Road Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg</td>
<td>Max</td>
<td>Stop</td>
</tr>
<tr>
<td>Single Down Train</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Single Up Train</td>
<td>-27%</td>
<td>-31%</td>
<td>-25%</td>
</tr>
<tr>
<td>Two-Train</td>
<td>-32%</td>
<td>-35%</td>
<td>-30%</td>
</tr>
<tr>
<td>Three-Train</td>
<td>-35%</td>
<td>-39%</td>
<td>-5%</td>
</tr>
<tr>
<td>Four-Train</td>
<td>-68%</td>
<td>-69%</td>
<td>-28%</td>
</tr>
</tbody>
</table>
Table 7.6 is a summary of the difference of the three South-North road vehicular traffic volumes used. The average length of the vehicular queue and the maximum length of the vehicular queue are both expressed in metres of queue; the numbers of vehicular stops within the queue are expressed in number of stops.

Single up train and two-train operations using the three road traffic ranges, indicates various degree of congestion mitigation in all queues lengths traffic flows and number of stops within queues. Multiple train operations experienced larger reduction in most queue lengths traffic flows and in the number of stops within queues.

### 7.6.1.1. Low-Range Road Vehicular Traffic Differences

South-North queue lengths using low-range road traffic volumes for multiple train ranges changed by:

- reduced from an average queue of thirty five per cent (\(-35\%)\) for three-train operation to an average queue of eighty two per cent (\(-82\%)\) for six-train operation;

- reduced from a maximum queue of thirty nine per cent (\(-39\%)\) for three-train operation to a maximum queue of seventy seven per cent (\(-77\%)\) for six-train operation; and

- the number of stops within queues for multiple trains mitigation fluctuated between five per cent (\(-5\%)\) for three-train operation to twenty eight per cent (\(-28\%)\) for four-train operation.

### 7.6.1.2. Mid-Range Road Vehicular Traffic Differences

South-North queue lengths using mid-range road traffic volumes for multiple train ranges changed by:

<table>
<thead>
<tr>
<th></th>
<th>-76%</th>
<th>-72%</th>
<th>-20%</th>
<th>-69%</th>
<th>-61%</th>
<th>-3%</th>
<th>-43%</th>
<th>-46%</th>
<th>49%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five-Train</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Six-Train</td>
<td>-82%</td>
<td>-77%</td>
<td>-20%</td>
<td>-76%</td>
<td>-68%</td>
<td>-8%</td>
<td>-42%</td>
<td>-23%</td>
<td>96%</td>
</tr>
</tbody>
</table>

Source: Simulation results comparison report
• reduced from an average queue of eight per cent (-8%) for three-train operation to an average queue of seventy six per cent (-76%) for six-train operation;

• reduced from a maximum queue of eighteen per cent (-18%) for three-train operation to a maximum queue of sixty eight per cent (-68%) for six-train operation; and

• the number of stops within queues for multiple trains fluctuated between an increase of eighteen per cent (18%) for three-train operation to a decrease of sixty eight per cent (-68%) for six-train operation.

7.6.1.3. Large-Range Road Vehicular Traffic Differences
South-North queue lengths traffic flow for multiple train ranges reduced by:

• from an average queue of two per cent (-2%) for three-train operation to an average queue of forty three per cent (-43%) for five-train operation;

• from a maximum queue of eighteen per cent (-18%) for three-train operation to a maximum of forty six per cent (-46%) for five-train operation; and

• the number of stops within queues fluctuated between decrease of eighteen per cent (-18%) for four-train and an increase of ninety six per cent (96%) for six-train operation.

7.6.2. North-South Road Vehicular Traffic Simulation Summary
The results for the North-South vehicular traffic comparisons indicate most average and maximum vehicle queues lengths also reduced by considerable amounts under the proposed system. The number of vehicles stops within queues at the intersection fluctuates between increases and decreases under the proposed system. Table 7.7 summarises the difference of the three North-South road vehicular traffic volumes used.
Table 7.7 is a summary of the difference of the three South-North road vehicular traffic volumes used. The average length of the vehicular queue and the maximum length of the vehicular queue are both expressed in metres of queue; the numbers of vehicular stops within the queue are expressed in number of stops.

Single up train operations indicates minor changes in queues lengths traffic flow and mitigation in number of stops within queues. Two-train operation indicates increases in average queue lengths traffic flow and mitigation in both maximum queue length traffic flow and number of stops within queues. Multiple trains operation experienced larger reduction in most queue lengths and fluctuating results in number of stops within queues.

7.6.2.1. Low-Range Road Vehicular Traffic Differences

North-South queue lengths traffic flow for multiple train ranges changed by:

- reduced from an average queue of thirty five per cent (-35%) for three-train operation to an average queue of seventy eight per cent (-78%) for six-train operation;
• reduced from a maximum queue of thirty one per cent (-31%) for three-train operation to a maximum queue of eighty three per cent (-83%) for six-train operation; and

• the number of stops within queues for multiple trains ranged increased from thirteen per cent (13%) for four-train operation to sixty per cent (60%) for six-train operation.

7.6.2.2. Mid-Range Road Vehicular Traffic Differences
North-South queue lengths traffic flow for multiple train ranges changed by:

• reduced from an average queue of thirty seven per cent (-37%) for three-train operation to an average queue of eighty four per cent (-84%) for five-train operation;

• reduced from a maximum queue of thirty eight per cent (-38%) for three-train operation to a maximum queue of seventy nine per cent (-79%) for six-train operation; and

• the number of stops within queues for multiple trains fluctuated between an increase of one hundred and thirteen per cent (113%) for six-train operation to reduction of forty six per cent (-46%) for four-train operation.

7.6.2.3. Large-Range Road Vehicular Traffic Differences
North-South queue lengths traffic flow for multiple train ranges changed by:

• decreased from an average queue of thirteen per cent (-13%) for three-train operation to an average queue of seventy six per cent (-76%) for six-train operation;

• reduced from a maximum queue of eight per cent (-8%) for three-train operation to a maximum queue of sixty five per cent (-65%) for four-train operation; and
the number of stops within queues fluctuated between increases of twenty three per cent (23%) for three-train operation to decreases of thirty three per cent (-33%) for four-train operation.

7.6.3. Simulation Models Closure Comparison Movies

The results of both simulations, the current and proposed operation environments using mid-range road vehicle traffic and the seven different train activation closures, are captured using 3D graphical animation presentations in Audio Video Interleave (AVI) file format. These fourteen simulations plus two additional background display simulations are included with the thesis results and presented in the magnetic media attached. It is noted that in VISSIM, all simulation movie are recorded at a speed other than the normal speed of the simulated event; the recording speed, between four and five times normal simulation speed, is used to minimise the size of the output generated AVI files and the time taken to view the files. Table 7.8 indicates the details of the sixteen simulation movies.

Table 7.8: Current and Proposed Environment Simulation Movies

<table>
<thead>
<tr>
<th>Simulation Movies Name and Details</th>
<th>Movie Duration (seconds)</th>
<th>Actual Simulation (cycles)</th>
<th>Intersection (cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Closed Period</td>
</tr>
<tr>
<td>Sample Movie</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSP ASP 0 Short 3D Test</td>
<td>27</td>
<td>108.0</td>
<td>n/a</td>
</tr>
<tr>
<td>DSP ASP 0 Trains 500 Cycles</td>
<td>124</td>
<td>500.0</td>
<td>n/a</td>
</tr>
<tr>
<td>Current Environment Operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSP – ASP 1 Single Down-Line</td>
<td>31</td>
<td>125.0</td>
<td>70.8</td>
</tr>
<tr>
<td>DSP – ASP 1 Single Up-Line</td>
<td>41</td>
<td>165.0</td>
<td>90.8</td>
</tr>
<tr>
<td>DSP – ASP 2 Two-Train</td>
<td>42</td>
<td>170.0</td>
<td>92.0</td>
</tr>
<tr>
<td>DSP – ASP 3 Three-Train</td>
<td>58</td>
<td>225.0</td>
<td>151.0</td>
</tr>
</tbody>
</table>
## Simulation Movies Name and Details

<table>
<thead>
<tr>
<th>Movie Name</th>
<th>Movie Duration (seconds)</th>
<th>Actual Simulation (cycles)</th>
<th>Intersection (cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSP – ASP 4 Four-Train</td>
<td>79</td>
<td>320.0</td>
<td>246.0 74.0</td>
</tr>
<tr>
<td>DSP – ASP 5 Five-Train</td>
<td>96</td>
<td>385.0</td>
<td>302.0 83.0</td>
</tr>
<tr>
<td>DSP – ASP 6 Six-Train</td>
<td>114</td>
<td>460.0</td>
<td>374.0 86.0</td>
</tr>
</tbody>
</table>

### Proposed Environment Operations

<table>
<thead>
<tr>
<th>Proposed Environment Operations</th>
<th>Movie Duration (seconds)</th>
<th>Actual Simulation (cycles)</th>
<th>Intersection (cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSP – DSP 1 Single Down-Line</td>
<td>31</td>
<td>125.0</td>
<td>70.4 54.6</td>
</tr>
<tr>
<td>DSP – DSP 1 Single Up-Line</td>
<td>31</td>
<td>125.0</td>
<td>70.4 54.6</td>
</tr>
<tr>
<td>DSP – DSP 2 Two-Train</td>
<td>31</td>
<td>125.0</td>
<td>71.2 53.8</td>
</tr>
<tr>
<td>DSP – DSP 3 Three-Train</td>
<td>58</td>
<td>225.0</td>
<td>143.8 81.2</td>
</tr>
<tr>
<td>DSP – DSP 4 Four-Train</td>
<td>66</td>
<td>265.0</td>
<td>121.8 143.2</td>
</tr>
<tr>
<td>DSP – DSP 5 Five-Train</td>
<td>96</td>
<td>385.0</td>
<td>191.8 193.2</td>
</tr>
<tr>
<td>DSP – DSP 6 Six-Train</td>
<td>114</td>
<td>460.0</td>
<td>257.8 202.2</td>
</tr>
</tbody>
</table>

Source: current and proposed level crossing simulation movies

Table 7.8 indicates the details of the sixteen simulation movies included with the research thesis. The two background display simulations are presented as a sample of the intersection environment; the Short 3D Test movie runs for twenty seven seconds (27s) and shows a closed-up 3D view of the operation of the intersection environment, with two trains arrivals; the Trains 500 Cycles movie runs for one hundred and twenty four seconds (124s) and shows a long 3D view of the operation of the intersection environment, operating a two-train intersection closure, a normal intersection closure with not trains, followed by a single up-line (to the city) train intersection closure; a total of three trains arrivals and departures intersection closures, with normal intersection signals operation period between train arrivals.
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The additional files presented indicate the details of the seven simulations emulating the current DSP-ASP environment and the seven simulations emulating the proposed DSP-DSP environment.

7.6.3.1. Current DSP–ASP Environment Simulation Movies
The seven simulations emulating the current DSP-ASP environment for:

- single down-line train closure runs for thirty one seconds (31s);
- single up-line train closure runs for forty one seconds (41s);
- two-train closure runs for forty two seconds (42s);
- three-train closure runs for fifty eight seconds (58s);
- four-train closure runs for seventy nine seconds (79s);
- five-train closure runs for ninety six seconds (96s); and
- six-train closure runs for one hundred and fourteen seconds (114s).

7.6.3.2. Proposed DSP-DSP Environment Simulation Movies
The seven simulations emulating the proposed DSP-DSP environment for:

- single down-line train closure runs for thirty one seconds (31s);
- single up-line train closure runs for thirty one seconds (31s);
- two-train closure runs for thirty one seconds (31s);
- three-train closure runs for fifty eight seconds (58s);
- four-train closure runs for sixty six seconds (66s);
- five-train closure runs for ninety six seconds (96s); and
- six-train closure runs for one hundred and fourteen seconds (114s).

7.6.3.3. Simulation Movies Delivery Medium
The fourteen simulations movies plus the additional background display simulation movies are included with the thesis results and presented in the magnetic media attached. It is intended that the movies, after the thesis
examination process is completed, will be made available in cloud facilities such as Dropbox or similar facility.

7.7. Intersection Closure Periods – Current vs Proposed

In Section 5.5, it was identified that there were differences in the average times in the level crossing closures between a single down-line trains and a single up-line trains; a train travelling in the latter direction, activated intersection closures, closing the intersection to road traffic for more than twice the period than an intersection closure activate by a train travelling in the former direction; the closures were for forty-six seconds (46s) as opposed to one minute and forty-one seconds (101s) respectively.

It was also identified that under the current configuration environment, there were occurrences of level crossing closures caused by multiple train arrivals within the same intersection closure event. These multiple train closure events, although representing a small percentage of all closure events, closed the intersection to road traffic for long periods, aggravating road traffic congestion.

In addition, these multiple train closure events overlapped multiple sets of train arrivals and intersection closure period events; the intersection road traffic congestion was not cleared in time before the next train arrived, adding to congestion and delays. Not all vehicles in the queues cleared the intersection before the following closure event. These events exacerbated road traffic congestion and more specifically, occurred during the morning and afternoon peak periods.

Simulation results confirmed that under the proposed environment, continual level crossing closures events of more than two trains will no longer occur. This is because the proposed level crossing closures under the Departure Side Platforms (DSP) arrangements, will be shorter than are currently experienced; the separation or headway between trains travelling on the same track and in the same direction, are longer than the maximum
level crossing closure period proposed under the new Departure Side Platforms (DSP) arrangement.

A detailed comparison and summary of the average level crossing closure periods between the current and proposed environment are presented; these indicate the expected period of closures will reduce under the proposed environment, and confirm the claim that the introduction of the proposed alternative, will mitigate level crossing intersection closures periods.

The detailed data of current average closure periods used for the comparison comes from the data collected during the level crossings data collection process; the proposed closure periods details are determined from the simulation results. The differences revealed represent the result of the differences between the actual and proposed closure periods. Table 7.9 indicates the differences between current average closure periods and the proposed closure periods.

**Table 7.9: Average Level Crossing Closures – Current vs Proposed**

<table>
<thead>
<tr>
<th>Closures per Trains Arrivals (in seconds)</th>
<th>Current Average Closure Periods</th>
<th>Proposed Closure Periods</th>
<th>Periods of Closure Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Down-Line Train Closure</td>
<td>46</td>
<td>46</td>
<td>0</td>
</tr>
<tr>
<td>Single Up-Line Train Closure</td>
<td>101</td>
<td>46</td>
<td>-45</td>
</tr>
<tr>
<td>Two-Train Closure – Best Time</td>
<td>108</td>
<td>46</td>
<td>-62</td>
</tr>
<tr>
<td>Two-Train Closure – Worst Time</td>
<td>153</td>
<td>92</td>
<td>-61</td>
</tr>
<tr>
<td>Multiple Trains Closure – Best Time</td>
<td>243</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Multiple Trains Closure – Worst Time</td>
<td>432</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Actual Longest Closure (Six Trains)</td>
<td>638</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

N/A = Not applicable any longer as crossings closures logically restricted to a maximum of two-train closures

Source: current vs proposed level crossing difference in closures
In the current versus proposed level crossing difference in closures table, level crossing closure periods presented are from details from Table 5.6: Level Crossing Closures Times 2008 – 2011 – 2012 and recorded during the data collection process; these are shown as the current environment closure periods. The proposed level crossing closure periods were extrapolated from these figures, using assumptions derived from simulation results of individual simulation details of the proposed environment, as presented in Table 7.9. The results are categorised in the following groups:

- single down-line train closure periods;
- single up-line train closure periods;
- two-train closure periods;
- multiple trains closure periods; and
- longest closure periods.

7.7.1. Single Down-Line Train Closure
The current average closure period activated by a single train on the Departure Side Platforms (DSP) down-line direction, was recorded as forty six seconds (46s); under simulated conditions of the proposed environment, the closure period for a single train in the down-line direction was recorded as seventy point four cycles (70.4c), equivalent to the forty six seconds (46s) recorded during the data collection process. As no changes affecting the current down-line Departure Side Platforms (DSP) environment were made, the recorded closure periods of forty six seconds (46s) continues to apply under the proposed environment.

7.7.2. Single Up-Line Train Closure
The current average closure period activated by a single train on the Arrival Side Platform (DSP) up-line direction, was recorded at one minute and forty one seconds (101s). Under simulated conditions of the proposed environment, after modification conducted for the removal the current
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Arrival Side Platform (DSP) and the establishment of the new Departure Side Platform (DSP) for the up-line train direction, the closure period for a single train in the up-line direction is also recorded at seventy point four cycles (70.4c).

This indicates that the changes made to the platform environment had the desired effect and the new platform environment for an up-line direction train represents a true or mirror image of the current platform environment for a down-line direction train. Thus, the seventy point four cycles (70.4c) or the equivalent of the forty six seconds (46s) that apply for a single train on the Departure Side Platform (DSP) down-line direction closure, also applies for the proposed Departure Side Platform (DSP) up-line direction closure.

7.7.3. Two-Train Closure
The current average closure period activated by two-train arriving at the Departure Side Platform (DSP) and the Arrival Side Platform (ASP), regardless of the train activating the initial closure process, was recorded at two minutes and seven seconds (127s) (refer Table 5.6). Under the proposed two Departure Side Platforms (DSP) environments, the closure period for two-train activated closure, will be dependent on the timing of the first activation of the train detector procedures; the closure period will vary depending on the timing of the actual detection of the combined activation of the trains travelling on the opposite directions.

This period of closure will vary depending on the timing of the activation procedure of the closure period and will be between one of the following: a) shorter or best closure period, will be attained when both trains travelling on opposite directions, trigger the activation of the closure procedures at about the same time; or b) the longer or worst closure period, will be attained when the both trains activated the corresponding detection triggers far apart from each other, but within the same closure activation process (i.e. one train is arriving at the station platform, while the second train is arriving at the activation trigger point).
7.7.3.1. Two-Train Closure – Shortest Time

The two-train activation shorter or best closure will be attained when both trains travelling on opposite directions, arrive at the position of each corresponding detection activation trigger, located each side of the tracks at about 700 metres away from the level crossing intersection, at about the same time. The current average by two-train closure period was recorded at two minutes and seven seconds (127s) (refer Table 5.6); under the proposed two Departure Side Platforms (DSP – DSP) environment, the two train activation best or shorter closure period is proposed to be forty six seconds (46s), the same as a single train closure, as the closure activation period and the closure deactivation period, taking the same time as a single train activation and deactivation period.

7.7.3.2. Two-Train Closure – Longest Time

The two-train longer or worst activation closure occurs when the first detection trigger activating train was arriving at the platform area and close to the closure deactivation trigger for that track, and another train travelling in the opposite direction, activated that track detection trigger. The current average by two-train closure period was recorded at two minutes and seven seconds (127s) (refer Table 5.6); under the proposed two Departure Side Platforms (DSP – DSP) environment, the first train closure period was close to end its forty six seconds (46s) period, as a single train activation closure, as the second train reached the detection trigger activation location, forcing the closure cycle period in operation to be extended and continue for a further forty six seconds (46s). Therefore, the longest or worst closure period for two train activation closure will be one minute and thirty two seconds (92s) or equal to the sum of two single trains activation closure periods under the current DSP-ASP platform environment.

7.7.4. Multiple Trains Closures

The proposed environment simulations results confirm that continual level crossing closures of more than two trains will no longer be operationally
possible or supported. This is because the proposed level crossing closures under the two Departure Side Platforms (DSP) arrangements will be much shorter than the closures experienced under the current environment. Tracks axle counting technology enforces and ensures a minimum of two and half minutes (150s) headways or separation between trains travelling on the same track and in the same direction is maintained. Therefore, the two and half minutes (150s) headway between trains is a longer period than the longest Departure Side Platforms (DSP) proposed platform environment closure of one minute and thirty two seconds (92s) for two-train closures.

7.8. Summary

The final results from the computer simulation of the implementation of Departure Side Platforms (DSP) indicates that a significant alleviation on vehicle queues and numbers of vehicles stopping within road queues would be derived from the implementation of Departure Side Platforms (DSP), thus, mitigating road traffic congestion at level crossing intersections. Sixteen simulations movies, comprising both the current and proposed environment, are presented to illustrate and corroborate the simulation findings of this study.

The results presented and summarised in this chapter, indicate closure and congestion mitigation across the different areas of the simulated environment. Closure and congestion mitigation was obtained in the road intersection closure periods, the road intersection open periods, the road vehicles average and maximum queue lengths, and the number of road vehicles stops within queues. These results, involving different road vehicles traffic flow volumes, indicate that road traffic congestion mitigation would be derived from the implementation of Departure Side Platforms (DSP). The road traffic congestion mitigation varies depending on the number and destination of train(s) activating the level crossing closure.

The current average closure activated by a single train on the down-line direction was recorded as forty six seconds (46s). Under simulated
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conditions, the closure period for a single train in this direction was seventy point four cycles (70.4c). Thus and because no changes were introduced at this platform location, the equivalent of the actual conditions of forty six seconds (46s) recorded for a single train in this direction, continues to apply under the proposed environment.

The current average closure activated by a single train on the up-line direction, was recorded as one minute and forty one seconds (101s). Under simulated conditions, the closure period for a single train in this direction was also seventy point four cycles (70.4c). Thus, the equivalent of the forty six seconds (46s) recorded for a single train also applies under the proposed environment.

The current average closure activated by two trains was recorded at two minutes and seven seconds (127s). Under the proposed environments, the closure period for two-train activated closure will vary between a short closure period and a long closure period.

A short closure occurs when both trains travelling on opposite directions, arrived at the detection activation trigger at about the same time. Under simulated conditions, the closure period for two-train was the equivalent forty six seconds (46s), the same as a single train closure.

The long closure occurs when the first activating train arrived at the platform area and another train, travelling in the opposite direction, activates the track detection trigger. Therefore, the longest closure for two-train was the equivalent one minute and thirty two seconds (92s), equal to the sum of two single trains activation closures.

Multiple train closures, under the new platform arrangements, will no longer be operationally possible or supported, due to the safety standards requirements. The longest closures under the proposed arrangement will be for the equivalent of one minute and thirty two seconds (92s), much shorter than the two and half minutes of (150s) headway between trains are forced and required to maintain.
In summary, the simulation results indicate the intersection closure for single trains, regardless of the direction of the train, would be forty six seconds (46s). Two trains intersection closure would be between forty six seconds (46s) and one minute and thirty two seconds (92s). Multiple train closures would no longer be operationally possible or supported.

In addition, the results of both the current and proposed simulations and the extrapolation of these figures and the comparison to the actual recorded closure times indicated in Table 5.6 are the intended analysis and reporting of the research results; there is no physical DSP – DSP platform environment available in Victoria to test the results of this research.

According to the research simulation results, the implementation of Departure Side Platforms (DSP) mitigates railway stations intersection closure periods, which in turns reduces and alleviates road traffic congestion at railway stations intersection level crossings areas. This is discussed in more details as part of the research question in the next chapter.
Chapter 8: Discussion and Conclusion

8. DISCUSSION AND CONCLUSION

8.1. Introduction

This chapter discusses the results of answering the research question: “How does modifying platform configuration at railway stations mitigate level crossings roads closure times?”

Using Melbourne as a case study, this research presented an original idea that formulates a new approach in addressing an existing problem. It is claimed in this study that station infrastructure, more specifically, station platform positioning, causes level crossing intersection to stay closed for long periods, creating unnecessary road traffic congestion.

The method and processes carried out explored the proposition of answering the thesis research question. Computer simulation was used to test the effect of railway station platform arrangements and its impact on vehicle traffic congestion at a railway station level crossing. Implications, benefits and limitations of the proposed alternative are presented, and future research is also discussed.

The processes conducted in this research contribute to theoretical knowledge by developing a new theory, the theory of Departure Side Platforms (DSP).

8.2. Overview of the Research

Computer simulation models were used to test and evaluate the effect of railway station platform arrangement modifications on level crossing closures and its impact on motor vehicle traffic congestion at or near railway stations precincts. The platform repositioning approach mitigated train arrivals activated intersection closure periods at the railway station level crossing. As a direct result, the platform repositioning approach also mitigated road traffic congestion caused by such closures at the level crossings railway station precinct.
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Simulation testing results of both single, two-train and multiple trains arrivals and departures using the current and proposed environment, evaluated the proposition which has generated theory that results in mitigating road traffic congestion at level crossings railway stations precinct. Further, simulation result analysis conducted, using the three different road traffic volume levels, confirms that the theory works when both single and two-train arrivals and departures operated at the level crossing.

The intersection closure periods were shorter under the proposed environment changes and the intersection open periods were longer under the proposed environment change. The level crossing intersection lesser periods of closure and additional open periods resulted in mitigating of road traffic congestion. In addition, the simulation results confirmed that under the proposed platform environment, continual level crossing closures of more than two trains would no longer occur.

8.3. Findings of this Research

There is evidence indicating that by the mid 2020’s, some Melbourne rail lines would carry, during peak-hour periods of the day, almost 40 trains per hour, close to double the present service levels. The difficulty facing transport authorities is that additional train traffic creates further problems; the additional train traffic causes further closure activity at intersection level crossings, exacerbating road traffic congestion at most intersection level crossing locations (Section 1.3).

The additional train traffic has positive implications for train commuters and train operators resulting from the additional services; in actual fact, the increases in train services are needed and warranted. All the negative implications are for road commuters; road commuters suffer the consequences of the additional intersection level crossing closures caused by the additional train services. The additional train services are beneficial to train commuters, to the detriment of road users; the roads will closed at
level crossings intersections for longer periods because of the additional train services, creating further road traffic congestion.

The generated theory that mitigation of intersection closures at station railway level crossings in Melbourne could be derived or achieved by making alterations to the infrastructure of the railway station, was proven correct. It is claimed in this study the infrastructure modifications to the position of platforms at railway station results in reducing level crossings intersections closure periods. This in turn, mitigates road congestion ‘arising from inefficiency’ (Blunden 1983, p. 2), congestion considered an obstacle to the efficient performance of the road networks. The intention is that by having the intersection open to road traffic for longer, would allow the flow of traffic through the intersection more efficiently and freely, generating less road congestion.

The observations, data collection and level crossing closure period measurements of this research were conducted at a site in Melbourne. Thus, the implications of this research are based on the conditions under Victorian safety standards of level crossings of 25 seconds warning of the impending arrival of a train or trains at the intersection and the limitation of the minimum headway separation between trains travelling in the same direction.

The computer simulation results confirmed mitigation at intersection level crossings areas, including in: reduction on the closure periods of the intersection for all single trains to forty six seconds (46s), and between forty six seconds (46s) and one minute and thirty two seconds (92s) for two-train closures; additional periods of opening of the intersection for a single up-line train of forty five seconds (45s) and between one minute and one seconds (61s) and one minute and two seconds (62s) for two-train closures.

Multiple train closures would no longer be operationally possible or supported. Reduction in road vehicles queue lengths and reduction on the number of road vehicles stops within queues varied according to the
combination of trains activating the closure. Further, the intersection closure and open periods comparison between the simulation models of the current and proposed environments, confirmed the period of intersection closures reduced and the period of intersection open periods increased, under the proposed environment changes.

The final results of both single and multiple trains simulations conducted, analysed, compared and reported, confirmed the claim that the introduction of the proposed alternative, will mitigate the level crossing intersection closures periods, thus the research question, was answered. These results, simulated using different road vehicles traffic flow volumes, concurred that road traffic congestion mitigation would be derived from the implementation of Departure Side Platforms (DSP) theory.

### 8.4. Implications of the Research

As a direct result of implementing the Departure Side Platforms (DSP) as a proposed alternative, costly grade separations at rail station level crossings could be postponed or deferred from implementation; implementation of Departure Side Platforms (DSP) reduces the urgency for these costly projects to be planned, commenced or implemented. This would allow transport authorities to redirect capital investments and resources in other more pressing areas of the networks. It could also allow transport authorities to pursue the implementation of Departure Side Platforms (DSP), either temporarily or permanently, at many more level crossing locations, thus tackling the negative legacies from the past resulting from the introduction of both rail and road networks.

The research contributes to the body of knowledge and the implications of this research are grouped and discussed in three main areas:

- implications to practice;
- implications to research; and
- implications to methods.
8.4.1. Implications for Practice

Road traffic congestion affects the transport mode to work, as well as the service delivery, freight and distribution tasks. Currently, the avoidable costs of road traffic congestion costs Australians about 2% of GDP (Section 1.2). All road users will be affected by further congestion on the roads network; seventy eight per cent (78%) of all transport mode to work is by motor vehicles; only ten per cent (10%) is by trains. Commercial services, deliveries and freight are affected as well; nineteen per cent (19%) of all road traffic in Melbourne is made by commercial vehicles; eleven point five per cent (11.5%) is by light commercial vehicles; and seven point five per cent (7.5%) is by trucks.

Transport authorities are looking for solutions and alternatives to level crossing problems (Section 1.3). However, the main focus has been and continues to be on grade separation projects, generally accepted as the most safe and practical alternative for the treatment of urban areas level crossing problems (Section 3.5.1). Plans are being prepared and signed for several grade separation projects to be completed over the next decade (Section 3.5). But the level crossing legacy will remain; after the work of the removal of these level crossings is completed, Melbourne metropolitan area will still be home to about 160 level crossings (Section 3.5).

While grade separations are the most effective alternative, as a solution, grade separations are heavy on resources, requiring much time for full implementation, and extremely costly from a financial point of view; each grade separation project costs an average $160 million (Section 3.5) and takes from one to three years from planning to completion, and at times even longer. In addition, the current method used for grade separation, tunnelling under the road, causes the most interruptions to rail operations and rail commuters. It causes the least amount of interruption to road commuters and the community surrounding the grade separation station area. All recent, underway and planned grade separation projects in
Melbourne, use tunnelling under the road method of separating road and rail infrastructure networks.

All current solutions, including tunnelling under the road method, address the symptom of the problem, instead of the cause of the problem. Departure Side Platforms (DSP), on the other hand, addresses the cause of the problem. This developed theory is complimentary to the three options currently available to deal with level crossing problems (Section 3.5.2). Departure Side Platforms (DSP) is considered as an additional option or resource, either a permanent or a temporary option. It is not proposed Departure Side Platforms (DSP) to replace the current options for the process of treatment of railway station level crossings problems, but to enhance the number of options available to use.

Departure Side Platforms (DSP) mitigates road traffic congestion at level crossings intersections. Under the proposed simulation environment, the intersection closure periods were less than under the current simulation environment and the intersection open periods were longer than under the current simulation environment; the level crossing intersection lesser periods of closure and additional open periods mitigated road traffic congestion.

There is another area where the implementation of Departure Side Platforms (DSP) could have an impact: this is in DWL. This deadweight loss (DWL) is termed the social cost of congestion or what BTRE terms ‘the cost of doing nothing about congestion’ (BTRE 2007, p. 32). This BTRE concept suggests that there is a cost associated with the non-removal of the many level crossings in the Melbourne metropolitan area.

The Government does not have the resources to grade separate all the one hundred and seventy two level crossings in the Melbourne metropolitan area; using the tunnelling method of separation, it would cost more than $28 billion (NPV) for the Melbourne level crossings problem to be fully resolved (Section 3.5). The implementation of Departure Side Platforms (DSP) concept is a much cheaper option, with unsubstantiated
early estimates indicating costing between $1 and $2 million each level crossing, an option that would contribute in reducing the social cost of congestion.

Other jurisdictions in Australia and overseas could benefit from the Departure Side Platforms (DSP) theory. Potential users would have review their own safety standards and level crossing safety warning system operations to ensure that the DSP concept can be accommodated as presented.

8.4.2. Implications for Research
This research contributes to the body of knowledge by presenting a new theory in Departure Side Platforms (DSP), a new alternative method for the treatment of railway station level crossings problems that enhances the number of options available to deal with level crossing problems. This new option permits costly grade separations at rail station level crossings postponed or deferred from implementation.

The research also contributes to the understanding of the problem of road traffic congestion at level crossing locations in Melbourne. Most level crossings research conducted previously in Victoria are related to fatalities and injuries resulting from collisions between a train and a motor vehicle at level crossings. Other research conducted is related to the understanding of motor vehicle driver’s behaviour at level crossings, road congestion and signal preemption at level crossings. Accidents at level crossings are infrequent, but when occur, can have detrimental consequences (Section 2.5); in Victoria, seventy nine per cent (79%) of the all accidents at level crossings between a train and a motor vehicle, occur at level crossings protected with boom barriers, lights and bells (Section 1.7).

8.4.3. Implications for Methods
The computer simulation techniques used to analyse, test, and evaluate the proposition are also a contribution by enhancing in the area of computer simulation research knowledge. The use of the computer simulation software, VISSIM in this case, assisted into the understanding
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of the problem and in formulating the development of the proposed solution to that problem.

Furthermore, this research contributed to knowledge by adapting and modifying Law’s research design methodological approach for computer simulation modelling to suit the simulation modelling of this study, thus contributing by adding to the understanding of appropriate methodologies for such research.

Advances in computer technology and traffic flow theory have permitted the creation and use of traffic simulation models to plan, operate, and design transportation infrastructure. In this research, computer simulation and visualisation techniques were used as the process to test and provide evidence for the study. In addition, the research methodology used in conjunction with and driving the computer simulation design modelling was developed using authored computer simulation modelling techniques, modified to fit the specific requirements of this research (Section 4.6).

Computer simulation allowed and simplified the methods to study, analyse and evaluate the level crossings operation conditions that could not be studied under normal circumstances; the simulation model depicts a construct of the system in an endeavour to understand and test the behaviour of the system. In this process, the three tenets of qualitative research, describing, understanding and explaining, were satisfied. The research used computer simulation in an innovative manner to test the effect of platform arrangements on level crossing closures and its impact on motor vehicle traffic congestion at railway stations level crossings. The innovative manner used refers to the developing of two simulation models and using the results from each simulation processes, comparing and analysing these to derive to the differences between current simulated and proposed simulated operation environments, providing outcomes confirming the merits of the theory.

The aim of these models was to test the effect of platform arrangements on level crossing closures and its impact on motor vehicle traffic
congestion at a railway station level crossings location. The simulation models of both the current and proposed operations and the resulting comparison reports and analysis, confirmed that the theory of Departure Side Platforms (DSP) worked and the simulation process resulted in forty-two (42) different combination of simulations performed.

The techniques used in the simulation model development ensured the operation validity and replicability of a simulation design model created. The results from both simulation models were compared to provide evidence to the claim, with comparison results reported using formatted output reports; visual outputs from the simulations were produced in 3D graphical animation video presentations.

8.5. Departure Side Platforms (DSP) Benefits and Limitations

There is no question grade separations are the most effective alternative method to resolve level crossings problems; grade separation removes the level crossing all together. Departure Side Platforms (DSP) is a new complimentary theory to address level crossings problems that adds to the three options currently available to deal with level crossing problems. The implementation of Departure Side Platforms (DSP) presents many benefits and a number of limitations.

The research was conducted in Melbourne, thus the implications of the research are based on the Victorian standards of level crossings twenty-five seconds safety warning of a train impending arrival and minimum headway separation between trains travelling in the same direction. These facts suggest that the results of this research are confined to jurisdictions that use a similar warning safety standard and similar platform infrastructure as the Melbourne rail network, and which experience similar level crossing closure periods and road congestion as the Melbourne road network.
8.5.1. Departure Side Platforms (DSP) Benefits

The concept proposes an alternative solution for the treatment of railway station level crossing, as a calming alternative for the intersection level crossing traffic congestion problem. Some of the direct benefits derived from implementing the Departure Side Platforms (DSP) concept are:

- shorter level crossing closures than the current closure periods, making closures for trains from either directions equal in time as of the observed conditions or as per the shortest time;
- multiple train level crossings closures would involve only two-train closures; three-train closures, four-train closures, five-train closures and six-train closures will no longer occur under the proposed Departure Side Platforms (DSP) environment;
- shorter level crossing closures periods when access to/from trains is required by disabled people using wheelchairs or motorised scooters; the processes would remain as previously, still taking approximately sixty seconds (60s) of dwell time, but would be conducted while the intersection is open to road traffic;
- travel with less interruption, thus generating less traffic congestion;
- better utilisation of manpower resources by reducing waiting time;
- less resource wastage, including vehicle operating costs (fuel and vehicles maintenance);
- reduced delay and productivity losses (private and public transport, JIT, deliveries, etc.);
- less pollution generated, including less use of energy (i.e. fossil fuels) and less greenhouse gas emissions;
- reduced travel time and less travel time variability;
- safer and a more amenable environment provided for commuters, residents and traders alike, at railway stations precincts;
- reduced the social cost of congestion; and
• no signal systems logic changes, rail or road, are required or necessary to be changed, as the changes affect only platform positioning.

8.5.2. Departure Side Platforms (DSP) Limitations

The implementation of Departure Side Platforms (DSP), as a calming alternative for the intersection level crossing traffic congestion problems, requires some modification to existing facilities, the creation of alternative facilities, and presents a number of drawbacks, for instance:

• The research was conducted in Melbourne, where the Victorian standard of level crossing safety warning of the impending train arrival is twenty-five seconds and minimum headway separation between trains travelling in the same direction, thus limited to such conditions. Other jurisdictions, for example other states in Australia, the standard warning is twenty seconds, or the UK, the standard warning is twenty seven seconds, will require further analysis to verify if the Departure Side Platforms (DSP) theory is applicable under those standards.

• The repositioning of the Departure Side Platforms (DSP) would require the relocation of current facilities or the building of new facilities at or near the new platform location. Current facilities include bus stops, pedestrian crossings, parking facilities and other amenities that are not already available at the new location. New facilities include the building of the actual platform area and periphery entry and exit points that include disable access to and from the platform area, shelter areas, waiting covered areas and service facilities (i.e. toilets, lockup room, storage room, etc.).

• Unsubstantiated early estimates indicate the implementation of Departure Side Platforms (DSP) as an alternative, could cost between $1 and $2 million each level crossing, a fraction of current alternatives. Future research could consider the costing of developing and implementing the Departure Side Platforms (DSP) theory, taking into consideration the need of each railway station level crossing project,
specifically if there is a need to acquire property as part of the implementation of a DSP – DSP solution.

- There will be more closures of the level crossing than currently; in most cases, each arriving train will activated intersection closures, but the closures will be for shorter intervals, similar in length to that of road signal cycles.

- Intersecting roads motor vehicles traffic currently benefiting from additional green light sequence periods, resulting from long intersection closures, would experience a more balanced signal operations environment of green and red light sequence periods. This has the potential to create road congestion at intersecting roads that perhaps have not experienced congestion in the past.

- The on-street public transport bus stop at the south-bound inner lane at the corner of Clayton and Carinish Roads could cause North-South vehicular traffic flow to slow down or to even generate traffic congestion. Future research could contemplate this issue endeavouring a solution to the potential problem.

In addition, the early work conducted by this research was communicated to the Government, the Department of Transport, VicRoads and RACV, during 2009; their response suggested limitations with the proposed concept. For example, the Hon Lynne Kosky MP, the then Minister for Public Transport at the time, commented:

… proposal to relocate Clayton Railway Station may overcome some of the traffic management issues around the Station Precinct, but his solution is very narrowly focused and would only be a short terms solution at best.6

The concept as presented, if implemented as a temporary measure, could provide short term solution producing immediate results, as opposed to the non-implementation of long term solutions.

6 (Kosky 2009)
8.6. Suggestions for Future Research

The results and findings of this research were used to identify and bring insight into other similar level crossings with the same characteristics and the same safety warning standards. There are 102 station level crossings in metropolitan Melbourne with similar infrastructure characteristics, the same safety warning standards and located in close proximity to the intersection, and with the same headway separation requirements. These could be investigated, using the “theoretical generalisability” or ‘G’ theory concept, to identify potential recipients for the implementing Departure Side Platforms (DSP).

Future research could investigate the implementation of Departure Side Platforms (DSP) in regards to:

- the cost and other variables associated with the proposed system, as no official costing has been conducted in terms of the proposed system. These could include, but are not restricted to, the cost of: relocation of current facilities or the building of new facilities at or near the new platform location; facilities such as bus stops, pedestrian crossings, parking facilities and other amenities necessitated by the building of the actual platform area; and periphery entry and exit points that include disabled access to and from the platform area, shelter areas, waiting covered areas and service facilities (i.e. toilets, lockup room, storage room, etc.).

- the cost benefits analysis associated with travelling with less interruption, with less traffic congestion, requiring less travel time and with less travel time variability;

- the actual variance in greenhouse gas emissions resulting from the implementation of the concept;

- other locations within country Victoria and Australia in general could benefit from the implementation of the concept. These jurisdictions will necessitate the standard of level crossing safety warning of the impending arrival of a train and the minimum headway separation
between trains travelling in the same direction, are the same as in Victoria; otherwise will require further analysis to verify that the DSP theory can be applied under their own safety warning and headway separation standards, rules and settings;

- other countries could also benefit from the implementation of the concept. These jurisdictions will require further analysis to verify that the DSP theory can be applicable under their own safety warning standards, rules and settings;

- the social cost of congestion benefits in relations to level crossings grade separation; and

- the DWL cost associated with doing nothing about level crossings traffic congestion.

8.7. Final Reflections

This study set out to test the proposition and in the process developed the theory that implementing Departure Side Platforms (DSP) at a railway station in the vicinity of an intersection, would impact in reducing road traffic congestion at the intersection. The use of computer simulation modelling techniques was an invaluable tool in the process of generating the theory to answer the research question. According to the results obtained and presented, the thesis research question *How does modifying platform configuration at railway stations mitigate level crossings road closure times?*, can be conclusively answered and confirmed, through the illustration of the Melbourne case study.

The implementation of the new theory, Departure Side Platforms (DSP), addresses the cause of level crossing problem and not the symptom of the problem, mitigates railway station intersection closure periods, which in turn reduces and alleviates road traffic congestion at railway station intersection level crossings. Under the new theory, intersection closure periods are shorter than currently and the intersection open periods are longer than currently, mitigating road traffic congestion. As a direct result,
road traffic has the potential to flow through the intersection level crossing more efficiently and freely; this will mitigate road congestion, reduce travel time and travel time costs, decrease environmental greenhouse gas emissions and pollution costs, reduce fuel consumption and costs, and minimise wear-and-tear and maintenance costs to vehicles, thus alleviating some of the burdens road congestion imposes on the community.
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Appendices

Appendix A  Literature Review Additional Material

Appendix A contains additional material pertinent to the Literature review Chapter.

Station Level Crossings in Melbourne

The Melbourne metropolitan area is home to 172 level crossings. More than one hundred (102) of these suburban station level crossings are next to or in the close proximity of a railway station. Figure A-1 indicates train stations level crossings location in metropolitan Melbourne.

Figure A-1: Metropolitan Melbourne Train Station Level Crossings

![Figure A-1: Metropolitan Melbourne Train Station Level Crossings](image)

Source: Metlink modified image

Figure A-1 shows the approximate location of suburban station level crossings that are next to or in the close proximity of a railway station.
Appendices

Images of Railway Stations and Platforms

Legacy images of four stations platform infrastructure are presented, including: Flemington Racecourse Station, Malvern Station, Ascot Vale Station and Caulfield Station. Picture A-1 illustrates Flemington Racecourse Station in 1870.

Picture A-1: Racecourse Platforms Flemington 1870

![Racecourse Platforms Flemington 1870](source: (RailVic 1870))

Picture A-2 illustrates the facing platforms and train holding areas at Flemington Racecourse Station in 1870. Some larger stations also incorporated an overhead footbridge or subway to permit commuters entry and exit to the station and safe passage between platforms.

Picture A-2 illustrates Malvern Station in about 1910.
Appendices

Picture A-2: Passenger Train at Malvern Station Post 1910

![Image of Malvern Station with overhead footbridge](Image)

Source: (RailVic c1910b)

Picture A-2 illustrates Malvern Station with an overhead footbridge to facilitate ingress, egress and safe passage between platforms and the station.

Picture A-3 illustrates Ascot Vale Station in 1880.

Picture A-3: Ascot Vale Station Circa 1880s

![Image of Ascot Vale Station in 1880s](Image)

Source: (RailVic 1880)
Appendices

Picture A-3 depicts Ascot Vale station platforms areas in 1880; the station platforms look then much the same as in present days.

Picture A-4 illustrates Caulfield Station circa 1910.

**Picture A-4: Caulfield Station Post 1910**

Picture A-4 illustrates the Caulfield Station platforms with a service crossing between platforms specifically for the use of station staff.

**Different Types of Station Platforms**
There are 210 train stations in the Melbourne urban rail network and the platforms were built in the different configurations; the images show four different station infrastructure used in the Melbourne rail network, noting that a large majority, sixty six per cent (66%) of Melbourne stations, comprise of Opposite Platforms Station. Picture A-5 depicts the four different types of station platforms combinations.
### Picture A-5: Different Types of Station Platforms

<table>
<thead>
<tr>
<th>Single Platform Station</th>
<th>Opposite Platforms Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomastown Station</td>
<td>Ascot Vale Station</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Isle Platform Station</td>
<td>Combination Platforms Station</td>
</tr>
<tr>
<td>Keon Park Station</td>
<td>Surrey Hill Station</td>
</tr>
</tbody>
</table>

Source: Images from Google Earth 2013

Picture A-5 illustrates four stations and the type of platforms infrastructure at the stations, including: Thomastown Station, a Single Platform Station; Ascot Vale Station, an Opposite Platforms Station; Keon Park Station, an Isle Platform Station; and Surrey Hill Station, a Combination Platforms Station, comprising of an Isle Platform and a Single Platform.

**Station Infrastructure Platform Combinations**

There are different ASP and DSP platforms combinations of station infrastructure used in the Melbourne rail network. Picture A-6 depicts the different ASP and DSP platforms combinations.
### Picture A-6: Different Combinations of ASP – DSP Platforms

<table>
<thead>
<tr>
<th>ASP – DSP Platforms</th>
<th>DSP – ASP Platforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitcham Station</td>
<td>Clayton Station</td>
</tr>
<tr>
<td>Kensington Station</td>
<td>St Albans Station</td>
</tr>
</tbody>
</table>

Source: Images from Google Earth 2013

Picture A-6 illustrates the different ASP and DSP platforms combinations, including: Mitcham Station and Kensington Station, both ASP – DSP Platforms stations; and Clayton Station and St Albans Station, both DSP – ASP Platforms stations.
Appendices

Appendix B - Analysis of the Problem and Current Solutions Additional material

Appendix B contains additional material relevant to the Analysis of the Problem and Current Solutions Chapter.

Level Crossings Risk Assessment and Prioritisation

The Victorian Government completed the ALCAM model analysis of all level crossings in the state and published the list in mid-2008 (Mitchell 2008; VicGov 2008). In addition, other methods of selection had been used in Victoria in the past, beside the ALCAM methodology, to prioritise level crossing remediation programs. For instance, Crawford and Taylor discuss a multi-criteria approach for ‘strategic fit’ to specific transport network requirements (Taylor, J & Crawford 2010, p. 1); another method can be as simple as a change of Government resulting from an election or from election promises. Figure B-1 is an extract from the ALCAM Priority List.

Figure B-1: Victoria ALCAM Priority List Sample 2008

<table>
<thead>
<tr>
<th>List</th>
<th>Location</th>
<th>Region</th>
<th>PCR #</th>
<th>Street</th>
<th>Suburb</th>
<th>Route Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metro</td>
<td>Connex</td>
<td>374</td>
<td>Springvale Rd</td>
<td>Nunawading</td>
<td>RICHMOND - RINGWOOD</td>
</tr>
<tr>
<td>2</td>
<td>Metro</td>
<td>Connex</td>
<td>170</td>
<td>Springvale Rd</td>
<td>Springvale</td>
<td>CAUFIELD - DANDENONG</td>
</tr>
<tr>
<td>3</td>
<td>Metro</td>
<td>Connex</td>
<td>380</td>
<td>Mitcham Rd</td>
<td>Mitcham</td>
<td>RICHMOND - RINGWOOD</td>
</tr>
<tr>
<td>4</td>
<td>Metro</td>
<td>Connex</td>
<td>584</td>
<td>Main Rd</td>
<td>St Albans</td>
<td>NORTH MELBOURNE - SYDENHAM</td>
</tr>
<tr>
<td>5</td>
<td>Metro</td>
<td>Connex</td>
<td>301</td>
<td>Furlong Rd</td>
<td>St Albans</td>
<td>NORTH MELBOURNE - SYDENHAM</td>
</tr>
<tr>
<td>6</td>
<td>Metro</td>
<td>Connex</td>
<td>245</td>
<td>Bell St</td>
<td>Coburg</td>
<td>NORTH MELBOURNE - UPPFIELD</td>
</tr>
<tr>
<td>7</td>
<td>Non-Metro</td>
<td>ARTC</td>
<td>1337</td>
<td>Werribee St</td>
<td>Werribee</td>
<td>WERRIBEE - GEELONG</td>
</tr>
<tr>
<td>8</td>
<td>Metro</td>
<td>Connex</td>
<td>160</td>
<td>Clayton Rd</td>
<td>Clayton</td>
<td>CAUFIELD - DANDENONG</td>
</tr>
<tr>
<td>9</td>
<td>Metro</td>
<td>Connex</td>
<td>266</td>
<td>Macaulay Rd</td>
<td>Kensington</td>
<td>ESSENDON JUNC - BROADMeadows</td>
</tr>
<tr>
<td>10</td>
<td>Metro</td>
<td>Connex</td>
<td>490</td>
<td>Bell St</td>
<td>Preston</td>
<td>CLIFTON HILL - EPPING</td>
</tr>
<tr>
<td>11</td>
<td>Metro</td>
<td>Connex</td>
<td>283</td>
<td>Glenroy Rd</td>
<td>Glenroy</td>
<td>ESSENDON JUNC - BROADMeadows</td>
</tr>
<tr>
<td>12</td>
<td>Metro</td>
<td>Connex</td>
<td>147</td>
<td>Grange Rd</td>
<td>Carnegie</td>
<td>CAUFIELD - DANDENONG</td>
</tr>
<tr>
<td>13</td>
<td>Metro</td>
<td>Connex</td>
<td>382</td>
<td>Cherry St</td>
<td>Werribee</td>
<td>NEWPORT - WERRIBEE</td>
</tr>
<tr>
<td>14</td>
<td>Metro</td>
<td>Connex</td>
<td>361</td>
<td>Unison Rd</td>
<td>Surrey Hills</td>
<td>RICHMOND - RINGWOOD</td>
</tr>
<tr>
<td>15</td>
<td>Metro</td>
<td>Connex</td>
<td>42</td>
<td>North Rd</td>
<td>Ormond</td>
<td>SOUTH YARRA - FRANKSTON</td>
</tr>
<tr>
<td>16</td>
<td>Metro</td>
<td>Connex</td>
<td>828</td>
<td>Aviation Rd</td>
<td>Laverton</td>
<td>NEWPORT - WERRIBEE</td>
</tr>
<tr>
<td>17</td>
<td>Metro</td>
<td>Connex</td>
<td>371</td>
<td>Blackburn Rd</td>
<td>Blackburn</td>
<td>RICHMOND - RINGWOOD</td>
</tr>
<tr>
<td>18</td>
<td>Metro</td>
<td>Connex</td>
<td>274</td>
<td>Buckley St</td>
<td>Essendon</td>
<td>ESSENDON JUNC - BROADMeadows</td>
</tr>
<tr>
<td>19</td>
<td>Metro</td>
<td>Connex</td>
<td>331</td>
<td>Old Geelong Rd</td>
<td>Hoppers Crossing</td>
<td>NEWPORT - WERRIBEE</td>
</tr>
<tr>
<td>20</td>
<td>Metro</td>
<td>Connex</td>
<td>199</td>
<td>Mc Gregor Rd</td>
<td>Fakenham</td>
<td>DANDENONG - Pakenham</td>
</tr>
<tr>
<td>21</td>
<td>Metro</td>
<td>Connex</td>
<td>458</td>
<td>Riverdale Rd</td>
<td>Camberwell</td>
<td>CAMBERWELL - ALAMEN</td>
</tr>
<tr>
<td>22</td>
<td>Metro</td>
<td>Connex</td>
<td>314</td>
<td>Ferguson St</td>
<td>Williamstown</td>
<td>NEWPORT - WILLIAMSTOWN</td>
</tr>
<tr>
<td>23</td>
<td>Metro</td>
<td>Connex</td>
<td>554</td>
<td>Lower Plenty Rd</td>
<td>Rosanna</td>
<td>FLINDERS STREET - HURSTBRIDGE</td>
</tr>
<tr>
<td>24</td>
<td>Metro</td>
<td>Connex</td>
<td>540</td>
<td>Station St</td>
<td>Fairfield</td>
<td>FLINDERS STREET - HURSTBRIDGE</td>
</tr>
<tr>
<td>25</td>
<td>Metro</td>
<td>Connex</td>
<td>494</td>
<td>Murray Rd</td>
<td>Preston</td>
<td>CLIFTON HILL - EPPING</td>
</tr>
</tbody>
</table>
Appendices

Source: (ALCAM 2008)

Figure B-1 report presented is an extract from the ALCAM Priority List first page and shows the first twenty five level crossings in Victoria in priority order.

**Springvale Road Nunawading Station Grade Separation**

Figure B-2 depicts the grade separation project work at Nunawading Station.

**Figure B-2: Nunawading Station Grade Separation Project**

Source: (VicGov 2010)

Figure B-2 shows the existing Nunawading station and platforms; the tunnelling under Springvale Road; and the new (proposed at the time) Nunawading station and platforms.

**Collins Street Extension Bridge**

Picture B-1 shows the Collins Street Extension bridge.
Appendices

Picture B-1: Collins Street Extension

Source: Image from Goggle Earth 2014

Picture B-1 shows Southern Cross Station (at right) and the four-lane and two-tram-tracks bridge Collins Street Extension built over twelve railway tracks.

NSW Sandgate Grade Separation Project

Picture B-2: shows the new flyover at Sandgate grade separation project.

Picture B-2: Sandgate Flyover – 3 Trains Passing 12 June 2008
Current and Future Remediation Plans

The proposed Melbourne’s grade separation projects from 2010 have become a political football; the projects had not been selected using the ALCAM ranking finalised in Victoria in 2008 (ALCAM 2008) or by strategic fit (Taylor, J & Crawford 2010). Rather, the ranking list was based on political electoral promises made during the 2010 Victorian election campaign. Thus, these grade separation project rankings do not follow the ALCAM priority ranking (Gough 2011) or any other mentioned approach.

For example, the current grade separations level crossing projects underway rank numbers 2 (Springvale Road, Springvale), 3 (Mitcham Road, Mitcham) and 124 (Rooks Road, Nunawading) of the ALCAM priority list. The next proposed grade separation projects ranking numbers of the ALCAM priority list are: 4 (Main Road, St Albans); 15 (North Road, Ormond); 17 (Blackburn Road, Blackburn); 67 (Burke Street, Glen Iris); 87 (Mountain Highway, Bayswater) and 48 (Scoresby Road, Bayswater) (Gough 2011). Figure B-3 illustrates the proposed 2010 Melbourne’s level crossing grade separations.
Figure B-3: Melbourne 2010 Proposed Grade Separations

Figure B-23 illustrates the proposed 2011 Melbourne level crossing grade separations, including cost and ALCAM priority ranking for each of the proposed grade separations.

Further, the grade separation plans announced during March and April 2014, indicated five grade separations to be conducted over the next decade (Carey & Millar 2014; Dowling 2014; Johnston & Campbell 2014; Zielinski 2014). These grade separation projects priority ranking number on the ALCAM list are: 37 (Koornang Road, Carnegie); 79 (Murrumbeena Road, Murrumbeena); 8 (Clayton Road, Clayton); and 27 (Centre Road, Clayton). The latest addition to the list of grade separations, as announced at the end of April, is number 4 (Main Road, St Albans) ranking in the ALCAM priority; that level crossing had already been scheduled for grade separation under the 2010 proposal. Figure B-24 illustrates the latest proposed Melbourne level crossing grade separations projects.
Figure B-24 illustrates the 2014 proposed Melbourne level crossing grade separations, including the project total cost (including trains acquisition costs) and ALCAM priority ranking for each of the proposed grade separations.

Once these four level crossings along the Pakenham-Cranbourne corridor are grade separated, these lines will still be home to twenty five level crossings; five of these are station level crossings and twenty are non-station level crossings (Guzman, Peszynski & Young 2014b).
Appendix C - Research Methodology – Computer Simulation Additional Material

Appendix C contains additional material relevant to the Research Methodology – Computer Simulation Chapter.

Criteria for Using Simulations
Table C-1 indicates when and why it is appropriate to use computer simulation.

Table C-1: Carson’s Criteria for Using Simulations

<table>
<thead>
<tr>
<th>When to Use Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• There is no simple analytic model, spread sheet model or calculation that is accurate to analyse the situation.</td>
</tr>
<tr>
<td>• The real system is bedded in, and its components and their interaction can be defined.</td>
</tr>
<tr>
<td>• The real system is complex, with interaction or interdependence between various components and the effect of proposed changes difficult or impossible to predict.</td>
</tr>
<tr>
<td>• Designing a new system, considering major changes in physical layout or operating rules in an existing system, or being faced with new and different demand.</td>
</tr>
<tr>
<td>• Considering a large investment in a new or existing system and it represents a system modification of a type for which you have little or no experience and hence face considerable risk.</td>
</tr>
<tr>
<td>• Agree on a set of assumptions, and then can see the results and effects of those assumptions. That is, the simulation process as well as the simulation model can be used to get common understanding.</td>
</tr>
<tr>
<td>• Simulation with animation is an excellent training and educational device, based on the idea 'don't tell me, show me'. For large systems, simulation animation may be the only way in which to visualise how it works.</td>
</tr>
</tbody>
</table>

Source: (Carson II 2005)

Table C-1 describes when and why it is appropriate to use computer simulation as prescribed by Carson (2005).

Computer Simulation Pitfalls
Table C-2 provides a list of computer simulation pitfalls prescribed by Law (2007) is presented below.
Table C-2: Short List of Pitfalls in Simulation

<table>
<thead>
<tr>
<th>Pitfalls in Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure to have a well-defined set of objectives at the beginning of the simulation</td>
</tr>
<tr>
<td>study</td>
</tr>
<tr>
<td>Inappropriate level of model detail</td>
</tr>
<tr>
<td>Misunderstanding of simulation process</td>
</tr>
<tr>
<td>Treating a simulation study as if it were primarily an exercise in computer programming</td>
</tr>
<tr>
<td>Failure to have people with knowledge of simulation methodology and statistics on the</td>
</tr>
<tr>
<td>modelling team</td>
</tr>
<tr>
<td>Failure to collect good system data</td>
</tr>
<tr>
<td>Inappropriate simulation software</td>
</tr>
<tr>
<td>Obliviously using simulation-software products whose complex macro statements may not</td>
</tr>
<tr>
<td>be well documented and may not implement the desired modelling logic</td>
</tr>
<tr>
<td>Belief that easy-to-use simulation packages, which require little or no programming,</td>
</tr>
<tr>
<td>require a significantly lower level of technical competence</td>
</tr>
<tr>
<td>Misuse of animation</td>
</tr>
<tr>
<td>Failure to account correctly for sources of randomness in the actual system</td>
</tr>
<tr>
<td>Using arbitrary distributions (e.g., normal, uniform, or triangular) as input to the</td>
</tr>
<tr>
<td>simulation Analysing the output data from one simulation run (replication) using</td>
</tr>
<tr>
<td>formulas that assume independence</td>
</tr>
<tr>
<td>Making a single replication of a particular system design and treating the output</td>
</tr>
<tr>
<td>statistics as the ‘true answers’</td>
</tr>
<tr>
<td>Failure to have a warm-up period, if the steady-state behaviour of a system is of</td>
</tr>
<tr>
<td>interest</td>
</tr>
<tr>
<td>Comparing alternative system designs on the basis of one replication for each design</td>
</tr>
<tr>
<td>Using the wrong performance measures</td>
</tr>
</tbody>
</table>

Source: (Law 2007)

Table C-2 provides a list of computer simulation pitfalls as prescribed by Law (2007).

Computer Simulation Software

Table C-3 presents the different computer simulation software available.
Table C-3: Simulation Software Types and Techniques

<table>
<thead>
<tr>
<th>Simulation Name</th>
<th>Simulation Type</th>
<th>Main Features or Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORSIM</td>
<td>Microscopic</td>
<td>Surface streets, freeways, actuated signals, weaving sections, incidents, variable message signs, 2-D animation</td>
</tr>
<tr>
<td>SimTraffic</td>
<td>Microscopic</td>
<td>Surface streets, actuated signals, pedestrians, roundabouts, 3-D animation</td>
</tr>
<tr>
<td>AIMSUN</td>
<td>Microscopic, distributed computing technique</td>
<td>Surface streets, freeways, actuated signals, dynamic traffic assignment, variable message signs, 3-D animation, telematics</td>
</tr>
<tr>
<td>VISSIM</td>
<td>Microscopic</td>
<td>Surface streets, freeways, ramp metering, pedestrians, transit operations, 3-D animation</td>
</tr>
<tr>
<td>PARAMICS</td>
<td>Microscopic, distributed computing technique</td>
<td>Surface streets, freeways, transit operations, 3-D animation, roundabouts, congested networks</td>
</tr>
<tr>
<td>INTEGRATION</td>
<td>Mesoscopic</td>
<td>Surface streets, freeways, traffic assignment, intelligent transportation system, toll plaza, vehicle emissions, HOV</td>
</tr>
<tr>
<td>DynaMIT</td>
<td>Mesoscopic, real time computer system</td>
<td>Operation of Advanced Traveler Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS), dynamic estimation of network state, a variety of real time scenarios, simulation of each trip</td>
</tr>
<tr>
<td>MITSIMLab</td>
<td>Microscopic</td>
<td>ATIS and ATMS</td>
</tr>
<tr>
<td>CORFLO</td>
<td>Macroscopic</td>
<td>Surface streets, freeways</td>
</tr>
<tr>
<td>SATURN</td>
<td>Microscopic</td>
<td>Individual junctions, traffic assignment</td>
</tr>
<tr>
<td>Micmac</td>
<td>Hybrid</td>
<td>SITRA B+ (microscopic model) and SIMRES (macroscopic model) are coupled, and the synchronization of the models is sequential</td>
</tr>
<tr>
<td>Hystra</td>
<td>Hybrid</td>
<td>Macroscopic and microscopic models are combined, both models are based on the (Lighthill–Whitham–Richards) LWR traffic flow theory</td>
</tr>
<tr>
<td>KRONOS</td>
<td>Macroscopic</td>
<td>Freeway lane changing, merging, diverging, and weaving, the simultaneous development of queues and propagation of congestion on both the freeway and its ramps</td>
</tr>
<tr>
<td>KWaves</td>
<td>Macroscopic, discrete, deterministic</td>
<td>Freeways, throughput, bottlenecks, queues, ramp metering, incident management</td>
</tr>
</tbody>
</table>

Source: (Ratrout & Rahman 2009)

Table C-3 presents the different computer simulation software available and their characteristics, as well as their main features and capabilities as prescribed by Ratrout and Rahman (2009).
Appendices

Computer Simulation Commentary

There are differences between the types of software used previously in research to conducted transport simulation studies. These show some have stronger point and preferences above other types, their usability and differences in the cost of acquiring the software. These also indicated some require particular calibration of parameters to derive to acceptable results, use similar car-following algorithms and vehicle behaviour under road congested conditions. This information provided an initial filtering of available traffic simulation software relevant to this research problem. Reviewers’ commentary on the available computer simulation software is presented in Table C-4.
### Table C-4: Computer Simulation Reviewers Commentary

<table>
<thead>
<tr>
<th>Reviewer</th>
<th>Software Compared</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rakha and Van Aerde (1996)</td>
<td>TRANSYT and INTEGRATION</td>
<td>The types of more complex signal timing problems, which at present cannot be examined by the TRANSYT model, can be examined using the dynamic features of INTEGRATION. INTEGRATION simulates traffic-signalized networks in a manner that is consistent with TRANSYT for conditions in which TRANSYT is valid and it can simulate conditions that represent the limitations to the current TRANSYT model.</td>
</tr>
<tr>
<td>Taori and Rathi (1997)</td>
<td>NETSIM, NETFLO I, and NETFLO II</td>
<td>The models were evaluated for the traffic networks with fixed-time signal control. The speed values generated by NETSIM were found to be the lowest; NETFLO II values were the highest. NETFLO I values in all cases were between NETFLO II and NETSIM values. The execution times for NETSIM were found to be higher than those of NETFLO II and NETFLO.</td>
</tr>
<tr>
<td>Wang and Prevedouros (1998)</td>
<td>INTEGRATION, TSIS/CORSIM, and WATSim</td>
<td>The models can simulate traffic operations on mixed arterial and freeway networks and produced reasonable and comparable results on most network links. Only INTEGRATION can simulate U-turns, and TSIS/CORSIM is the best at replicating lane-changing behaviour. Although WATSim needed the least calibration for producing good results, its animation is inferior and its capacity based car-following parameters are undesirable.</td>
</tr>
<tr>
<td>Middleton and Cooner (1999)</td>
<td>CORSIM (FRESIM component), FREQ and INTEGRATION</td>
<td>Models were used to simulate congested freeway conditions. Although all models performed relatively well for uncongested conditions, they were inconsistent in their ability to accurately model congested conditions.</td>
</tr>
<tr>
<td>Prevedouros and Wang (1999)</td>
<td>INTEGRATION, CORSIM, and WATSim</td>
<td>Field data for a large integrated (street and freeway) network were used as input and all three software programs were able to replicate field-measured volumes well. INTEGRATION required extensive modifications to approximate complex signal timing plans and WATSim needed the fewest modifications. WATSim and CORSIM speeds were close to each other.</td>
</tr>
<tr>
<td>Bloomberg and Dale (2000)</td>
<td>CORSIM and VISSIM</td>
<td>Models compared for congested arterials. They found that models produced consistent results among them. Moreover, both models are equally user friendly with respect to initial coding.</td>
</tr>
</tbody>
</table>
## Appendices

<table>
<thead>
<tr>
<th>Reviewer</th>
<th>Software Compared</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxill and Yu (2000)</td>
<td>CORSIM, INTEGRATION, AIMSUN and PARAMICS</td>
<td>The study evaluated the models based on their ability to simulate ITS. AIMSUN and PARAMICS have significant potential for modelling ITS but require more calibration and validation for the CORSIM and INTEGRATION seem to have the highest probability of success in real-world applications with respect to familiarity and extensive calibration/validation.</td>
</tr>
<tr>
<td>Prevedouros and Li (2000)</td>
<td>INTEGRATION, KRONOS and KWaves</td>
<td>INTEGRATION produced acceptable results for all traffic conditions but its lane changing replication was not realistic. KRONOS required the fewest modifications to achieve good results but it overestimated the benefits of adding a lane to the mainline freeway. KWaves98 is limited to the simulation of freeway operations under heavy traffic conditions.</td>
</tr>
<tr>
<td>Barrios et al. (2001)</td>
<td>CORSIM, VISSIM, PARAMICS and SimTraffic</td>
<td>The simulation tools were evaluated based on their graphical presentation (animation) capabilities specifically to simulate bus operations. A review of transit-related and visualization capabilities of each model is presented and the study selected VISSIM due to its 3-D capabilities.</td>
</tr>
<tr>
<td>Trueblood (2001)</td>
<td>CORSIM and SimTraffic</td>
<td>There was little difference between models for arterials with low to moderate traffic. The study focused on the importance of user familiarity with models and need to properly validate and finally compared the ability of models to accurately simulate a freeway interchange.</td>
</tr>
<tr>
<td>Choa et al. (2002)</td>
<td>CORSIM, PARAMICS and VISSIM</td>
<td>According to this study, CORSIM outperformed others due to the least difficulty in coding and its ability to compute control delay for individual approaches. The simulations of PARAMICS and VISSIM, along with their 3-D capabilities, were more closely reflected actual conditions.</td>
</tr>
<tr>
<td>Tian et al. (2002)</td>
<td>CORSIM, SimTraffic and VISSIM</td>
<td>Signalized arterials were studied in this study. It was found out that outputs varied with link length, speed range, and volume levels, and the variation was greater when volume approached capacity. CORSIM displayed stable results compared to SimTraffic.</td>
</tr>
<tr>
<td>Bloomberg et al. (2003)</td>
<td>CORSIM, INTEGRATION, MITSIMLab, PARAMICS, VISSIM and WATSIM</td>
<td>All six models were applied to signalized intersections and freeways and the study revealed that all models performed reasonably well and were fairly consistent.</td>
</tr>
<tr>
<td>Kosman et al. (2003)</td>
<td>VISSIM and CORSIM</td>
<td>Either model may perform adequately for estimating average speeds as input to project-level emissions analysis, provided that proper validation is adopted.</td>
</tr>
</tbody>
</table>
### Appendices

<table>
<thead>
<tr>
<th>Reviewer</th>
<th>Software Compared</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones et al. (2004)</td>
<td>CORSIM, SimTraffic, and AIMSUN</td>
<td>AIMSUN was found to operate acceptably well compared to both SimTraffic and CORSIM and it possesses features that would be useful for creating large urban and regional networks. Its dynamic traffic assignment capability is unmatched by either SimTraffic or CORSIM, but AIMSUN requires cumbersome coding.</td>
</tr>
<tr>
<td>Middleton and Cooner (2003)</td>
<td>CORSIM (FRESIM component), FREQ and INTEGRATION</td>
<td>The authors aimed to find appropriate models for simulating congested freeways, and test the calibration and validation performance of those models using data collected for Dallas freeways. The CORSIM program had the best overall performance in this project and shows promise for future application for the operational evaluation of congested freeway facilities.</td>
</tr>
<tr>
<td>Panwai and Dia (2005)</td>
<td>AIMSUN, PARAMICS and VISSIM</td>
<td>They evaluated car-following behaviour in the mentioned traffic simulators and found lower error values for the Gipps-based models implemented in AIMSUN and similar error values for the psychophysical spacing models used in VISSIM and PARAMICS.</td>
</tr>
<tr>
<td>Xiao et al. (2005)</td>
<td>AIMSUN and VISSIM</td>
<td>It was found that both simulators are capable of incorporating most of the standard features used in traffic modelling. The accuracy of both simulators was found to be similar.</td>
</tr>
<tr>
<td>Hadi et al. (2007)</td>
<td>CORSIM, VISSIM, AIMSUN</td>
<td>For all three models, it was required to calibrate model parameters to produce acceptable reductions in capacity due to incidents. In the case of AIMSUN and VISSIM, there was a need to introduce incident-specific time-variant calibration parameters.</td>
</tr>
</tbody>
</table>

Source: (Ratrout & Rahman 2009)
Table C-4 indicates reviewers’ commentary on the available computer simulation software as mentioned by Ratrout and Rahman (2009).

**Simulation Software Selection Matrix**

A matrix was used in the process of determining that VISSIM was the simulation software that met all but one of the selection criteria requirements. Specifically, this was the only software available able to simulate heavy rail, a must for this research. AIMSUN was close second, addressing many of the requirements, but providing limited level crossings signal capabilities and only light rail simulation capabilities. CORSIM came third, with a number of limitations. The simulation software selection matrix is presented in Table C-5.

**Table C-5: Simulation Software Selection Matrix Summary**

<table>
<thead>
<tr>
<th>Software Criteria Matrix</th>
<th>MATLAB</th>
<th>ARENA</th>
<th>CORSIM</th>
<th>AIMSUN</th>
<th>VISSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to run under Windows XP</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Microscopic simulation software</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-modal traffic simulation including:</td>
<td>No</td>
<td>No</td>
<td>Yes/No</td>
<td>Yes/Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>- Cars &amp; taxis</td>
<td>Yes/No</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
</tr>
<tr>
<td>- Public &amp; private buses</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
</tr>
<tr>
<td>- 4WDs</td>
<td>Yes/No</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
</tr>
<tr>
<td>- Trucks and long trucks</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>- Motorcycles &amp; bicycles</td>
<td>No/No</td>
<td>No/No</td>
<td>No/No</td>
<td>No/No</td>
<td>No/No</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>Yes/No</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
</tr>
<tr>
<td>Trams &amp; articulated trams:</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>- Light rail (Off Road)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>- Heavy rail (Trains)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Operation of traffic signals</td>
<td>No</td>
<td>No</td>
<td>Limited</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Actuated</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pre-timed</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>NEMA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VAP</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
### Software Criteria Matrix

<table>
<thead>
<tr>
<th>Software Criteria Matrix</th>
<th>MATLAB</th>
<th>ARENA</th>
<th>CORSIM</th>
<th>AIMSUN</th>
<th>VISSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level crossings multiple signal simulation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>Output Animation</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes/No</td>
<td>Yes/No</td>
<td>Yes/No</td>
</tr>
<tr>
<td>TRANSYT-7F</td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3D</td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>.mov format</td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2D only</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: (Choa, Milam & Stanek 2003; Kotusevski & Hawick 2009; Pulugurtha & Desai 2007; Ratrout & Rahman 2009)

Table C-5 presents the simulation software selection matrix used for the research software selection process.

### Recommended Design Methods

Simulation practitioners have different views and approaches to the process of defining, designing and developing computer simulation models. They also have different views as to the number of steps the simulation modelling process should take. For some, this is a twelve-step process (Shannon 1998), a nine-step process (Ulgen, Gunal & Shore 1996), a seven-step process (Law 2008; Law 2014; Law, Kelton & Kelton 1991), a five-step process (Carson II 2005), or even a four-step process (Raychaudhuri 2008). The recommended design methods are presented in Table C-6.
### Table C-6: Recommended Design Methods

<table>
<thead>
<tr>
<th>Problem Definition</th>
<th>Project Planning</th>
<th>System Definition</th>
<th>Conceptual Model Formulation</th>
<th>Preliminary Experimental Design</th>
<th>Input Data Preparation</th>
<th>Model Translation</th>
<th>Verification and Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define the Problem</td>
<td>Define the Problem</td>
<td>Design the Study</td>
<td>Design the Conceptual Model</td>
<td>Formulate Inputs, Assumptions, and Process Definition</td>
<td>Build, Verify, and Validate Model</td>
<td>Experiment with the Model look for Design of Experiments</td>
<td>Document and Present Results</td>
</tr>
<tr>
<td>Introduction to Modelling and Simulation</td>
<td>Project Initiation</td>
<td>Project Work</td>
<td>Model Verification and Validation</td>
<td>Experimentation, Analysis and Reporting</td>
<td>Design, Conduct, and Analyse Experiments</td>
<td>Document and Present the Results</td>
<td></td>
</tr>
<tr>
<td>Static Model Generation</td>
<td>Input Distribution Identification</td>
<td>Random Variable Generation</td>
<td>Analysis and Decision Making</td>
<td>Is the Programmed Model Valid?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulate the Problem</td>
<td>Collect Information /Data and Construct an Assumptions Document</td>
<td>Is the Assumptions Document Valid?</td>
<td>Program the Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Pitfalls of Simulation Modelling and how to avoid them by using a robust Simulation Methodology: Ulgen et al. (1996)
- Introduction to Modelling and Simulation: JS Carson II (2005)
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<table>
<thead>
<tr>
<th>Introduction to the Art and Science of Simulation</th>
<th>Pitfalls of Simulation Modelling and how to avoid them by using a robust Simulation Methodology</th>
<th>Introduction to Modelling and Simulation</th>
<th>Introduction to Monte Carlo Simulation</th>
<th>How to build Valid and Credible Simulation Models</th>
</tr>
</thead>
</table>

**Final Experimental Design**
- Define the Model Life Cycle

**Experimentation**

**Analysis and Interpretation**

**Implementation and Documentation**


Table C-6 presents the recommended design methods as mentioned by a number of authors.
Appendices

Appendix D - Level Crossings Operations and Data Collection Processes Additional Material

Appendix D contains additional material relevant to the Level Crossings Operations and Data Collection Processes Chapter.

Picture D-1 illustrates part of the failsafe system, the track’s ‘dead man’ switch mechanism in the OFF position.

**Picture D-1: Dead Man Switch Off**

![Dead Man Switch Off Image](image)

Source: Research data collection image

Picture D-1 illustrate the track’s ‘dead man’ switch mechanism in the OFF position, indicating the track section in front is vacant and available for this train movement.

When the two counts are not the same (count in does not equal count out), the section is flagged as occupied by a train and signals are activated to that effect (VRIOG 2009c). Picture D-1 illustrates part of the failsafe system, the track’s ‘dead man’ switch mechanism in the ON position.
Picture D-2: Dead Man Switch On

Source: Research data collection image

Picture D-12 illustrate the track’s ‘dead man’ switch mechanism in the ON position, indicating the track section in front is currently occupied by a train movement.

If a train attempts to enter a section that is not free from the train ahead, a ‘dead man’ switch on the track comes in contact with the offending train’s ‘dead man’ trigger, activating the train emergency braking, forcing the train to come to an abrupt halt. Picture D-3 illustrates part of the failsafe system, showing both the train’s ‘dead man’ trigger and the track’s ‘dead man’ switch mechanism in the OFF position.
Picture D-3: Train Dead Man Trigger

Source: Research data collection image

Picture D-3 illustrate both the train’s ‘dead man’ trigger and the track’s ‘dead man’ switch mechanism in the OFF position, indicating the track section in front is currently available for this train to access.

To complete the axle counter operational cycle, the mechanism is activated when a train passes a detection head, locking the section of track for the exclusive use of the train travelling along that section of the track. The section remains locked down until the train passes the detection head at the end of that section. Picture D-4 illustrates the ‘dead man’ switch being turned ON and not fully expanded as yet.
Appendices

Picture D-4: Detection Head Turns Dead Man Switch On

Source: Research data collection image

Picture D-4 illustrate the ‘dead man’ switch in the process of being turned ON and not fully expanded as yet, by the detection head, locking that section of the track immediately as the train passes the detection point and while the train is still in between two sections of the track.

Figure D-1 is an example of the intersection analysis worksheet using the data collected.

Figure D-1: Intersection Activity Worksheet Analysis

| Time (Min) | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | Time | Period of | Period of | Period of |
| 02:16:30  | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 02:17:00  | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 02:17:30  | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 02:18:00  | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |

Source: Research data collection worksheet analysis

Departure Side Platforms as a Measure to Mitigate Level Crossing Road Closures: An Investigative Study Using Simulation Modelling
William M. Guzman
Appendices

Figure D-1 presents an example of the intersection analysis worksheet used for the data collection process.

Caulfield Group Services and Patronage

A review of the 2013 timetables for Metro and V/Line services along the corridors indicate that the total daily traffic at Caulfield Station, is 504 train services per day (Guzman, Peszynski & Young 2014b; Metro 2013a, 2013b; V/Line 2013). Metro schedules 434 services per day and also runs 27 unscheduled out of service movements every day, giving Metro a total 461 movements per day. V/Line provides 43 services per day (Guzman, Peszynski & Young 2014b; Metro 2013a, 2013b; V/Line 2013).

Published estimates indicate the Frankston line patronage at around 45,000 boarding's per day (Mees 2007a). Published estimates indicate the Dandenong lines patronage at around 60,000 boarding's per day (Mees 2007a). During 2013 and for the first time, PTV published figures from a train stations patronage Origin and Destination Survey (OD) (PTV 2013a). The estimates are indicative of entries into stations and are said to be the best estimates currently available. The counts are based on entries to each station and are not a precise estimate of entries, growth of patronage or indicative of the intended direction of travel; a person entering a station precinct is recorded, but not the direction or destination of the journey (PTV 2013a).

The Frankston and Dandenong Lines Corridors

Metro uses the Frankston line to service Southern suburban stations. Several operators use the Dandenong lines corridor; Metro uses the lines to service the South-eastern suburban stations with services to Dandenong, Pakenham and Cranbourne; V/Line uses the lines for regional services to Bairnsdale and Traralgon; freight operators use the lines as well.

The Frankston line is 43.9 kilometres in length, services 26 stations and shares servicing of seven stations with the three Dandenong lines and two
stations with the Sandringham line. The Pakenham line is 58.2 kilometres in length from the CBD; the Cranbourne line is 45.1 kilometres in length from the CBD; the Dandenong line is 31.2 kilometres in length from the CBD. In all, the lines service 29 stations: combined, they service 19 stations to Dandenong; the Pakenham line services an additional seven stations from Dandenong; the Cranbourne line services an additional three stations from Dandenong. The lines share the servicing of seven stations with the Frankston line and two stations with the Sandringham line.
Appendix E - Computer Simulation Process
Additional Material

Appendix E contains additional material relevant to the Computer Simulation Process Chapter.

The VISSIM Traffic Flow Simulator

The simulator itself consists of two main components, the actual simulator and a signal generator controller component. These two components are essential in generating valid processes of the simulation model and an integral part of the process of the calibration and validation of developing traffic modelling applications.

The simulator role is to generate the traffic and the actual graphical representation of the network. This is achieved using imported photographic aerial images of the required segments of the network. The network is *planted* or digitised on top of the images with the attributes collected from data collection being applied, including road widths, traffic directions, speeds and speed zones, detector locations, etc., to the graphical representation, which then becomes the test bed for the simulation model.

The signal generator module sits outside the simulator and is where all signal logic is defined, and where each intersection signal controlling logic are loaded into the VAP database or file. The characteristics of intersection signals are represented, including phase sequences and other parameters including: minimum green times, actuated forced-off, and gap out of times; these are the sequences controlling the intersection signals.

VISSIM Additional Tools Required

The VAP programming language is a VISSIM additional tool specifically designed for programming traffic actuated signal control used by VISSIM computer simulation models. Signal control logic needs to be described or coded in the VAP language, and during execution of a simulation process, VAP interprets the logic and the current status of variables, such as...
Appendices

detectors and predictors, to perform and simulate the desire environment. Figure E-1 is a sample of this research VAP language generated code.
Appendices

Figure E-1: Vehicle Actuated Programming (VAP) Program

/* MAIN PROGRAM */
S00Z001: IF NOT init THEN
S01Z002: init := 1
ELSE
S00Z002: cycSecond := cycSecond + 1
END;
S00Z004: Set_cycle_second ( cycSecond );
S00Z005: IF NOT uptrainDemand THEN
S01Z005: IF NOT (NOT downtrainDemand) THEN
S00Z007: IF uptrainDemand THEN
S01Z007: trainDemand := 1; trainDemandUp := 1;
S02Z007: inter51 := 1; uptrainDemand := 0;
S00Z009: IF downtrainDemand THEN
S01Z009: trainDemand := 1; trainDemandDown := 1;
S02Z009: inter53 := 1; downtrainDemand := 0;
S00Z011: IF trainDemandUp AND trainDemandDown THEN
S01Z011: inter513 := 1
END
ELSE
GOTO S00Z011
END
ELSE
GOTO S00Z009
END
END
ELSE
GOTO S00Z007
END;
S00Z013: IF NOT uptrainCancel THEN

Source: research VAP language generated code

Figure E-1 illustrates an example of the VAP generated code used during the simulation model logic design.

To facilitate the simulation development process, VISSIM provides, in addition to the VAP programming language, VisVap, another VISSIM tool, which makes an easy method of generating VAP programming code, that allows the use of flowcharts as the mechanism to create and edit VAP signals logic, that is then be used as input to the VISSIM simulation process for signal processing generation and operation. Figure E-2 shows an example of the VisVap desktop.
Source: research VisVap generated code

Figure E-2 illustrates the VisVap desktop, parameters and the flowchart developed to generate this simulation model logic; the design flowchart and parameters were specifically designed for the target area of this research. The main body of the pane contains the logic flowchart and the parameters section contains parameters required for the processing of code logic, in this case minimum and maximum signal periods; the arrays sections shows no arrays, as no arrays were used for the simulation model; the expressions section contains the expressions and initial values of the expressions used; the subroutines section shows any subroutine used.

Figure E-3 shows the VISSIM desktop.
Figure E-3: VISSIM Desktop Work Environment

Source: VISSIM desktop work environment

Figure E-3 illustrates the VISSIM simulation modelling desktop work environment at the start of the modelling task.

Figure E-4 shows the target simulation area in 3D.

Figure E-4: Rail and Road Networks – in 3D Mode

Source: target intersection – road and rail infrastructure in 3D
The figure illustrates the target simulation area in 3D visual display, in comparison to the same view in 2D visual display as presented in Figure 6.3.

Figure E-4 shows the target simulation area rail and road network links and centrelines.

**Figure E-5: Rail and Road Network – Links and Centre Lines**

![Image of railway network diagram with colours and labels](image)

Source: target intersection – centre lines with links and connectors

Figure E-4 shows the centre lines of the target area, excluding visible background, connectors, links, pedestrian areas and public transport stops.

The colours used are:

- blue – for normal road or track links;
- green – for links with no visualisation (e.g. tunnel, underpass);
- pink – for connectors; and
- red – for public transport stops.

Pedestrian walk and waiting areas are depicted within black lines; pedestrian crossings are shown as a black rectangular object with a blue line in the middle.
West-South Road Route

Haughton Road West-South is one of the intersecting roads and in the model design is designated as static routing decision number three. The route encompasses four static route traffic flow destination movements. The first static route traffic flow is along Haughton Road east-bound traffic turning right into Clayton Road to continue in a southerly direction, and carries the largest proportion of the route traffic. The second static route traffic flow is from Haughton Road east-bound traffic turning left into Clayton Road in a northerly direction to continue the journey along Clayton Road, carrying a small proportion of the route traffic. The third static route traffic flow is also from Haughton Road east-bound traffic turning left into Clayton Road in a northerly direction but for this route, it is for pre-positioning for a right turn into Haughton Road in an easterly direction, and carrying a very small proportion of the route traffic. The fourth static route traffic flow is again from Haughton Road east-bound traffic turning left into Clayton Road in a northerly direction and in preparation for pre-positioning for a right turn into Haughton Road in a westerly direction, also carrying a small proportion of the route traffic. Figure E-6 shows the West-South road route with all possible traffic interactions and turns from the route.

Figure E-6: Rail and Road Network – West-South Road Route
Figure E-6 illustrates the main traffic flow destination movements available for the west-south intersecting route.

**East-West Road Route**
Carinish Road East-West is one of the intersecting roads and in the model design is designated as static routing decision number four. The route encompasses three static route traffic flow destination movements. The first static route traffic flow is along Carinish Road west-bound traffic, and carries the largest proportion of the route traffic. The second static route traffic flow is from Carinish Road west-bound traffic turning right into Clayton Road in a northerly direction, to continue the journey along Clayton Road, and carrying a small proportion of the route traffic. The third static route traffic flow is also from Carinish Road west-bound traffic turning left into Clayton Road in a southerly direction, carrying a small proportion of the route traffic. Figure E-7 shows the East-West road route with all possible traffic interactions and turns from the route.

**Figure E-7: Rail and Road Network – East-West Road Route**

Source: target intersection – east-west route in 2D

Figure E-7 illustrates the main traffic flow destination movements available for the east-west intersecting route.
West-East Road Route

Carinish Road West-East is one of the intersecting roads and in the model design is designated as static routing decision number five. The route encompasses four static route traffic flow destination movements. The first static route traffic flow is along Carinish Road east-bound traffic, and carries the largest proportion of the route traffic. The second static route traffic flow is from Carinish Road east-bound traffic turning right into Clayton Road in a southerly direction, to continue the journey along Clayton Road, and carrying a small proportion of the route traffic. The third static route traffic flow is also from Carinish Road west-bound traffic turning left into Clayton Road in a northerly direction, carrying a small proportion of the route traffic. The fourth static route traffic flow is again from Carinish Road east-bound traffic turning left into Clayton Road in a southerly direction and in preparation for prepositioning for a right turn into Haughton Road in a westerly direction, and carrying a smaller proportion of the route traffic. Figure E-8 shows the West-East road route with all possible traffic interactions and turns from the route.

Figure E-8: Rail and Road Network – West-East Road Route

Source: target intersection – west-east route in 2D
Appendices

Figure E-8 illustrates the main traffic flow destination movements available for the west-east intersecting route.
Appendices

Appendix F - Computer Simulation Analysis and Results Additional Material

Appendix F contains additional material relevant to the Computer Simulation Analysis and Results Chapter.

Single Down-Line Trains Comparison Analysis

Table F-1 provides a detailed analysis of both the current and proposed operations for single down-line train simulation process.

Table F-1: Single Down-Line Train Analysis Report

<table>
<thead>
<tr>
<th>Estimated Road Traffic / Link</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumes per Link</td>
<td>Avg</td>
<td>Max</td>
</tr>
<tr>
<td>DSP – ASP Single Down-Line 125c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>19</td>
<td>55</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>29</td>
<td>87</td>
</tr>
<tr>
<td>Large-Range</td>
<td>42</td>
<td>130</td>
</tr>
<tr>
<td>DSP – DSP Single Down-Line 125c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>19</td>
<td>55</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>29</td>
<td>87</td>
</tr>
<tr>
<td>Large-Range</td>
<td>42</td>
<td>130</td>
</tr>
<tr>
<td>Differences DSP – ASP and DSP – DSP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range - Number</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low-Range - Percentage (as %)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mid-Range - Number</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mid-Range - Percentage (as %)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large-Range - Number</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large-Range - Percentage (as %)</td>
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<td>0</td>
</tr>
</tbody>
</table>
Source: Simulation results comparison reports

**Single Up-Line Train Comparison Analysis**

Table F-2 provides a detailed analysis of both the current and proposed closure operations for single up-line train simulation process.

**Table F-2: Single Up-Line Train Analysis Report**

<table>
<thead>
<tr>
<th>Estimated Road Traffic / Link</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg</td>
<td>Max</td>
</tr>
<tr>
<td>DSP – ASP Single Up-Line 165c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>26</td>
<td>80</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>38</td>
<td>127</td>
</tr>
<tr>
<td>Large-Range</td>
<td>52</td>
<td>174</td>
</tr>
<tr>
<td>DSP – DSP Single Up-Line 125c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>19</td>
<td>55</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>29</td>
<td>87</td>
</tr>
<tr>
<td>Large-Range</td>
<td>42</td>
<td>130</td>
</tr>
</tbody>
</table>

**Differences DSP – ASP and DSP – DSP**

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<thead>
<tr>
<th></th>
<th>Low-Range - Number</th>
<th>Low-Range - Percentage</th>
<th>Mid-Range - Number</th>
<th>Mid-Range - Percentage</th>
<th>Large-Range - Number</th>
<th>Large-Range - Percentage</th>
</tr>
</thead>
<tbody>
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<td>-27%</td>
<td>-9</td>
<td>-24%</td>
<td>-10</td>
<td>-19%</td>
</tr>
<tr>
<td>Low-Range - Percentage</td>
<td>-25%</td>
<td>-31%</td>
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<td>-31%</td>
<td>-44</td>
<td>-25%</td>
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<td>-7</td>
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<td>-13</td>
<td>-23%</td>
</tr>
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<td>Avg</td>
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<td>0%</td>
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<td>9%</td>
<td>4</td>
<td>11%</td>
</tr>
<tr>
<td>Max</td>
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<td>1%</td>
<td>-6</td>
<td>-5%</td>
<td>-3</td>
<td>-2%</td>
</tr>
<tr>
<td>Stop</td>
<td>-2</td>
<td>-8%</td>
<td>-5</td>
<td>-13%</td>
<td>-3</td>
<td>-7%</td>
</tr>
</tbody>
</table>

Source: Simulation results comparison reports

**Two-Train Comparison Analysis**

Table F-3 provides a detailed analysis of both the current and proposed operations for two-train simulation process.
## Table F-3: Two-Train Analysis Report

<table>
<thead>
<tr>
<th>Estimated Road Traffic / Link</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg</td>
<td>Max</td>
</tr>
<tr>
<td>DSP – ASP Two-Train 170c</td>
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<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>28</td>
<td>85</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>41</td>
<td>133</td>
</tr>
<tr>
<td>Large-Range</td>
<td>50</td>
<td>165</td>
</tr>
<tr>
<td>DSP – DSP Two-Train 125c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>19</td>
<td>55</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>29</td>
<td>87</td>
</tr>
<tr>
<td>Large-Range</td>
<td>42</td>
<td>130</td>
</tr>
</tbody>
</table>

### Differences DSP – ASP and DSP – DSP

<table>
<thead>
<tr>
<th></th>
<th>Low-Range - Number</th>
<th>Low-Range - Percentage</th>
<th>Mid-Range - Number</th>
<th>Mid-Range - Percentage</th>
<th>Large-Range - Number</th>
<th>Large-Range - Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Range</td>
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<td>-12</td>
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<td>-16%</td>
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<tr>
<td>Mid-Range</td>
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<td>-35%</td>
<td>-46</td>
<td>-35%</td>
<td>-12</td>
<td>-21%</td>
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<tr>
<td>Large-Range</td>
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<td>3%</td>
<td>5</td>
<td>14%</td>
</tr>
</tbody>
</table>

Source: Simulation results comparison reports

### Three-Train Comparison Analysis

Table F-4 provides a detailed analysis of both the current and proposed operations for three-train simulation process.
### Table F-4: Three-Train Analysis Report

<table>
<thead>
<tr>
<th>Estimated Road Traffic / Link</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg</td>
<td>Max</td>
</tr>
<tr>
<td>DSP – ASP Three-Train 225c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>46</td>
<td>129</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>71</td>
<td>194</td>
</tr>
<tr>
<td>Large-Range</td>
<td>90</td>
<td>261</td>
</tr>
<tr>
<td>DSP – DSP Three-Train 225c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>30</td>
<td>79</td>
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<tr>
<td>Mid-Range</td>
<td>65</td>
<td>159</td>
</tr>
<tr>
<td>Large-Range</td>
<td>88</td>
<td>214</td>
</tr>
<tr>
<td>Differences DSP – ASP and DSP – DSP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range - Number</td>
<td>-16</td>
<td>-50</td>
</tr>
<tr>
<td>Low-Range - Percentage</td>
<td>-35%</td>
<td>-39%</td>
</tr>
<tr>
<td>Mid-Range - Number</td>
<td>-6</td>
<td>-35</td>
</tr>
<tr>
<td>Mid-Range - Percentage</td>
<td>-8%</td>
<td>-18%</td>
</tr>
<tr>
<td>Large-Range - Number</td>
<td>-2</td>
<td>-47</td>
</tr>
<tr>
<td>Large-Range - Percentage</td>
<td>-2%</td>
<td>-18%</td>
</tr>
</tbody>
</table>

Source: Simulation results comparison report

### Four-Train Comparison Analysis

Table F-5 provides a detailed analysis of both the current and proposed operations for four-train simulation process.
Table F-5: Four-Train Analysis Report

<table>
<thead>
<tr>
<th>Estimated Road Traffic / Link</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg</td>
<td>Max</td>
</tr>
<tr>
<td>DSP – ASP Four-Train 320c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>81</td>
<td>199</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>125</td>
<td>302</td>
</tr>
<tr>
<td>Large-Range</td>
<td>159</td>
<td>387</td>
</tr>
<tr>
<td>DSP – DSP Four-Train 265c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>26</td>
<td>62</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>54</td>
<td>136</td>
</tr>
<tr>
<td>Large-Range</td>
<td>94</td>
<td>221</td>
</tr>
<tr>
<td>Differences DSP – ASP and DSP – DSP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range - Number</td>
<td>-55</td>
<td>-137</td>
</tr>
<tr>
<td>Low-Range - Percentage</td>
<td>-68%</td>
<td>-69%</td>
</tr>
<tr>
<td>Mid-Range - Number</td>
<td>-71</td>
<td>-166</td>
</tr>
<tr>
<td>Mid-Range - Percentage</td>
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<td>-55%</td>
</tr>
<tr>
<td>Large-Range - Number</td>
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<td>-166</td>
</tr>
<tr>
<td>Large-Range - Percentage</td>
<td>-41%</td>
<td>-43%</td>
</tr>
</tbody>
</table>

Source: Simulation results comparison report

Five-Train Comparison Analysis

Table F-6 provides a detailed analysis of both the current and proposed operations for five-train simulation process.
Table F-6: Five-Train Analysis Report

<table>
<thead>
<tr>
<th>Estimated Road Traffic / Link</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg</td>
<td>Max</td>
</tr>
<tr>
<td><strong>DSP – ASP Five-Train 385c</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>106</td>
<td>261</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>160</td>
<td>368</td>
</tr>
<tr>
<td>Large-Range</td>
<td>210</td>
<td>492</td>
</tr>
<tr>
<td><strong>DSP – DSP Five-Train 385c</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>25</td>
<td>73</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>49</td>
<td>142</td>
</tr>
<tr>
<td>Large-Range</td>
<td>119</td>
<td>267</td>
</tr>
<tr>
<td><strong>Differences DSP – ASP and DSP – DSP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range - Number</td>
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<td>-188</td>
</tr>
<tr>
<td>Low-Range - Percentage</td>
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<td>-72%</td>
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<tr>
<td>Mid-Range - Number</td>
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<td>Mid-Range - Percentage</td>
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<td>-61%</td>
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<tr>
<td>Large-Range - Number</td>
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<td>-225</td>
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<tr>
<td>Large-Range - Percentage</td>
<td>-43%</td>
<td>-46%</td>
</tr>
</tbody>
</table>

Source: Simulation results comparison report

**Six-Train Comparison Analysis**

Table F-7 provides a detailed analysis of both the current and proposed operations for six-train simulation process.
### Table F-7: Six-Train Analysis Report

<table>
<thead>
<tr>
<th>Estimated Road Traffic / Link</th>
<th>South-North Traffic</th>
<th>North-South Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg</td>
<td>Max</td>
</tr>
<tr>
<td>DSP – ASP Six-Train 460c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>136</td>
<td>315</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>190</td>
<td>440</td>
</tr>
<tr>
<td>Large-Range</td>
<td>256</td>
<td>492</td>
</tr>
<tr>
<td>DSP – DSP Six-Train 460c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Range</td>
<td>24</td>
<td>73</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>46</td>
<td>142</td>
</tr>
<tr>
<td>Large-Range</td>
<td>149</td>
<td>381</td>
</tr>
<tr>
<td>Differences DSP DSP – ASP and DSP DSP – DSP</td>
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<td>-77%</td>
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<td>Mid-Range - Number</td>
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<td>Mid-Range - Percentage</td>
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<td>Large-Range - Percentage</td>
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</tbody>
</table>

Source: Simulation results comparison report