Departure Side Platforms: a road congestion mitigation measure

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ABSTRACT

This study investigates the impact of level crossings closures on traffic congestion at crossings adjacent to or in the close proximity of railway stations, proposing the theory 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, presenting an opportunity to mitigate road closure periods at level crossing intersections, thus alleviating road traffic congestion.

To test the theory, named Departure Side Platforms (DSP), the station environment of one station on the Melbourne rail network was simulated using computer 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 was conducted in two phases, one to emulate the current environment and the other to emulate the proposed environment.

Simulation results testing single, two-train and multiple-train arrivals and departures at the current and proposed environment, confirmed the platform repositioning approach of the new theory, results in mitigating road traffic congestion at level crossings railway station precincts. 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 further confirmed that under the proposed platform environment, continual level crossing closures of more than two trains would no longer occur.

INTRODUCTION

Vehicular traffic congestion is increasing in most urban areas (OECD/ECMT, 2007, SKM et al., 2008, Taylor and Crawford, 2010, VicGov, 2013) and in locations where populations and city economies are growing and it is likely to continue to increase (COAG, 2006, OECD/ECMT, 2007, Taylor, 2002, VicGov, 2012). Melbourne, like many other metropolises, 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, a severe underinvestment in transport infrastructure during the decades of the 1980’s and 1990’s, restrictions and capacity constraints within the road and transport networks, inability for increases on public transport services after long periods of low patronage, and from the ever-increasing demand for more capacity derived from population growth and our increasing dependence on the motor vehicle as a mode of transport; all of which exacerbate the road traffic congestion problem (DoT, 2008, Stanley and Barrett, 2010, VicGov, 2007, DoI, 2007, DoT/DoI, 2006, Mees and Groenhart, 2012, VAGO, 2012, Cervero, 1998).

One area where vehicular traffic congestion is prevalent is at railway level crossings (Hall and Somers, 2012, Lucas, 2010, Taylor and Crawford, 2010, VicGov, 2009, Webb and Gaymer, 2009, Fitzgerald, 1950). There are approximately 9,400 level crossings in Australia (Henley and Harrison, 2009, RISSB, 2009, Wallace, 2008). According to the latest count, the Greater Melbourne area is home to the largest number of level crossings in metropolitan areas in Australia, 182 level crossings (Hall and Somers, 2012, PTV, 2013b, Taylor and Crawford, 2010). The metropolitan Melbourne urban rail network is home to 172 level crossings (PTV, 2013b).

Given the large number of level crossings in Melbourne, 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. Road traffic congestion worsens during peak hour periods, creating further disruption for road commuters (ENVICT, 2005, VAGO, 2012, Guzman et al., 2014b).

This paper structure is divided into a number of sections. The literature review examines the implementation of rail networks and the cohabitation problems introduced with the introduction of motor vehicles as a mode of transport, the changes on patronage over the last century, the legacy of railway level crossings and platform positioning, road congestion and its associated cost. This is followed by an analysis of the current solutions to deal with the level crossing legacy, including level crossing closures and grade separation solutions. The research methodology and computer simulation processes are presented next, including the simulation modelling of the current and proposed platform arrangements. Finally, it provides the results of the computer simulation efforts and the conclusions derived from these results.

LITERATURE REVIEW

The first railway line in Australia opened in Melbourne on 12 September 1854. By the turn of the 20th century, the main mode of transport in Australia was largely by rail. This mode of transport was carrying about 90% of the total workforce to work (Cosgrove, 2011). By 1910 and with a population of about 600,000 people, Melbourne rail network patronage was close to 120 million passengers boarding per year (Webb and Gaymer, 2009).

However, patronage changed with the introduction of the motor vehicle as a means of transportation (Cosgrove, 2011). Furthermore, the proliferation of the motor vehicle dictated the introduction of safety equipment at level crossings, the point where rail and road compete for the same ground space. Today, with a population of 4.248 million people (ABS, 2012), Melbourne's rail network consists of 16 radial lines divided into five separate groups currently servicing more than 210 stations (PTV, 2013b).

Rail patronage almost doubled between 1910 and 1950 to about 200 million passengers boarding per year, then steadily declined to 90 million passengers boarding per year by 1980 (Webb and Gaymer, 2009). By 1999, the patronage had increased to 124 million passengers boarding per year, similar to the patronage levels of 1910. During the period between 2004-05 and 2012-13, Melbourne experienced large train patronage increases, from 145.1 million to 225.0 million passengers per year (Guzman et al., 2014a, DoT, 2011, Dowling, 2012, PTV, 2013a).

Intersections 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 a dilemma. 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 and road traffic congestion (COAG, 2006, Edquist et al., 2009, Lucas, 2010, Maslen, 2010, Fitzgerald, 1950). 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 (Tey et al., 2009, Wigglesworth and Uber, 1991). Currently, all 172 Melbourne metropolitan level crossings are fully protected with automatic boom barrier systems (PTV, 2013b).

Taylor and Crawford (2010) indicated that by 2021, some Melbourne rail lines would carry almost 40 trains per hour during peak periods, close to double the present volume levels (Taylor and Crawford, 2010). The problem facing transport authorities is that the additional train traffic will generate further closures at level crossings. The additional closure activity will lead to further vehicular road traffic congestion at level crossing intersections, intersections already affected by road traffic congestion (Guzman, 2008, Guzman, 2011, Guzman et al., 2014a, Guzman et al., 2014c, Lucas, 2010).

Platform Positioning

The issue of platform positioning has only come to light recently and its implications have not been fully researched or understood (Guzman, 2008, Guzman, 2011, Guzman et al., 2014c). The issue of platform positioning is considered to be exacerbating motor vehicle traffic congestion at level crossings adjacent to, or in the vicinity of, railway stations (David, 2009, Guzman, 2008, Guzman, 2012, Guzman et al., 2014b, Higgs, 2009). The impact of the platform position relates to the long periods of intersection closures being experienced at level crossings locations (Cooper, 2012, Guzman, 2012, Guzman, 2011, Hall and Somers, 2012).

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, 2006). It is suggested that a more appropriate name for the road congestion phenomenon is '*the avoidable cost of congestion*' (BTRE, 2007), as it is 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, and fuel consumption costs; there are also additional costs of wear-and-tear for the additional running and travel (Luo et al., 2007). Other effects from traffic congestion include increased fuel usage, higher vehicle maintenance cost, more idle time of commuters, increased productivity lost, longer delivery times, increased undelivered goods, delivery delays, and increased supply chain disruption (Coyle et al., 2010, Gargett and Gafney, 2005).

Studies indicate urban road congestion already costs Australia about 2% of GDP (PJPL, 2005), and there are reports that indicate the annual cost of congestion to be $9.4 billion (BTRE, 2007, COAG, 2006). In Victoria, VCEC estimated the current economic cost of congestion in Melbourne is in the range of $1.3 billion to $2.6 billion per year (VCEC, 2006).

ANALYSIS OF CURRENT SOLUTIONS

The first option in addressing the level crossing problem should always be the closure of the crossing (NCHRP, 1999, RSC, 2008). Crossing closures can be achieved by closing the crossing to road traffic, closing the crossing to rail traffic, or by grade separation (Glennon, 2005, Wallace et al., 2008).

Level Crossing Closure

The elimination of level crossings '*is the only way to truly address catastrophic risk*' (VicGov, 2009). Elimination of level crossings is suggested to be the most effective measure of improving safety and reducing the risk of collision at these locations (LCSC, 2013, Wigglesworth, 2008). The closure of roads or tracks at level crossings as remediation is impractical in urban areas, because most rail lines carry hundreds of train services per day. Affected roads carry many thousands of road commuters; closing one of these would have the effect of closing that arterial or major road and transferring the problem somewhere else in the road network (Ogden, 2007, PTSV, 2009).

Level Crossing Grade Separation

Grade separation is the name given to the engineering process of separating both traffic modes, by way of building a tunnel or a bridge. Grade separation eliminates the problem altogether; it separates both modes of transport, rail and road, from each other's path (McNamara and Cox, 1979, VicGov, 2009). Grade separation of level crossings creates safer and more reliable travel for commuters, vehicular traffic, walking public and the community in general; it reduces road congestion and its bi-products.

Grade separation, in most cases, is the Victorian Governments preferred solution to resolve level crossing problems, but while grade separation is the most effective alternative, it is also an extremely costly solution (CfM, 2011, VicGov, 2009). For example, the cost of removing all level crossings in Victoria, while an unrealistic proposition, has been calculated to cost between $60 billion and $80 billion (NPV) (Lucas, 2009). The Committee for Melbourne estimates indicate that, based on $100 million per level crossing removal by way of grade separation, it would cost $17.2 billion (NPV) to remove all level crossing from the Melbourne metropolitan area (CfM, 2011).

The railroad level crossings remediation process can be achieved by one of the following engineering solutions: (a) lowering the rail line by tunnelling under the road; (b) lowering the road by tunnelling under the rail line; (c) building a road bridge over rail line; and (d) building a rail bridge over road (NewAustralia, 2010, VicGov, 2009, Wallace, 2008).

During the last two decades, grade separations have seen the removal of five metropolitan train stations level crossings from the Melbourne network. Current plans and developments are underway for about 12 train stations level crossings grade separations projects over the next ten years, costing Victorian taxpayers $3.0 billion (Freemantle, 2011, VicRoads, 2011, Dowling, 2014). 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.

RESEARCH METHODOLOGY

Current analytical and road transport theories were explored and considered for this research. These included Queuing theory and other road transport theories, techniques and strategies, such as Travel Demand Management (TDM) and Traffic Operational Strategies (TOS). Queuing theory was initially explored, as queuing theory and its probabilistic methods are a widely utilised theory that mathematically explores waiting lines, congestion and queues (Breuer and Baum, 2005, Laval and Leclercq, 2010, Mounce, 2006, Sztrik, 2012). However, these analytical road transport theories designed to address road transport problems created by road transport conditions, were considered inappropriate for this research; the combined complexities of the components of road and rail traffic network operations are not prescribed under these models.

Rather, computer simulation modelling was used to assess the benefits of the proposed solution. Computer simulation is said to be one of the most powerful tools available for modelling and simulation activities in an interactive mode, as it allows and simplifies the methods used to study, analyse and evaluate conditions that could not be studied under normal circumstances (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 (Yin, 2003, Tellis, 1997, Law and McComsa, 1991, Law, 2008).

There are a number of traffic computer simulation software packages purposely made for addressing the issue of road transport and traffic assignments. VISSIM, a multi-modal microscopic traffic flow simulation software purposely developed by Planung Transport Verkehr AG (PTV AG) (Choa et al., 2003), was deemed the most appropriate of the packages available, as it allows the simulation of all types of road traffic and specifically heavy rail (trains), a must for the research. VISSIM offers more flexibility than the other contenders because of its ability to model unusual sites, for example railroad crossings, as well as providing powerful 3D and movie capture facilities (Fontaine 2012).

The research methodology was developed using Law’s (2008) design model and expanded to fit the specific requirements of this research, incorporating two simulation processes, ensuring that this new design model incorporated into its design, the validity, reliability, and replicability features from Law's method (Law, 2008).

CURRENT PLATFORM ARRANGEMENT

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

In this research, platforms at a station are classified as either Departure Side Platform (DSP) or Arrival Side Platform (ASP); this classification is dependent upon the relative position of the platform in relation to the level crossing intersection. Figure 1 illustrates the current station DSP – ASP platforms infrastructure.

Figure 1: Current DSP – ASP Station Platforms

Source: Target level crossing current DSP – ASP station platforms environment superimposed over Google™earth images

At the DSP platform, a train travelling from west to east or *down-line*, triggers the intersection closure, the train then passes through the level crossing intersection to get to the platform, passenger's disembark and board and the train then continues its journey; during disembarking and boarding, the road is open to road and pedestrian traffic, as the train cleared the level crossing before stopping at the platform.

At the ASP platform, a train travelling east to west or *up-line*, triggers the intersection closure, arriving at the ASP platform before crossing the level crossing intersection, passenger's disembark and board. During this process, the intersection remains closed to all road and pedestrian traffic; the train then proceeds through the level crossing opening the intersection to road traffic. The proposition presented involves repositioning a station platform, the Arrival Side Platform (ASP).

PROPOSED PLATFORM ARRANGEMENT

This research extends previous work on platform positioning (Guzman, 2008) and proposes that congestion at station level crossings is not caused by the level crossing intersection closure operation, but rather by trains at the platform and/or arriving, forcing the intersection to remain closed for long intervals. This new theory presents a level crossing congestion calming alternative not otherwise investigated or implemented previously. This alternative could hypothetically be simple to implement and one that could cost a small fraction of the costs involved with each grade separation. Unsubstantiated estimates indicate the proposed alternative to costs between $1 and $2 million for each station level crossing project.

Computer simulation models were used to emulate both the current operation and the proposed approach of the level crossing 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. The current operations were simulated using the level crossing closure activation and signals data, collected at one railway station of the Melbourne train network, and was tested many times, ensuring the operational validity and replicability of the simulation design model created. Once this was achieved, a new model was 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.

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. 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 trains, 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.

In the simulation model of the proposed environment, the current ASP up-line platform was decommissioned and a new platform, a DSP up-line platform, was built about 200 metres further away from the current position, but immediately after the intersection level crossing. This new platform environment for the up-line train represents a true or mirror image of the current platform environment for the down-line platform environment. The proposed station platform structure and operation of the new DSP – DSP station platform arrangement, supporting two Departure Side Platforms, was simulated and tested accordingly.

SIMULATION RESULTS

VISSIM provided a variety of output reports and the results indicate road traffic queue differences, including differences in the average queue length, maximum queue length and number of stops within queues. Additional analysis of the current, proposed and differences of level crossing closures were also generated and reported. The simulation results confirmed that under the proposed platform environment, continual level crossing closures of more than two trains would no longer occur. Table 1 indicates the differences between the current and proposed closure periods.

Table 1: Average Level Crossing Closures – Current vs Proposed

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

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

The current average closure activated by a single train on the down-line direction was recorded as forty six seconds (46s). Since no changes were introduced at this platform location, the 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 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. The 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. 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 (46s + 46s = 92s).

CONCLUSION

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. The processes conducted in the research contribute to theoretical knowledge by developing the Departure Side Platforms (DSP) theory. This new theory addresses the cause of level crossing problems and not the symptom of the problems, 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 experienced and the intersection open periods are longer than currently experienced, 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 mitigates road congestion, reduces travel time and travel time costs, decreases environmental greenhouse gas emissions and pollution costs, reduces fuel consumption and costs, and minimises wear-and-tear and maintenance costs to vehicles, thus alleviating some of the burdens road congestion imposes on the community.

However, this research is not without its limitations. Although the DSP concept is an alternative solution for station level crossings in its own rights, the DSP concept could potentially be used as an interim solution until implementation of the more permanent grade separated solution. No official costing has been conducted in terms of the proposed system. Future research could look into the costing and other benefits associated with the proposed alternative.

References

ABS 2012. Australian Demographic Statistics. Canberra, Australia: Australian Bureau of Statistics (ABS).

BREUER, L. & BAUM, D. 2005. *An introduction to queuing theory and matrix-analytic methods*.

BTRE 2007. Estimating urban traffic and congestion cost trends for Australian cities. Canberra, ACT, Australia: Bureau of Transport and Regional Economics (BTRE).

CERVERO, R. 1998. *The Transit Metropolis: A Global Inquiry*, Washington, Island Press.

CFM 2011. $17 Billion to Separate Rail and Road Crossings. Can Melbourne afford not to do it? *In:* MELBOURNE, C. F. (ed.). Committee for Melbourne.

CHOA, F., MILAM, R. T. & STANEK, D. 2003. CORSIM, PARAMICS, and VISSIM: What the Manuals Never Told You. *Ninth TRB Conference on the Application of Transportation Planning Methods.*

COAG 2006. Review of Urban Congestion. Trends, Impacts and Solutions. Competition and Regulation Working Group, Council of Australian Governments.

COOPER, A. 2012. Rail crossing frustrations rise as peak hour gridlocks suburbs *The Age*, 2 July 2012, p.2 July.

COSGROVE, D. C. 2011. Long-term patterns of Australian public transport use. *Australasian Transport Research Forum 2011*. Adelaide, Australia.
COYLE, J. J., NOVACK, R. A., GIBSON, B. J. & BARDI, E. J. 2010. *Transportation: A supply chain perspective*, CengageBrain. com.
DAVID, R. 2009. Easing the Squeeze - Extra platform will do the trick. *Springvale Dandenong Leader*, 10 August 2009, p.1.
DOI 2007. Strategic Directions 2007 - 2010. Melbourne: Department of Infrastructure, State of Victoria.
DOT 2008. The Victorian Transport Plan - VTP. Department of Transport, Victoria.
DOT. 2011. *Metropolitan and regional patronage 2010-11* [Online]. Victorian Transport Services, Department of Transport (DoT), Victoria. [Accessed 29 November 2011].
DOT/DOI 2006. Meeting Our Transport Challenges - Connecting Victorian Communities. . Department of Infrastructure/Department of Transport.
DOWLING, J. 2012. Fall-off tipped in train passengers. *The Age*, 4 May 2012, p.6.
DOWLING, J. 2014. New trains for south-east as part of $2.5 b rail promise. *The Age*, 7 March.
EDQUIST, J., STEPHAN, K., WIGGLESWORTH, E. C. & LENNÉ, M. 2009. A Literature Review Of Human Factors Safety Issues at Australian Level Crossings. Monash University Accident Research Centre sponsored by the Department of Transport (DoT), Victoria.
ENVICT 2005. Inquiry into Managing Transport Congestion. Environment Victoria.
FITZGERALD, F. 1950. Melbourne's 232 Level Crossings Should Go. *The Argus*, 30 March 1950.
FREEMANTLE, R. 2011. VicRoads Program for 2011-12. *ICN's Major Projects Forum 2011*. Melbourne, Australia: Industry Capability Network (ICN).
GARGETT, D. & GAFNEY, J. 2005. Traffic Growth in Australian Cities: Causes, Prevention and Cure. BTRE staff papers.
GLENNON, J. C. 2005. Rail-Highway Grade Crossing Design and Maintenance. *Train Accident Reconstruction and FELA and Railroad Litigation.* Lawyers & Judges Publishing Company.
GUZMAN, W. 2008. The Impact of Traffic Bottlenecks on Port Corridor Development: A Case Study at Clayton Station Level Crossing. *In:* UNIVERSITY, R. (ed.) *Master of Business (Logistics Management) unpublished thesis.* Melbourne, Australia: RMIT University
GUZMAN, W. 2011. Trains come at a price - Boom gates to create road chaos: A Reply. *The Age*, p.31 December.
GUZMAN, W. 2012. Extra hour spent waiting - A reply. *The Age*, p.30 May.
GUZMAN, W., PESZYNSKI, K. & YOUNG, L. 2014a. Zonal Operations: a method to rationalise operations *In:* WIT (ed.) *14th International Conference on Railway Engineering Design and Optimization.* Rome, Italy: Wessex Institute of Technology.
GUZMAN, W., PESZYNSKI, K. & YOUNG, L. 2014b. Zonal Operations: a method to rationalise operations. *In:* BREBBIA C. A., T. N., TZIEROPOULOS P., MERA J. M. (ed.) *Computers in Railways XIV: Railway Engineering Design and Optimization.* United Kingdom: WIT Press.
GUZMAN, W., YOUNG, L. & PESZYNSKI, K. 2014c. Departure Side Platforms: A Measure to Mitigate Road Congestion. *International Symposium on Logistics (ISL 2014).* Ho Chi Minh City, Vietnam.
HALL, M. & SOMERS, A. 2012. Investigating efficiency at level crossings: simulation of road and rail signalling improvements. *In:* ARRB (ed.) *Shaping the future: Linking policy, research and outcomes.* Perth, Australia.

HENLEY, G. & HARRISON, J. E. 2009. Serious injury due to transport accidents involving a railway train, Australia, 2002–03 to 2006–07. *In:* STATISTICS, I. A. R. (ed.) *Series Number 54.* Adelaide: Australian Institute of Health and Welfare (AIHW) and the Department of Infrastructure, Transport, Regional Development and Local Government (ATSB).

HIGGS, P. 2009. Platform's the ticket in Clayton. *Oakleigh Monash Leader*, 20 January 2009, p.1.

INGALLS, R. G. 2008. Introduction to Simulation *In:* S. J. MASON, R. R. H., L. MÖNCH, O. ROSE, T. JEFFERSON, J. W. FOWLER (ed.) *40th Winter Simulation Conference.* Miami, Florida, USA.

LAVAL, J. A. & LECLERCQ, L. 2010. Continuum Approximation for Congestion Dynamics Along Freeway Corridors. *Transportation Science,* 44**,** 87.

LAW, A. M. 2008. How to Build Valid and Credible Simulation Models. *In:* S. J. MASON, R. R. H., L. MÖNCH, O. ROSE, T. JEFFERSON, J. W. FOWLER (ed.) *40th Winter Simulation Conference.* Miami, Florida, USA.

LAW, A. M. & MCCOMSA, M. G. 1991. Secrets Of Successful Simulation Studies. *In:* BARRY L. NELSON, W. D. K., GORDON M. CLARK (ed.) *1991 Winter Simulation Conference.*

LCSC 2013. Yearly Report 20011 12 Level Crossings NSW Safety Improvement Programs Level Crossing Strategy Council of NSW.

LUCAS, C. 2009. Melbourne's big squeeze. *The Age*, 21 March 2009.

LUCAS, C. 2010. *Level crossings choking city traffic flow: RACV* [Online]. Melbourne: The Age. Available: http://www.theage.com.au/victoria/level-crossings-choking-city-traffic-flow-racv-20100920-15jqs.html [Accessed 21 September 2010].

LUO, Q., JUAN, Z., SUN, B. & JIA, H. 2007. Method Research on Measuring the External Costs of Urban Traffic Congestion. *Transportation Systems Engineering and Information Technology,* 7**,** 9-12.

MASLEN, G. 2010. Putting rail safety on the right track. *The Age*, 21 September 2010.

MCNAMARA, G. & COX, J. J. 1979. Melbourne - The City of Level Crossings. *In:* IRSE (ed.) *30th Annual General Meeting.* Melbourne, Australia: The Institution of Railway Signal Engineers - Australian Section

MEES, P. & GROENHART, L. 2012. Transport Policy at the Crossroads: Travel to work in Australian capital cities 1976-2011. Melbourne: RMIT University.

MOUNCE, R. 2006. Convergence in a continuous dynamic queueing model for traffic networks. *Transportation Research Part B: Methodological,* 40**,** 779-791.

NCHRP 1999. Traffic Signal Operations Near Highway-Rail Grade Crossings. *Synthesis of Highway Practice 271.* Washington, D.C.: National Cooperative Highway Research Program (NCHRP), National Research Council, Transportation Research Board (TRB).

NEWAUSTRALIA. 2010. *Replacing Hundreds of Level Crossings with Road Bridges* [Online]. NewAustralia. Available: http://www.newaustralia.net/transport_rail.html [Accessed 10 October 2010].

OECD/ECMT 2007. Managing Urban Traffic Congestion. Transport Research Centre, Organisation for Economic Co-Operation and Development (OECD) & European Conference of Ministers of Transport (ECMT).

OGDEN, B. D. 2007. Railroad-Highway Grade Crossing Handbook. *In:* FHWA, F. H. A.-. (ed.). Washington, DC: Institute of Transportation Engineers (ITE), USA.

PJPL 2005. Reforming and Restoring Australia’s Infrastructure. Port Jackson Partners Limited for The Business Council of Australia.

PTSV 2009. Road/Rail Safety Interface Agreements, Public Transport Safety Victoria. *SIA - Safety Interface Agreements.* Melbourne, Victoria: Victorian Government, Melbourne.

PTV 2013a. Metropolitan Public Transport Demand Forecast Report. *In:* VICTORIA, P. T. (ed.). Melbourne: Public Transport Victoria

PTV. 2013b. *Railway Level Crossings in Victoria 2010* [Online]. Available: http://ptv.vic.gov.au/projects/railway-crossings/road-crossings-and-pedestrian-crossings/ [Accessed 31 December 2013].

RISSB 2009. Level Crossing Stocktake. Australia: Rail Industry Safety and Standards Board (RISSB).

RSC 2008. Inquiry into Improving Safety at Level Crossings: report of the. Melbourne: Parliament of Victoria.

SHANNON, R. E. 1998. Introduction to the Art and Science of Simulation. *1998 Winter Simulation Conference.*

SKM, MAUNSELL & EVANS & PECK 2008. East West Link Needs Assessment (EWLNA) - Transport Supply and Demand. *In:* EDINGTON, S. R. (ed.) *EWLNA.* Department of Transport, Victoria.

STANLEY, J. & BARRETT, S. 2010. Moving People - Solutions for a growing Australia. Report for Australasian Railway Association, Bus Industry Confederation and UITP.

SZTRIK, J. 2012. *Basic Queueing Theory*.

TAYLOR, B. 2002. Rethinking Traffic Congestion. *UCTC Access, University of California Transportation Center (UCTC),* 21**,** 9.

TAYLOR, J. & CRAWFORD, R. 2010. Prioritising Road-Rail Level Crossings for Grade Separation Using a Multi-Criteria Approach. *CORE 2010: Rail, Rejuvenation and Renaissance.* Wellington, New Zealand: Railway Technical Society of Australasia (RTSA).

TELLIS, W. 1997. Introduction to Case Study. *The Qualitative Report,* 3**,** 18.

TEY, L.-S., FERREIRA, L. & DIA, H. 2009. Evaluating Cost-effective Railway Level Crossing Protection Systems. *32nd Australasian Transport Research Forum.*

VAGO 2012. Public Transport Performance. *In:* AUDITOR-GENERAL (ed.). Melbourne: Victorian Auditor-General’s Office.

VCEC 2006. Making the right choices: options for managing transport congestion - Part B. Victorian Competition and Efficiency Commission (VCEC).

VICGOV 2007. Making the right choices: options for managing transport congestion - Victorian Government Response. Department of Treasury and Finance, Victoria

VICGOV 2009. Inquiry into Improving Safety at Level Crossings - Victorian Government Response. Victoria State Government

VICGOV 2012. Victoria's Submission to Infrastructure Australia. *In:* CABINET, D. O. P. A. (ed.). Melbourne.

VICGOV 2013. Plan Melbourne, Metropolitan Planning Strategy. *In:* GOVERNMENT, V. (ed.). Melbourne.

VICROADS 2011. ICN’s Major Projects Forum 2011.

WALLACE, A. 2008. *Motorist Behaviour at Railway Level Crossings: The Present Context in Australia.* Ph.D PhD, Queensland University of Technology, QUT.

WALLACE, A., MCCUSKER, L. & HIRSCH, L. 2008. Level Crossings Research Database. *In:* CRC (ed.). CRC for Rail Innovation under the Australian Government’s Cooperative Research Centres Program.

WEBB, M. & GAYMER, S. 2009. Changes in Travel Demand in Melbourne - is it time for a new paradigm? *Australian Transport Research Forum.*

WIGGLESWORTH, E. C. 2008. Ergonomics, Safety And Railway Level Crossings. *HFESA - Human Factors and Ergonomics Society of Australia* 21**,** 9.

WIGGLESWORTH, E. C. & UBER, C. B. 1991. An Evaluation of the Railway Level Crossing Boom Barrier Program in Victoria, Australia. *Safety Research,* 22**,** 8.

WINSBERG, E. 1999. Sanctioning Models: The Epistemology of Simulation. *Science in Context* 12**,** 29.

YIN, R. K. 2003. *Case Study Research - Design and Methods*, Thousand Oaks.