

## **Grade separations and improving intermodal transfer at railway stations in Melbourne**

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### **Abstract**

The successful implementation of network planning for mass transit depends to a large extent on the ease, safety, amenity and accessibility of transfers between modes at nodes on the network. Bearing on this functionality are the relationships between spatial layout, proximity of transit modes, accessibility to diverse users, ease of wayfinding, transfer passenger throughput and the quality of the network node as a place in terms of environmental and urban amenity. Amenity implies that travelling on public transport may be seen as an integral part of passengers' everyday routines of living. This strongly suggests that greater integration between transit nodes and other land uses, especially non-residential ones, adds to the effectiveness of their transport function.

This paper reports on work in progress in developing assessment criteria for designing and assessing the intermodal transfer experience of rail-road grade separations. This is a particularly timely study for Melbourne, which has over 170 level crossings on the passenger rail system, 106 which are used by buses and, to a lesser extent, trams. A new state government was elected in late 2014 with a commitment to remove at least 50 level crossings. This paper reports on analysis of recent and past grade separations within Melbourne, and draws on precedents elsewhere in Australia and internationally. We propose that for most places, a limited range of grade separation scenarios will provide the optimum range of potentials to create the conditions for functional as well as attractive intermodal transfer nodes.

## 1. Introduction

The principles of integrating multiple modes of mass transit to achieve a 'network effect' are well-established under the rubric of 'network planning' (Thompson et al 1976; Nielsen et al 2005; Nielsen and Lange 2008; Vuchic 2007; Mees 2000, 2010). The primary aims of this approach are two-fold. First, to create a 'simple and stable inter-connected network of public transport lines throughout the day with a structure and timetable that is easy for users to learn and understand'. Second, to 'accept and support the proposition that many, potentially even a majority of travellers will need to transfer between services to access their selected destination' (Mees and Dodson 2011, p. 25). In their review of the literature, Mees and Dodson identify five key practices that support network planning: simple and direct network structures, hierarchically planned lines, high service quality (speed, consistency and reliability and frequencies of at least 10 but preferably five minutes), co-ordinated and convenient transfers, and clear, ubiquitous and consistent information and marketing (pp. 3-4). While all of these five practices are essential to the effective operation of an intermodal mass transit network, it is the nature of the transfer nodes or 'interchanges' that is the focus of this paper. One of the key aspects of the network approach is that it can provide high levels of mass transit service to dispersed and low-density forms of urbanisation, such as those that predominate in Australian cities. Many successful exemplars of network planning are found in high as well as low-density urban environments, such as cities in South East Asia (notably Japan) and Europe (for example, London, Zurich or Berlin). Another key element of the approach is that it is less concerned with modelling and predictions of ridership, but instead premised on adequacy of coverage and ubiquity of access to provide viable alternative modes of transport to the private car (Mayor of London 2002).

Mees and Dodson also concluded that there were significant shortfalls in service provision and mode shares compared to what could be achieved if network planning was properly implemented (2011). This is particularly the case for Melbourne, Australia's second-largest city and the only one with extensive systems across the three modes of train, tram and bus. Despite their extent, these systems have mainly been conceived, planned and managed separately rather than as complementary modes within an integrated network. The establishment of Public Transport Victoria in late 2011 is part of an attempt to facilitate such integration. However, the benefits of network integration must compete for attention in policy against politically attractive expenditure on new infrastructure, and this is one of the tensions in the public discourse around improvements to public transport in Melbourne. This paper focuses on Melbourne for three reasons. First, it has an unusually high number of level crossings for an urban rail system in a developed country. Second, Melbourne's public transport system is about to undergo one of the most significant transformations in a century with the much-needed removal of a large number of level crossings. Third, level crossing removal presents great opportunities to enhance network performance.

We are keen to understand the role that grade separations could have in enhancing network performance within the broader issues of station design, station access, and better integration of stations into the surrounding urban form (Coxon, Burns and DeBono 2008; Maher and Skinner 2011; Semmler and Hale 2010; Hale 2011, 2013; Hale and Miller 2012; Hale and Eagleson 2014; Curtis and Scheurer 2012; Charles and Galiza 2013; Woodcock and Wollan 2013). Grade separations have traditionally been approached from two perspectives. First, and primarily, level crossings are conceived as an issue of safety (Hughes 2003; Mcpherson and Daff 2005). Second, they are seen as a problem for motorists and pedestrians in terms of congestion and access (Taylor and Crawford 2009; Lill and Kane 2012). These two issues feature prominently in the political rhetoric around level crossings

and the need for their removal. It is rarely observed that many level crossings are also used by buses and trams, perhaps reflecting the still relatively marginal status of mass transit in mainstream Australian culture. This latter aspect, and the fact that grade separations involve significant expenditure of public funds and frequently involve rebuilding station facilities, means that level crossing removals are about far more than safety and road congestion for private motorists. The relationship of grade separations to the broader urban design context and its impacts on travel behaviour, especially in relation to transfers, and the potential for public transport services to be improved across all modes, all need to be better understood.

### **Melbourne's level crossings**

By the end of the 19<sup>th</sup> century, Melbourne had one of the world's most extensive passenger rail systems, built to serve a metropolitan area twice the size of London (the world's largest city at the time in terms of inhabitants) but with half a million people, less than one-twelfth London's population. Since then, Melbourne's rail system has seen little renewal, few extensions and a lack of maintenance. Due to increasing internal and external immigration, Melbourne is struggling to cope with a legacy of significant numbers of outdated stations and level crossings that cause road congestion and limit attempts to improve rail services. Notably, another aspect of Melbourne's rail-based heritage is a tram network that is the largest in the world. While cities globally were dismantling their tram systems in the 1950s and '60s, Melbourne retained most of its lines. However, Melbourne's trams are now among the slowest and least efficient. Like the rail network, whose efficiency is hampered by outdated stations and over 170 level crossings, almost 70 per cent of Melbourne's tramways run in mixed traffic. While rail/road grade separations were an important aspect of some parts of the early rail system during its development in the latter half of the 19<sup>th</sup> and early 20<sup>th</sup> centuries, they were not extensive. Even so, the remaining surface and shared alignments did not seem to hamper the ability of the trains and trams to run far more frequent services and carry far larger volumes of passengers up to the peak in 1950 than they do now. Since then the exponential growth of car ownership and a tripling of the population has meant that road congestion has slowed trams and placed significant constraints on train service frequencies due to the ubiquity of level crossings. Apart from some minor acknowledgements, this understanding has not found its way either into broader public discourse or into many technical studies supporting recent plans to improve rail transport in Melbourne. In November 2014, a new state government was elected with an agenda presaging dramatic changes in Melbourne's transport prospects. The new government cancelled a highly controversial plan to build an inner-city tollway, to focus on implementing a bold promise to remove 50 level crossings at a faster rate than at any time in the state's history. At least thirty new stations will result from currently-proposed grade separations due to the proximity of many level crossings to stations. Mostly these are ordinary suburban stations that serve as transfer nodes, mainly between buses and trains, though some involve trams also. It is at such nodes that intermodal mass transit networks succeed or fail. So, it is vital to understand the effect of various ways of separating grades can have on intermodal transfer.

The history of station redevelopment and grade separation in Melbourne is marked by an early preference for elevating lines and stations on embankments or lowering them in wide, landscaped trenches to allow roads and tramways to cross them unimpeded. Both of these approaches have mostly left attractive legacies in local urban design terms, and occur mainly in leafier, more affluent suburbs in Melbourne's east. In the 1950s and 1960s, numerous road-over-rail grade separations were carried out, with disastrous results for local suburban centres, exacerbating the disconnection between communities caused by the presence of surface rail. More recently, grade separations have been done by lowering the tracks into narrow trenches lined with rough concrete walls and anti-suicide fences. This approach lacks

the landscaping potential of earlier trenching designs and exacerbates ground-level disconnection of communities due to the inordinately high costs of building over them, foreclosing opportunities for better integration of stations with local neighbourhoods. Trenching has become a 'one size fits all' approach due to the belief among project designers that rail-over-road will be unacceptable to the community. In what follows, we outline the situation in Melbourne regarding the degree to which intermodal transfer is already apparent in the use of the system, despite its many shortcomings. We then provide an overview of the principles under development that could be used to assess grade separation proposals in terms of their effectiveness as interchanges.

## **Intermodality In Melbourne**

### **Melbourne's mass transit system and mode shares**

Melbourne has 372km of passenger railways, comprising 16 lines serving 204 stations that in the 2013-14 financial year carried 232 million people (PTV 2014, p.26). Melbourne's tram system comprises 250km of track, 25 routes with 1,763 stops and in the financial year 2013-14, carried 176.9 million people (PTV 2014, p. 27) Melbourne's bus system comprises approximately 330 routes totalling almost 7,000km in length, about 14,500 stops, with 127.6 million passengers recorded in the 2013-14 year (PTV 2014, p.28). Patronage on public transport has been steadily rising since an all-time low in 1996, with ridership increasing faster than population growth, while the overall mode share for car-based commuting has fallen in the same period (Mees and Groenhart 2012). These patterns are similar to the other Australian state capital cities. At the last census in 2011, overall mode share for public transport in Melbourne was 16% in 2011, the second-highest for Australian capital cities (Mees and Groenhart 2012, p. 14). In 2011, within the public transport sector, the mode shares were: rail 72.7%, tram 16.2% and bus 11.1%. Since then, there has been a dramatic relative rise in patronage on trams and buses, such that by 2013-14, the mode shares were: rail 43.2%, tram 33% and bus 23.8%.

As noted by Hale and Eagleson, the intermodal network characteristics of Melbourne's mass transit system are obscured by much planning documentation (Hale and Eagleson 2014, p. 335). For example, PTV's Annual Report 2014 provides no figures for transfers, nor does it discuss the issue. The only PTV data accessible for analysing intermodal transfer is from 2012 relating to Melbourne's train system (PTV 2013). According to this data, transfers to rail from trams and buses together comprised 13.3% of access mode share overall, with bus access being 7.7% and tram access 5.6%. However, these gross figures are far less enlightening than the more detailed picture taken across all of the 169 stations where interchanges occur, a substantial 83% of the system. As indicated in Table 1, there are 32 stations outside the central city where transfers from bus, tram or both account for between 20% and 50% of rail boardings at that point. In terms of station access categories, such stations should be a special case (Hale 2011; Hale and Eagleson 2014), while the remainder that are served by buses and trams should also be classified as such in order to obtain policy visibility and capital works programs (Alford and Wild 2007). These stations would warrant not only investigation of the conditions that generate such numbers, but also the adequacy of the design of the station and immediate surrounds to cater for such high demands for modal interchange.

From our personal knowledge of these stations, most are operating as high-use interchanges due to proximity of services and are not formally supported by planning and design treatments that enhance traveller experience. A few, such as Box Hill, Dandenong,

Frankston, and Broadmeadows, have long functioned as major transport interchanges in keeping with their 'Central Activities' status in metropolitan planning schemes such as *Melbourne 2030* and *Plan Melbourne*.

**Table 1: Melbourne railway station with high transfer usage**

Data source: Public Transport Victoria 2013 (Station-by-Station Fact Sheet); Totals are for the whole system and include data not shown.

STATION	BUS		TRAM		COMBINED %	To CBD KM	Local Government
	ACCESS	%	ACCESS	%			
<b>Total</b>	<b>57,260</b>	<b>7.7</b>	<b>41,056</b>	<b>5.6</b>	<b>13.3</b>		
Essendon	2,151	35.5	897	14.8	50.3	8.0	Moonee Valley
Huntingdale	2,292	48.6			48.6	18.3	Monash
Springvale	2,343	43.4			43.4	24.5	Gr. Dandenong
Hoppers Crossing	1,917	37.4			37.4	27.7	Wyndham
Broadmeadows	781	31.3			31.3	16.8	Hume
Dandenong	2,817	30.5			30.5	31.2	Gr. Dandenong
Keon Park	382	29.7			29.7	17.5	Whittlesea
Box Hill	2,477	26.2	307		26.2	16.2	Whitehorse
Blackburn	1,326	29.4			29.4	18.7	Whitehorse
Cranbourne	663	28.3			28.3	45.1	Casey
Ringwood	1,432	26.4			26.4	25.8	Maroondah
Greensborough	851	26.4			26.4	22.9	Banyule
Croydon	777	25.5			25.5	31.0	Maroondah
Roxburgh Park	400	24.6			24.6	22.0	Hume
Frankston	1,966	24.5			24.5	44.0	Frankston
Elsternwick	176	5.3	622	18.6	23.9	11.0	Glen Eira
Lilydale	692	23.5			23.5	39.1	Yarra Ranges
North Richmond			441	23.3	23.3	4.2	Yarra
Mentone	854	23.3			23.3	24.4	Kingston
Keilor Plains	446	23.1			23.1	19.6	Brimbank
Coburg	534	22.3	12		22.3	10.1	Moreland
Oakleigh	1,261	22.8			22.8	16.6	Monash
Clayton	1,198	22.4			22.4	20.5	Monash
Glen Iris	220	16.1	79	5.8	21.9	11.5	Boroondara
Glen Waverley	1,344	21.7			21.7	22.2	Monash
Jolimont			501	21.4	21.4	2.9	Melbourne
Nunawading	612	21.2			21.2	21.1	Whitehorse
Royal Park	35	3.9	155	17.0	20.9	5.5	Melbourne
Epping	446	20.6			20.6	22.5	Whittlesea
Sydenham	1,150	20.3			20.3	23.3	Brimbank
Narre Warren	528	20.1			20.1	40.8	Casey
Craigieburn	490	20.1			20.1	26.7	Hume

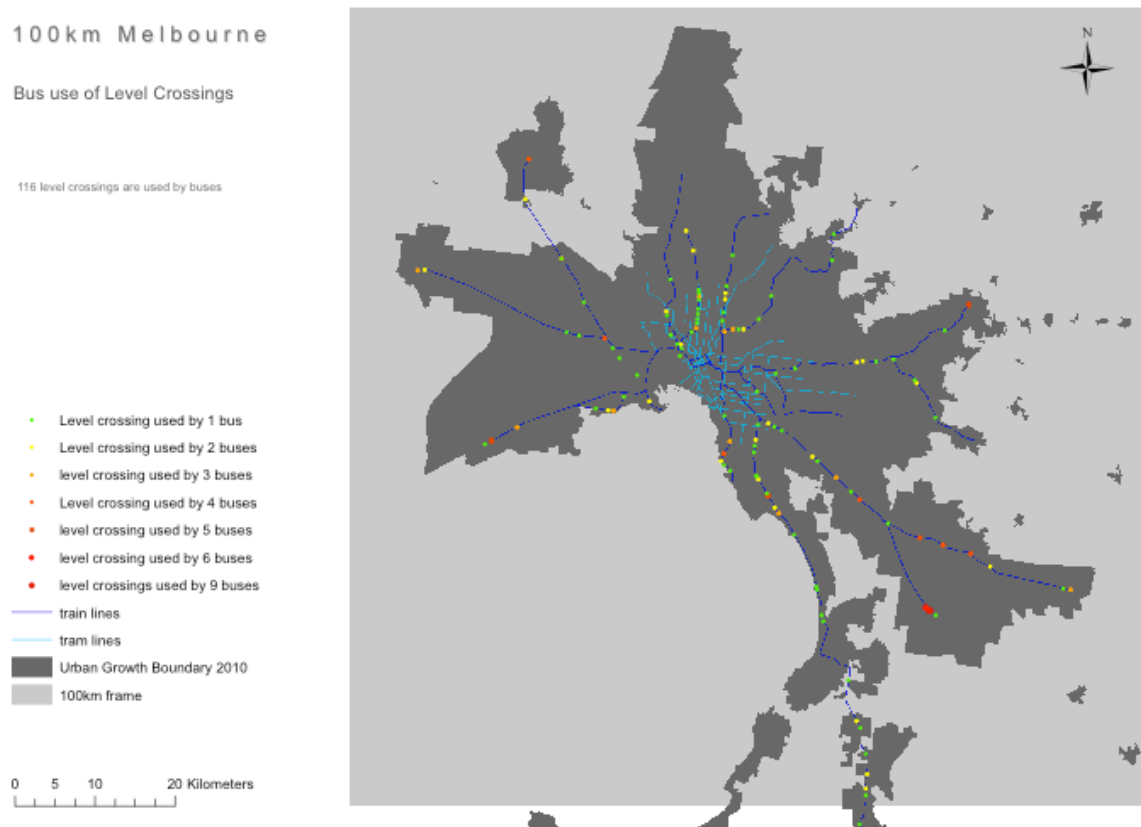
At the same time, it is notable that these station facilities themselves leave a lot to be desired in comparison to best practice globally. Roxburgh Park and Craigieburn are relatively new stations constructed in the last decade or so, though again, as interchanges they lack full weather protection and many station amenities. Epping, Nunawading and most recently, Springvale have new station facilities because of grade separation projects and so add to the suite of places that could provide a good basis for further empirical research on the effectiveness of stations as interchanges. Ringwood is currently being upgraded. The remainder are primarily operated with minimalist transport facilities that lack good connection with their immediate urban contexts, have low levels of weather protection. They generally function as interchanges by default rather than design, while failing to make the most of the opportunities presented by stations as public places (Coxon, Burns and DeBono 2008; Maher and Skinner 2011; Hale and Miller 2012; Woodcock and Wollan 2013). However, what

is most significant is that large numbers of stations that are not end-of-line or 'central activities' nodes perform significant intermodal functions (Hale and Eagleson 2014).

### Melbourne's level crossings and road-based public transport

Beyond issues of safety and traffic congestion, Melbourne's level crossings create significant obstacles to improving a large proportion of bus services and a small number of tram services, with consequences for overall network performance. As shown in Figure 1, 116 level crossings in Melbourne are used by buses, while four are used by trams. This is over 70% of the total crossings on the passenger system. Many of these crossings are used by more than one bus route, some are used by as many as 9 different bus services.

**Figure 1: Level crossings used by bus routes** (Image: Lucy Pike)



All of Melbourne's buses and most of its trams run in mixed traffic, meaning that traffic congestion, however caused, directly affects service speeds and punctuality. So, any reduction in traffic congestion will facilitate improvements in service quality. However, even if buses and trams ran in their own rights of way (assuming it were feasible within the roads actually in use), they must use these level crossings at some point, meaning there would still be significant constraints on speed and reliability. Even if Melbourne's bus routes were rationalised into a more direct, grid-like network (Mees 2010), the number of level crossings used would remain the same or very similar.

**Table 2: Melbourne railway stations with transfer usage (adjacent to level crossings only)**

Data source: Public Transport Victoria 2013 (Station-by-Station Fact Sheet) and Victorian Department of Economic Development, Jobs, Transport and Resources (Level crossing removal locations); Totals are for the whole system and include data not shown (except the two columns on the RHS)

STATION	BUS		TRAM		Combined %	LEVEL X REMOVALS	
	BUS	%	TRAM	%		2014-2018	2018-2022
	57,260	7.7	41,056	5.6	13.3	12	20
Essendon	2,151	35.5	897	14.8	50.3		1
Hoppers Crossing	1,917	37.4			37.4		
Keon Park	382	29.7			29.7		
Blackburn	1,326	29.4			29.4	1	
Cranbourne	663	28.3			28.3		
Croydon	777	25.5			25.5		
Lilydale	692	23.5			23.5		1
Mentone	854	23.3			23.3		1
Coburg	534	22.3	12	0.5	22.8		1
Clayton	1,198	22.4			22.4	1	
Glen Iris	220	16.1	79	5.8	21.9	1	
Royal Park	35	3.9	155	17.0	20.9		
Sydenham	1,150	20.3			20.3		
Narre Warren	528	20.1			20.1		
Werribee	763	19.7			19.7		1
Riversdale			193	19.5	19.5		
Laverton	1,085	19.0			19.0		
Reservoir	699	18.2			18.2		1
Thornbury	29	2.1	223	15.8	17.8		
Aircraft	172	16.2			16.2		
Parkdale	265	16.2			16.2		
Upper Ferntree Gully	149	14.7			14.7		
Lalor	262	14.3			14.3		
Edithvale	190	13.9			13.9		1
Hallam	358	13.8			13.8		1
Thomastown	346	13.7			13.7		
Altona	129	13.4			13.4		
Ginifer	321	13.2			13.2	1	
Upfield	131	12.6			12.6		
Berwick	370	11.2			11.2		1
Kensington	185	11.2			11.2		
St Albans	671	11.2			11.2	1	
Westgarth	95	10.2			11.1		
Bentleigh	304	10.4			10.4	1	
Ormond	279	10.4			10.4	1	
Glenhuntly			371	10.3	10.3		
Heatherdale	185	10.3			10.3		1
Hughesdale	176	10.1			10.1	1	
Rosanna	188	10.1			10.1		1
Ivanhoe	310	10.0			10.0		
Sandringham	205	9.6			9.6		
Highett	166	9.6			9.6		
Yarraville	284	9.6			9.6		
Eltham	249	9.4			9.4		
Regent	141	8.8			8.8		
Carnegie	246	8.6			8.6	1	
Gowrie	63	8.5			8.5		
Cheltenham	293	8.3			8.3		1
Moonee Ponds	212	7.4	16	0.6	8.0		
Moreland	23	2.1	59	5.4	7.4		1
Macleod	164	7.4			7.4		
Mordialloc	164	7.3			7.3		
Batman	53	5.6	14	1.5	7.1		
Glenroy	296	7.1			7.1		1
Preston	156	5.9	26	1.0	6.9		
Albion	175	6.9			6.9		
Hampton	104	6.8			6.8		
Lynbrook	67	6.5			6.5		
Pakenham	142	6.3			6.3		
Middle Brighton	119	6.2			6.2		
Chelsea	127	6.2			6.2		
Gardiner			85	6.2	6.2		
Dennis	72	6.0			6.0		
North Brighton	159	5.6			5.6		
Kooyong			57	5.3	5.3		
Northcote	66	5.1	2	0.2	5.3		
Fairfield	117	5.1			5.1		
Mckinnon	64	4.5	7	0.5	5.0	1	
North Williamstown	57	4.7			4.7		1
Noble Park	236	4.7			4.7	1	
Prahran	28	0.7	130	3.2	3.9		
Beaconsfield	33	3.8			3.8		
Brunswick	34	3.8			3.8		
Bell	55	3.7			3.7		1
Bayswater	67	3.7			3.7		1
Seaford	56	3.3			3.3		
Fawkner	18	3.1			3.1		
Murumbeena	85	3.0			3.0	1	
Westona	27	3.0			3.0		
Carrum	49	2.9			2.9		1
Merlynston	36	2.8			2.8		
Anstey	32	2.8			2.8		
Merinda Park	27	2.3			2.3		1
Surrey Hills	48	2.0			2.0		
Mooroolbark	50	1.9			1.9		1
Seaholme	7	1.8			1.8		
Oak Park	20	1.4			1.4		
Clifton Hill	37	1.2			1.2		
Croxton	8	0.9			0.9		
Ringwood East	12	0.8			0.8		
Ripponlea	16	0.7			0.7		
Jewell			5	0.3	0.3		
Tooronga	5	0.3			0.3		
Merri			2	0.2	0.2		

The principle that traffic congestion at level crossings places constraints the frequency of rail services also applies to road-based public transport. There are limits on the reliability and consistency of bus and tram services that can be achieved with level crossings in place. Many transport planners have proposed that increasing the frequency of buses is the most cost-effective way to improve access to public transport across a dispersed metropolitan area like Melbourne. Certainly, this proposition has a lot of merit. Many bus services in Melbourne operate at frequencies of between two and three an hour, shut down in the evenings and are hard to find on weekends. The performance of Melbourne's buses on the basis of passengers per service kilometre is extremely poor by world standards. That infrequent and indirect services play a large part in this has been proven by the success of the 'Smart Bus' lines since their introduction in 2002, notably with routing that largely avoids level crossings. However, it is questionable how reliable five or even 10-minute frequencies could ever be for the majority of services that are routed across the inner, middle and outer suburbs. This is especially true during the peak periods, when boom gates are down at some level crossings for between 30 and 87 minutes between 7.00 and 9.00 am (Josh Gordon 'Busiest boom gates down for two-thirds of morning peak time for commuters', The Age, 7 May 2015)

**Figure 2: PTV Network Development Plan 2012**

Source: PTV 2012

**Figure 17-1: Schematic diagram of the long-term network**



PTV's network development plan (PTV 2012) is a long-term plan to develop Melbourne's rail system. There are three primary objectives: 'untangling' the City Loop so that most lines run through the city centre rather than in and then out again; providing a number of additional lines and line extensions; and allowing for dramatically increased service frequencies. Whatever the merits of this plan, the last of these ambitions will be very difficult to achieve without removing large numbers of level crossings, since boom gates would be down far more frequently than currently and roads would become grid-locked. Such a situation would

make improvements to bus and tram services impossible and lead to further reductions in reliability of current timetables.

### Melbourne's interchange railway stations and level crossings

The limits to on-road public transport imposed by level crossings have a direct impact on the effectiveness of railway stations as transfer nodes in an intermodal network. Of Melbourne's 169 interchange stations, 107, almost two-thirds, have adjacent level crossings. Table 2 collates bus and tram access data for these stations. While all of these stations have passengers accessing rail via bus or tram, in a few cases, the adjacent level crossing is not used by road-based public transport. Such stations have been included because beyond buses and trams, level crossings are also used by pedestrians and cyclists, whose needs for convenient, safe and attractive paths of movement around stations are also important. This is not just because non-motorised transport should predominate in a sustainable, well-integrated station precinct, it is also because all public transport users are fundamentally pedestrians.

**Figure 3: Level crossings and interchange rail stations** (Image: Lucy Pike)

100km Melbourne

Relationship between level crossings and rail stations

an 800m buffer is applied to all level crossings used by bus routes, and the section of rail affected is shown.

800m is based on requirement to allow at least 675m on either side of rail for grade separation

Of the 235 train stations within the UGB, 96 of these are within 800m of a level crossing used by a bus

145km of the rail network is within 800m of level crossing used by a bus



This complex ensemble of relationships between level crossings, stations, intermodal transfers and service frequencies required to enhance network planning efforts provide a way of thinking about the task of level crossing removal from a strategic perspective that goes beyond the local issues of the quality of the interchange itself (Figure 3). The assessment of 'gaps' between desirable facility standards and actual conditions is worthy in its own right (Alford and Wild 2007). However, the patronage data makes it clear that even some of the least well-designed stations are places of high interchange use. Essendon and Huntingdale stations have the highest proportions of access share from bus or tram on the system (see Table 1), yet the station facilities are very much in need of modernisation. A

thorough consideration of the relationships between level crossings, transfer nodes and desirable service frequencies should make the removal of level crossings on Melbourne's rail system part of the strategic planning for network functionality. What is notable about this approach is that because of the spatial relationships related to grade separation and the relative proximity of stations and level crossings, in many parts of Melbourne a series of corridors emerge. This strongly suggests that the place-based focus on grade separation projects and their related station upgrades need to be conceived strategically as corridors. This means thinking about a much wider set of relationships along rail lines and the spaces between stations as much as the stations themselves. In addition, different methods of constructing a grade separation have different implications for the ways that an interchange might work in the future and assessment criteria used to make decisions where and how grade separations should be constructed need to consider this. It is notable that the current list of the 50 level crossing removals planned by the Victorian State Government differs considerably from the high-use intermodal transfer locations (see Table 2, right-hand columns)

## **Interchanges and grade separation assessment criteria**

A simple definition of transfer or 'interchange' is "when people transfer from one mode to another, or between two services of the same mode. In addition, people join or leave the public transport system on foot, by bicycle, motorcycle, and car." (Mayor of London 2002, p. 3). In some places this happens simply because the services or modes are located close to each other ( 'proximity interchanges'), other places have been intentionally designed to foster this behaviour ('formal interchanges') (Mayor of London, p.3). This distinction appears simple, but it is significant because in the second group an emphasis has been placed on the interchange experience from the perspective of those using it. Much has been written about the criteria that are relevant to enhancing interchanges in terms of ensuring that passengers are safe, comfortable, can find their way easily, have direct and short transfer routes and so on. In Australia, less has been made of the potential to enhance the transfer experience in terms of two related aspects: first, the potential for expansion of the station and its intermodal facilities, and second, the inclusion of complementary, non-transport uses within stations. Organisations such as Transport for London and many other advanced mass transit agencies have long included such potential in their assessment criteria, building on a well-established tradition of building stations that are integrated into the urban precincts they serve. Recent scholarship in Australia has begun to promote the idea that stations can and should be multi-functional places where commercial and community uses build a virtuous cycle with the high levels of footfall that transit attracts (Coxon, Burns and Debono 2008; Maher and Skinner 2011; Hale and Miller 2012; Hale 2013; Woodcock and Wollan 2013). This growing literature suggests that rather than stations being opportunities for higher-density residential development, non-residential uses such as retail, commercial, recreational, community and public space are more conducive with realising the benefits of intermodal mass transit (Mees 2014). The more that stations and their immediate precincts become destinations in their own right, the more reason travellers have to choose transit over the private car to get to them.

This approach to stations suggests that two key additional criteria need to be added to the list when assessing grade separations that include station upgrade components. First, it must be asked: what form of grade separation provides the best improvements in local ground-level connectivity for communities on either side of the rail line, beyond the mere fact of creating a roadway free of rail lines? Second, does the grade separation provide the maximum potential for integration of complementary non-transit land uses within and in close proximity to the station? An overview of the six possible forms of grade separation are set out in Table 3 with a summary of the positives and negatives of each one.

**Table 3: Types of grade separation**

GRADE SEPARATION TYPE	POSITIVES	NEGATIVES	COSTS
Pedestrians UNDER	<ul style="list-style-type: none"> <li>• Shortest distance.</li> <li>• Minimal disruption</li> </ul>	<ul style="list-style-type: none"> <li>• Very poor amenity</li> <li>• No access for other PT</li> <li>• No network benefits</li> <li>• Limited development potential</li> <li>• Limited station integration potential with context</li> </ul>	Minimal
Pedestrians OVER	<ul style="list-style-type: none"> <li>• Better amenity than under.</li> <li>• Bridge as wayfinding/place-marker.</li> <li>• Minimal Disruption</li> </ul>	<ul style="list-style-type: none"> <li>• Weather exposure.</li> <li>• No access for other PT</li> <li>• No network benefits</li> <li>• Limited development potential</li> <li>• Limited station integration potential with context</li> </ul>	Low
Road UNDER	<ul style="list-style-type: none"> <li>• May minimise disruption</li> <li>• Access for other PT (only with low gradients)</li> <li>• (Network benefits)</li> </ul>	<ul style="list-style-type: none"> <li>• Poor pedestrian amenity.</li> <li>• Very difficult to activate public realm.</li> <li>• Destroys existing streetscapes.</li> <li>• Limited development potential</li> <li>• Reduces station integration potential with context</li> </ul>	High
Road OVER	<ul style="list-style-type: none"> <li>• Minimises disruption.</li> <li>• Access for other PT (only with low gradients)</li> <li>• (Network benefits)</li> </ul>	<ul style="list-style-type: none"> <li>• Poor amenity for pedestrians.</li> <li>• Very difficult to activate public realm.</li> <li>• Destroys existing streetscapes</li> <li>• Limited development potential</li> <li>• Reduces station integration potential with context</li> </ul>	High
Rail UNDER	<ul style="list-style-type: none"> <li>• Minimises visual impact of station facility.</li> <li>• Level access for other PT</li> <li>• Network benefits</li> <li>• Passenger amenity needs good design.</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum service disruption.</li> <li>• Limited urban precinct connectivity gains</li> <li>• Few development benefits due to cost of decking and bridges.</li> <li>• Visual impact of trenching on passenger experience</li> <li>• Limits station integration potential on most sites</li> </ul>	Highest
Rail OVER	<ul style="list-style-type: none"> <li>• Maximum ground level connectivity for PT.</li> <li>• Network benefits</li> <li>• Development opportunities at grade in all markets.</li> <li>• Enhances passenger experience (views)</li> <li>• Limited service disruption</li> <li>• Prominent station as place marker/maker</li> <li>• Sound attenuation – design opportunity (c/f Fwys)</li> </ul>	<ul style="list-style-type: none"> <li>• Visual impact of station facility and elevated tracks – needs good design.</li> <li>• Cultural prejudices about elevated rail (c/f Inner east/south east suburban stations – eg. Glenferrie, etc)</li> <li>• Sound attenuation? International exemplars indicate this technical issue can easily be managed.</li> </ul>	High (60% – 80% of cost of Rail UNDER)

Those grade separations that involve putting the roadway above or below the rail line solve the issue of separating transport flows. However, as the legacy of these kinds of projects makes all too clear, this has been to the significant detriment of pedestrian and cyclist amenity that is very difficult, if not impossible to rectify because of the way the road geometry prevents such over- and under-passes being turned into attractive urban environments that can be activated with suitable land uses. It is possible that such approaches can be visually ameliorated with design treatments, but making them functional as genuine urban environments makes this approach unsuitable for use with stations in suburban environments that are already or are intended to become activity nodes, at whatever scale.

This leaves the primary options for grade separations to lowering or raising the rail line in relation to the road. Both achieve the functional aspects of transport flow separation and allow road-based mass transit modes to be ideally located at the station entry. However, 'rail under' in most suburban locations means a trench (see Figure 4) rather than a tunnel, the latter being far too costly for all but central city and other very high value locations. On flat terrain, the overall length of the trench is likely to be of the order of 400-600m either side of former level crossing, a total of up to 1.4km including a station, all lined with anti-suicide fencing. This situation creates little potential for improving the connectivity between the communities on either side of the railway line beyond the roadway itself. The maximum area of connectivity that could be made available at ground level would be via decking over the station area (since the trench either side cannot be decked over because of the rising tracks requiring clearance), but this is prohibitively expensive as a way to create public open space.

**Figure 4: Rail under road grade separation at Mitcham Station, Melbourne** (Photo: Ian Woodcock, 2014)

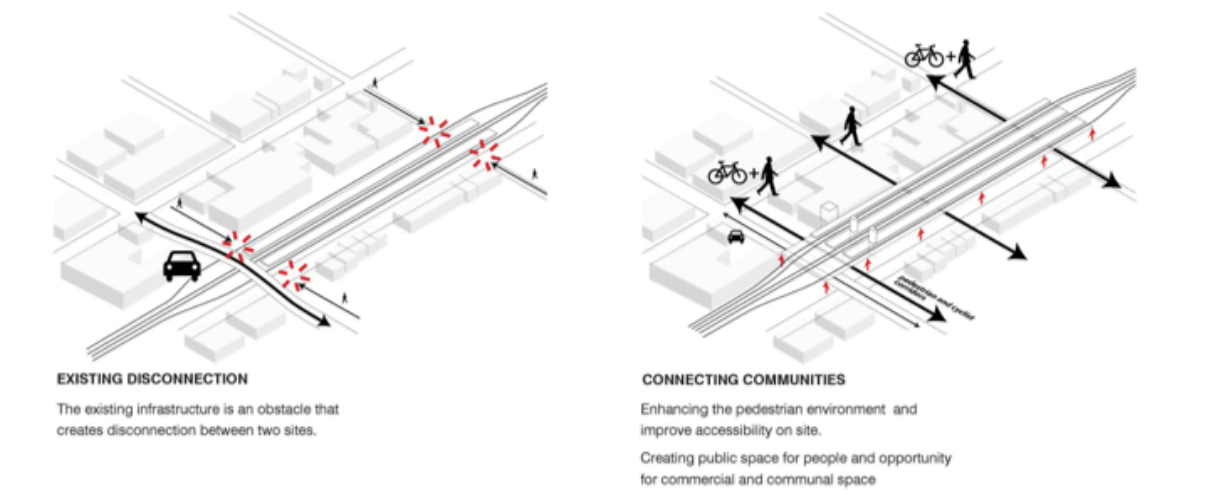


**Figure 5: Rail over road grade separation at Glenferrie Station, Melbourne** (Photo: Ian Woodcock, 2014)



In addition, land values in most suburbs are too low to enable development to be economically viable on such decking. In contrast, 'Rail over road' grade separations release the land formerly occupied by the rail tracks, with most of it being potentially usable except that at either end of the ramps where the headroom is too low. This land not only maximises the potential for ground-level connectivity between communities either side of the rail line, but it allows for a multitude of land uses at different scales and costs to be developed over time to complement the station facility, enhancing the transfer experience and its utility in the everyday lives of travellers as well as local residents and workers (See Figure 6).

**Figure 6: Rail Over Road grade separation** (Image: Farah Yusof)



## Concluding remarks

Melbourne already has a legacy of 'rail over road' grade separations (See figure 5 for an example) that demonstrate not only how well they can perform transport transfer functions, but also, how complementary land uses can be integrated. Most of these have embankments either side of the station which create severance at ground level, but for grade separations yet to come, road over rail could be carried out with viaducts to ensure the future development potential of the new ground-level space created is realisable. While most suburban stations in Melbourne needing grade separations are unlikely to ever become significant activity centres, the example of Chatswood in Sydney illustrates that 'rail over road' grade separations are no barrier to intensive development where conditions occur to sustain it in the long term.

This paper has been written to articulate some emerging qualitative assessment criteria that should be applied to the huge task of removing level crossings in Melbourne. It demonstrates the importance of this program for improving the performance of genuine intermodal mass transit network in Melbourne and the ability of stations to function as effective commercial and community activity centres, in addition to the currently stated objectives of traffic congestion relief and safety. Further work to gather local and international evidence for the effectiveness of meeting these objectives through 'rail over road' design solutions is continuing

This qualitative work forms the basis for future development of more rigorous quantitative assessment criteria.

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