Australasian Transport Research Forum 2021 Proceedings
8-10 December, Brisbane, Australia
Publication website: http://www.atrf.info

Research paper: The catalytic effects of public transport infrastructure on urban renewal: the case of level crossing removal projects in Melbourne

Abdulrhman M Gbban[1, 3], Md. Kamruzzaman[1], Alexa Delbosc[2], Selby Coxon[1]

[1]Monash Art Design and Architecture, Monash University, Melbourne, Australia

[2]Department of Civil Engineering, Monash University, Melbourne, Australia

[3]Department of Urban & Regional Planning, Faculty of Architecture & Planning, King Abdul-Aziz University, Jeddah, Saudi Arabia

Email for correspondence: abdulrhman.gbban@monash.edu

Abstract

Transportation and land use are closely linked, and therefore, changes in public transport infrastructure can influence the land use and activities of the surrounding area. Understanding these effects enables developers to implement transportation services that are most useful to the local area and residents as part of urban renewal projects. However, the by-product effects of transport infrastructure on other sectors, such as land use, have been minimally researched. This paper aims to present the first empirical insight into the catalytic effects (i.e. impacts on other industries) of improvements to public transport infrastructure on urban development, redevelopment, and regeneration. The study employed a case-control study design method; a total of 13 cases of level crossing removals in Melbourne were selected, along with 13 control sites. Changes in land use patterns were measured between the case and control sites, between 2015 (prior to level crossing removal) and 2020 (at least two years after the removal), using historical Nearmap, complemented by Google Earth, Google Street View, and official land use data. Difference-in-difference (DiD) models were estimated to identify the effects of the level crossing removal on the surrounding built environment. The study found that the case sites experienced a statistically significant increase in commercial land (DiD score = 10.71%), open space (7.67%), and parking (4.95%), at a spatial distance of 100 metres from level crossing removal; however, a decrease in residential land was found at 200 metres (-28.5%), and railroad on the ground (40+%) at all spatial distances. Overall, these changes are expected to improve the quality of life for residents living near the case sites.

1. Introduction

The effects of transport infrastructure have been broadly classified into direct (i.e. activity within the sector, such as job creation), indirect (i.e. impact on the supply chain, such as construction companies), and catalytic (i.e. spin-off effects on other sectors) (Baker et al., 2015). While the direct and indirect effects of transport infrastructures are well established (Forouhar and

Kheyroddin, 2016; Lee, 2008; Mehdipanah et al., 2018), only a few studies have assessed the catalytic effects, particularly concerning public transport infrastructure; hence, this is a fairly uncovered area of research (De Gruyter and Currie, 2016). Catalytic effects of transport infrastructure can be measured in various ways, including changes in land use patterns, construction investments, real estate or rent prices, the image of an area, and community resistance (Legacy and Taylor, 2016).

Regarding the development of desirable land use, Bhattacharjee and Goetz (2015) identified a significant increase in commercial land around the newly implemented rail transit system in Denver, USA, between 2000 and 2010. Likewise, there had been considerable growth of multi-family residential land surrounding the rail transit system, yet this was not found to be statistically significant compared with control sites. However, minimal change in other land use types around the rail system led the authors to conclude that the increase in commercial land could not unequivocally be attributed to the rail transit system; therefore, the positive associations with public transport infrastructure become less clear.

In Bogotá, Colombia, distinct improvements to cycle pathways and an extension to the local Bus Rapid Transit system have been linked to reduced crime in the area (Ravazzoli and Torricelli, 2017). Moreover, these transport upgrades also contributed to the re-population of public spaces in the city, due to the creation of new libraries and parks in the surrounding areas. However, unlike these public and active transport services, Ravazzoli and Torricelli (2017) noted negative catalytic effects of automobile related infrastructure. Urban spaces previously used as sidewalks and public streets for pedestrians or cyclists have now become parking spaces or primarily cater to vehicles, making many cities less “livable” for some residents.

Further negative effects were determined by Lee et al. (2020), who found that the Jubilee Line Extension, a transport-led urban renewal project on the London Underground, had led to the implementation of a mixed-use development project at the station, which had subsequently restricted Tube users’ access to the station. In addition, station users complained that the regenerated public space around the urban renewal project site had become inferior in quality and appearance (Lee et al., 2020).

Certain studies have focused on changes in real estate prices or land value uplift in relation to public transport infrastructure (Nelson, 1992; Liang and Lee, 2019). Although land use represents the most sensitive and significant indicator of the catalytic impacts of transport infrastructure projects (Gospodini, 2005), very few studies have examined catalytic effects on urban development, redevelopment, or regeneration - collectively referred to as transport-led urban renewal in this paper. Again, the findings from these studies are inconclusive. For example, Gospodini (2005) found that the land use patterns before and after the realisation of public transport infrastructure projects remained almost untouched in six out of the 12 investigated European cities (Athens, Lyon, Madrid, Manchester, Tyne and Wear, and Vienna). In an earlier study, Hearle (1964) found that in 297 urban renewal projects covering 102 cities, the mean proportions of land stayed the same for street areas, whilst residential land use reduced, and commercial land use increased. Nevertheless, most of these studies focused on the effects on land use of new public transport infrastructure, and there is a lack of evidence regarding the impact of upgrades to existing public transport infrastructure on land use in the surrounding areas. This deserves investigation as developers should be well-informed of the potential consequences of developing existing transport infrastructure, such as the aforementioned positive and negative impacts, prior to project commencement. Therefore, this paper aims to address this gap in the literature by exploring the impact of the removal of existing rail crossings on surrounding land uses in Melbourne, Australia. It should be noted that land use changes through joint development processes (e.g., in the form of transit oriented development) are not a catalytic effect, because in such a setting, both land use and public transport are jointly developed (Ali et al., 2021).

2. Study context

This study investigated whether an investment in existing public transport infrastructure significantly changes land use patterns; Melbourne's level crossing removal project (LXRP) was used to address this research aim.

The LXRP in Melbourne is viewed as one of the most important public transport infrastructure projects in Australia and is the largest level crossing removal project on a global scale, with a total of 85 level crossings expected to be removed in phases across the city (Wigglesworth and Uber, 1991; Nelson, 1992; Woodcock, 2016; Woodcock and Martin, 2016; Woodcock and Stone, 2016). The selection of the LXRP to study the catalytic effects of public transport infrastructure is justified as the goal of the LXRP is to increase public transport efficiency, improve safety, reduce road congestion, and improve communities' connectivity and accessibility. Furthermore, the project is not adding additional public transport infrastructure; rather, it is upgrading sections of existing track, and in some cases, redeveloping existing stations. The project was initially pledged in 2014, and so far, 47 level crossing projects have been completed.

3. Methodology

Of the 47 completed projects, this study selected 13 sites (Appendix A2) based on their completion being at least two years ago at 2018 , as this time period would enable urban renewal processes to occur and meaningful changes in land use patterns to be measured. For each of the 13 LXRP project sites, one control site was selected (Figure 1) to determine whether the changes in land use patterns had occurred as a result of wider economic effects (due to chance) or if they were caused by the LXRP. The control sites were selected using the following four criteria:

a. The presence of a road-level crossing
b. Are all a similar distance from the central business district (CBD)
c. Have a similar population density at baseline
d. Have a similar diversity of land uses at baseline

Figure 1. The 13 LXRP sites and 13 control sites investigated in this study

The baseline was selected as 2015. The land use patterns of the 13 case sites and 13 control sites at baseline were extracted from historic Nearmap images (spatial resolution: 30cm) and recorded in a geographic information system (GIS) database. If land use patterns were unclear from the Nearmap images (e.g. multistory buildings), this was further checked using Google Street View and administrative data. The procedure was repeated for a follow-up period (2020) (Figure 2). The accuracy of information was further enhanced through a site visit to each of the case/control sites in 2020. Each study site was classified into 11 land use categories following a land use classification scheme (Appendix A1).

The land use data were extracted at four different spatial scales: 100 metres along the railway track, and at a 200 metre, 400 metre, and 800 metre circular buffer from the sites. The 800 metre buffer was selected as the longest impact distance from the site because previous studies have shown that the catalytic effects of public transport infrastructure can be seen at 800 metres (Vale et al., 2018). Note that the effects observed at 100 metres spatial distance were not considered to reflect a catalytic effect, since any differences would have been direct project-related changes (e.g., reduction in railroads on the ground and increase in railroads either above ground and/or underground). Similarly, several land use types were not associated with the project's catalytic effects. Specifically, open space areas and pedestrian/cycling paths were part of the project planning (i.e., these areas were planned together with the level crossing removal; Appendix A2); thus, they were deemed catalytic effects.

A) B)

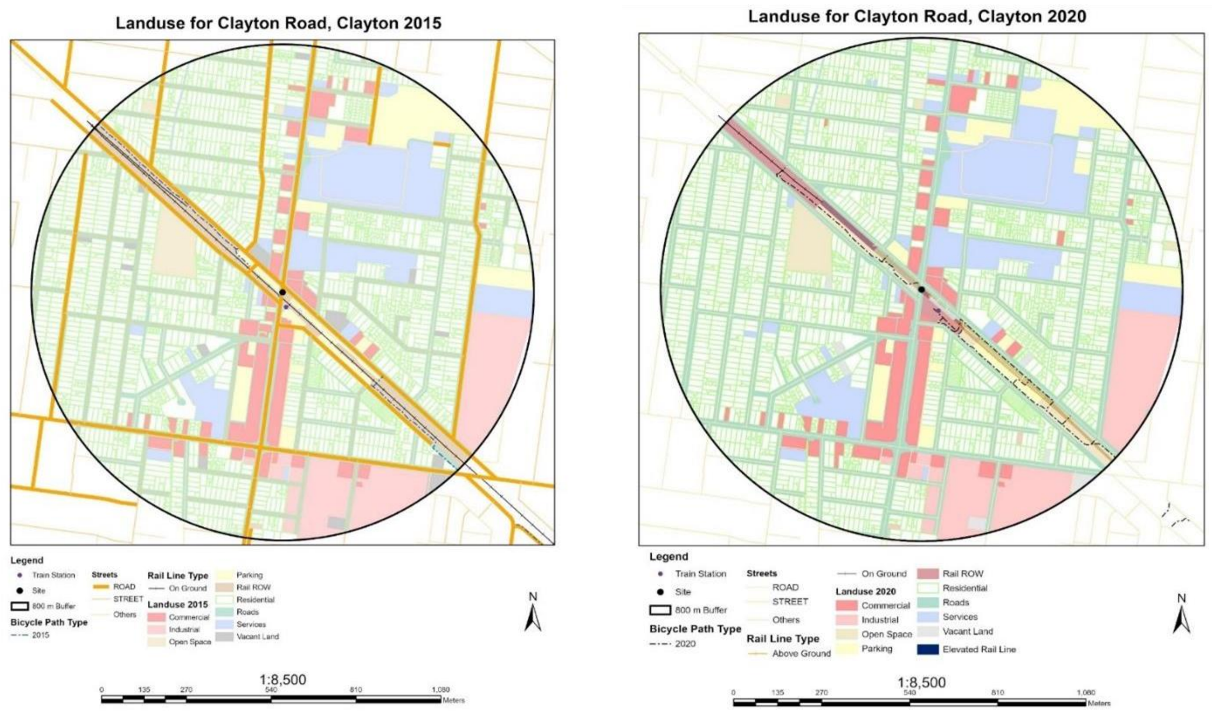

Figure 2. A) Land use classification for Clayton Road in 2015; B) Land use classification for Clayton Road in 2020

3.1 Statistical analysis

Given the case-control nature of the study design with data from two different time periods, a DiD modelling framework was applied to estimate the true catalytic effects of the LXRP. This method is particularly useful in quasi-experimental designs that compare the changes in outcomes over time between different groups. The DiD allows for causal inference even when randomisation is not possible (Fredriksson and Oliveira, 2019; Schwerdt and Woessmann, 2020). This effect is achieved by firstly contrasting the difference between the before- and after-treatment group's outcomes. Such a within-group comparison controls for factors that are constant over time in that group. In the second step, the same procedure is performed in the control group, which was exposed to the same set of environmental conditions as the treatment group, to capture time-varying factors. In the final step, the difference between steps 1 and 2 removes all time-varying factors, allowing us to compute an impact estimation = the DiD. Mathematically, the DiD model took the following form:

$$Y_{it} = \mathrm{A}_s + \mathrm{B}_t + \beta \mathrm{I}_{\mathrm{st}} + \epsilon_{ist}$$

where, A_s represents treatment/control group fixed effects, B_t refers to before/after fixed effects, I_{st} is a dummy equaling 1 for treatment observations in the after period (otherwise it is zero), and ϵ_{ist} is the error term.

All statistical tests were performed in R (4.0.3). To measure the mean changes between 2015-2020, the area values for 2015 were subtracted from those for 2020 and were presented separately for the LXRP and the control group in Tables 1-4. For the purpose of statistical analysis, a 2 (site: LXRP, control) x 2 (time: 2015, 2020) ordinary least squares (OLS) regression was conducted in the lm() function in R. All dependent variables were standardised prior to the analysis to ensure adequacy of interpretation. Specifically, each land type that was measured in hectares (Ha) was represented as a proportion of the total land size. This conversion was performed separately for each distance and site. The bicycle and pedestrian lanes were converted to a proportion of the total area in Ha (i.e., km of lanes per Ha). Finally, the three types of railroads (above the ground, on the ground, and underground) were standardised separately, i.e., these values represented a proportion of the area relative to the total area of railroads. During the analysis, the assumption of homoscedasticity was inspected visually by plotting the studentised residuals (i.e., division of a residual by an estimate of its standard deviation) versus the predicted values. The DiD analysis was performed separately for each distance condition (100, 200, 400, and 800 metres) and for each of the 11 land types.

4. Results

Table 1 shows the analysis of the DiD estimators at the 100 metre spatial scale. An obvious and expected difference was observed in the three variables that are directly linked to the aim of the LXRP: railroads above ground, railroads on the ground, and railroads underground. As seen from the proportion and difference scores, the observed significant DiD scores are driven by the changes specifically at the LXRP sites. These changes were positive for railroads above ground and underground, but reduced for railroads on the ground at the LXRP sites. Additionally, there were significant DiD scores for commercial, open space, and parking areas. In all of these cases, there was an increase in proportion at the LXRP, but not for the control sites. However, the greatest change was a decrease in the proportion of residential land for the LXRP sites, but this did not reach significance and was only marginal ($p < 0.1$).

Table 1. The proportion (%) of different land uses present in the LXRP and control sites (and the corresponding difference scores between years 2020 and 2015) at the 100 metre spatial scale

Land use type	LXRP sites			Control sites			
	2015	2020	Difference	2015	2020	Difference	DID
Rail above ground	1.00	42.00	41.00	0.00	9.20	9.20	31.80*
Rail on the ground	99.00	31.00	-68.00	100.00	90.70	-9.30	-58.70***
Rail underground	0.00	26.00	26.00	0.00	0.00	0.00	26.00**
Pedestrian/cycling	3.03	4.67	1.64	3.53	2.44	-1.09	2.70

Parking	6.79	11.82	5.03	6.75	6.84	0.08	4.90*
Commercial	9.53	20.66	11.14	11.02	11.45	0.43	10.70*
Industrial	4.91	3.41	-1,50	15.40	15.64	0.24	-1.70
Residential	63.15	42.07	-21.08	56.17	55.39	-0.79	-20.30'.'
Service	4.70	5.59	0.89	5.17	5.69	0.52	0.40
Open Space	8.29	15.94	7.64	3.77	3.75	-0.02	7.70*
Vacant	2.62	0.51	-2.12	1.71	1.26	-0.46	-1.70

Note. The proportions were computed separately for three groups of land uses: for all railroads. pedestrian and cycling paths, and the remaining land use types. *** significant at the 0.001 level, ** significant at the 0.01 level, * significant at the 0.05 level, "." strong numerical trend at $p < 0.1$ level.

Table 2 shows a similar analysis at the 200 metre spatial scale. There were significant DiD scores for railroads above ground, railroads on the ground, and railroads underground. Again, these scores increased for the LXRP group for the railroads above ground and underground but reduced for the railroads on the ground. Also, consistently with Table 1, there was a reduction in DID scores for residential land.

Table 2. The proportion (%) of different land uses present in the LXRP and control sites (and the corresponding difference scores between years 2020 and 2015) at the 200 metre spatial scale

Land use type	**LXRP sites**			**Control sites**			
	2015	2020	Difference	2015	2020	Difference	DID
Rail above ground	0.00	44.50	44.50	0.00	10.00	10.00	34.50*
Rail on the ground	100.00	8.20	-91.80	100.00	90.00	-10.00	-82.00***
Rail underground	0.00	47.30	47.30	0.00	0.00	0.00	47.00***
Pedestrian/cycling	5.12	5.04	-0.08	0.00	0.00	-0.00	-0.10
Parking	9.35	9.69	0.33	6.84	6.27	-0.57	0.90
Commercial	24.87	40.24	15.37	19.23	19.87	0.64	14.70
Industrial	2.59	1.39	-1.20	10.42	10.43	0.01	-1.20
Residential	50.35	21.26	-29.09	35.03	34.40	-0.63	-28.50*
Service	5.40	7.74	2.35	3.73	4.50	0.77	1.60
Open Space	6.30	19.27	12.98	23.95	23.96	0.01	13.00
Vacant	1.14	0.41	-0.73	0.81	0.58	-0.23	-0.50

Note. The proportions were computed separately for three groups of land uses: for all railroads, pedestrian and cycling paths, and the remaining land use types. *** significant at the 0.001 level, ** significant at the 0.01 level, * significant at the 0.05 level, "." strong numerical trend at $p < 0.1$ level.

Table 3 shows the results for the 400 metre distance condition. The only significant DiD values were found for parking (i.e., the values increased in the LXRP relative to control sites) and pedestrian and cycling lanes (i.e., LXRP resulted in fewer lanes). No other effects reached significance.

Table 3. The proportion of different land uses present in the LXRP and control sites (and the corresponding difference scores between years 2020 and 2015) at the 400 metre spatial scale

Land use type	LXRP sites			Control sites			
	2015	2020	Difference	2015	2020	Difference	DID
Rail above ground	13.20	46.15	32.95	0.00	20.00	20.00	13.00
Rail on the ground	64.60	0.00	-64.60	100.00	80.00	-20.00	-44.60
Rail underground	22.20	53.80	31.60	0.00	0.00	0.00	31.60
Pedestrian/cycling	1.59	0.00	-1.59	0.00	0.00	-0.00	-1.60***
Parking	4.49	7.92	3.43	3.40	0.00	-3.40	6.80***
Commercial	11.89	21.55	9.67	13.70	16.50	2.80	6.90
Industrial	1.45	1.07	-0.39	11.17	8.44	-2.73	2.30
Residential	67.95	50.58	-17.36	57.02	60.82	3.80	-21.20'.'
Service	5.75	6.38	0.63	5.13	4.25	-0.88	1.50
Open Space	7.17	12.00	4.84	8.88	9.99	1.11	3.70
Vacant	1.31	0.50	-0.82	0.70	0.00	-0.70	-0.10

Note. The proportions **(%)** were computed separately for three groups of land uses: for all railroads, pedestrian and cycling paths, and the remaining land use types. *** significant at the 0.001 level, ** significant at the 0.01 level, * significant at the 0.05 level, "." strong numerical trend at $p < 0.1$ level.

In Table 4, significant DiD scores are shown for railroads above ground, railroads on the ground, and railroads underground for the 800 metre condition. As previously seen, these scores increased for the LXRP group for the railroads above ground and underground but significantly reduced for the railroads on the ground. There were also significant increases in the DiD scores for commercial areas, as well as the total distance of pedestrian and cycling lanes.

Table 4. The proportion (%) of different land uses present in the LXRP and control sites (and the corresponding difference scores between years 2020 and 2015) at the 800 metre spatial scale

Land use type	LXRP sites			Control sites			
	2015	2020	Difference	2015	2020	Difference	DID
Rail above ground	0.70	34.10	33.40	0.00	0.00	0.00	33.00**
Rail on the ground	99.30	37.75	-61.55	100.00	100.00	0.00	-62.00***
Rail underground	0.00	28.15	28.15	0.00	0.00	0.00	28.00**
Pedestrian/cycling	0.48	1.66	1.18	0.46	0.63	0.18	1.00***
Parking	1.91	3.34	1.42	2.12	2.19	0.07	1.40
Commercial	4.53	13.84	9.31	11.07	11.31	0.24	9.10*
Industrial	3.75	3.65	-0.11	12.36	12.37	0.01	-0.10
Residential	74.18	61.60	-12.58	49.96	49.55	-0.42	-12.20
Service	5.80	6.43	0.63	6.40	6.56	0.16	0.50
Open Space	8.46	10.50	2.03	17.28	17.18	-0.10	2.10
Vacant	1.35	0.65	-0.71	0.81	0.85	0.04	-0.70

Note. The proportions were computed separately for three groups of land uses: for all railroads, pedestrian and cycling paths, and the remaining land use types. *** significant at the 0.001 level, ** significant at the 0.01 level, * significant at the 0.05 level, "." strong numerical trend at $p < 0.1$ level.

5. Discussion

As an expected, direct outcome of the project, the LXRP sites showed a significant reduction in railroads on the ground relative to the control sites. Furthermore, the results confirmed an LXRP project-related increase in the distance of railroads above the ground and underground; this was found at 100, 200, and 800 metre distances. The analyses also revealed increases in pedestrian and cycling lanes at 800 metres. Identifying the changes in the physical characteristics of an area is important as these spatial qualities are determining factors in the use of the space by the public for social interactions and physical activity.

Another observation was the increase of open space areas at LXRP sites, which was significant at 100 metres. Open space includes green spaces, such as grass, trees, or other vegetation, as well as schoolyards and playgrounds. Essentially, this urban renewal project appears to have led to the conversion of the free space following the removal of railroads on the ground into these types of open spaces. This is a positive finding, as a study by Durand et al. (2011) found that an increase in natural space results in increased physical activity of the residents in the surrounding areas, which would help to improve the overall health and well-being of the community. This idea has been further corroborated by another study whereby it was found that urban renewal resulted in increased time spent in the area and increased physical activity in a sample of adolescent residents, due to the enhanced public space (Anderson et al., 2017). However, the finding in the current study conflicts that of Bakir (2019), who found that gardens, parks, and open spaces had undergone destruction following urban renewal projects in Kayseri, Turkey. A possible explanation for this is the vague reference to urban renewal projects used by Bakir (2019), which could entail an array of renewal projects, and not just transport-led schemes. Additionally, the development of open spaces, public plazas, and parks was also planned as part of the LXRP (Appendix A2). Therefore, such a change was expected and was not catalytic in nature. Additionally, the current analysis revealed that there was minimal change in the area of vacant land at LXRP sites relative to control sites. However, there was a slight reduction in vacant land at the 800 metre distance at the LXRP sites compared with the control. This implies that free land following the LXRP project was immediately allocated to other land use purposes and was not kept vacant at LXRP sites at the 800 metre distance.

At 200 metres, a large reduction in the proportion of area used for residential purposes was identified (-28.5%). However, since this analysis concentrated on relative proportions, such a reduction does not imply a decrease in the number of houses and apartment buildings in absolute terms. Instead, other land use types increased their share in the total land area at LXRP sites. The results show these to be open spaces (+13%) and commercial areas (+14.7). Such a pattern of changes is somewhat expected, given that the corresponding areas were analysed only 1-4 years post-level crossing removal (Appendix A2), as this may not have been sufficient time for a) the residential area to decrease by 28%, and b) for more complex land use types to increase (e.g., industrial).

Another significant change was the increase in the area of land used for commercial purposes at LXRP sites at the 100 and 800 metre distances. Commercial areas refer to retail premises (single occupancy/single title/single stratum), office premises, multi-level office buildings, health clinics, automatic teller machines, commercial development sites, hotel-gaming, national company restaurants, commercial land (including buildings which add no value), veterinary clinics, mixed-use occupation, pub/tavern/hotel/licensed club/restaurant/licensed restaurant/nightclub, residential hotel/motel/apartment hotel, or complex. An increase in these areas suggests that the free land following the LXRP project was used to improve commercial availability for local residents around the targeted train stations, which in turn could improve quality of life. This is corroborated by Lee et al. (2020), who although identified certain negative consequences of the Jubilee Line Extension, also identified positive land use changes around the involved stations, such as increased public services and accessibility within the region. Lee et al. (2020) stated that this had improved the socio-economic status of the areas around the stations, and therefore, had somewhat advantaged the local population, as similarly suggested by the results of this study. It should be acknowledged that the free land identified in the present study was not used to create new housing or residential areas, since the area of land used for residential purposes showed only marginal effects in three of the four distances from the sites, and in fact, there was a significant reduction at 200 metres. However, there was a consistent increase in the area around the sites used for parking purposes at 100 metres; this mirrors Ravazzoli and Torricelli’s (2017) finding regarding the conversion of urban spaces into parking spaces to accommodate motorists. The amount of land used for industrial purposes remained constant between the two groups. This somewhat opposes the finding by Lee et al. (2020), whereby the increased commercialisation as a result of the transport-led renewal project had further contributed to major transformations within the area, which had benefitted the community.

Interestingly, whilst most of the distances around the sites showed the same results for land use, a slight impact of distance from sites was found on pedestrian and cycling routes at 800 metres. This contradicts research by Hurst and West (2014), who investigated the effect of the transport-led urban renewal project of the METRO Blue Line on land use in Minneapolis, USA, over a six-year period. Hurst and West (2014) concluded that proximity to the Blue Line had not affected land use change compared with pre-construction. However, Hurst and West (2014) used proximities within 0.5 miles and outside 0.5 miles of the operational stations involved in the construction of the Blue Line. This is considerably larger than the distances used in the present study, excluding the 800 metres, and therefore could account for the findings of certain land use changes at lesser distances in this research.

Nonetheless, this study was limited by its inability to measure the intensity or density of development; for example, whilst the area of residential land may not have changed significantly or only showed a numerical trend at 100, 400 and 800 metres, this does not account for the potential increase in the height of residential properties, such as multistorey apartments. This is important as it contributes to a greater increase in the number of residents in the area. Therefore, measuring the heights, as well as area, of land use patterns could be incorporated into future research to attain a more accurate insight into developmental changes following upgrades to existing public transport infrastructure. The claims regarding the catalytic nature of changes in land use as a result of the LXRP are also limited because the changes in the vicinity of the project stations (i.e., within 100 metres), as well as land use areas that were planned as part of the project (open spaces, pedestrian/cycling paths), represent a direct project-related effect, not a catalytic effect. Therefore, future work should attempt to more finely differentiate between these two sources of changes. For instance, control sites that were specifically planned to introduce changes in open areas and pedestrian/cycling paths could be used in a future study.

Finally, the current work measured the impact of the LXRP project at variable time intervals since site completion (2-4 years); this may have limited the observation of significant differences, since changes in certain types of land use may take longer than the time range studied. Based on previous literature, it is conceivable that the planning and preparation of changes, even at relatively small sites, can be a lengthy process. For example, Hurst and West (2014) examined land use changes six years after the construction project ended, while other studies conducted their analysis of land use changes over 10-20+ years (for an overview, see Kasraian et al., 2016).

6. Conclusion

Overall, the LXRP resulted in more open spaces, parking, and commercial land, while the relative proportion of residential areas showed a pattern of reduction. In addition, the LXRP achieved an increase in pedestrian and cycling lanes to replace railroads on the ground. These changes are expected to enhance the living environment for residents around the case sites. Whilst some of these results conflict with previous studies, there is strong support for many of the determined outcomes, especially the increased open, public spaces, and public services. Therefore, these findings provide a solid basis to continue exploring the impact of transport-led urban renewal projects on the built environment.

References

Ali, L., Nawaz, A., Iqbal, S., Aamir Basheer, M., Hameed, J., Albasher, G., Shah, S. A. R., Bai, Y. 2021. "Dynamics of transit oriented development, role of greenhouse gases and urban environment: A study for management and policy". *Sustainability*. 13, 2536.

Anderson, H. B., Christiansen, L. B., Klinker, C. D., Ersbøll, A. K., Troelsen, J., Kerr, J., and Schipperijn, J. 2017. "Increases in use and activity due to urban renewal: Effect of a natural experiment". *American Journal of Preventive Medicine.* 53 (3), 81-87.

Baker, D., Merkert, R., and Kamruzzaman, M. 2015. "Regional aviation and economic growth: cointegration and causality analysis in Australia". *Journal of Transport Geography*. 43, 140-150.

Bakir, N, Y. 2019. "Project-based urban renewal and transformation of urban landscape in Turkey". *Landscape Reclamation - Rising From What's Left; IntechOpen.* DOI: 10.5772/intechopen.84391

De Gruyter, C., and Currie, G. 2016. "Rail-road crossing impacts: an international synthesis". *Transport Reviews.* 36 (6), 793-815

Durand, C. P., Andalib, M., Dunton, G. F., Wolch, J., and Pentz., M. A. 2011. "A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning". *Journal of the International Association for the Study of Obesity.* 12, 173-182.

Forouhar, A., and Kheyroddin, R. 2016. "The impact of commercialisation on the spatial quality of residential neighbourhoods: Evidence from Nasr neighbourhood of Tehran". *Geographical Planning of Space Quarterly Journal*. 6 (20): 63–84.

Fredriksson, A., and Oliveira, G. M. D. (2019). Impact evaluation using Difference-in-Differences. RAUSP Management Journal, 54, 519-532.

Gospodini, A. 2005. "Urban development, redevelopment and regeneration encouraged by transport infrastructure projects: The case study of 12 European cities". *European Planning Studies*. 13, 1083-1111.

Hearle, E. F. R. 1964. *The impact of urban renewal on land-use*. Santa Monica, CA: RAND Corporation.

Hurst, N. B., and West, S. E. 2014. "Public transit and urban redevelopment: The effect of light rail transit on land use in Minneapolis, Minnesota". *Regional Science and Urban Economics.* 46 (2014), 57-72.

Lee, J. 2008. "Riad fever: heritage tourism, urban renewal and the médina property boom in old cities of Morocco". *E-review of Tourism Research*. 6 (4), 66-78.

Lee, J., Arts, J., Vanclay, F., and Ward, J. 2020. "Examining the social outcomes from urban transport infrastructure: Long-term consequences of spatial changes and varied interests at multiple levels". *Sustainability.* 12 (15), 5907.

Legacy, C., and Taylor, E. 2016. Resisting regeneration: Community opposition and the politicisation of transport-led regeneration in Australian cities, Urban Regeneration in Australia: Policies, Processes and Projects of Contemporary Urban Change, pp. 333-352.

Liang, C-M, and Lee, C-C. 2019. “Impacts of urban renewal on neighborhood housing prices: Predicting response to psychological effects”. *Journal of Housing and the Built Environment,* 35, 191-213.

Mehdipanah, R., Marra, G., Melis, G., and Gelormino, E. 2018. “Urban renewal, gentrification and health equity: a realist perspective”. *European Journal of Public Health* 28 (2), 243-248.

Nelson, A. C. 1992. “Effects of elevated heavy-rail transit stations on house prices with respect to neighbourhood income”. *Transportation Research Record*, (1359).

Ravazzoli, E., and Torricelli, G. P. 2017. “Urban mobility and public space. A challenge for the sustainable liveable city of the future”. *The Journal of Public Space*, 2 (2), 37-50

Schwerdt, G., and Woessmann, L. 2020. “Empirical methods in the economics of education”. *The Economics of Education*. 3-20.

Vale, D. S., Viana, C. M., and Pereira, M. 2018. “The extended node-place model at the local scale: Evaluating the integration of land use and transport for Lisbon's subway network”. *Journal of Transport Geography*, 69, 282-293.

Wigglesworth, E. and Uber, C. 1991. “An evaluation of the railway level crossing boom barrier program in Victoria, Australia”. *Journal of Safety Research*, 22(3), pp.133-140.

Woodcock, I. 2016. “The design speculation and action research assemblage: 'Transit for All' and the transformation of Melbourne's passenger rail system”. *Australian Planner*, 53(1), 15-27.

Woodcock, I., and Martin, S. 2016. “Of skyrails and skytrains - elevated rail in the Australasian urban transport environment”. Presented at the *38th Australasian Transport Research Forum (ATRF),* Melbourne, Victoria, Australia, November 2016.

Woodcock, I., and Stone, J. 2016. “The benefits of level crossing removals: Lessons from Melbourne's historical experience”. The University of Melbourne.

Appendix

A1. Land use classification framework

Main category	**Sub-category**
Commercial	Retail premises (single occupancy/single title/single stratum)
	Office premises
	Multi-level office building
	Health clinic
	Automatic teller machine
	Commercial development site
	Hotel-gaming
	National company restaurant
	Commercial land (including buildings which add no value)
	Veterinary clinic
	Mixed-use occupation
	Pub/tavern/hotel/licensed club/restaurant/licensed restaurant/nightclub
	Residential hotel/motel/apartment hotel complex
Residential	Vacant residential home site/surveyed lot
	Detached home
	Single strata unit/villa unit/townhouse
	Residential land (including buildings which add no value)
	Individual flat
	Residential investment flats
	Disability housing
	House and flat/studio
	Boarding house/private hotel/dormitory accommodation
	Strata unit or flat

	Unclassified private land
Main category	**Sub-category**
Industrial	General purpose warehouse General purpose factory Industrial land (including buildings which add no value) Industrial development site
Open space	Parks and gardens (local) Protected landscape - Public Reserved land
Parking	Parking
Pedestrian and cycling lanes	Pedestrian and cycling lanes
Railroad above ground	Railroad above ground
Railroad on the ground	Railroad on the ground
Railroad underground	Railroad underground
Service	Unspecified - transport, storage, utilities and communication Water - urban distribution network Electricity distribution/reticulation lines Daycare centre for children School primary - public/private Special needs school Church, temple, synagogue, etc. Early childhood development centre - kindergarten Cultural heritage centre (local) Indoor sports facilities
Vacant	Vacant land
Roads	VOID

A2. All LXRP stations/sites analysed in the current study

Station name	LXRP name	Removal date	Facilities
Gardiner Railway Station	Burke Road, Glen Iris	2016	The project included the consolidation of tram stops near the station on Burke Road and the addition of new walking and cycling paths nearby.
St. Albans Railway Station	Main Road, St Albans	2016	Walking and cycling paths were built, running parallel to the rail line.
Reservoir Railway Station	Reservoir level crossing	2018	The project has built a new public plaza and improved shared use paths for pedestrians and cyclists to create new direct connections between Edwardes Street and Broadway.
Bayswater Railway Station	Mountain Highway in Bayswater	2016	The new station precinct includes walking and cycling paths connecting Mountain Highway to Scoresby Road, and connecting to the wider bike path network.
Ginifer Railway Station	Furlong Road, St Albans	2016	Walking and cycling paths were built, running parallel to the rail line.
Hughesdale Railway Station	The Poath Road level crossing	2018	Open space and parks for the community.
Ormond Railway Station	The level crossing at North Road in Ormond	2016	The station is now safer, more user-friendly, and fully accessible, with lifts, ramps. and stairs down to platforms below ground level in the new rail cutting.
Clayton Railway Station	The Clayton Road level crossing	2018	Open space and parks for the community.
Carrum Railway Station	Station Street, Carrum	2018	Created four new community open spaces, and safer connections for drivers, pedestrians, and cyclists, and has reduced the

			number of rats in local streets, producing safer and quieter areas.
Murrumbeena Railway Station	The Murrumbeena Road level crossing	2018	Open space and parks for the community.
Bentleigh Railway Station	The level crossing at Centre Road, Bentleigh	2016	The station is now safer, more user-friendly, and fully accessible, with lifts, ramps, and stairs down to platforms below ground level in the new rail cutting.
McKinnon Railway Station	The level crossing at McKinnon Road	2016	The station is now safer, more user-friendly, and fully accessible, with lifts, ramps, and stairs down to platforms below ground level in the new rail cutting.
Carnegie Railway Station	The Grange Road level crossing	2018	Open space and parks for the community.