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The land use effects of transport infrastructure: Coherence and divergence between subjective and objective assessments

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Abstract

In recent years, several studies have objectively assessed the consequences of upgrading transport infrastructure in terms of changes in land use patterns. However, little is known about whether such objective changes are consistent with the subjective perception in local residents. Thus, it remains unclear whether people living in the vicinity of a major infrastructure project objectively perceive the changes in the built environment/land use. The aim of this paper is to determine whether the subjective perceptions of local residents correlate with objective changes to the land use, using the example of large-scale changes in transport infrastructure. We applied the case study of the Melbourne Level Crossing Removal Project to examine the changes around 13 rail level crossings. Objective changes in land use patterns were measured between 2015 (prior to level crossing removal) and 2020 (at least two years after the removal). Subjective perceptions of the changes were measured using questionnaires completed by residents living in the surrounding areas of project sites. The two measures (objective, subjective) were then compared by means of the Kappa test. The only significant finding in the level of agreement was observed for vacant lots, where the subjective and objective measurements were moderately coherent. Of some concern, no agreement was observed in the measurements of parks and playgrounds, and pedestrian/cycling facilities. Overall, these findings demonstrate that urban planning may need to focus more on the subjective perception of changes in land use among residents.

1. Introduction

Transport infrastructure is a crucial field of policymaking, which requires careful consideration and evaluation of the planned and implemented environmental adjustments. Changes in transport infrastructure can have direct effects (e.g., job creation) and indirect effects (e.g., influence on the supply chains), as well as catalytic effects (i.e., spin-off effects in other sectors; see Baker et al., 2015). The outcome of the changes in transport infrastructure can be measured either objectively, such as the proportion of different land use types (Forouhar & Kheyroddin, 2016; Lee, 2008; Mehdipanah et al., 2018), or subjectively, such as the extent to which people perceive the changes in different land use types (Dewulf et al., 2012; Gebel et al., 2009). These two approaches have been applied separately to understand the effects of transport infrastructure, yet little work measures the level of consistency between the objective and subjective measurements.

Previous studies have demonstrated that objective and subjective perceptions of the urban environment may conflict (Dewulf et al., 2012; Gebel et al., 2009; Macdonald, 2019; McGinn et al., 2007; Xu et al., 2022). One of the most common comparisons is between the subjective and objective measurements of the quality of life, i.e., residents' perception and general satisfaction with their urban living conditions. For instance, McCrea et al. (2006) collected geographical information systems (GIS) data to measure objective parameters that could be indicators of the quality of life in South East Queensland. Subsequently, the authors compared this objective information with the Survey of Quality of Life in South East Queensland, which served as a subjective measure of the same urban living conditions in that area. The results showed that there was a weak and unreliable relationship between the two types of measures.

In general, most studies have reported rather poor agreement between the objective and subjective measures of the city's land use environment (Dewulf et al., 2012; Gebel et al., 2009; von Wirth et al., 2014). Interestingly, the results of these previous works seem to have varied between different sub-groups of residents, with better agreement found in some specific sub-groups. Dewulf et al. (2012) reported stronger agreements in objective and subjective measurements of land use parameters, such as walkability (i.e., availability and quality of pedestrian lanes), among those participants that were physically active, while infrequent walkers tended to overestimate walking time. Furthermore, people who came from objectively low-walkable neighbourhoods underestimated walking times more frequently relative to those in high-walkable neighbourhoods. Similarly, McGinn et al. (2007) found a poor agreement between the subjective perception of neighbourhoods' walking facilities and the objective measures. In other words, adequate perception of the surrounding environment is also dependent on objective environmental factors as well as the personal characteristics of residents.

Although a considerable amount of previous work was dedicated to the evaluation of coherence and divergence between the objective and subjective measures of various land use types (Dewulf et al., 2012; Gebel et al., 2009; von Wirth et al., 2014; Xu et al., 2022), there remains no reliable conclusion about the nature of the association between the two measures. Specifically, while some studies found relatively good or mostly coherent relationships between the objective and subjective measurements (Lee & Talen, 2014; Shatu & Yigitcanlar, 2018; Xu et al., 2022), other studies reported rather poor levels of agreement between these two measurements (McGinn et al., 2007; von Wirth et al., 2014).

Furthermore, although previous works have explored a broad range of urban design factors, such as walkability, safety, complexity, and greenness, it is yet to be determined whether there is coherence in the way local residents view *changes* in different types of land use that might occur over time. In essence, this refers to whether residents can subjectively detect the *changes* occurring in land use due to larger-scale changes in the city's infrastructure. Nonetheless, it is well established that transport infrastructure projects can significantly change the proportion of different land use types; objective, catalytic changes in the urban environment due to changes in the public infrastructure have been explored extensively (Mehdipanah et al., 2018; Vale et al., 2018), as well as residents' opinions about the safety of transport infrastructure (Gössling & McRae, 2022). Yet, there is little evidence of whether objective changes to transport infrastructure are consistent with the subjective perceptions of local residents.

Why is it important that people have an accurate perception of changes in their urban environment? Would it matter how residents perceive their surroundings as long as there are some objective measures of the high-quality infrastructure? It was shown that an adequate perception of the built environment may play a crucial role in the life of local residents (Dewulf et al., 2012; Gebel et al., 2009). For instance, Gebel et al. (2009) showed that overweight people could not adequately assess the walkability of their neighbourhoods. These results were later corroborated by Dewulf et al. (2012), who demonstrated that people were significantly over- or under-estimating their walking times. In other words, it is possible that the objective perception of the neighbourhood as being low-walkable had resulted in lower activity levels among some groups of residents, which could consequently contribute to obesity and other related disorders that are associated with low levels of physical activity. Therefore, the first major goal of the current work was to explore whether objective catalytic changes in land use would be reflected in the subjective perception of changes by local residents. In doing so, the current work aims to understand how local residents perceive the objective changes so that local authorities can potentially adjust their urban policy strategies (see von Wirth et al., 2015).

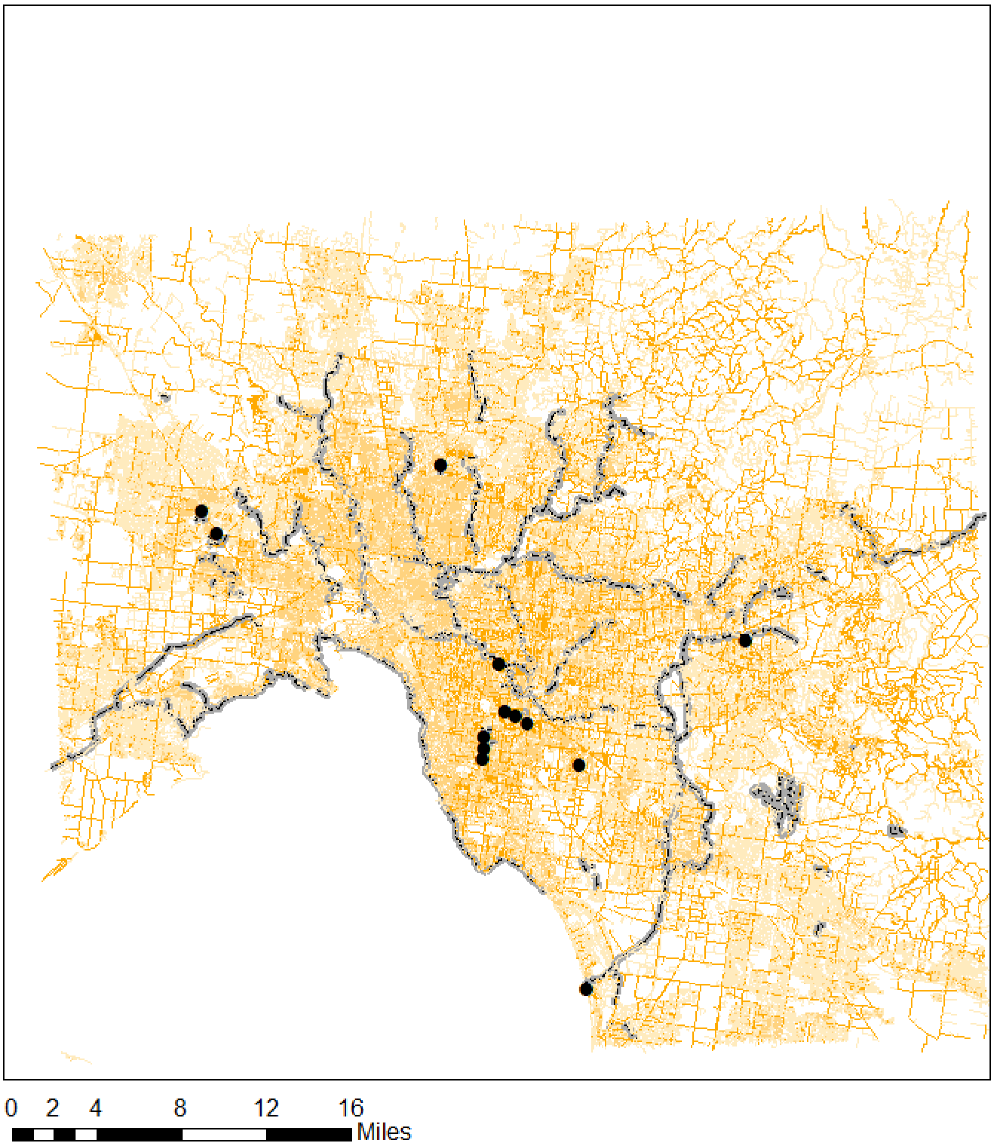
Furthermore, while some studies found relatively good or mostly coherent relationships between the objective and subjective measurements of different kinds of land use (e.g., Lee & Talen, 2014; Shatu & Yigitcanlar, 2018; Xu et al., 2022), other studies have reported rather poor levels of agreement between these two measurements (McGinn et al., 2007; von Wirth et al., 2014). Therefore, the second major goal of the current work was to once again examine whether local residents are able to subjectively notice the objective changes in the environment, using the example of large-scale changes in transport infrastructure.

2. Study context

This study aims to explore the level of agreement between objective evaluation and subjective perception of changes in the built environment (i.e., changes in the proportion of land use types) as a result of modifications to transport infrastructure. To address this research aim, we used Melbourne's Level Crossing Removal Project (LXRP) as the case study.

The LXRP is one of the largest transport infrastructure projects of its kind in the world and is considered one of the most important infrastructure projects in Australia. The project involves the removal of 85 level crossings, which are being removed in phases across the city (Woodcock, 2016; Woodcock & Martin, 2016; Woodcock & Stone, 2016). As a result of the project, it is expected that public transport efficiency will be increased, alongside improved safety, reduced road congestion, and improved connectivity and accessibility among communities. Since 2014, 65 level crossing removal sites have been completed.

Figure 1. The 13 LXRP sites investigated in this study



3. Methodology

Of the completed LXRP sites, this study selected 13 sites (Appendix A2) based on a completion date of 2018 or earlier to allow both the objective urban renewal processes to occur and meaningful changes in land use patterns to be subjectively detected and processed.

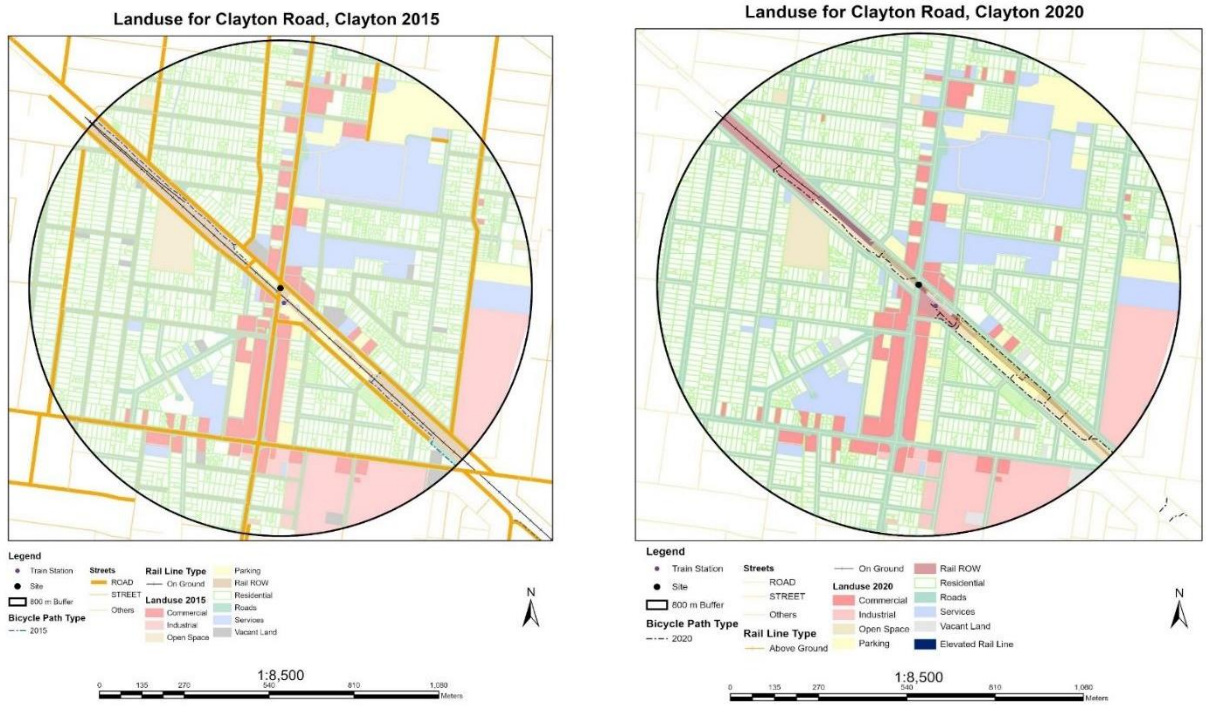
3.1 Objectively measured land-use changes

The year 2015 was set as the baseline. The land-use patterns of the 13 case sites at baseline were extracted from historic Nearmap images (spatial resolution: 30cm) and recorded in a GIS database. If land-use patterns were unclear from the Nearmap images (e.g., multistory buildings), this was checked further using Google Street View and administrative data. The procedure was repeated for a follow-up period of 2020 (Figure 2). The accuracy of information was enhanced through a site visit to each of the case 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 an 800 metre circular buffer from the sites. This buffer was selected as the longest impact distance from the site because previous studies have shown that the effects of transport infrastructure upgrades on land uses can be seen at up to 800 metres (Vale et al., 2018). Note that the proportion of railroads was measured separately from the proportion of all other land use types. Additionally, pedestrian/cycling infrastructure was measured by the length of footpath or bicycle path.

Figure 2. Land use classification for Clayton Road in a) 2015, and b) 2020

a) b)



3.2 Subjectively measured land-use changes

In 2021, residents living in a postcode nearest to the 13 LXRP sites used in the objective assessment were recruited to an online survey (Appendix A3) using a market research panel company. A total of 776 residents participated in the survey, where they reported their subjective perception of changes in different land use types (such as services, parks and playgrounds, and commercial facilities) over the previous three years by rating various statements that described such changes. The rating system comprised a scale from "decreased a lot" to "increased a lot". Some of the questions also required participants to evaluate whether it had become easier or more difficult to access different land use types either on foot or by bicycle. Finally, the respondents also provided some demographic information, including age group, gender, and socio-economic status (Table 1).

Table 1: Demographic data of the survey participants

Variable	Frequency/Average	%	SD
Female (ref: Male)	411	53,03	
Age group:			
18-19 years	17	2,19	
20-24 years	62	8,17	
25-29 years	85	6,13	
30-34 years	106	7,67	
35 years or over	506	39,47	
Motor vehicle availability:			
Yes	690	88,92	
No	80	10,31	
Other	6	0,77	
Driver's license: No (ref: Yes)	58	7,47	
Average household size	3,47		20,01
Average vehicles in household	2,09		8,01
Average bicycles in household	2,37		27,93
Household income:			
0-24,999 $	59	7,6	
25,000 - 49,999 $	116	14,95	
50,000 - 99,999 $	269	34,66	
Over 100,000 $	304	39,18	
Negative income	22	2,84	
Property type:			
Own	529	68,17	
Rent	212	27,32	
Other	35	4,51	
Type of dwelling:			
Flat or apartment	120	15,46	
Separate house	524	67,53	
Row or terrace house/townhouse	126	16,24	
Other	6	0,77	
Education:			
Primary school	4	0,52	
Secondary school	163	21,01	
Technical or further educational institutions	126	16,24	
Trade certification/apprenticenship	62	7,99	
University or other higher educational institutions	411	52,96	
Other	9	1,16	
Did not go to school	1	0,13	

3.3 Statistical methods

Given the study design with data from two different periods, the difference score between the years 2020 and 2015 was calculated to assess the changes in the proportion of land use types at LXRP sites. Subsequently, the data across the 13 sites were median-split to compose two groups: a lower change group and a higher change group.

The participants' survey responses were averaged according to the train station in their neighbourhood. These averaged responses were then also median-split into the groups with higher changes reported and lower changes reported.

For statistical analysis, 2 (objective: low, high changes) x 2 (subjective: low, high changes) Kappa tests (see Gebel et al., 2009; Roda et al., 2016) were conducted separately for each land use type. All statistical tests were performed in R (4.0.3) using the Kappa.test function. The formula for Cohen's kappa was calculated as follows:

$$k = (po - pe) / (1 - pe)$$

where: **po** refers to the relative observed agreement among raters and **pe** is the hypothetical probability of chance agreement. Essentially, the Cohen's Kappa test accounts for the fact that the raters may agree on some items purely by chance.

4. Results

Firstly, we evaluated the proportion of respondents who had noticed changes over the previous three years, as shown in Table 2. A significant proportion of people reported either a moderate increase or a substantial increase across different land use types. For instance, compared to "no changes" and both of the "decrease" responses ("moderately" and "decreased a lot"), there were larger scores for such land use types as houses and apartments (74% of participants reported some degree of increase), shops and restaurants (46%), and pedestrian and cycling facilities (49%). Also, there were a few land use types where more participants responded that they had observed some increase, relative to a decrease, but whose proportion was lower than the "unchanged" category: parks and playgrounds (33%, unchanged=58%), public buildings (31.64%, unchanged=61%), parking facilities (35%, unchanged=48%), and industrial buildings (32%, unchanged=57%).

Table 2: Proportion (%) of local residents' perception of changes over the last three years across different categories of land use

Land use in neighbourhood	Decreased a lot	Decreased by a moderate amount	Unchanged	Increased by a moderate amount	Increased a lot	Not applicable
Houses and apartments ***	1.9	2.9	20.1	38.1	35.7	1.2
Shops and restaurants ***	1.4	15.9	35.2	34.5	11.5	1.2
Parks and playgrounds ***	1.6	5.5	58.2	24.4	8.9	1.2
Public buildings (e.g., schools, kindergartens, libraries) ***	1.2	4.3	61.3	23.6	7.9	1.4
Vacant lots ***	8.7	22.9	37.4	19.8	9.4	1.6
Pedestrian and cyclist facilities (e.g., bicycle path, footpath, seating) ***	0.9	4.1	44.2	34.1	14.4	2.1
Parking facilities ***	2.1	14.2	47.5	24.8	10.1	0.9
Industrial buildings ***	0.7	4.8	56.7	23.6	8.7	5.3

Note: A significant difference in the frequency of responses was observed in all land use types by means of a X2 analysis (*** - $p < 0.001$).

Next, we explored the objective proportional changes of different land use types as measured between 2020 and 2015 (i.e., changes in the proportion of a certain land use type relative to all other land use types). As seen in the "difference" column of Table 3, there were some numerical differences across almost all land use types. The most pronounced positive changes (increases) were observed for the railroads above ground, railroads underground, and commercial buildings. The most pronounced negative changes (decreases) were found for railroads on the ground, as well as for residential land. All other land use types showed either a positive or negative change of < 2%.

Table 3. The proportion of different land uses present at the LXRP infrastructure change project site (and the corresponding difference scores between 2020 and 2015) at the 800 metre spatial scale

Land use type	LXRP sites		Difference
	2015	**2020**	
Rail above ground	0.7	34.1	33.4
Rail on the ground	99.3	37.8	-61.6
Rail underground	0.0	28.2	28.2
Pedestrian/cycling	0.5	1.7	1.2
Parking	1.9	3.3	1.4
Commercial	4.5	13.8	9.3
Industrial	3.8	3.6	-0.1
Residential	74.2	61.6	-12.6
Services	5.8	6.4	0.6
Open space	8.5	10.5	2.0
Vacant	1.4	0.6	-0.7

In the final step, we compared the subjective and objective measurements by means of a Kappa test (Table 4). The results showed that only one specific land use type produced a significant level of agreement: the proportion of vacant lots where the agreement was moderate and significant. Nevertheless, several land use types showed slight to fair agreements with marginally significant results. Specifically, this was the case for shops and restaurants, parking land, houses and apartments, and public buildings.

Table 4. Results of the Kappa tests

Variables	Kappa	% Agreement	p-value	Judgment
Commercial:				
Shops and restaurants	1.36	0.38	0.08	Fair agreement
Industrial:				
Industrial buildings	0.25	0.071	0.39	Slight agreement
Open space:				
Parks and playgrounds	-2.56	-0.72	0.99	No agreement
Parking land:				
Parking lots	1.36	0.38	0.086	Slight agreement
Pedestrian and cycling facilities:				
Pedestrian and cyclist facilities	0.25	0.071	0.39	Slight agreement
Facilities for pedestrians and cyclists	0.25	0.071	0.39	Slight agreement
Residential:				
Houses and apartments	1.36	0.38	0.086	Fair agreement
Services:				
Public buildings	1.36	0.38	0.086	Fair agreement
Vacant:				
Vacant lots	1.87	0.53	0.03	Moderate agreement

Note: Kappa ≤ 0 indicates no agreement, 0.01–0.20 indicates none to slight, 0.21–0.40 indicates fair, 0.41– 0.60 indicates moderate, 0.61–0.80 indicates substantial, and 0.81–1.00 indicates almost perfect agreement (Cohen, 1960).

5. Discussion

The results of the current work are largely consistent with previous literature that shows little to moderate levels of agreement between objective and subjective perceptions of the surrounding environment (Dewulf et al., 2012; Gebel et al., 2009; Xu et al., 2022). For instance, the current findings align with those of von Wirth et al. (2014) who examined a group of 1,693 residents in Switzerland. The aim of that study was to measure objective and subjective measures of the quality of life in urban areas by assessing such parameters as green spaces, traffic, crime level, and accessibility of different locations. Consistent with the findings in the current work, the authors also reported a low-to-moderate level of agreement between the objective and subjective measures.

It is of particular concern that perceptions of parks/playgrounds and pedestrian/cyclist facilities were so inconsistent between the two measures, given that the LXRP project aims to deliver high-quality parks and active transport facilities. The proportion of land designed for these purposes did, on average, increase; furthermore, on average, half of the residents believed that there was no change or a decrease. Potentially, these land uses are not visited or visible to many local residents, such as those who do not have a bicycle or who do not have pets or children to visit playgrounds. Thus, a considerable proportion of such residents would have underestimated the objective changes.

One land use type that showed a fair and significant amount of agreement between the two measurements was the proportion of vacant land, which decreased slightly on average. It is possible that the removal of level crossings resulted in the obvious and easily observable removal of vacant land around the train stations. Moreover, the change from vacant land to other uses may be more memorable than, for example, a change from housing to commercial land use.

Most of the land use changes resulted only in marginally significant coherence between subjective and objective measures. There are two potential explanations for this finding that are both related to human psychology. On the one hand, it may be related to human perceptual processes, where small and incremental changes over multiple years may not be easily noticeable. On the other hand, it is possible that the changes that occurred in the last three years were initially detected, but the residents may have become familiar to those changes, and so, they were not remembered at the time of the survey.

To assess these possibilities, future studies could examine whether explicit communication of the changes to local residents would result in higher agreement between the observed and objective changes. Future investigations could also explore whether subjective ratings would be more in line with objective changes if measured soon after the changes were implemented, i.e., before participants became habituated to the new environment.

Despite the interesting study findings, certain limitations were identified. Firstly, the number of sites where the changes were examined was limited. Only 13 LXRP sites were examined in this study, which also minimised the statistical power of the analyses. Therefore, as the LXRP project continues, future work should analyse more sites to produce more reliable conclusions. Another limitation of the study concerns the way the changes were measured. Specifically, the GIS analysis solely relied on the proportion of land use changes but was unable to measure the direction the changes may have occurred, such as the height. Hence, it is possible that some of the buildings may have grown in height, which may not have been captured by our objective methods and could have contributed to the relatively weaker association between objective and subjective evaluations. Finally, it was not controlled whether the local residents who participated in the survey lived in the nearest vicinity of the train station (e.g., 100 meters) or further away (e.g., 800 meters). This variance may potentially explain the low-to-moderate objective vs. subjective correspondence observed in the current work and should be taken into account in future studies.

6. Conclusion

To our knowledge, the current work is the first piece of evidence that compares subjective and objective measurements of the *changes* in the surrounding environment relative to the evaluation of existing conditions. While previous studies primarily concentrated on the subjective evaluation of different aspects of urban planning, the primary aim of this work was to measure whether residents had noticed the objective land use changes that had occurred in their neighbourhoods over the previous three years. Our findings demonstrated that although a number of objective changes were detected in land use across LXRP sites, these changes were not subjectively perceived by local residents. Therefore, policy makers should take residents' subjective perception of the positive changes into consideration by explicitly highlighting the presence of certain amenities and facilities in their neighbourhoods.

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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
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
Services	- Unspecified - transport, storage, utilities, and communication - Water - urban distribution network - Electricity distribution/reticulation lines - Daycare centre for children - Primary school - public/private - Special educational 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

A3. Questionnaire

Questionnaire participants will be required to answer the following question topics:

1. Qualifying questions to determine their eligibility for the research, based on inclusion and exclusion criteria
2. Questions related to the physical characteristics of their neighbourhood, such as “How much change have you experienced regarding the physical aspects of your area before and after the LXRP?”
3. Questions related to their daily travel and activities and how these have changed from before and after the LXRP
4. Questions related to their experiences and interactions within their neighbourhood
5. Questions related to their socio-demographic status

The questionnaire can be viewed from the link below:

https://monash.az1.qualtrics.com/jfe/preview/SV_4Mcgm7ICgYa1iaF?Q_CHL=preview&Q_SurveyVersionID=current