Investigating the Effect of Train Proximity on Apartment Prices: Haifa, Israel as a Case Study

Authors

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Abstract

The present study investigates the effect of urban rail on the market prices of residential properties, considering train proximity as both a source of improved access and a local disamenity. For the analysis, 926 housing sales in the city of Haifa, Israel were used. The analysis indicates a relatively narrow buffer zone near train tracks (about 50–100-meters wide) that "absorbs" about 13% of price decline. Beyond this zone, apartment prices rise to their "peaks" at approximately 100–150 meters from the train tracks, and then decline by an average of 0.7% for each additional 100-meter increase in the train line distance.

Urban rail is often the main form of access to jobs and places of entertainment in large cities; in many cases, the train system spurs the establishment of new businesses along the rail lines, and migrants are encouraged to settle down near new commercial and labor areas created nearby (Cervero, 1984).

In real estate studies, the effect of train access on property prices is perceived as twofold. First, according to several empirical studies, property prices are likely to be higher near train stations than elsewhere, due to improved access to business areas, shopping, schools, and entertainment venues (Landis, Cervero, Guhathukurta, Loutzenheiser, and Zhang, 1995; Lewis-Workman and Brod, 1997; and Debrezion, 2006). Second, as indicated by several other studies, there may be a price-dumping effect of train proximity, due to noise pollution and unattractive views (Weinberger, 2001; and Simons and Jaouhari, 2004).

From the real estate perspective, the entire train system may thus be split into two principal components: 1) train stations, which provide access to urban activity foci and connect to other modes of urban transportation, and 2) areas surrounding rail lines (often saturated with dilapidated industrial estates and warehouses), proximity to which is a disamenity for adjacent residential development.

Most studies investigating the influence of urban rail systems on housing property market have been focused mainly on proximity to train stations (see Appendix 1) and generally overlooked the fact that train stations and rail lines may have different effects on residential property values. Only a handful of empirical studies attempted to evaluate separately the effects of train proximity on housing prices in areas adjacent to train stations and to rail lines (e.g., Armstrong, 1994; and Cambridge Systematic, 1999).

The present study attempts to investigate the effects of urban rail on the market prices of adjacent residential properties, considering train proximity as both a source of improved access and a local disamenity. To investigate these effects, data on 926 recent housing sales in the city of Haifa, Israel (approx. 270,000 residents) were used. As the study indicates, proximity to train tracks appears to have stronger effect on apartment prices than proximity to stations. According to the explanation proposed, this outcome may be explained by the fact that in the study area, train stations do not form large transportation and commercial hubs and thus do not serve as obvious "reference points" for either property sellers or buyers. Although the proximity to rail lines appears to have a positive effect on residential property prices overall, the study also detected a relatively narrow (about 50 meters) buffer zone in which housing prices tend to be lower than elsewhere.

The paper starts with a brief outline of previous studies dealing with the effect of urban rail on house prices. It is followed by a brief description of data sources, techniques of the analysis, and the main findings of the research. Topics for future research and applications of the study for appraisal and urban planning practice are introduced in the concluding section of the paper.

Studies of the Effect of Urban Rail on Residential Property Values

The effect of neighborhood amenities and disamenities (such as open spaces, thoroughfares, landscape views, etc.) on residential property values is thoroughly investigated in the real estate literature (e.g., Wang, Grissom, Webb, and Spellman, 1991; Asabere and Huffman, 1996; Chan, Chu, Lentz, and Wang, 1998; Des Rosiers, Thériault, Kestens and Villeneuve, 2002; Ding, Simons, and Baku, 2002; and Portnov, Odish, and Fleishman, 2006). Thus, as Chan et al. (1998) demonstrate, the net impact of a given externality (such as a park, green space or recreational area) on property values depends on the trade-off between the benefits and costs of proximity, and on the socioeconomic characteristics of the neighborhood or residential block in which the property is located. By examining 897 condominium units in the cities of Irvine and Santa Ana in Orange County, California, the authors of the study concluded that, at a micro-level, the impact of proximity of individual housing units to intra-project externalities appears to be highly statistically significant.

Several empirical studies carried out to date attempted to quantify the effect of urban rail and inter-city rail as a function of distance from railway stations, the number of trains per day, the use of horns, and view obstruction (e.g., Hughes and Sirmans, 1992; and Simons and Jaouhari, 2004). Using the hedonic price approach as the main research tool, most of these studies detected a real estate price impact at varying ranges from train stations and/or rail lines (see Appendix 1).

Simons and Jaouhari (2004) examined the impact of freight trains on the prices of residential properties adjacent to rail lines. The study analyzed small apartments that had an average value of approximately $76,000 and detected a 5% to 7% reduction in the value of residential properties within up to 230 meters from the train tracks. However, with larger apartments, the findings of the study were less conclusive. The study also found a positive association between apartment prices and proximity to railway stations. However, this advantage was not related to freight trains, as they do not serve the public directly.

In another study, Hughes and Sirmans (1992) found a 1% decline in apartment prices for each 1,000 trains crossing urban areas annually, and a 0.5% price drop in the suburbs. In particular, residential properties close to rail lines, where the frequency of trains was between 5,000 and 10,000 trains annually, lost, on average, from 5% to 10% of their market value, as compared to residential properties located in more quiet neighborhoods. A similar price drop was also reported by Poon (1978), who found a reduction of 7%–10% in property prices within a 100-meter range from train tracks.

Debrezion (2006) analyzed the impact of railway proximity on house prices in the Netherlands, taking into account distances to railway stations, frequency of railway service, and distances to railway tracks. As he found, dwellings located close to a railway station were on average 25% more expensive than dwellings located at a distance of 15 kilometers or more. A doubling of the train frequency increased house values by about 2.5%, on average, with the price appreciation effect ranging from 3.5% for houses located close to the station to 1.3% for houses located farther away. Wilhelmsson (2000) analyzed the impact of noise pollution caused by urban transportation, including trains, on the market values of houses. He found that a house valued at $750,000 and located near a major road lost about 30% of its potential market value compared to an identical house located farther from the road.

Rapoza (1999) found that train noise affects residential property prices at the distance of up to some 300 meters (1,000 feet) from the train tracks. The greater the use of horns, the greater reduction in house value that was detected.

U.S. Federal Transit Administration (2000) carried out a comprehensive study that assessed approximately 33,000 market transactions. The research showed that from 250 to 500 feet from the train tracks (80–170 meters), the reduction in house value reached approximately 5%. Moreover, when the volume of journeys was added to the assessment (i.e., the number of trains per day), there was a significant correlation between distance and reduction in value.

Landis, Cervero, Guhathukurta, Loutzenheiser, and Zhang (1995) examined the residential price effects of railroad proximity across five California Rail Transit Systems, connecting San Mateo Country to San Francisco and San Jose; Bay Rapid Transit (BART lines) in San Francisco Bay Area, and Light Rail Systems in Sacramento, San Jose, and San Diego. In most cases, no statistically significant nuisance effect was found. Only residential properties adjacent to the CalTrain commuter line (within 300 meters from the rail line) were found to lose approximately \$50,000 of their market value. The authors attributed this effect to a defective design in the train system. A \$197 decrease in property prices was also found for every 100 meters of proximity to the San Jose Light Rail tracks. However, it was concluded that the aforementioned price decrease could also be explained, at least in part, by the proximity of residential properties to other urban disamenities, such as heavy industries and "noisy" commercial uses.

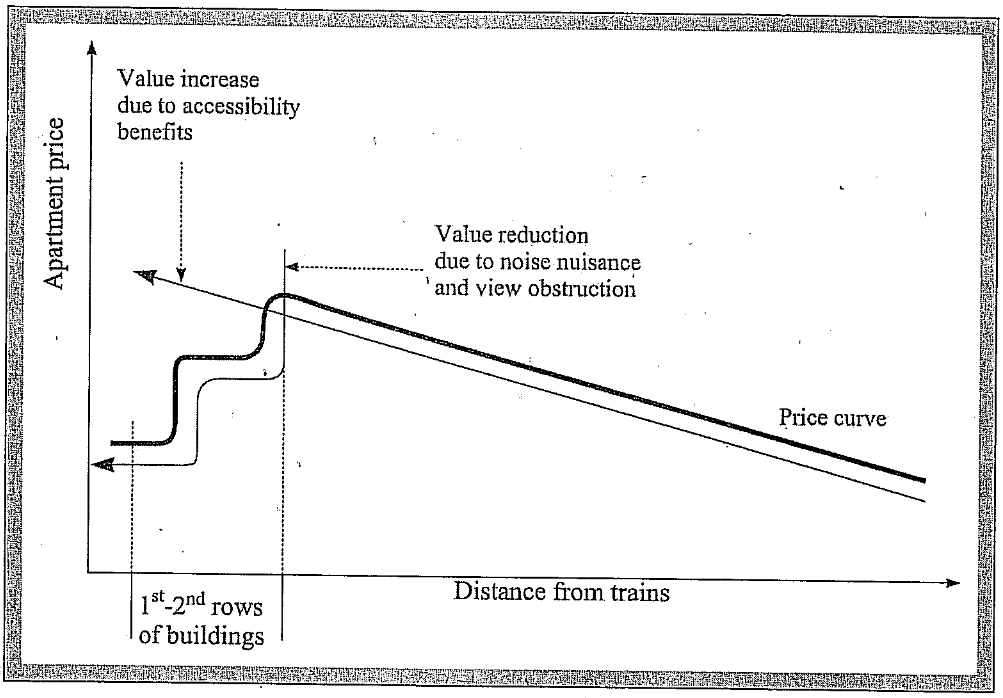
In another study, Knapp, Hopkins, and Pan (1996) noticed that property values within a half mile of the Portland Max Light Rail Transit (LRT) line were lower than in more distant areas, because of the same negative externalities (that is, proximity to industrial areas, unattractive views, and noise pollution).

In a separate study, Armstrong (1994) found a negative effect of proximity to Boston's Fitsburg railroad on single-family residential property prices. Thus, for instance, the average value of a house located within 400 feet from the line was found to be approximately 20% lower than outside this buffer zone. However, the author found it difficult to attribute the above effect to either freight rail or commuter rail that operate simultaneously on the Fitchburg line.

Using a meta-analysis technique, Debrezion, Pels, and Rietveld (2007) investigated the impact of railway stations on residential and commercial property values. As the authors of the survey found, commercial properties located within a quarter mile ring from a railroad station were, on the average, 12.2% more expensive than residential properties. Commuter railway stations were also found to have a consistently higher impact on the property value than light and heavy railway and metro stations.

Most previous studies have analyzed the effects of train tracks' and train stations' proximity in separation. In contrast, the present study considers urban rail as both a source of improved access and a local disamenity and investigates these effects in interrelation. According to our expectations, the effect of train proximity on residential property values should be non-linear. In particular, there should expectedly be a relatively narrow "depression" zone along the train line, which is likely to include the first and, possibly, second row of buildings adjoined to the train tracks (Exhibit 1). A similar "price depreciation" zone was detected by Des Rosiers, Lagana, Thériault, and Beaudoin (1996) and Des Rosiers, Lagana, and Thériault (2001), who used the gamma density function to study several urban features with "dual" effects on property prices, such as shopping centers and primary schools. Beyond this zone, which is likely to "absorb" most of the price decline (attributed to noise nuisance and view obstruction), apartment prices

Exhibit 1 | The Expected Relationship between Train Distance and Apartment Prices

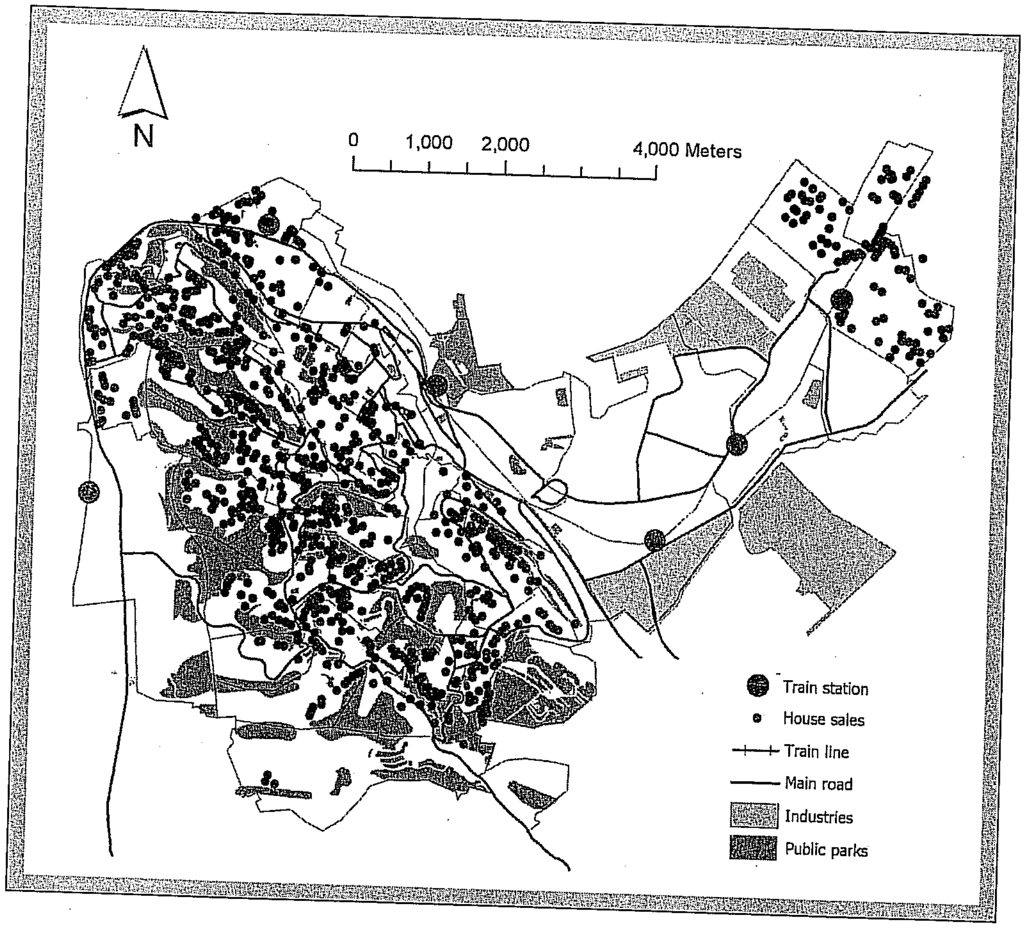


should expectedly "recover" and reach their peaks (all else being equal) beyond the immediate vicinity of the train tracks. Then, apartment prices should expectedly decline due to impeded access to trains (Exhibit 1).

Data Sources and Methods of Analysis

A sample of 926 housing units sold in 1998–2007 in the city of Haifa (270,000 residents, as of 2006) was drawn from the following two sources: the Apartments & Houses' Sales (AHS) Database, maintained by the Israel Tax Authority, and the database on recorded market transactions of residential properties maintained by a local real estate appraiser agency. Both databases report the sale prices of individual residential properties, their street addresses, the date of sale, and several basic physical characteristics of individual properties, such as an apartment's floor area and the number of rooms.[1] Only apartments in multi-story buildings were covered by the analysis, because sales of individual houses in the city of Haifa are infrequent due to their relatively small share in the local housing stock (approximately 5%). All the apartments covered by the study are privately owned. The apartments for the analysis were drawn from the two databases at random, in order to minimize sampling bias, and found to be distributed fairly evenly across the city's neighborhoods (Exhibit 2).

Exhibit 2 | Map of the Study Area



The list of research variables is given in Appendix 2 and their descriptive statistics are reported in Exhibit 3. Some research variables deserve comment.

Proximities to local amenities and disamenities, such as industrial zones, major roads, parks, train stations, etc., are important location characteristics of individual properties. The information on these variables was assembled in two steps. First, all major amenities and disamenities in the city neighborhood were identified by field surveys and mapped as separate layers in the ArcGIS9™ software. Next, aerial distances from each apartment in the sample to the amenities and disamenities were calculated using the 'spatial join' tool. This analytical tool matches rows from different geographic layers to the target layer based on the spatial relationship between them (Minami, 2000).

Since the early 1930s, the city of Haifa and its suburbs have developed into Israel's primary industrial region. The area hosts the country's largest oil refineries (with

Exhibit 3 | Descriptive Characteristics of the Research Variables

Variable	Cases	Min.	Max.	Mean	Std. Dev.	Skewness	Kurtosis
Price (US$1,000)	926	52.00	550.00	149.97	52.21	1.27	4.65
Floor area (m^2)	926	46.00	157.00	104.17	13.71	0.29	1.86
Sale year	926	1998	2007	2005.46	1.39	−1.27	4.20
SO_2 level, mg/m^3	926	4.60	9.90	6.31	0.99	1.30	2.38
Elevation, m	926	5.00	370.00	160.75	107.78	−0.25	−1.35
D_industry, m	926	17.82	4527.72	476.38	547.30	5.51	34.06
D_road, m	926	3.76	1653.78	247.83	278.05	2.25	5.82
D_park, m	926	3.00	6552.56	723.06	1697.75	2.49	4.34
D_train, m	926	21.96	3526.07	1444.19	914.97	0.16	−1.03
D_station, m	926	34.23	4568.03	1949.33	882.11	0.27	−0.24
Train buffer zone (< 50 m)	904/23*	0.00	1.00	0.02	0.15	6.26	37.32
Train buffer zone (50–100 m)	898/27*	0.00	1.00	0.03	0.17	5.50	28.26
Train buffer zone (100–150 m)	896/30*	0.00	1.00	0.03	0.18	5.29	26.05
*Train*road interaction term*	903/23*	0.00	1.00	0.02	0.16	6.12	35.48

Note:
*Number of zero/non-zero values.

the total production capacity of 8 million tons of oil per year), a major oil-fired power plant (about 430 megawatt), as well as several smaller petrochemical and agrochemical facilities. The location of large industrial complexes in the area, its complex hilly topography, and unique sea-land meteorology result in distinctive spatial patterns of air pollution (Yuval, Broday, and Carmel, 2005). Since differences in air pollution levels may influence the willingness to pay for residential accommodations in different parts of the city, they are also likely to affect house prices. In the analysis, SO_2 air pollution levels were therefore included in the analysis as an additional explanatory variable. Air pollution data were obtained from 20 air quality monitoring stations located in the study area. These stations continuously measure and report half-hour SO_2 concentration levels. In the analysis, we used the average annual values of SO_2 recorded in parts per billion (ppb) and transformed into $\mu g/m^3$ by the Department of Civil and Environmental Engineering of the Israel Institute of Technology. At the next stage of the analysis, the average annual values of SO_2 recorded by the monitoring stations were interpolated by kriging (e.g., McCoy and Johnston, 2001), to obtain a continuous SO_2 pollution surface covering the entire study area. The locations of individual apartments were then juxtaposed over this surface, to obtain SO_2 pollution estimates for the locations of individual apartments in the sample.

In a similar manner (i.e., using the 'spatial join' tool), we calculated the elevation of each apartment above the sea level, using the layer of elevation contours provided by the Engineering Department of the Haifa municipality. The "elevation" variable is particularly important in the local context. In the hot and humid climate of the area, the higher the dwelling is above sea level, the higher is the cross-ventilation of indoor spaces, which is especially important during long and hot summers. High elevations also tend to provide better views of open spaces, and other attractive landscape features, such as sea and greenery. Therefore, in Haifa, higher elevations are closely associated with the most expensive housing and, generally, with a high socio-economic status (Portnov, Odish, and Fleishman, 2006). In the absence of more specific data, the elevation variable was considered as a proxy for the welfare levels of local residents.

Distances from individual properties to the local *railway* were estimated separately for the train track and the six train stations located in the study area (Exhibit 2). Splitting the "train" predictor into two separate proximity variables was needed to verify our assumption that proximities to train tracks and train stations may have different effects on property prices.[2] As with other location variables, aerial distances to these features were calculated using the "spatial join" tool in the ArcGIS9™ software.

The analysis also included three additional dichotomous variables, termed the "train buffer zone" dummies. Each of these variables takes on value 1 if a property is located within a given distance range from the train track (either less than 50 meters, 50–100 meters, or 100–150 meters, which corresponds to the first three rows of buildings adjacent to the train tracks), and zero otherwise. The variables are mutually exclusive, which allowed us to introduce them simultaneously in the regression analysis. We also included in the analysis an interaction term of train track and road proximity. The value of this variable was set to 1 if a property was located within 100 meters from *both* rail tracks and a main road, and zero otherwise. As assumed, the close proximity of an apartment to both features might exacerbate their effect on the apartment's value.[3]

It should be noted that the list of the explanatory variables covered by the study is, by no means, exhaustive. Thus, the number of apartments per floor, building age, the presence of a storage shed, balcony, parking lot, etc., and other physical characteristics of properties, may also influence sale prices, but were unavailable in the databases. Despite this limitation, the list of variables covered by the study included a range of essential price-influencing factors, such as the physical size of individual properties, sale year, several essential location characteristics, such as proximities to major amenities and disamenities, local topography (elevation above sea level), and local air pollution levels.

Statistical Analysis

The strength of the association between apartment prices and the explanatory variables (Appendix 2) was investigated using multiple regression analysis (MRA). The ordinary least squares (OLS) model used in the analysis employed the following general equation:

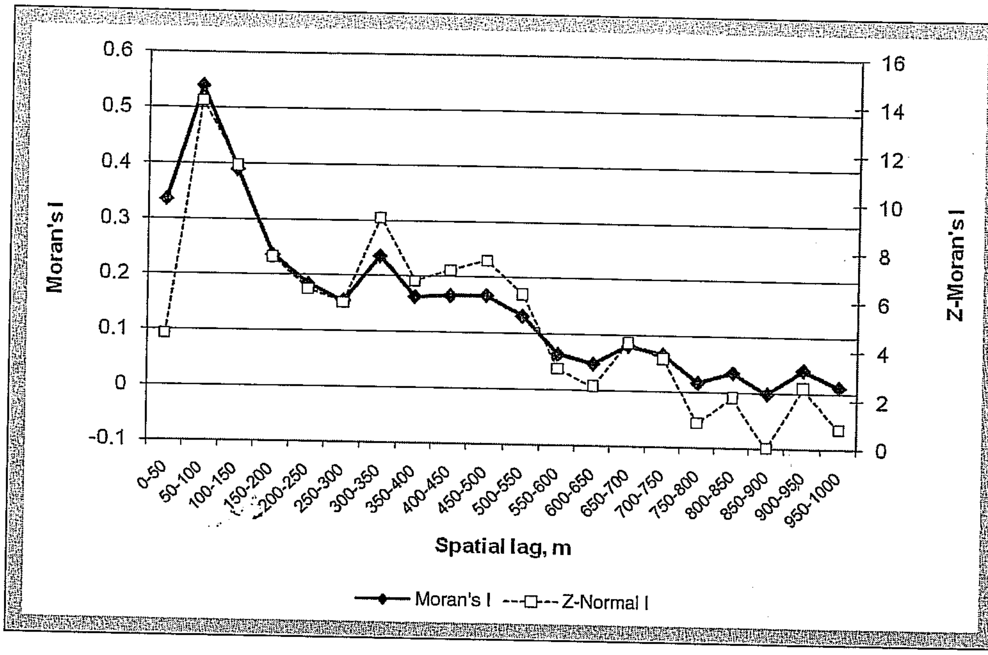
$$P_i = b_0 + b_1{*}A_{1i} + \ldots + b_n{*}A_{ni} + \varepsilon_i, \tag{1}$$

where P_i is the market price of apartment i; n is the number of predictors (property attributes); $b_0,\ldots b_n$ are regression coefficients; $A_1,\ldots A_n$ are the values of predictors; and ε_i is the error in the observed value for the i^{th} case.

The threshold for statistical significance was set to $p < .05$ (two-tailed). The following discussion will be limited to the variables that emerged as statistically significant at this significance level. Several functional forms of models (that is, double linear, log-linear, and mixed models) were tested. In the following discussion, only the best performing models (i.e., with logarithmically transformed apartment price variable and logarithmically transformed access variables) will be reported. In most cases, these models provided the best fit for the data, with their adjusted R^2 being at least 10% higher than for other model types.

Testing the normality of regression residuals by the Kolmogorov-Smirnov (KS) test revealed that their distribution was fairly normal (KS $Z > 1.2$, $p > .10$). Concurrently, the investigation of regression residuals from the OLS models indicated a significant spatial autocorrelation within up to 700–750 meters (Z Moran's $I > 2.4$; $p < .05$; see Exhibit 4 and Appendix 3). With the spatial autocorrelation of regression residuals, the assumption of uncorrelated errors is

Exhibit 4 | Spatial Dependence of OLS Regression Residuals



violated, making regression estimates inefficient (Anselin, 1999). Therefore, the spatial lag (SL) model was used during the second stage of the analysis. The SL model implements a positive diffusion process in which events (e.g., apartment prices) in one place are used to predict a likelihood of similar events in neighboring places and is given to the following equation:

$$P_i = b_0 + \rho^*(\textit{spatially lagged dependent variable } P) + b_1{}^*A_{1i} + \ldots + b_n{}^*A_{ni} + \varepsilon_i, \quad (2)$$

where P is apartment price; A_1, ... A_n are independent variables (property attributes); ρ (*rho*) is spatial autoregressive coefficient; b_0 ... b_n are regression coefficients; and ε is a random error term. GeoDa095i© software was used for the SL.

Research Results and Discussion

The results of OLS and SL modeling are reported in Exhibits 5–8. The OLS model reported in Exhibit 5 includes all the predictors covered by the analysis, apart from railroad and main road dummies. Concurrently, Exhibit 6 reports the

Exhibit 5 | Factors Affecting Apartment Sale Price

Variable	B[a]	t[b]	Tol.[c]
Constant	0.900	2.562**	
Floor area (ln), m^2	0.813	12.765**	0.776
SO_2 *level*, mg / m^3	−0.043	−5.094**	0.819
Elevation, meters	0.002	13.717**	0.222
D_industry (ln), meters	0.037	2.920**	0.780
D_road (ln), meters	0.024	3.383**	0.779
D_park (ln), meters	−0.002	−0.463	0.579
D_track (ln), meters	−0.017	−1.182	0.236
D_station (ln), meters	0.014	0.667	0.375
Year Dummies			
1999	0.232	1.485	0.726
2000	0.253	2.010*	0.558
2001	0.164	1.165	0.666
2002	0.199	1.265	0.714
2003	−0.150	−1.056	0.658
2004	−0.102	−1.216	0.051
2005	−0.097	−1.164	0.038
2006	−0.147	−1.732	0.060
2007	−0.043	−0.514	0.038
R^2	0.551		
Adj. R^2	0.543		
Std. Error of the Estimate	0.230		
Moran's I	0.281**		
Log-likelihood	56.519		
F	65.576**		

Note: There are 926 observations. The dependent variable is *apartment price* (ln) in US$1,000: method – MRA.
*Significant at the 0.05 level (two-tailed test).
**Significant at the 0.01 level (two-tailed test).
[a]Regression coefficient.
[b]*t*-Statistic.
[c]Tolerance (multicollinearity diagnostic).

OLS model in which the railroad and main road dummies are added to the original set of predictors. The model in Exhibit 7 covers only the statistically significant predictors, filtered out by the stepwise regression procedure. Lastly, Exhibit 8 reports a SL model, which preserves the same setting as the model in Exhibit 7, but also includes the price lag component, *rho*. This component measures the

Exhibit 6 | Factors Affecting Apartment Sale Price

Variable	B[a]	t[b]	Tol.[c]
Constant	1.213	3.245**	
Floor area (ln), m^2	0.804	12.662**	0.774
SO_2 level, mg/m^3	−0.044	−5.144**	0.781
Elevation, meters	0.002	12.471**	0.147
D_industry (ln), meters	0.040	3.124**	0.738
D_road (ln), meters	0.025	3.379**	0.727
D_park (ln), meters	−0.002	−0.375	0.570
D_track (ln), meters	−0.045	−2.009*	0.095
D_station (ln), meters	−0.003	−0.159	0.340
Train buffer zone (<50m)	−0.209	−2.495*	0.347
Train buffer zone (50–100 m)	−0.005	−0.074	0.392
Train buffer zone (100–150 m)	−0.027	−0.497	0.622
Train*Road interaction term	−0.013	−0.190	0.468
Year Dummies			
1999	0.227	1.458	0.725
2000	0.253	2.014*	0.556
2001	0.164	1.169	0.666
2002	0.218	1.390	0.712
2003	−0.152	−1.077	0.658
2004	−0.107	−1.269	0.051
2005	−0.100	−1.196	0.038
2006	−0.152	−1.790	0.060
2007	−0.049	−0.583	0.038
R^2	0.556		
Adj. R^2	0.546		
Std. Error of the Estimate	0.229		
Moran's *I*	0.276**		
Log-likelihood	61.772		
F	53.996**		

Notes: There are 926 observations. The dependent variable is *apartment price* (ln) in US$1,000: Method – MRA; train buffer zone dummies added.

*Significant at the 0.05 level (two-tailed).

**Significant at the 0.01 level (two-tailed).

[a] Regression coefficient.

[b] *t*-Statistic.

[c] Tolerance (multicollinearity diagnostic).

Exhibit 7 | Factors Affecting Apartment Sale Price

Variable	B[a]	t[b]	Tol.[c]
Panel A: Variables in the equation			
Constant	1.068	3.332**	
Floor area (ln), m^2	0.800	13.182**	0.843
SO_2 level, mg / m^3	−0.043	−5.250**	0.852
Elevation, meters	0.002	15.648**	0.233
D_industry (ln), meters	0.039	3.115**	0.782
D_road (ln), meters	0.026	3.692**	0.825
D_track (ln), meters	−0.041	−2.593*	0.195
Train buffer zone (< 50 m)	−0.198	−3.289**	0.668
Year Dummies			
1999	0.326	2.437*	0.975
2000	0.344	3.534**	0.920
2001	0.263	2.255*	0.961
2002	0.309	2.293*	0.958
2006	−0.050	−2.298*	0.903
2007	0.051	2.614*	0.705
R^2	0.555		
Adj. R^2	0.549		
Std. Error of the Estimate	0.228		
Moran's *I*	0.274		
Log-likelihood	57.750		
F	87.551		
Panel B: Excluded variables			
Variable	Beta In	t	Tol.
D_park (ln), meters	−0.011	−0.374	0.585
D_station (ln), meters	−0.003	−0.082	0.356
Train buffer zone (50–100 m)	0.001	0.036	0.608
Train buffer zone (100–150 m)	−0.012	−0.470	0.777
Train*Road interaction term	−0.002	−0.055	0.631
Year Dummies:			
2003	−0.011	−0.481	0.939
2004	−0.010	−0.401	0.773
2005	0.005	0.160	0.579

Notes: There are 926 observations. The dependent variable is *apartment price* (ln) in US$1,000: Method – MRA (step-wise).
*Significant at the 0.05 level (two-tailed).
**Significant at the 0.01 level (two-tailed).
[a]Regression coefficient.
[b]t-Statistic.
[c]Tolerance (multicollinearity diagnostic).

Exhibit 8 | Factors Affecting Apartment Sale Price

Variable	B[a]	t[b]
Constant	−1.269	−3.979**
Price lag (ln)	0.610	16.145**
Floor area (ln), m^2	0.691	12.965**
SO_2 level, mg/m^3	−0.017	−2.242*
Elevation, meters	0.001	6.517**
D_industry (ln), meters	0.013	1.206
D_road (ln), meters	0.009	1.439
D_track (ln), meters	−0.028	−2.021*
Train buffer zone (<50m)	−0.141	−2.680**
Year Dummies		
1999	0.318	2.729**
2000	0.227	2.665**
2001	0.315	3.097**
2002	0.252	2.138*
2006	−0.049	−2.580*
2007	0.041	2.416*
R^2	0.657	
Lag coefficient (*Rho*)	0.610	
Std. Error of the Estimate	0.199	
Log-likelihood	161.663	

Notes: There are 926 observations. The dependent variable is *apartment price* (ln) in US$1,000: Method – Spatial Lag Model.
*Significant at the 0.05 level (two-tailed).
**Significant at the 0.01 level (two-tailed).
[a] Regression coefficient.
[b] *t*-Statistic.

degree of spatial dependency of apartment price in a given location on apartment prices observed in the 100-meter range, within which the maximum spatial dependency of OLS regression residuals is detected (Exhibit 4).

As Exhibit 5 shows, the sale prices of apartments tend to increase, ceteris paribus, with the elevation of houses above the sea level (*Elevation*), increasing distances from main thoroughfare roads (*D_road*), and industrial areas (*D_industry*) ($p <$ .01). Close proximity to public parks also tends to increase apartment prices, albeit its influence is not significant ($p >$ .1).

Concurrently, apartment prices tend to increase with apartment size (*Floor area*: $p <$ .01), and decline with increasing SO_2 pollution levels (*SO_2 level*: $p <$ .01;

Exhibit 5). Characteristically, both "train station" (*D_station*) and "train track" (*D_track*) distances are statistically insignificant in the model ($p > .05$; Exhibit 5).

Although the introduction of the "train buffer zone" variables into the model appears to change its fit only marginally (R^2-adjusted = .546; Exhibit 6 vs. R^2-adjusted = 0.543; Exhibit 5), both *D_track* and the train buffer zone (<50 meters) variables emerge in it as statistically significant (Exhibit 6). In particular, as Exhibit 6 shows, train track proximity tends to increase, everything else being equal, apartment prices (*D_track*: $b = -0.045$; $p < .05$), whereas the immediate adjacency to train tracks appears to have a detrimental effect on apartment prices (train buffer zone (< 50 meters): $b = -0.209$; $p < .05$; Exhibit 6). This result is thus fully consistent with our initial research assumption that the proximity to rail lines should have a positive effect on residential property values overall, excluding a relatively narrow buffer zone in which housing prices should be lower than elsewhere (Exhibit 1).

However, the results reported in Exhibits 5 and 6 should be treated with caution due to relatively high levels of multicollinearity (Tol. < 0.1), which may bias regression estimates. To address this issue, we reran the analysis, using the stepwise regression analysis, so as to include in the resulting models only statistically significant variables with relatively low multi-collinearity levels ($T >$ 0.19). The results of the rerun analysis are reported in Exhibit 7.

As Exhibit 7 shows, the proximity to train station (*D_station*) variable is excluded from the resulting model as statistically insignificant ($p < .5$), while the train track proximity and the train buffer zone (< 50 meters) variables are retained in the resulting model and even increased their significance levels [*D_track*: $t = -2.593$; $P < .05$ (Exhibit 7) vs. $t = -2.009$; $p < .05$ (Exhibit 6)]; train buffer zone [(< 50 meters): $t = -3.289$; $p < .01$ (Exhibit 7) vs. $t = -2.495$; $p < .05$ (Exhibit 6)].

The exclusion of the *D_station* variable from the resulting model may have a simple explanation. It is possible that in drawing their "mental maps" of city neighborhoods, both buyers and sellers may find it easier to reference the locations of individual properties by train tracks, which run uninterruptedly through the city, than by discrete station points, especially if they are located close to each other and do not form large transportation and commercial hubs. Such a "preference" for train tracks as "reference points" may, of course, be less likely in intercity areas, where train stations are sparse, thus becoming more palpable reference points for defining a residential property's location.

Other possible explanations are that the absence of any statistically significant effect of train station proximity, detected by the present analysis, may be attributed to the fact that only three of the stations are located relatively close to housing (Exhibit 2), or, alternatively, by the fact that the local residents may prefer other modes of transportation over trains. However, these explanations may be less palpable because we found that the train track variable emerged in the analysis as statistically significant after a train buffer effect was added to the regression model (Exhibit 6). The negative and statistically significant sign of the regression coefficient of the train track variable thus indicates that, in making their real estate decisions, local residents *are not* indifferent to trains, as could be expected if the above explanations were totally exhaustive.

The regression estimates from the SL models (Exhibit 8) are essentially similar to the OLS estimates (Exhibit 7), with both the *D_track* and train buffer zone (< 50 meters) variables retaining their 0.05% significance levels.

Conclusion

Most real estate studies carried out to date consider proximity to urban trains as a "one-dimensional" variable. That is, most of these studies deal with either proximity to railway tracks or with proximity to train stations (e.g., Hughes and Sirmans, 1992; Landis, Cervero, and Guhathukurta, 1995; Knapp, Hopkins, and Pant, 1996; Rapoza, 1999; Simons and Jaouhari, 2004; and Debrezion, 2006). In the present study of recent apartment sales in the city of Haifa, Israel, we attempted to investigate these two effects of urban rail in interrelation. Our specific objective was to determine whether the above positive and negative effects of train proximity could be incorporated into a single empirical model. The analysis was carried out using both ordinary least squares regressions and spatial lag models, which take into account the possibility that prices of adjacent residential properties show more similarities than the prices of apartments that are wider apart.

As our sensitivity test (see Exhibit 9) indicates, the price depreciation in the 100-meter train buffer zone appears to reach approximately 13%, whereas beyond this zone residential prices tend to recover and then gradually drop by a proportion that decreases from roughly 1.9% between 100 meters and 200 meters to 0.3% between 900 meters and 1000 meters.

The results are thus generally consistent with the results of previous studies that indicate that residential property prices tend to decrease by about 5%–20% within a few hundred meters from train tracks, due to noise nuisance and view obstructions (Hughes and Sirmans, 1992; Armstrong, 1994; Knapp, Hopkins, and Pant, 1996; Rapoza, 1999; Federal Transit Administration, 2000; and Simons and Jaouhari, 2004).

However, in contrast to several previous studies (e.g., Debrezion, 2006; and Debrezion, Pels, and Rietveld, 2007), we found *no* significant effect of train station proximity on residential property values. In particular, when the train track and train station variables were introduced simultaneously into the hedonic price model, the "train station" variable was filtered out as statistically insignificant by the stepwise regression procedure. In our view, this outcome may be explained by the fact that both buyer and sellers may find it easier to "reference" the locations of individual properties by train tracks, which run uninterruptedly

Exhibit 9 | Sensitivity Test of Apartment Prices to Plausible Changes in Railroad Proximity

Railroad Proximity[a]	Estimated Apartment Price[b]	% Change
50	132,123	—
100	149,205	12.93
200	146,337	−1.92
300	144,685	−1.13
400	143,525	−0.80
500	142,631	−0.62
600	141,904	−0.51
700	141,293	−0.43
800	140,766	−0.37
900	140,302	−0.33
1000	139,889	−0.29

Note: Based on Exhibit 8. The values of all variables (except for train proximity and train buffer zone) are set to the average values observed in the study area, viz.: price lag = US$150,000; floor area = 104 m^2; sale year = 2006; SO_2 level = 6.3 mg/m^3; elevation = 166 meters; *D_industry* = 390 meters; *D_road* = 260 meters.
[a]Meters.
[b]US$.

through the city, rather than by discrete station points, especially if the stations are located close to each other and do not form large transportation and commercial hubs.

A suggested approach for detecting the "price depreciation" zone around urban features with "dual" effects on property prices assumes a non-linear relationship between a feature's proximity and its property price effect (e.g., Des Rosiers, Lagana, Thériault, and Beaudoin, 1996; and Des Rosiers, Lagana, and Thériault, 2001). We used an alternative approach to delineating such a "price depression" zone, based on several dichotomous variables, termed "buffer zone" fixed effect or "buffer zone" dummies. These variables take on a value of one if a property is located within a given distance from the train track (either less than 50 meters, 50–100 meters, or 100–150 meters, which correspond to the first three rows of buildings), and zero otherwise. The variables are mutually exclusive, making it possible to introduce them simultaneously in the regression analysis. We also included in the analysis an interaction term of train track and road proximity. The value of this variable was set to one if a property was located within 100 meters of both train tracks and main roads.

As assumed from the outset of the analysis, the price depreciation effect of rail track proximity is likely to be localized and limited to the first and second rows of buildings adjacent to the train tracks (Exhibit 1). Therefore, the "dichotomous" buffer zone variables "fit" the underlying assumptions better than the "gamma density" approach, based on continuous distance estimates.

Characteristically, the train track variable emerged as significant only after a train buffer was included (Exhibits 4 and 5). This phenomenon further supports our initial hypothesis about the non-linearity of relationships between train proximity and residential property values (Exhibit 1).

Several previous studies examined separately the effects of train proximity on housing prices in areas adjacent to train station and to train lines (e.g., Armstrong, 1994; and Cambridge Systematic, 1999). However, in addition to providing more empirical evidence about the impact of urban features with potentially dual effect on adjacent property values (such as railroads, sport centers, shopping malls, schools, etc.), the main contribution of this study lies in the consideration of the impact of distance buffers, as "adjustments" to continuous proximity variables.

The "buffer zone" approach used in the analysis has several advantage for empirical studies, as compared to an alternative gamma function approach (e.g., Des Rosiers, Lagana, Thériault, and Beaudoin, 1996; and Des Rosiers, Lagana, and Thériault, 2001). In particular, it makes it possible to account for a virtually unlimited combination of "overlapping" features (such as train line and main road, park and railroad, etc.). For instance, it may be expected that the effect of urban rail on property values may be either enhanced or weakened by the proximity of train tracks to High-Voltage Transmission Lines (HVTL), warehouses, and industrial estates, which are often adjacent to train tracks. Although the present analysis provided no significant evidence of this effect, in future studies, the combined effects of these features on real estate prices may deserve in-depth investigation. If found that their effects overlap and exacerbate each other, it could lead to the conclusion that combining urban disamenities with rail lines should be examined thoroughly at the planning stage so as to avoid unnecessary damage to local property owners.

Appendix 1

The Effect of Rail Transit on Residential Property Values: Summary of Studies

Place (Source)	Rail System	Results	Comments[a]
San Francisco (Lewis-Workman and Brod, 1997)	Rapid rail: BART	Average house prices declined by about $1,600 for every 100 feet further from the station.	Study area was defined by one-mile radius from a single station area (Pleasant Hill). Access was measured as ground distance to the station.

Appendix 1 (continued)

The Effect of Rail Transit on Residential Property Values: Summary of Studies

Place (Source)	Rail System	Results	Comments[a]
New York (Lewis-Workman and Brod, 1997)	Rapid rail: City MTA	Average home prices declined by about $2,300 for every 100 feet further from the station.	Study area was defined by one-mile radius from three different stations (Forest Hills, 67 Avenue, and Rego Park). Access was measured as ground distance to the nearest station.
San Francisco Bay Area (Landis et al., 1995)	Rapid rail: BART	Single family home prices appeared to decline by $1–$2 per meter of distance from a BART station in Alameda and Contra Costa Counties. (The study found no price-depreciation effect for commercial property.)	The proximity was measured as ground distances to BART stations.
San Francisco Bay Area (Landis et al., 1995)	Commuter Rail: Ca/Train	Houses located within 300 meters from the train tracks were sold at a $51,000 discount.	Access was measured as ground distance.
Washington, D.C. (Benjamin and Sirmans, 1996)	Rapid rail: Metro	Rents decrease by 2.4% to 2.6% for each one-tenth mile increase of distance from a Metro station.	Study looked at over 250 rental observations from 81 apartment complexes. Access measured ground distance to nearest station.
Boston (Armstrong, 1994)	Commuter Rail: MBTA, Fitchburg Line	Single family residences located in communities with a rail station had a market value ca. 6.7% greater than in communities w/o train stations. The study also found a property value loss of about 20% for properties located within 400 feet from the train tracks.	Study area was defined as municipalities located within 10 miles from the train line. The study was focused on station areas as well as on right-of-way (nuisance) impacts. As concluded, the nuisance impact may be attributed mainly to proximity to freight rail rather than to commuter rail.

Appendix 1 (continued)

The Effect of Rail Transit on Residential Property Values: Summary of Studies

Place (Source)	Rail System	Results	Comments[a]
Philadelphia (Voith, 1993)	Rapid rail: SEPTA	The study detected a price premium for single family homes with access to rail stations of 7.5% to 8.0% over an average home's value.	Access to rail was defined as proximity of a house to the closest train station, measured in census tracts.
Portland (Lewis-Workman and Brod, 1997)	LRT: MAX, Eastside line	On the average, property values dropped by $75 for every 100 feet away from a station (up to 2,500–5,280 ft. radius).	Access to rail was defined according to proximity from a given house to the train station, measured in census tracts.
Portland (Knaap et al., 1996)	LRT: MAX, Westside line	The values of parcels located within ½ mile from the train line increased as function of distance from the train lines, but fell with distance from the train stations.	The study looked at property values within 2–3 miles from the LRT line in the Washington county.
San Diego (Landis et al. 1995)	LRT: San Diego Trolley	A typical home was sold for $272 more for every 100 meters closer to the light rail station. No effect was found for commercial properties	City-wide analysis, with access measures based on ground distance proximity to train stations
Sacramento (Landis et al. 1995)	LRT: Sacramento Light Rail	No effects found.	-"-
San Jose (Landis et al., 1995)	LRT: San Jose Light Rail	A typical house was found to be worth $197 less for every 100 meters closer to train tracks.	City-wide analysis, with access measures based on ground distances to the station. Homes nearby train tracks were found to older and accommodated low income households.

Appendix 1 (continued)

The Effect of Rail Transit on Residential Property Values: Summary of Studies

Place (Source)	Rail System	Results	Comments[a]
Santa Clara, County (Weinberger, 2001, 2000;	LRT: Guadalupe line	Commercial space within a ¼-mile of a station received an average of 2.3¢ to 5.0¢ more per square foot than commercial spaces located more than ¾-mile from the station.	County-wide analysis; access to transit is measured as ¼-mile distance rings.
Cambridge Systematics, Inc., 1999)		Office space sold within a ¼-mile of a station received an average of $4.87 per square foot more per gross building square foot, compared to office space located more than ¾-mile from the station.	
Portland (Knaap et al., 1996)	LRT: MAX, Westside line	The values of parcels located within ½-mile of the line rise with distance from the lines, but fall with distance from the stations.	Study looked at property values in advance of the Westside LRT beginning operations. Study area included land within two to three miles of the line in Washington County. Access is measured by ½-mile distance rings.
San Diego (Landis et al., 1995)	LRT: San Diego Trolley	A typical home sold for $272 more for every 100 meters closer to a light rail station; no effect fount for commercial properties.	City-wide analysis with access estimates based on ground distance to the station.

Notes:
[a]Three distance measuring methods are referred to in this column. "Ground distance" refers to the distance traveled on the ground (i.e., by walking, riding a bike, or driving). It is contrasted with "air distance," which is measured as a straight-line distance from a given property to the nearest train station (or nearest train line). The third method involves the use of "access rings" circling a train station (usually divided into ¼ or ½- mile bands). All properties within each ring are considered as having the same access.

Appendix 2

Description of the Variables

Variable	Description
Dependent Variable	
Apartment price (ln)	Natural logarithm of sale price in US$1,000.
Explanatory Variables (neighborhood and apartment characteristics)	
D_industry	Distance to the closest industrial zone (meters).
D_park	Distance to nearby public park (meters).
D_road	Distance to the closest arterial road (meters).
D_station	Distance to the nearest train station (meters).
D_train	Distance to the train track (meters).
Elevation	Elevation of the building above the sea level (meters).
Floor area	Total floor area of the apartment (m^2).
Sale year	Nine dummy (0/1) variables for each year with 1998 used as the reference.
SO_2 level	Mean concentration of SO_2 air pollutant at an apartment's location (mg/m^3 in 2003–2006).
Train buffer zone	Three dummy variables, taking on value 1, if the property is located within a given buffer zone from the train track (e.g., < 50 meters, 50–100 meters and 100–150 meters) and 0 otherwise.
*Train*road*	Dummy variable taking on value 1 if a property located within 100 meters from both train track and major thoroughfare road and 0 otherwise.

Appendix 3

Spatial Autocorrelation of OLS Regression Residuals

Spatial Lag[a]	# Neighbor Pairs	Moran's *I*	Z-Normal *I*	Sign.
0–50	171	0.335	4.403	<0.001
50–100	670	0.540	14.022	<0.001
100–150	844	0.389	11.368	<0.001
150–200	1026	0.236	7.616	<0.001
200–250	1143	0.185	6.300	<0.001
250–300	1344	0.155	5.752	<0.001
300–350	1516	0.236	9.257	<0.001
350–400	1620	0.164	6.674	<0.001

Appendix 3 (continued)

Spatial Autocorrelation of OLS Regression Residuals

Spatial Lag[a]	# Neighbor Pairs	Moran's I	Z-Normal I	Sign.
400–450	1799	0.166	7.135	<0.001
450–500	1981	0.168	7.557	<0.001
500–550	2149	0.132	6.185	<0.001
550–600	2295	0.064	3.149	0.001
600–650	2436	0.048	2.458	0.007
650–700	2617	0.082	4.255	<0.001
700–750	2764	0.068	3.632	<0.001
750–800	2889	0.018	1.016	0.154
800–850	3047	0.036	2.082	0.019
850–900	3160	−0.001	0.022	0.492
900–950	3287	0.042	2.497	0.006
950–1000	3433	0.012	0.800	0.212

Notes: Table based on Exhibit 7.
[a]Meters.
*Significant at the 0.05 level (two-tailed test).
**Significant at the 0.01 level (two-tailed test).

Endnotes

1 Access to AHS records is not open to the general public and there is a fee for each real estate transaction drawn individually from the database. In order to achieve a reasonable sample size, approximately 450 apartment transactions drawn from the AHS database were matched by a corresponding number of residential transactions recorded in a separate database maintained by a local appraisal agency.

2 The train line in the Haifa Bay area is served by inter-city commuter trains, linking the city of Beersheba in the south of the country with the town of Nahariya in the north. There are about 60 passenger trains crossing the area daily in each direction at an average speed of approximately 50 km per hour. There are also several freight trains crossing the area daily, but their movement is less frequent.

3 Out of the 80 apartments located within 150 meters of the train tracks and covered by the study, 45 apartments were either immediately adjacent to the train tracks or separated from them by another row of buildings. The rest (that is, 35 apartments) were separated from the train tracks by a major thoroughfare road, with 23 apartments being within 100 meters of both train tracks and buildings.

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The authors are grateful to Ko Wang and to three anonymous reviewers for their numerous helpful comments and suggestions.

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