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Research Article

The Impact of Urban Transit Systems on Property Values: A Model and Some Evidences from the City of Naples

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A hedonic model for estimating the effects of transit systems on real estate values is specified and calibrated for the city of Naples. The model is used to estimate the external benefits concerning property values which may be attributed to the Naples metro at the present time and in two future scenarios. The results show that only high-frequency metro lines have appreciable effects on real estate values, while low-frequency metro lines and bus lines produce no significant impacts. Our results show that the impacts on real estate values of the metro system in Naples are significant, with corresponding external benefits estimated at about 7.2 billion euros or about 8.5% of the total value of real estate assets.

1. Introduction

Urban transit systems play a fundamental role for the social and economic development of large urban areas, as well as significantly affecting the quality of life in such areas. Mobility and accessibility are two important factors that influence everyday life, social inclusion, and the competitiveness of firms and commercial operators. The quality of urban transit systems also affects real estate values: the higher the quality and quantity of transit system services in an urban area, the higher the active and passive accessibility of the area, and the higher the average real estate values.

When a public authority invests in transportation infrastructures and/or in transit services, it generates some external (or social) costs and benefits; a cost [benefit] is considered "external" if it is produced by subject A and borne [enjoyed] by subject B, without any compensation between the subjects [1–3]. Usually, the external costs of transportation are associated with air pollution, greenhouse gas emissions, noise, accidents, and congestion. While there is extensive literature on such external costs [4–8] which are nowadays taken into account in some transportation planning processes, less attention is devoted to external benefits that are hardly ever explicitly considered in economic and social analyses of transport investments. Besides the high direct benefits due to improved accessibility, reduced generalised trip costs, and the lower environmental impacts produced by less use of private cars, investments in transit systems, especially in railways and metros, may generate an appreciable increase in property values in the zones served; this benefit should be explicitly considered inside cost-benefit analyses. Note that even if the increases in property values mainly regard most of the users that live near rail stations, they have to be considered external benefits since they are enjoyed by all property owners, regardless of whether they use the transit system or live near the stations. In terms of social equity, especially if there are major differences between the transit supply in different urban areas, an evident disequilibrium is created; indeed, some inhabitants have available a high level-of-service transit system and, moreover, if property owners, also a benefit on the value of their properties. On the other hand, people living in areas not served by good quality transit systems suffer a double disadvantage: on transportation systems and property values. Since transit systems are subsidised strongly with public money and, then, by the whole society, a more equitable transit supply should be an important objective of transport policy. This imbalance can in part be compensated by introducing local taxes on property [9]. Another aspect of the problem is related to the optimal taxation in the presence of (positive or negative) externalities; this topic is outside the aims of this paper, but the reader may refer to Cremer et al. [10], Auerbach and Hines [11], and Christiansen and Smith [12].

In order to consider explicitly in transportation planning the impacts of transit system investments on real estate values as external benefits, we need to estimate the hedonic price of the presence of transit systems. According to hedonic theory [13], it is assumed that the price of a complex good, such as a house, can be expressed as a function of its extrinsic and intrinsic attributes: the coefficient of each attribute represents its implicit (hedonic) price. Calibration of hedonic pricing models, taking the availability of transit systems into explicit consideration, allows us to estimate the hedonic price of the presence of such systems in an area or in proximity to an area.

In the literature, much evidence can be found of the impact of transit system availability on real estate values. Obviously, most papers refer to specific case studies since it is very difficult to generalise models and analyses. Almost all research findings have underlined a positive correlation between the availability of transit systems (nearby) and property values, especially with respect to high-quality systems, whether railways [14–26] or bus rapid transit lines [19, 27–30]. Fewer have also studied the negative effects of transit system proximity [31, 32], due to externalities (mainly noise). Brandt and Maenning [33] and Szczepańska et al. [34], instead, studied the influence of road noise on real estate values. Interesting meta-analyses were proposed by Mohammad et al. [35], examining 102 estimates from 23 studies for the impact of rail projects on land and property values, and by Debrezion et al. [25].

From the modelling point of view, almost all papers propose hedonic price models (HPMs) for estimating property values and their correlation with transit system availability. Regarding the functional forms of the models in question, several types have been proposed: multiple linear regression (MLR) models [13, 14, 30, 31, 36, 37], also with a semilogarithmic form [16–18, 22, 23, 33, 38]; a multilevel model was proposed by Cervero and Kang [27], a quantile regression model was by Bohman and Nilsson [15], a Box-Cox linear transformation regression was by Chen and Haynes [16], a cross-sectional model was by Sun et al. [22], spatial econometric models were by Ibeas et al. [36], Efthymiou and Antoniou [32], Chen and Haynes [16], and Mulley et al. [19], a DID (Difference-in-Differences) estimator was by Dubé et al. [26], random utility models were by Jun [29], and a spatial Durbin model was by Zhong and Li [24].

This paper proposes a (nonspatial) hedonic model for evaluating the impacts of urban transit systems on property values. In the literature, numerous spatial hedonic models can be found [39–43] that may be able to improve the results, but their application requires very small zones or, at the limit, single buildings; as will be described in the following, the available zoning is not suitable for the application of this approach. Other approaches proposed in the literature require more detailed data that are not available for the case study in the object.

The main objectives of this paper are (i) to estimate the impacts of transit systems on real estate values in the city areas; (ii) to evaluate the corresponding external benefits; (iii) to evaluate the effects of some interventions on the Naples metro system on real estate values and on the corresponding external benefits for the areas concerned.

The remainder of the paper is organised as follows: in Section 2 the case study and the data used are described; in Section 3 the data are analysed and the hedonic model is formulated and calibrated; the impacts on real estate values and on the corresponding external benefits are estimated in Section 4; some analyses of two future scenarios are reported in Section 5; Section 6 concludes the paper.

2. Case Study and Data

The main objective of this paper is to estimate the impact of transit systems on real estate values in the city of Naples (Italy) and to evaluate the corresponding external benefits. The proposed approach can be applied, with the necessary modifications, to other large towns and cities. Naples is the largest city in southern Italy with about one million inhabitants (962,003 at the last census). It is the capital of the region of Campania and is close to some of the world's best known tourist destinations. Naples and its metro system were recently studied by Pagliara and Papa [20] who evaluated the impact of metro investments on property values and residents' location, analysing the changes produced by the opening of new stations with a pre- and postanalysis in the zones affected. In this paper, instead, we propose a model applicable to the whole city for estimating the impact of transit systems on property values and we explicitly estimate the external benefits produced by the presence of a metro system.

For the aims of this paper, three kinds of data were required:

(i) census data on population, density, quality of buildings, number and area (in m^2) of buildings, retail businesses;

(ii) real estate values;

(iii) transit system data.

All census data were obtained from the Italian National Institute of Statistics (ISTAT) and refer to the last national survey [44]. The available data are aggregated into 4,307 census subzones (see Figure 1). The data that we used in our model were resident population, density, number of residential buildings classified by state of conservation (very good, good, medium, and poor), total area of residential buildings, and retail employees (as a proxy of retail businesses in the city zones).

Real estate values were obtained from the Real Estate Market Observatory (OMI) [45], which is a database provided by the Italian Revenue Agency about real estate values in all Italian cities, subdivided by homogeneous zones. In this database, Naples is partitioned into 65 zones, as reported in Figure 2; the dimensions of the zones are not compatible with the use of spatial hedonic models. For each OMI zone, the database provides some data; in our study we refer to the following data: (a) minimum and maximum real estate values for residential buildings in a normal state of conservation; (b) kind of zone (central, semicentral, peripheral, suburban, and rural). The median real estate values for OMI zones are summarised in Figure 3; the classes of zones are reported in Figure 4. From the database of OMI zones, we eliminated five zones (R1, R2, D28, D31, and E41) for which no real estate

Figure 1: Census zones [44].

Figure 2: OMI zones [45].

values were associated, since there were too few real estate sale contracts to be statistically significant or they were not present. Therefore we refer to a database of 60 OMI zones.

Data on the transit supply system were collected directly from the operators and involved the following services:

(i) 4 funiculars (Centrale, Chiaia, Montesanto, and Mergellina);

(ii) 7 metro lines (Line 1, Line 2, Cumana, Circumflegrea, and 3 Circumvesuviana lines);

(iii) 76 bus lines.

In Table 1, the list of railway lines with the corresponding average daily frequencies is reported. In Table 2, the average daily frequencies of bus lines are summarised. It can be noted that average bus line frequencies are very low for urban services, except for a few lines; it is due to a strong financial crisis suffered in the last decade by the municipality that owns the urban bus firm and by the region that finances the largest part of transit services. The metro and bus lines are illustrated in Figures 5 and 6, respectively. Figure 5 also shows the metro lines currently under construction (black lines).

This case study is very appropriate for the proposed analysis since the Naples transit system covers the various areas of the city with very different levels of service: (a) some zones are served by medium/high-frequency metro lines or funiculars, besides some bus services; (b) other zones are served by low-frequency metro lines, besides some bus services; (c) some zones are served only by low-frequency bus lines; (d) some

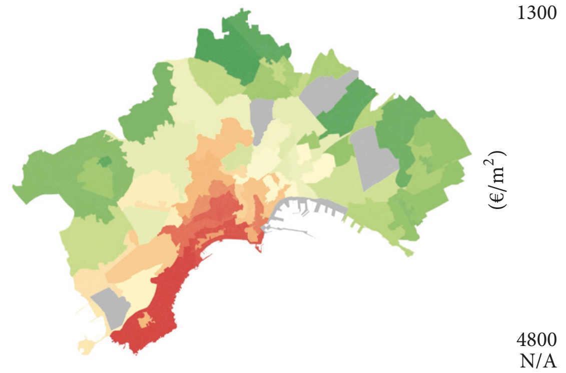

Figure 3: Median real estate values.

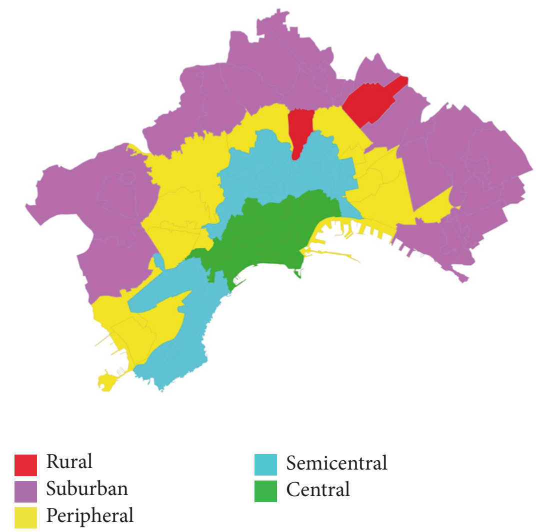

Figure 4: Classification of OMI zones.

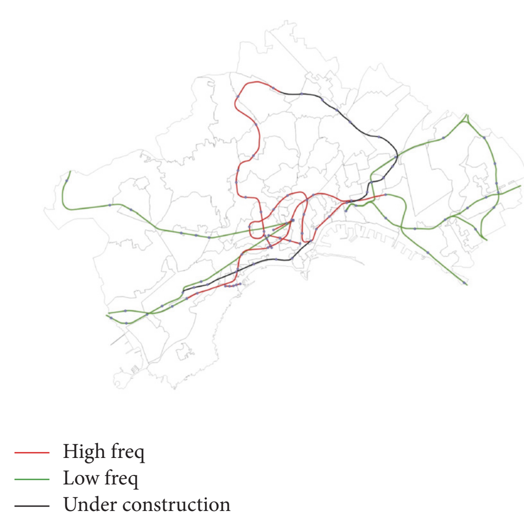

Figure 5: Metro network.

Table 1: Railway lines.

Line	From–to	Service time and headways	Average daily frequency [train/h]
Line 1	Garibaldi–Piscinola	6:20–6:40 (20′) 6:40–21:44 (8′) 21:44–23:02 (14′)	7.00
Line 2	Pozzuoli–Gianturco	5:20–23:20 (8′)	7.50
Cumana railway	Montesanto–Torregaveta	5:21–22:30 (20′)	3.00
Circumflegrea railway	Montesanto–Torregaveta	5:12–21:43 (20′)	3.00
Circumvesuviana railway (suburban)	Napoli–Sorrento	6:09–21:39 (28′)	2.14
	Napoli–Baiano	6:04–20:18 (26′)	2.31
	Napoli–Sarno	6:32–20:02 (39′)	1.54
	Napoli–Poggiomarino	5:55–19:55 (36′)	1.67
	Napoli–San Giorgio	6:11–18:11 (36′)	1.67
"Central" funicular	Augusteo–Piazza Fuga	6:30–00:30 (10′)	6.00
"Chiaia" funicular	Parco Margherita–Cimarosa	6:30–00:30 (10′)	6.00
"Montesanto" funicular	Montesanto–Morghen	7:00–22:00 (10′)	6.00
"Mergellina" funicular	Mergellina–Manzoni	7:00–22:00 (10′)	6.00

Figure 6: Bus services.

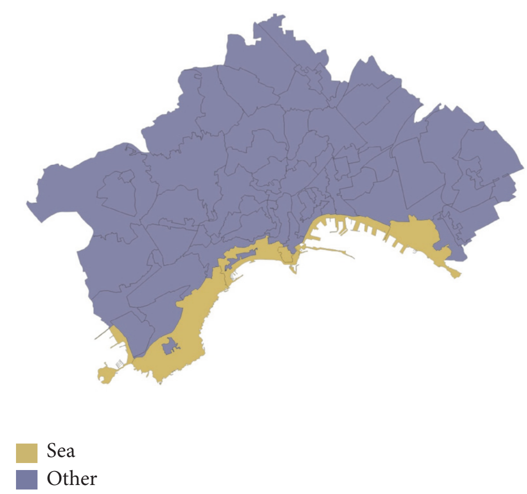

Figure 7: Classification of OMI zones by the variable Sea.

zones are only partially served by low-frequency bus lines; (e) outlying zones are only marginally served by the transit system. These differences may significantly affect the real estate values of the various zones; indeed, in cities where the transit service is more equally distributed among zones the impact on property values may be very low or very difficult to quantify.

Once all transportation system data have been gathered, we can construct a database that associates the corresponding data to each OMI zone, which we adopt as zoning since they correspond to real estate values. As for census data, all the data regarding the particular census subzones are associated with each OMI zone. Transportation data are associated with the OMI zones in the following ways: (1) a metro station is associated with a zone if it is contained in the zone or if the zone boundary is no farther than 250 m from the station; (2) a bus line is associated with a zone if it crosses the zone or runs along a road forming the zone boundary. In Table 3, all data associated with each OMI zone that are used to draw up the hedonic model are described, some of which are obtained with simple elaboration from starting data.

Moreover, the zones are also classified in function of three variables referring to some important features of the area: *Sea*, if the zone is seafront; *Hill*, if the zone belongs to one of the hill districts of the city (Vomero, Posillipo, Camaldoli, and Colli Aminei); *Prestige*, if the zone is commonly assumed to be prestigious (Posillipo, Chiaia). Figures 7–9 report the classification of OMI zones regarding these variables.

3. Data Analysis and Model Calibration

Before specifying and calibrating the model, we examined the dataset in order to explore the correlation between the real estate values and the variables associated with the OMI zones. First of all, we calculated the correlation coefficient, $r^j{}_{x,y}$, between the real estate values, y_i, and each variable, $x_{i,j}$, where i indicates the OMI zones and j the independent variable. The correlation coefficient $r^j{}_{x,y}$ can be positive,

Table 2: Bus lines.

Line code	Average daily frequency [bus/h]
1	5.00
2	3.33
4	4.00
12	2.07
20	2.07
128	2.22
130	3.00
132	2.50
139	2.72
140	3.53
147	3.33
150	2.73
151	5.00
154	2.86
168	3.75
178	2.14
180	1.67
181	3.33
182	2.61
183	1.94
184	3.00
185	2.61
191	2.73
192	3.00
193	1.18
194	2.61
195	2.50
201	3.75
202	3.16
203	2.61
503	1.88
640	2.40
Alibus	2.86
C1	1.94
C12	2.73
C13	2.40
C14	0.92
C16	3.53
C18	1.54
C18E	1.88
C2	1.76
C21	2.86
C24	1.20
C25	2.40
C27	2.07
C31	2.14
C33	2.50
C33E	2.50
C36	1.20
C38	1.62
C40	2.22
C41	2.07
C44	2.07
C5	0.97
C51	1.54
C52	1.54
C59	0.94
C6	2.31
C63	2.50
C65	2.22
C68	2.31
C76	2.31
C91	2.00
C94	1.30
C96	1.36
C98	1.13
C99	1.71
E1	2.14
E2	2.31
E6	1.62
R2	6.67
R4	5.00
R5	2.07
R6	4.00
R7	2.40
V1	1.25

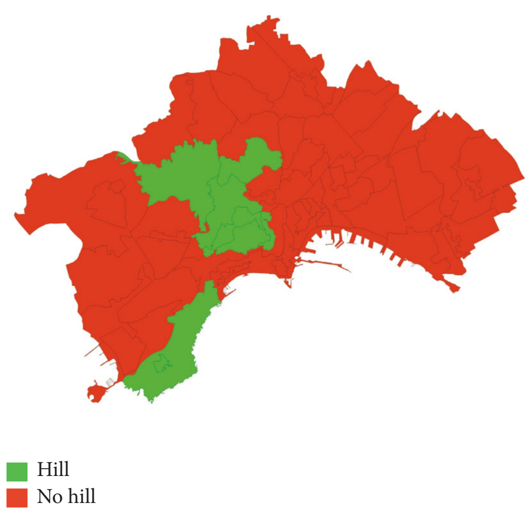

Figure 8: Classification of OMI zones by the variable Hill.

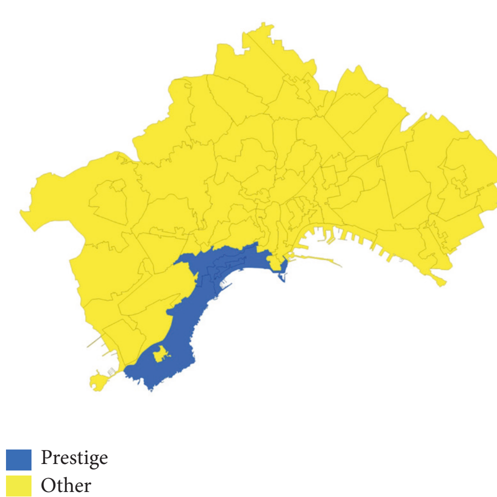

Figure 9: Classification of OMI zones by the variable Prestige.

between 0 and 1, or negative, between −1 and 0, and the more its value is proximal to 1 [−1], the higher the positive [negative] correlation is between the variables. In Table 4, the values of the correlation coefficient for each independent variable are reported. The variables *Pop*, *Surface*, *BD_1*, *BD_2*, *BD_3*, *BD_4*, and *Retail_emp* were not considered since they were used only for calculating other variables; the variable *rural* was not considered since in these areas there are no real estate values available.

Upon analysing the results, it can be noted that density is not at all correlated with real estate values (the value is very close to 0); probably, it is due to the almost equal (high) density in all zones. As regards the other variables, only certain variables presented a significant correlation ($r^j{}_{x,y} > 0.5[< -0.5]$); these variables are *HF_rail_st*, *Central*, *Suburban*, *Hill*, and *Prestige*. It is worth noting that low-frequency railway stations are not correlated to real estate values: the value is very low, in absolute value, and even negative. We may assume that all variables with an absolute value of the correlation coefficient lower than 0.25 are not correlated with property values and, then, are not useful as explanatory variables. This first analysis highlights that the *HF_rail_st* variable is highly correlated with real estate values (it presents the maximum absolute value of the correlation coefficient). The correlation between possible explanatory variables is examined, reporting the correlation coefficient matrix in Table 5. Examining the matrix, a strong (negative) correlation is, obviously, between variables %*BD_3* and %*BD_1_2*, since one is nearly complementary to the other; in the specification of the model, both variables will not be jointly considered. The other variables highly correlated are *HF_rail_st* versus *Central* (0.69), since in central areas there are more metro stations, and *Suburban* versus *CF_bus* (−0.55) since buses cover almost equally the other areas except for the suburban ones, where the transit service is very marginal. However, about these other correlations, the calibration of the model and, in particular, the *t-stat* tests will be able to verify if the variables are significant even if considered jointly in the model.

Starting from this preliminary analysis, we formulated and calibrated a hedonic linear regression model (LRM) for estimating real estate values. The general formulation of the model is the following:

$$E(Y \mid X) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_j X_j + \cdots + \beta_p X_p, \quad (1)$$

where $E(Y \mid X)$ is the expected value of the dependent variable Y, in our case the real estate value (REV) of a zone, conditional upon the terms on the right side of equation, X_j, which are the independent variables; β_0 is the *intercept*, which is a parameter invariant with the values assumed by the-independent variables, X_j; β_j are the parameters (or coefficients) of the model, which have to be calibrated; X_j are the independent variables.

This model has to be specified (the independent variables X_j to be considered in the model have to be identified) and calibrated (the values of parameters βs that are best able to reproduce the observed values of Y have to be estimated).

We assume that the 60 real estate values, y_i, corresponding to the 60 OMI zones, for which the data are available, are the observed data that we collect in a vector $\mathbf{Y}$. The values of independent variables assumed in correspondence of each observation, which are usually called predictors, $x_{i,j}$, are collected in a matrix $\mathbf{X}$; there are always 60 rows in this matrix, while the number of columns depends on the number of model parameters. We also introduce the vector of the regression coefficients, $\boldsymbol{\beta}$, and the vector of statistical errors, $\mathbf{e}$. Vectors and the matrix are reported below, where subscript p indicates the number of parameters:

$$\mathbf{Y} = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_i \\ \vdots \\ y_{60} \end{pmatrix}$$

$$\mathbf{X} = \begin{pmatrix} 1 & x_{1,1} & x_{1,2} & \cdots & x_{1,j} & \cdots & x_{1,p} \\ 1 & x_{2,1} & x_{2,2} & \cdots & x_{2,j} & \cdots & x_{2,p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{i,1} & x_{i,2} & \cdots & x_{i,j} & \cdots & x_{i,p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{60,1} & x_{60,2} & \cdots & x_{60,j} & \cdots & x_{60,p} \end{pmatrix}$$

$$\boldsymbol{\beta} = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_j \\ \vdots \\ \beta_p \end{pmatrix} \quad (2)$$

$$\mathbf{e} = \begin{pmatrix} e_1 \\ e_2 \\ \vdots \\ e_i \\ \vdots \\ e_{60} \end{pmatrix}.$$

Adopting this matrix notation, the multiple linear regression model can be written as

Table 3: Data.

Name	Type	Unit of measurement	Description
OMI	Alphanumeric	-	The code of the zone as provided by the OMI database
Med_REV	Integer	€	The median real estate value as provided by the OMI database
Pop	Integer	Inhabitants	Population in the OMI zone
Area	Real number	Km^2	Surface area of the OMI zone
Density	Real number	$Inhabitants/km^2$	Population density in the OMI zone
BD_1	Integer	Number of buildings	Number of buildings with a "very good" conservation state in the OMI zone
BD_2	Integer	Number of buildings	Number of buildings with a "good" conservation state in the OMI zone
BD_3	Integer	Number of buildings	Number of buildings with a "medium" conservation state in the OMI zone
BD_4	Integer	Number of buildings	Number of buildings with a "poor" conservation state in the OMI zone
% BD_1	Percentage	%	Percentage of buildings with a "very good" conservation state in the OMI zone
% BD_2	Percentage	%	Percentage of buildings with a "good" conservation state in the OMI zone
% BD_3	Percentage	%	Percentage of buildings with a "medium" conservation state in the OMI zone
% BD_4	Percentage	%	Percentage of buildings with a "poor" conservation state in the OMI zone
% BD_1_2	Percentage	%	Percentage of buildings with a "very good" or "good" conservation state in the OMI zone
Retail_emp	Integer	Employees	Employees in retail businesses in the OMI zone
Retail_emp_d	Real number	$Employees/km^2$	Density of employees in retail businesses in the OMI zone
HF_rail_st	Integer	Stations	Number of high-frequency (≥6.00 trains/h) railway stations assigned to the OMI zone
LF_rail_st	Integer	Stations	Number of low-frequency (<6.00 trains/h) railway stations assigned to the OMI zone
CF_bus	Real number	bus/h	Cumulated frequency of all bus lines assigned to the OMI zone
Central	Boolean	0/1	1 if the zone is classified as "central" in the OMI database
Semicentral	Boolean	0/1	1 if the zone is classified as "semicentral" in the OMI database
Peripheral	Boolean	0/1	1 if the zone is classified as "peripheral" in the OMI database
Suburban	Boolean	0/1	1 if the zone is classified as "suburban" in the OMI database
Rural	Boolean	0/1	1 if the zone is classified as "rural" in the OMI database
Hill	Boolean	0/1	1 if the zone belongs to one of the hill districts of the city (Vomero, Posillipo, Camaldoli, Colli Aminei)
Sea	Boolean	0/1	1 if the zone is seafront
Prestige	Boolean	0/1	1 if the zone is commonly assumed to be prestigious (Posillipo, Chiaia)

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{e}. \tag{3}$$

Indicating with $\mathbf{x'}_i$ the ith row of the matrix $\mathbf{X}$, we can write

$$y_i = \mathbf{x'}_i\boldsymbol{\beta} + e_i \tag{4}$$

and hence

$$e_i = y_i - \mathbf{x'}_i\boldsymbol{\beta}. \tag{5}$$

The values of coefficients βs can be estimated with the well-known ordinary least squares (OLS) method that minimises the sum of the square residuals:

$$\begin{aligned}\boldsymbol{\beta}^{\wedge} &= \mathrm{Arg}_{\boldsymbol{\beta}} \min \Sigma_i \left(y_i - \mathbf{x'}_i\boldsymbol{\beta}\right) \\ &= \mathrm{Arg}_{\boldsymbol{\beta}} \min \left[\left(\mathbf{Y} - \mathbf{X}\boldsymbol{\beta}\right)^T \left(\mathbf{Y} - \mathbf{X}\boldsymbol{\beta}\right)\right],\end{aligned} \tag{6}$$

where $\Sigma_i(y_i - \mathbf{x'}_i\boldsymbol{\beta})$ is usually indicated with RSS($\boldsymbol{\beta}$). Indicating with SYY the term $\Sigma_i(y_i - \overline{y})^2$, a very important

Table 4: Correlation coefficients.

Variable v	$r^j_{x,y}$
Density	0.0075
% BD_1	0.2137
% BD_2	0.2126
% BD_3	−0.2649
% BD_4	−0.1468
% BD_1_2	0.2758
Retail_emp_d	0.2956
HF_rail_st	0.7162
LF_rail_st	−0.1570
CF_bus	0.3661
Central	0.6633
Semicentral	0.2407
Peripheral	−0.0911
Suburban	−0.6585
Hill	0.5055
Sea	0.3742
Prestige	0.6136

indicator of the goodness of the model is the *coefficient of determination*, R^2, that is given by

$$R^2 = 1 - \left(\frac{\mathrm{RSS}}{\mathrm{SYY}}\right). \tag{7}$$

This indicator measures the proportion of variability in the variables Y_i which is explained by the linear regression model; the closer R^2 to 1 (statistical errors equal to 0 and perfect reproducibility of the phenomenon), the higher the goodness of the calibrated model.

The coefficient of determination cannot be the only indicator for evaluating the goodness of a model. Indeed, it does not always decrease (usually increases) with the number of parameters β_j, even if some are not actually useful for explaining the phenomenon. The other indicators that have to be used to evaluate the model are the *tests of hypotheses* that are able to measure whether the parameters adopted in the model are actually significant for reproducing the phenomenon. Below, we use as tests of hypotheses the F-test, obtained by the analysis of variance, and the t-test, regarding the significance of each independent variable. We will assume that a model is acceptable if the significance F is close to 0 (at least <0.05) and if the t-test of each coefficient β_j is higher [lower] than t_{95} [$-t_{95}$] for positive [negative] β_j, where t_{95} is the value of the t-distribution corresponding to the degrees of freedom (df) of the model with a confidence of 95%.

We calibrated several models by adopting an adding method for identifying the parameters to consider in the model. Limiting the analysis only to variables where the absolute value of the correlation terms is greater than 0.25, we started with a model with only one df (one parameter) considering that with the higher value of correlation coefficient (see Table 4). We calculated the corresponding values of R^2, significance F, and t-test.

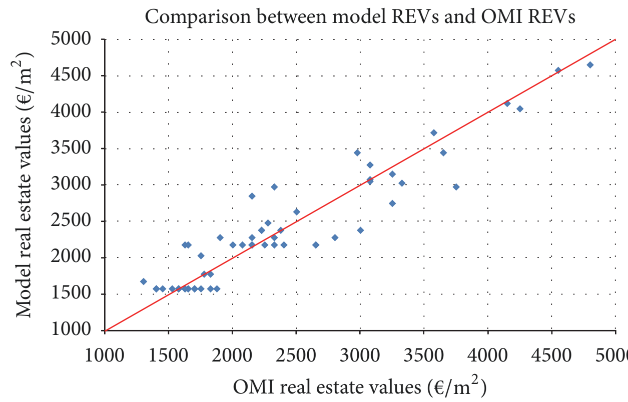

Figure 10: Model versus real estate values.

If the model obtained is significant in terms of F and t-test, we add another variable to the model, the next in terms of correlation coefficient. The new added variable is maintained in the model if all significance tests are verified; otherwise it is eliminated and the procedure continues with another variable. When all variables are examined, we try to add to the model some variables previously discarded (the significance of a variable can change with different df, since the t_{95} value changes). Since R^2 always increases (or, at least, it does not change) when we add a variable, the final model obtained with this procedure will respect all significance tests and will have the highest value of R^2 of all models examined. In Table 6, the results of the procedure are summarised: globally, we tested 12 models.

The results reported in Table 6 identify number 11 as the best model, which is as follows:

$$\begin{aligned} E(\mathrm{REV}) = {} & 2179.69 + 100.61 * \mathrm{HF}_{\mathrm{rail}_{\mathrm{st}}} + 394.23 \\ & * \mathrm{Central} - 602.76 * \mathrm{Suburban} + 570.31 \\ & * \mathrm{Hill} + 454.50 * \mathrm{Sea} + 1046.27 \\ & * \mathrm{Prestige}. \end{aligned} \tag{8}$$

Table 7 summarises all statistical tests and the analysis of variance (ANOVA) for the calibrated model. The residuals are reported in Table 8, while in Figure 10 the comparison is shown between the real estate values (REVs) obtained from the OMI database and the corresponding values estimated with the proposed model.

The analysis of the results shows that the model presents a good coefficient of determination (over 0.88) which indicates that over 88% of the variability in REVs is explained by the considered variables.

An important result to underline is that low-frequency rail stations and (low-frequency) bus lines have no significant influence on REVs. By contrast, the high-frequency rail stations have a significant and nonnegligible impact on REVs, as will be seen in the next section. The lack of significance of low-frequency services (bus and metro) on REVs is probably due to the fact that these services cover more or less all areas of the city and, then, their presence has not a practical impact on

Table 5: Correlation coefficient matrix.

	% BD_3	% BD_1_2	Retail_emp_d	HF_rail_st	CF_bus	Central	Semicentral	Peripheral	Suburban	Hill	Sea	Prestige
% BD_3	1.00	−0.96	0.20	−0.13	0.02	−0.05	−0.20	0.12	0.10	−0.17	−0.08	−0.24
% BD_1_2	−0.96	1.00	−0.19	0.13	−0.10	0.05	0.13	−0.10	−0.07	0.20	0.09	0.25
Retail_emp_d	0.20	−0.19	1.00	0.14	0.15	0.23	−0.02	0.12	−0.27	0.09	0.02	0.10
HF_rail_st	−0.13	0.13	0.14	1.00	0.45	0.69	0.06	−0.22	−0.41	0.41	0.08	0.33
CF_bus	0.02	−0.10	0.15	0.45	1.00	0.34	0.37	−0.05	−0.55	0.02	−0.01	0.11
Central	−0.05	0.05	0.23	0.69	0.34	1.00	−0.25	−0.26	−0.36	0.19	0.17	0.39
Semicentral	−0.20	0.13	−0.02	0.06	0.37	−0.25	1.00	−0.29	−0.40	0.27	−0.01	0.02
Peripheral	0.12	−0.10	0.12	−0.22	−0.05	−0.26	−0.29	1.00	−0.42	−0.10	−0.02	−0.15
Suburban	0.10	−0.07	−0.27	−0.41	−0.55	−0.36	−0.40	−0.42	1.00	−0.30	−0.10	−0.20
Hill	−0.17	0.20	0.09	0.41	0.02	0.19	0.27	−0.10	−0.30	1.00	0.06	0.09
Sea	−0.08	0.09	0.02	0.08	−0.01	0.17	−0.01	−0.02	−0.10	0.06	1.00	0.40
Prestige	−0.24	0.25	0.10	0.33	0.11	0.39	0.02	−0.15	−0.20	0.09	0.40	1.00

Table 6: Models.

	1	2	3	4	5	6	7	8	9	10	*11*	12
% BD_3										x		
% BD_1_2									x			
Retail_emp_d								x				x
CF_bus						x						
HF_rail_st	x	x	x	x	x	x	x	x	x	x	*x*	x
Central		x									*x*	x
Suburban			x	x	x	x	x	x	x	x	*x*	x
Hill					x	x	x	x	x	x	*x*	x
Sea							x	x	x	x	*x*	x
Prestige				x	x	x	x	x	x	x	*x*	x
df	1	2	2	3	4	5	5	6	6	6	*6*	7
t_{95}	6.314	2.920	2.920	2.353	2.132	2.015	2.015	1.943	1.943	1.943	*1.943*	1.895
R^2	0.513	0.567	0.672	0.808	0.846	0.849	0.868	0.876	0.872	0.871	*0.883*	0.889
Signif. F	≅0	≅0	≅0	≅0	≅0	≅0	≅0	≅0	≅0	≅0	*≅0*	≅0
t-stat$_0$	21.237	22.271	22.227	28.165	29.918	20.252	30.945	24.713	13.981	18.838	*32.288*	25.867
t-stat$_1$	7.816	4.097	6.429	6.258	5.285	−0.994	5.895	1.932	1.359	−1.084	*3.292*	1.605
t-stat$_2$		2.678	−5.249	−6.293	−6.291	5.240	−6.578	6.003	5.964	5.919	*2.678*	3.462
t-stat$_3$				6.304	3.706	−5.948	3.811	−6.112	−6.671	−6.573	*−6.576*	2.425
t-stat$_4$					7.210	3.204	2.955	3.898	3.524	3.624	*4.379*	−6.172
t-stat$_5$						7.039	5.877	3.082	3.005	2.981	*2.904*	4.397
t-stat$_6$								5.932	5.458	5.529	*5.626*	3.011
t-stat$_7$												5.683
Sign. tests	Yes	No	Yes	Yes	Yes	No	Yes	No	No	No	*Yes*	No

property values. With the calibrated model, the lower REVs of few unserved areas are explained by the variable *Suburban* that, actually, regards only zones where the transit service is very scarce or absent.

4. Impact of the Naples Metro System on Real Estate Values and Estimation of External Benefits

With the model calibrated in the previous section it is possible to estimate the impact of the Naples metro system on REVs and the corresponding external benefits. The predicted contribution of high-frequency rail stations to REVs is reported in Table 9 for each OMI zone; the same table also reports the percentages of this contribution. The percentage contributions for areas containing at least one high-frequency rail station are summarised in Figure 11, while Figure 12 reports the absolute values of the contributions. It can be noted that the contribution to REVs is significant for many zones: for two zones it is higher than 20%, for nine other zones it is higher than 10%, and for nine others it is higher than 5%.

For estimating the corresponding external benefits, some hypotheses have to be assumed. From the ISTAT census data on total areas of residential buildings and on the number

Table 7: Statistical tests for model 11.

Regression statistics						
Multiple R	0.940					
R^2	0.883					
Adjusted R^2	0.870					
Standard error	304.246					
Observations	60					
ANOVA	df	SS	MS	F	Significance F	
Regression	6	37198377	6199729	66.976	$5.61E-23$	
Residual	53	4905988	92565.81			
Total	59	42104365				
	Coefficients	Standard error	t-stat	p value	Lower 95%	Upper 95%
Intercept	2179.69	67.51	32.288	$1.56E-36$	2044.29	2315.10
HF_rail_st	100.61	30.57	3.292	0.001776	39.30	161.92
Central	394.23	147.24	2.678	0.009851	98.91	689.55
Suburban	−602.76	91.67	−6.576	$2.17E-08$	−786.62	−418.90
Hill	570.31	130.23	4.379	$5.64E-05$	309.11	831.52
Sea	454.50	156.48	2.904	0.005354	140.64	768.36
Prestige	1046.27	185.98	5.626	$7.09E-07$	673.23	1419.30

of buildings belonging to different classes of "conservation state," we may calculate the area (m^2) of residential buildings attributable to each class. Regarding the OMI REVs, the minimum and maximum values are available; we assume that the ISTAT "very good" classification corresponds to an expected REV equal to the maximum OMI REV, while the "poor" classification corresponds to the minimum OMI REV. The other two classes correspond to a linear interpolation of the two extreme data, assuming uniform distances between classes. Estimation of external benefits is obtained by applying the percentages estimated in Table 9 to the current REVs. In Table 10, the results of this analysis are reported for all OMI zones. Thus the external benefits, in terms of REVs, can be estimated at €7.2 billion (8.53% of the total value of real estate assets), with an average benefit per inhabitant amounting to €7,490 or an average benefit for each residential unit (100 m^2) of €23,034. These benefits express the increase in real estate values enjoyed by property owners; such estimates can be useful to policy-makers, to study equalisation actions, and to transportation planners, to evaluate the total benefits of interventions, including the external ones.

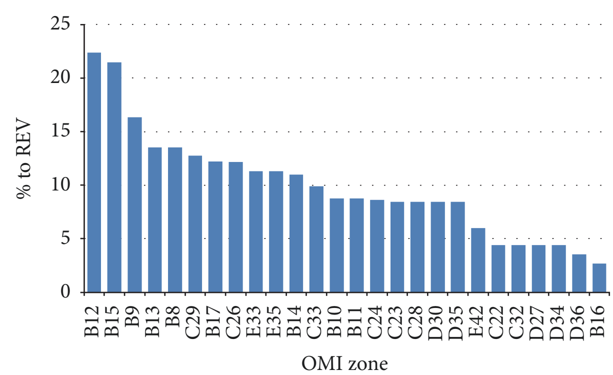

Figure 11: Contribution of high-frequency rail stations to real estate values (%).

5. Scenario Analyses

The proposed model and procedure were also applied to two future scenarios; the first (Scenario 1) considers the completion of Line 1 of the metro network in Naples and of Line 6, which is now entirely closed. Currently, Line 1 (a more detailed description can be found in [46]) starts from Piscinola and ends in Piazza Garibaldi (railway central station); under the full project, instead, the line will be extended to form a circle, including Capodichino Airport and the city's business district (Centro Direzionale); Line 6 is currently closed, even if part of it is completed, and is expected to be extended as far as the metro station Municipio of Line 1. Finally, we also consider the opening of Duomo station on Line 1 which is currently under construction. For both lines, we assume that the operation will provide a daily average frequency equal to or greater than 6 trains/h. The OMI zones affected by the project are B14 (+4 stations), E29 (+3 stations), B16, C28, D24, and E34 (+2 stations), and B18, B8, B9, D21, D22, D34, E36, E42, and E46 (+1 station); zone R2 is also affected, although it is excluded by the model since it only concerns the airport.

Scenario 2 considers, besides the interventions provided in Scenario 1, also an increase in the frequencies in the "Cumana" and "Circumflegrea" metro lines up to 6 trains/h. Thus their stations will become of high frequency. Compared with Scenario 0, Scenario 2 involves the following OMI zones: B14 (+5 stations), C28 (+4 stations), D23, D26, D29, D33, and E29 (+3 stations), B16, D24, E28, E34, and E39 (+2 stations), and B11, B15, B17, B18, B8, B9, D21, D22, D30, D34, E36, E42, and E46 (+1 station). The scenarios are illustrated in Figure 13.

For both scenarios, the calibrated model is used to estimate the REVs. The results concerning the contribution of

Table 8: Residuals for model 11.

OMI zone	OMI REV	Model REV	Residuals
B10	3650	3446.07	203.93
B11	2975	3446.07	−471.07
B12	4250	4049.73	200.27
B13	3750	2976.37	773.63
B14	4550	4577.74	−27.74
B15	3075	3278.20	−203.20
B16	3575	3720.80	−145.80
B17	4150	4123.24	26.76
B18	3325	3028.42	296.58
B8	2325	2976.37	−651.37
B9	3075	3076.98	−1.98
C21	2250	2179.69	70.31
C22	2150	2280.30	−130.30
C23	2225	2380.91	−155.91
C24	4800	4653.21	146.79
C25	2075	2179.69	−104.69
C26	2275	2481.52	−206.52
C27	2325	2179.69	145.31
C28	3000	2380.91	619.09
C29	3250	3152.45	97.55
C30	2000	2179.69	−179.69
C31	3250	2750.01	499.99
C32	2800	2280.30	519.70
C33	3075	3051.84	23.16
D21	1625	2179.69	−554.69
D22	1650	2179.69	−529.69
D23	2150	2179.69	−29.69
D24	2150	2179.69	−29.69
D25	2150	2179.69	−29.69
D26	2400	2179.69	220.31
D27	1900	2280.30	−380.30
D29	2650	2179.69	470.31
D30	2375	2380.91	−5.91
D32	2500	2634.19	−134.19
D33	2650	2179.69	470.31
D34	2325	2280.30	44.70
D35	2225	2380.91	−155.91
D36	2150	2850.62	−700.62
E27	1400	1576.93	−176.93
E28	1575	1576.93	−1.93
E29	1650	1576.93	73.07
E3	1700	1576.93	123.07
E30	1750	1576.93	173.07
E31	1700	1576.93	123.07
E32	1450	1576.93	−126.93
E33	1825	1778.15	46.85
E34	1825	1576.93	248.07

Table 8: Continued.

OMI zone	OMI REV	Model REV	Residuals
E35	1775	1778.15	−3.15
E36	1400	1576.93	−176.93
E37	1525	1576.93	−51.93
E38	1625	1576.93	48.07
E39	1650	1576.93	73.07
E40	1875	1576.93	298.07
E42	1300	1677.54	−377.54
E43	1750	2031.43	−281.43
E44	1625	1576.93	48.07
E45	1575	1576.93	−1.93
E46	1700	1576.93	123.07
E47	1575	1576.93	−1.93
E48	1400	1576.93	−176.93

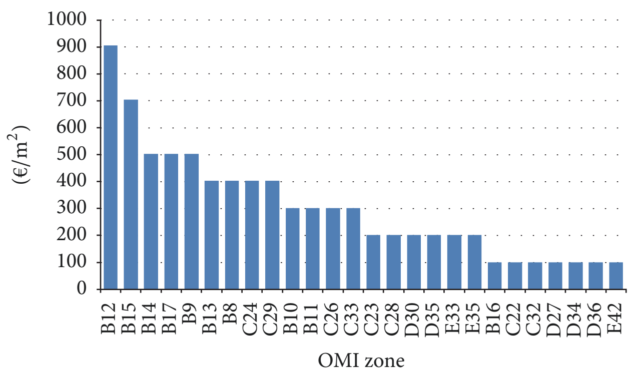

Figure 12: Contribution of high-frequency rail stations to real estate values (€).

all scenarios to REVs are summarised in Table 11; the same results are reported in Figure 14. By contrast, Table 12 reports the estimation of external benefits. These results show that the interventions provided in Scenario 1 increase the external benefits by about 1.6 billion euros, while under Scenario 2 the benefits could increase by up to €3.5 billion with respect to Scenario 0. In Scenario 1, the external benefits increase up to €9,169 per inhabitant and €28,197 per residential unit of 100 m^2; in Scenario 2 to €10,662 per inhabitant and €34.084 per residential unit of 100 m^2.

6. Conclusions

In this paper, we specified and calibrated a hedonic model to estimate the impact of transit systems on real estate values and the corresponding external benefits for the city of Naples. The analyses led to some important conclusions regarding the case study.

High-frequency metro lines (≥6 trains/h) produce significant impacts on real estate values, while no such correlation was found with low-frequency metro lines and bus lines. This underlines that only high-quality transit systems affect property values in Naples.

The estimated value of external benefits correlated to this aspect is high both in terms of absolute value (€7.2 billion, €7,490 per inhabitant and €23,034 per 100 m^2 residential unit) and in terms of percentage value (8.53% of total real estate assets). In some areas, the contribution to real estate value is very high, reaching as much as 22% of the total amount. These benefits may be explicitly considered in cost-benefit analyses.

The proposed model and procedure applied to two future scenarios are able to estimate the corresponding increases in the external benefits regarding real estate values. Our results show that interventions on the network with a view to increasing the number of high-frequency metro lines may produce an appreciable increase in real estate values.

Future research will be addressed to test other approaches in the case study, considering log-linear models and hedonic spatial models and evaluating socioeconomic impacts of a single transit line on the crossed zones. Moreover, to test the procedure on other European cities, recalibrating the model as required, and to consider this approach in cost-benefit analyses will be the object of future research too.

Conflicts of Interest

The author declares that he has no conflicts of interest.

Table 9: Contribution of high-frequency rail stations to real estate values.

OMI zone	Model REVs	Contribution of HF_rail_st variable	%
B10	3446.07	301.83	8.8%
B11	3446.07	301.83	8.8%
B12	4049.73	905.50	22.4%
B13	2976.37	402.44	13.5%
B14	4577.74	503.05	11.0%
B15	3278.20	704.27	21.5%
B16	3720.80	100.61	2.7%
B17	4123.24	503.05	12.2%
B18	3028.42	0.00	0.0%
B8	2976.37	402.44	13.5%
B9	3076.98	503.05	16.3%
C21	2179.69	0.00	0.0%
C22	2280.30	100.61	4.4%
C23	2380.91	201.22	8.5%
C24	4653.21	402.44	8.6%
C25	2179.69	0.00	0.0%
C26	2481.52	301.83	12.2%
C27	2179.69	0.00	0.0%
C28	2380.91	201.22	8.5%
C29	3152.45	402.44	12.8%
C30	2179.69	0.00	0.0%
C31	2750.01	0.00	0.0%
C32	2280.30	100.61	4.4%
C33	3051.84	301.83	9.9%
D21	2179.69	0.00	0.0%
D22	2179.69	0.00	0.0%
D23	2179.69	0.00	0.0%
D24	2179.69	0.00	0.0%
D25	2179.69	0.00	0.0%
D26	2179.69	0.00	0.0%
D27	2280.30	100.61	4.4%
D29	2179.69	0.00	0.0%
D30	2380.91	201.22	8.5%
D32	2634.19	0.00	0.0%
D33	2179.69	0.00	0.0%
D34	2280.30	100.61	4.4%
D35	2380.91	201.22	8.5%
D36	2850.62	100.61	3.5%
E27	1576.93	0.00	0.0%
E28	1576.93	0.00	0.0%
E29	1576.93	0.00	0.0%
E3	1576.93	0.00	0.0%
E30	1576.93	0.00	0.0%
E31	1576.93	0.00	0.0%
E32	1576.93	0.00	0.0%
E33	1778.15	201.22	11.3%

Table 9: Continued.

OMI zone	Model REVs	Contribution of HF_rail_st variable	%
E34	1576.93	0.00	0.0%
E35	1778.15	201.22	11.3%
E36	1576.93	0.00	0.0%
E37	1576.93	0.00	0.0%
E38	1576.93	0.00	0.0%
E39	1576.93	0.00	0.0%
E40	1576.93	0.00	0.0%
E42	1677.54	100.61	6.0%
E43	2031.43	0.00	0.0%
E44	1576.93	0.00	0.0%
E45	1576.93	0.00	0.0%
E46	1576.93	0.00	0.0%
E47	1576.93	0.00	0.0%
E48	1576.93	0.00	0.0%

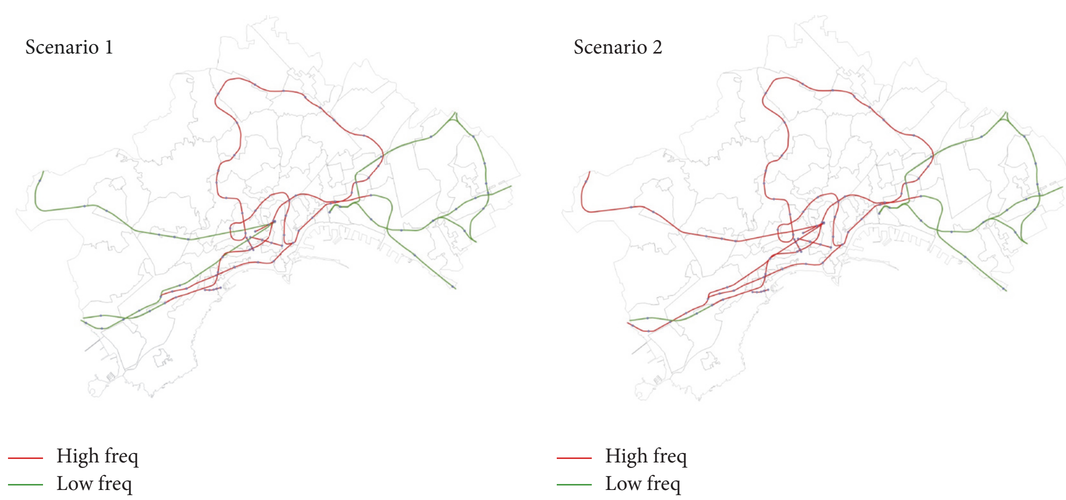

Figure 13: Scenarios.

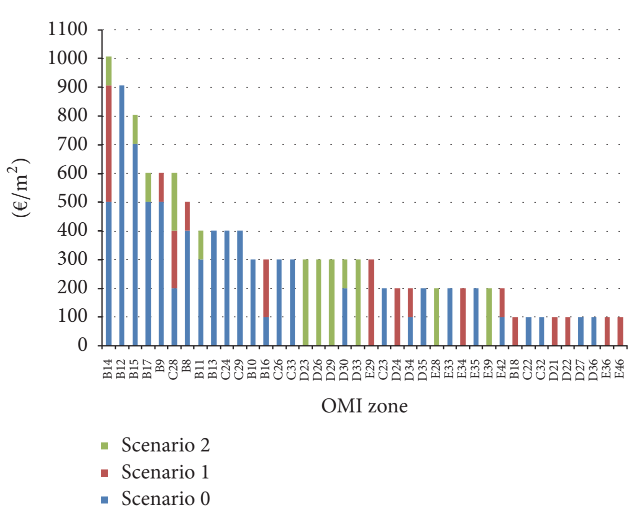

Figure 14: Contribution of high-frequency rail stations to real estate values for each scenario.

Table 10: Estimation of external benefits.

OMI	Resident building (m^2)	BD_1 (m^2)	BD_2 (m^2)	BD_3 (m^2)	BD_4 (m^2)	REV BD_1 (€/m^2)	REV BD_2 (€/m^2)	REV BD_3 (€/m^2)	REV BD_4 (€/m^2)	Total REV (€ million)	Metro REV contrib. (€ million)
B10	1,393,303	185,774	848,943	336,985	21,602	4,400	3,905	3,395	2,900	5,339	467.65
B11	225,398	13,543	116,085	88,031	7,739	3,600	3,188	2,763	2,350	680	59.57
B12	1,096,268	59,050	811,289	207,957	17,972	5,100	4,539	3,961	3,400	4,868	1,088.55
B13	294,826	13,805	133,115	137,060	10,846	4,500	4,005	3,495	3,000	1,107	149.65
B14	1,052,991	154,419	741,211	151,478	5,883	5,500	4,873	4,227	3,600	5,123	562.94
B15	1,236,737	39,755	326,685	781,279	89,017	3,700	3,288	2,863	2,450	3,676	789.64
B16	205,626	5,469	127,969	64,532	7,656	4,300	3,822	3,329	2,850	749	20.26
B17	657,613	131,523	425,577	96,236	4,277	5,000	4,439	3,861	3,300	2,932	357.77
B18	239,533	27,416	118,324	76,478	17,316	4,000	3,555	3,096	2,650	813	-
B8	874,051	15,984	278,451	513,999	65,617	2,800	2,487	2,164	1,850	1,971	266.44
B9	529,521	26,667	229,522	239,046	34,286	3,700	3,288	2,863	2,450	1,621	265.10
C21	460,933	48,816	321,057	86,366	4,694	2,700	2,403	2,097	1,800	1,093	-
C22	547,236	14,967	132,833	202,992	196,444	2,600	2,303	1,997	1,700	1,084	47.83
C23	1,012,735	41,107	330,727	442,838	198,062	2,700	2,387	2,064	1,750	2,161	182.61
C24	1,125,018	228,652	582,377	305,520	8,469	5,800	5,140	4,460	3,800	5,714	494.22
C25	257,763	38,282	137,814	80,391	1,276	2,500	2,220	1,931	1,650	559	-
C26	1,211,187	49,030	594,485	527,069	40,603	2,750	2,437	2,114	1,800	2,770	336.96
C27	244,131	15,624	179,680	44,920	3,906	2,800	2,487	2,164	1,850	595	-
C28	1,560,064	61,538	1,184,185	282,741	31,600	3,600	3,204	2,796	2,400	4,882	412.60
C29	2,154,220	255,034	1,418,059	437,717	43,410	3,900	3,471	3,029	2,600	7,355	939.00
C30	222,178	29,169	92,471	90,609	9,930	2,400	2,136	1,864	1,600	452	-
C31	46,990	280	12,866	32,166	1,678	3,900	3,471	3,029	2,600	148	-
C32	251,375	122,546	83,792	43,991	1,047	3,400	3,004	2,596	2,200	785	34,63
C33	725,595	166,840	451,726	99,159	7,870	3,700	3,288	2,863	2,450	2,405	237.91
D21	150,463	5,614	103,303	34,809	6,737	1,950	1,736	1,515	1,300	252	-
D22	46,602	590	19,467	24,776	1,770	2,000	1,769	1,531	1,300	76	-
D23	650,172	9,132	308,649	303,170	29,221	2,600	2,303	1,997	1,700	1,390	-
D24	446,193	7,794	395,533	42,216	649	2,600	2,303	1,997	1,700	1,017	-
D25	218,929	8,519	27,260	163,558	19,593	2,600	2,303	1,997	1,700	445	-
D26	541,086	17,722	253,097	259,189	11,076	2,900	2,570	2,230	1,900	1,301	-
D27	225,659	16,073	112,508	90,006	7,072	2,300	2,036	1,764	1,500	435	19.21
D29	671,634	49,751	407,170	153,180	61,534	3,200	2,837	2,463	2,100	1,821	-
D30	407,391	11,178	299,333	94,396	2,484	2,850	2,537	2,214	1,900	1,005	84.92
D32	9,418	409	3,481	4,709	819	3,000	2,670	2,330	2,000	23	-
D33	309,237	-	192,330	115,021	1,886	3,200	2,837	2,463	2,100	833	-
D34	98,633	4,759	18,169	66,621	9,085	2,800	2,487	2,164	1,850	219	9.68
D35	287,795	23,072	114,754	138,433	11,536	2,700	2,387	2,064	1,750	642	54.26
D36	435,528	44,393	275,291	110,589	5,254	2,600	2,303	1,997	1,700	979	34.56
E27	77,481	2,460	11,889	60,263	2,870	1,700	1,502	1,298	1,100	103	-
E28	511,087	40,895	244,126	217,347	8,719	1,900	1,686	1,465	1,250	818	-
E29	494,260	34,495	418,576	40,159	1,030	2,000	1,769	1,531	1,300	872	-
E3	270,574	51,751	168,701	46,454	3,667	2,050	1,819	1,581	1,350	491	-
E30	192,859	8,517	96,125	82,132	6,084	2,100	1,869	1,631	1,400	340	-
E31	496,806	35,658	252,981	200,939	7,228	2,050	1,819	1,581	1,350	861	-
E32	142,406	8,018	69,485	60,895	4,009	1,750	1,552	1,348	1,150	209	-

Table 10: Continued.

OMI	Resident building (m^2)	BD_1 (m^2)	BD_2 (m^2)	BD_3 (m^2)	BD_4 (m^2)	REV BD_1 (€/m^2)	REV BD_2 (€/m^2)	REV BD_3 (€/m^2)	REV BD_4 (€/m^2)	Total REV (€ million)	Metro REV contrib. (€ million)
E33	631,618	8,073	338,129	278,292	7,124	2,200	1,953	1,698	1,450	1,161	131.35
E34	537,587	44,578	237,218	236,156	19,635	2,200	1,953	1,698	1,450	991	-
E35	328,820	26,577	227,036	71,532	3,676	2,150	1,903	1,648	1,400	612	69.26
E36	166,475	20,273	74,465	53,022	18,714	1,700	1,502	1,298	1,100	236	-
E37	54,480	7,106	19,937	26,845	592	1,850	1,636	1,415	1,200	84	-
E38	550,268	33,750	297,389	205,922	13,206	1,950	1,736	1,515	1,300	911	-
E39	1,042,468	125,221	475,059	431,231	10,957	2,000	1,769	1,531	1,300	1,765	-
E40	122,213	13,262	67,533	38,357	3,060	2,250	2,003	1,748	1,500	237	-
E42	1,169,908	13,840	428,233	604,900	122,934	1,550	1,385	1,215	1,050	1,479	88.68
E43	659,668	21,185	387,180	251,302	-	2,100	1,869	1,631	1,400	1,178	-
E44	775,193	69,333	315,757	346,665	43,438	1,950	1,736	1,515	1,300	1,265	-
E45	168,456	6,289	50,312	83,554	28,301	1,900	1,686	1,465	1,250	254	-
E46	430,411	27,911	345,211	52,883	4,407	2,050	1,819	1,581	1,350	775	-
E47	139,821	477	40,562	95,918	2,863	1,900	1,686	1,465	1,250	213	-
E48	194,576	45,709	81,772	46,128	20,967	1,700	1,502	1,298	1,100	283	-
Total										**84,459**	**7,205**

Table 11: Contribution of high-frequency rail stations to real estate values for all scenarios.

OMI	Scenario 0			Scenario 1			Scenario 2		
	Model REV	HF_rail_st contribution	%	Model REV	HF_rail_st contribution	%	Model REV	HF_rail_st contribution	%
B10	3446.07	301.83	8.8%	3446.07	301.83	8.8%	3446.07	301.83	8.8%
B11	3446.07	301.83	8.8%	3446.07	301.83	8.8%	3546.68	402.44	11.3%
B12	4049.73	905.50	22.4%	4049.73	905.50	22.4%	4049.73	905.50	22.4%
B13	2976.37	402.44	13.5%	2976.37	402.44	13.5%	2976.37	402.44	13.5%
B14	4577.74	503.05	11.0%	4980.19	905.50	18.2%	5080.80	1006.11	19.8%
B15	3278.20	704.27	21.5%	3278.20	704.27	21.5%	3378.81	804.88	23.8%
B16	3720.80	100.61	2.7%	3922.02	301.83	7.7%	3922.02	301.83	7.7%
B17	4123.24	503.05	12.2%	4123.24	503.05	12.2%	4223.85	603.66	14.3%
B18	3028.42	0.00	0.0%	3129.03	100.61	3.2%	3129.03	100.61	3.2%
B8	2976.37	402.44	13.5%	3076.98	503.05	16.3%	3076.98	503.05	16.3%
B9	3076.98	503.05	16.3%	3177.59	603.66	19.0%	3177.59	603.66	19.0%
C21	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2179.69	0.00	0.0%
C22	2280.30	100.61	4.4%	2280.30	100.61	4.4%	2280.30	100.61	4.4%
C23	2380.91	201.22	8.5%	2380.91	201.22	8.5%	2380.91	201.22	8.5%
C24	4653.21	402.44	8.6%	4653.21	402.44	8.6%	4653.21	402.44	8.6%
C25	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2179.69	0.00	0.0%
C26	2481.52	301.83	12.2%	2481.52	301.83	12.2%	2481.52	301.83	12.2%
C27	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2179.69	0.00	0.0%
C28	2380.91	201.22	8.5%	2582.13	402.44	15.6%	2783.36	603.66	21.7%
C29	3152.45	402.44	12.8%	3152.45	402.44	12.8%	3152.45	402.44	12.8%
C30	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2179.69	0.00	0.0%
C31	2750.01	0.00	0.0%	2750.01	0.00	0.0%	2750.01	0.00	0.0%
C32	2280.30	100.61	4.4%	2280.30	100.61	4.4%	2280.30	100.61	4.4%
C33	3051.84	301.83	9.9%	3051.84	301.83	9.9%	3051.84	301.83	9.9%
D21	2179.69	0.00	0.0%	2280.30	100.61	4.4%	2280.30	100.61	4.4%
D22	2179.69	0.00	0.0%	2280.30	100.61	4.4%	2280.30	100.61	4.4%
D23	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2481.52	301.83	12.2%
D24	2179.69	0.00	0.0%	2380.91	201.22	8.5%	2380.91	201.22	8.5%
D25	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2179.69	0.00	0.0%
D26	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2481.52	301.83	12.2%
D27	2280.30	100.61	4.4%	2280.30	100.61	4.4%	2280.30	100.61	4.4%
D29	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2481.52	301.83	12.2%
D30	2380.91	201.22	8.5%	2380.91	201.22	8.5%	2481.52	301.83	12.2%
D32	2634.19	0.00	0.0%	2634.19	0.00	0.0%	2634.19	0.00	0.0%
D33	2179.69	0.00	0.0%	2179.69	0.00	0.0%	2481.52	301.83	12.2%
D34	2280.30	100.61	4.4%	2380.91	201.22	8.5%	2380.91	201.22	8.5%
D35	2380.91	201.22	8.5%	2380.91	201.22	8.5%	2380.91	201.22	8.5%
D36	2850.62	100.61	3.5%	2850.62	100.61	3.5%	2850.62	100.61	3.5%
E27	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E28	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1778.15	201.22	11.3%
E29	1576.93	0.00	0.0%	1878.76	301.83	16.1%	1878.76	301.83	16.1%
E3	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E30	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E31	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%

Table 11: Continued.

OMI	Scenario 0			Scenario 1			Scenario 2		
	Model REV	HF_rail_st contribution	%	Model REV	HF_rail_st contribution	%	Model REV	HF_rail_st contribution	%
E32	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E33	1778.15	201.22	11.3%	1778.15	201.22	11.3%	1778.15	201.22	11.3%
E34	1576.93	0.00	0.0%	1778.15	201.22	11.3%	1778.15	201.22	11.3%
E35	1778.15	201.22	11.3%	1778.15	201.22	11.3%	1778.15	201.22	11.3%
E36	1576.93	0.00	0.0%	1677.54	100.61	6.0%	1677.54	100.61	6.0%
E37	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E38	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E39	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1778.15	201.22	11.3%
E40	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E42	1677.54	100.61	6.0%	1778.15	201.22	11.3%	1778.15	201.22	11.3%
E43	2031.43	0.00	0.0%	2031.43	0.00	0.0%	2031.43	0.00	0.0%
E44	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E45	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E46	1576.93	0.00	0.0%	1677.54	100.61	6.0%	1677.54	100.61	6.0%
E47	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%
E48	1576.93	0.00	0.0%	1576.93	0.00	0.0%	1576.93	0.00	0.0%

Table 12: Estimation of external benefits for all scenarios.

OMI	Scenario 0		Scenario 1		Scenario 2	
	Total REV (€ million)	Metro REV contrib. (€ million)	Total REV (€ million)	Metro REV contrib. (€ million)	Total REV (€ million)	Metro REV contrib. (€ million)
B10	5,339.24	467.65	5,339.24	467.65	5,339.24	467.65
B11	680.15	59.57	680.15	59.57	700.01	79.43
B12	4,868.42	1,088.55	4,868.42	1,088.55	4,868.42	1,088.55
B13	1,106.81	149.65	1,106.81	149.65	1,106.81	149.65
B14	5,122.70	562.94	5,573.05	1,013.29	5,685.64	1,125.88
B15	3,675.57	789.64	3,675.57	789.64	3,788.38	902.45
B16	749.16	20.26	789.68	60.77	789.68	60.77
B17	2,932.43	357.77	2,932.43	357.77	3,003.99	429.32
B18	812.87	-	839.88	27.01	839.88	27.01
B8	1,970.55	266.44	2,037.16	333.05	2,037.16	333.05
B9	1,621.49	265.10	1,674.51	318.12	1,674.51	318.12
C21	1,092.86	-	1,092.86	-	1,092.86	-
C22	1,084.16	47.83	1,084.16	47.83	1,084.16	47.83
C23	2,160.67	182.61	2,160.67	182.61	2,160.67	182.61
C24	5,714.40	494.22	5,714.40	494.22	5,714.40	494.22
C25	558.88	-	558.88	-	558.88	-
C26	2,770.34	336.96	2,770.34	336.96	2,770.34	336.96
C27	594.93	-	594.93	-	594.93	-
C28	4,882.05	412.60	5,294.65	825.21	5,707.25	1,237.81
C29	7,355.42	939.00	7,355.42	939.00	7,355.42	939.00
C30	452.31	-	452.31	-	452.31	-
C31	147.54	-	147.54	-	147.54	-
C32	784.87	34,63	784.87	34.63	784.87	34.63
C33	2,405.48	237.91	2,405.48	237.91	2,405.48	237.91
D21	251.71	-	263.33	11.62	263.33	11.62
D22	75.85	-	79.35	3.50	79.35	3.50
D23	1,389.67	-	1,389.67	-	1,582.10	192.43
D24	1,016.59	-	1,110.43	93.85	1,110.43	93.85
D25	444.86	-	444.86	-	444.86	-
D26	1,300.89	-	1,300.89	-	1,481.03	180.14
D27	435.41	19.21	435.41	19.21	435.41	19.21
D29	1,820.85	-	1,820.85	-	2,072.99	252.14
D30	1,004.78	84.92	1,004.78	84.92	1,047.24	127.38
D32	23.13	-	23.13	-	23.13	-
D33	832.90	-	832.90	-	948.23	115.34
D34	219.44	9.68	229.13	19.36	229.13	19.36
D35	642.00	54.26	642.00	54.26	642.00	54.26
D36	979.20	34.56	979.20	34.56	979.20	34.56
E27	103.42	-	103.42	-	103.42	-
E28	818.38	-	818.38	-	922.81	104.43
E29	872.27	-	1,039.23	166.96	1,039.23	166.96
E3	491.35	-	491.35	-	491.35	-
E30	340.02	-	340.02	-	340.02	-
E31	860.71	-	860.71	-	860.71	-
E32	208.57	-	208.57	-	208.57	-

Table 12: Continued.

OMI	Scenario 0		Scenario 1		Scenario 2	
	Total REV (€ million)	Metro REV contrib. (€ million)	Total REV (€ million)	Metro REV contrib. (€ million)	Total REV (€ million)	Metro REV contrib. (€ million)
E33	1,160.69	131.35	1,160.69	131.35	1,160.69	131.35
E34	990.58	-	1,116.99	126.40	1,116.99	126.40
E35	612.07	69.26	612.07	69.26	612.07	69.26
E36	235.72	-	250.76	15.04	250.76	15.04
E37	84.44	-	84.44	-	84.44	-
E38	910.97	-	910.97	-	910.97	-
E39	1,765.28	-	1,765.28	-	1,990.54	225.26
E40	236.69	-	236.69	-	236.69	-
E42	1,478.59	88.68	1,567.27	177.36	1,567.27	177.36
E43	1,178.00	-	1,178.00	-	1,178.00	-
E44	1,264.69	-	1,264.69	-	1,264.69	-
E45	254.49	-	254.49	-	254.49	-
E46	774.71	-	824.14	49.43	824.14	49.43
E47	213.33	-	213.33	-	213.33	-
E48	283.46	-	283.46	-	283.46	-
Total	**84,459.03**	**7,205.25**	**86,074.29**	**8,820.51**	**87,915.89**	**10,662.11**

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