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The Impact of Railway Stations on Residential and Commercial Property Value: a Meta Analysis

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Abstract

Property values are affected by the properties' physical, accessibility and environmental features. Railway stations function as nodes in transport networks and places in an urban environment. They have accessibility and environmental impacts, which contribute to property value. The literature on the effects of railway stations on property value is mixed in its finding in respect to impact magnitude and direction, ranging from a negative to an insignificant or a positive impact. This paper attempts to explain the variation in the findings by meta-analytical procedures. Generally the variations are attributed to the nature of data, particular spatial characteristics, temporal effects and methodology. The data can vary in relation to the type of property under study. Some indication is found to support the assertion that commercial properties enjoy a higher positive impact compared to residential properties. Commuter railway stations have a consistently higher positive impact on the property value compared to light and heavy railway/Metro stations. The inclusion of other accessibility variables (such as highways) in the models reduces the level of reported railway station impact. However this effect becomes insignificant for properties within a quarter-mile of the station, leaving the railway station as a major accessibility point. Our analysis did not find a significant effect of spatial and temporal factors.

Key words: property value, railway station, accessibility, light railways, heavy railway/ Metro, commuter railway, meta-analysis.

1. INTRODUCTION

Location choice is a frequently discussed topic in urban economics. Generally, these discussions are normative or descriptive in nature. Some of the studies address the issue of optimal location conditional on a given set of constraints (Fujita 1989). Others are devoted to explaining the character (value) of a property at a given location. However, the issue of identifying the factors that affect property values is common to both sets of approaches. This paper discusses studies of the latter category, focussing on properties surrounding railway stations.

The term "property" should be defined at the outset of our discussion. Different definitions are encountered depending on the related discipline. Property in this context means an estate ranging from a vacant piece of land to an area occupied by all sorts of buildings: residential, commercial, industrial etc. (Brigham 1965). Many property value studies have been conducted. Most authors agree in listing the broad categories of factors affecting property value, namely physical, environmental and accessibility factors (Fujita 1989, Bowes and Ihlanfeldt 2001). However some authors have included historical factors and land use patterns into their analysis (Brigham 1965). Numerous detailed lists can be identified within each of these categories. As to the relevance of the factors to the analysis, the detailed list can differ from one place to another and thereby from study to study. These factors potentially trade off between each other.

Proximity to a railway station as a factor affecting property value has drawn some attention in the literature. This paper surveys studies on the effect of railway station proximity on property value. The question addressed in these studies was: what is the impact of railway station proximity on property value? In subsequent sections, we systematically discuss the theoretical foundation of the studies, presenting and comparing the empirical results of the various studies conducted. We also discuss future study prospects based on the result of the comparisons. In addition to reviewing the studies conducted in the area, we make a quantitative analysis of the results of the studies, using meta-analysis to explain the differences in the results. Thus the paper has two parts, a qualitative review and a quantitative analysis.

2. THEORETICAL BACKGROUND OF THE STUDY

The theory based on farmland study pioneered by Von Thünen (1863) is the well-recognized first attempt in this area. The theory stresses the primacy of transportation cost in determining land value and use. 'According to Von Thünen, for a given land of a given fertility, land value differentials are derived from the transportation savings afforded by the location of the land' (Grass 1992). In subsequent studies, economists improved the model in bid-rent terms (Alonso 1964 and Muth 1969). The basic idea behind the bid-rent model is that every agent is prepared to pay a certain amount of money depending on the location of the land. This leads in equilibrium to a rent gradient that declines with distance from the central business district for sites that yield equal utility. Up to this point the dominant factor explaining the difference between land (property) values was the accessibility as measured by the distance to the Central Business District (CBD) and the associated transportation costs. The physical characteristics of the land (fertility in the case of Thünen) were assumed given.

However, as the hedonic pricing approach become popular, the physical characteristics of the property were integrated as important components in explaining the difference in property values. Along with the accessibility factor, the physical characteristics are also explained in relation to the distance from the CBD. The bid-rent model assumes size of parcels (properties) increase as the distance to the CBD increases (Fujita 1989). For urban properties, the transport cost perspective (as a measure of accessibility) seems narrow, however. In successive studies, a more general concept of accessibility was introduced. The concept of accessibility thus encompasses all variables that contribute to the potential of opportunities of a location for interaction (Hansen 1959 and Martellato et al., 1998). Though a comprehensive definition of the concept of accessibility is available, the lack of data and appropriate measuring technique implies that simple measures are used. Thus, in the literature we see a focus on some factors only, especially a CBD oriented interaction related to employment and shopping. In most property value studies, the social interaction variables were missing from the model.

The basic theory in real estate price studies can be put forward as follows. As a location becomes more attractive, as a result of certain characteristics, demand increases. This results in price increase. In most cases CBDs are the centres of many activities. Thus closeness to the CBD is considered as an attractive quality that increases property prices. Investments in transport infrastructure reduce this friction at the CBD to some degree (Fejarang 1994). Properties close to the investment area also enjoy benefits from these investments. Being close to a transport facility increases the accessibility of the property and thus the value of the transport facility is capitalized in the property value. It may be expected that a price curve will have a negative slope; when we move away from the station, prices decrease. However, because areas close to a station are attractive and, naturally, transport stations lead to polycentric structures, a linear polycentric city is likely to have a price curve (rent gradient) with a sinusoidal pattern. Local peaks occur at the station areas, and the global peak will be found around the CBD.

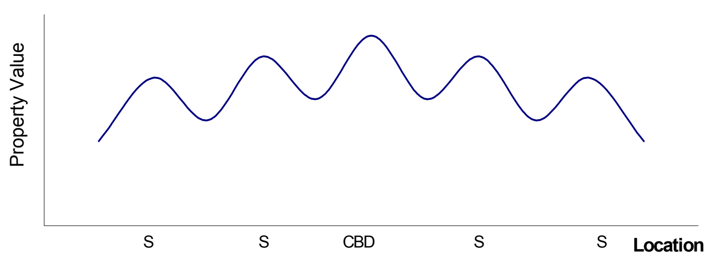

Figure 1: sinusoidal patter of property value along a line station centred by the CBD

The accessibility measurement problem also appears to be a major challenge. In bid-rent models accessibility variables had to be measured as the distance (or the cost of transportation) to the destination. This approach is applied for most accessibility studies. It is important to note, however, that this approach stems from the definition of the concept of accessibility: the ease by which the CBD may be reached. However, in the literature we observe different definitions of accessibility, depending on the purpose of the study (Rietveld and Bruinsma 1998). In some cases we may need additional parameters (other than cost, travel distance/time, fare etc.), including interaction patterns. However, even though the concept seems subjected to definition and measurement problems, its basic theoretical relationship to the property value remains the same. A higher accessibility index for the property in question implies a higher property value.

In the earlier property value studies, environmental amenities were not included. However the hedonic price approach calls for their inclusion. The concept of environmental amenities is subjected to more definition and measurement problems than the concept accessibility. Having succeeded in defining and measuring the concept of environmental amenities, the relation to the property value is explained in the same manner: the higher the favourable amenity index corresponding to the property, the higher its value. The dominant theoretical framework for most studies remains the one that includes physical features, accessibility and amenity factors.

3. RAILWAY STATION AND PROPERTY VALUE

Recently, in different places, urban planning is gaining popularity as a tool to increase efficient land use. This is due to the increasing fragmentation of urban developments. The larger part of the literature on railway systems focuses on it as a feasible solution to the rising congestion posed by automobile traffic and urban sprawls. Railway transport investment is expected to support a more compact urban structure and therefore it serves the urban planning purpose (Goldberg 1981). The theory on land prices and settlement indicates that a higher accessibility of a location leads to a dense settlement. One way of investigating this assertion is to measure the premium that residents are willing to pay to remain close to the railway stations. Naturally, railway stations have an effect on both land value and land use patterns (Ferguson et al, 1988). Our study, however, focuses on land value effects. Thus, we defer the land use effect for later studies. Grass (1992) indicates that public infrastructure has a profound influence on the pattern of urban development and spatial distribution of urban property values. ‘The presence of other facilities that increase accessibility like highways, sewer services and other facilities influence the impact area in the same fashion.’ The benefits of these facilities and services are also capitalized into urban property values (Damm et al, 1980). Thus, in order to conclude anything about the effect of a railway station on property values, one would need to separate the accessibility benefit attributed to the railway station. Whatever the result of the study will be in relation to the significance of the railway station effect, at this point we would like to emphasize the relationship between the railway (as a public investment) as a transport means and the real estate market.

In recent literature, a station is seen from two angles: as a node in a transport system and a place in an area (Bertolini and Spit 1998). In line with this approach, stations pose two types of effects on nearby properties, namely accessibility and amenity. This relatively new approach solves the difference in relative impact of stations to property values in different places and over different periods of time. As pointed out earlier, the first impact was dominant in the earlier property value studies. However, recent studies also emphasize the latter impact, as we now will explain.

Property values are affected by the inherent characteristics of the property and by positive or negative external amenities. The inherent characteristics of the property are the physical characteristics they offer. Many hedonic price analyses for property values (specially residential areas) have listed a broad range of these characteristics (Grass 1992, Kruk 2001). The external amenities that affect the value of property emanate from the surrounding physical environment and the activities undertaken there. The intensity of the external amenity emanating from an area (railway station for example) on property tends to vary. Immediate locations are expected to have higher effects than locations further away. The high population movement gives rise to the development of retail activities but may at the same time attract criminality (Bowes and Ihlanfeldt 2001).

Accessibility to the place of interest (predominantly the CBD) is determined by different travel alternatives (railways, highways, etc). Some property value studies determine the impact of the variables on property values by measuring the impact of each separate variable on property value. On the other hand, some studies keep some accessibility variables constant, and only capture the impact of the remaining variables (in most cases railway stations). As Voith (1993) has pointed out, highway accessibility is an important competitor to rail accessibility. However, in some recent studies no explicit consideration of the highway accessibility impact share in property value was given (McDonald and Osuji, 1995; Bowes and Ihlanfeldt, 2001).

Different properties can surround railway station areas. Due to the unique nature of the property, interaction with the railway station can have substantially different impacts on the property value. Though Brigham mentions, in passing, that property value models could behave differently for different property types, his empirical study is devoted to residential property values (Brigham, 1965).

4. EMPIRICAL FINDINGS ON PROPERTY VALUES

The empirical studies conducted in this area are diverse in methodology and focus. In order to single out the effect of proximity to a railway station, the impact of other characteristics of the property under consideration are often incorporated in the models. Although the functional forms can differ from study to study, the most common methodology encountered in the literature is hedonic pricing. The empirical studies on the impact of railway stations range in scope from broad economic matters of employment and settlement densities (Bollinger and Ihlanfeldt 1996) to specific impact on property values (Bowes and Ihlanfeldt 2001).

The studies in property values mainly consider three groups of determinants: the physical characteristics, accessibility and environmental amenities. In the physical characteristics category, the inherent factors representing the qualitative and quantitative features of property are identified. Environmental amenities are the externalities (bad or good) that emanate from the neighbourhood. Railway stations possess two impact characteristics: an environmental amenity and an accessibility character. Most of earlier studies consider the accessibility variable only. The impact of railway stations on property values becomes smaller as one goes farther away from the station. However, the effect of railway station does not necessarily have a circular pattern, especially if the lines run above ground. The negative environmental externalities, on the other hand, can have an effect on properties along the railway line.

Generally speaking, no consistent relationship between proximity to railway stations and property values is recorded in the literature. Furthermore, the magnitudes of these effects can be minor or major. No clear consensus exists, therefore. Studies on residential property value usually show that property value increases in response to transportation cost savings (Boyce et al., 1972). One of the earliest studies, Dewees (1976), also analysed the relationship between travel costs by rail and residential property values. Dewees found that a subway station increases the site rent perpendicular to the facility within a one-third mile walk to the station. Similar findings confirmed that the distance of a plot of land from the nearest station has a statistically significant effect on the property value of the land (Damm et al, 1980). Consistent with these conclusions, Grass (1992) later found a direct relationship between the distance of the newly opened metro and residential property values. Some of the extensively studied metro stations in the U.S., though ranging from small to modest impact, show that properties close to the station have a higher value than properties farther away (Giuliano 1986; Bajic 1983; Voith 1991a). However there are studies, which have also found insignificant effects (Lee 1973; Gatzlaff and Smith 1993). On the other hand, contrary to the general assumption, Dornbusch (1975), Burkhart (1976) and Landis et al, (1995) traced a negative effect to the proximity of stations. Evidence from other studies indicates little impact in the absence of favourable factors (Gordon and Richardson 1989; Guiliano 1986). For detailed documentation of the findings, we refer to (Vessali 1996; Smith 2001; NEORail 2001; CIP annual conference 2002; RICS 2002). In general, some studies indicate a decline in the historical impact of railway stations, on property values. This was attributed to improvements in accessibility, advances in telecommunications, computer networks, and other areas of technology that were said to make companies "footloose" in their location choices (Gatzlaff and Smith 1993).

The larger part of the empirical literature on property value focuses on residential properties rather than commercial properties. Generally, it is claimed that the range of the impact area of railway stations is larger for residential properties, whereas the impact of a railway station on commercial properties is limited to immediately adjacent areas. In addition, there are claims that railway stations have a higher effect on commercial than on residential properties (Weinstein and Clower 1999; Cervero and Duncan 2001). This finding is in line with the assertion that railway stations - as focal, gathering points - attract commercial activities, which increase commercial property values. However contrary to this assertion, Landis et al, (1995) determined a negative effect on commercial property values.

In subsequent studies addressing the variation in the findings, the noise and other negative externalities of railway stations were treated separately from the accessibility and other positive amenities. Bowes and Ihlanfeldt (2001) pointed out the retail employment and crime that stations attract. A significant relation was observed between stations and crime rates. However, no proximity variable shows a significant effect on retail employment. In this model, the immediate neighbourhood is affected by the negative impact of the station. Thus the most immediate properties (within a quarter of a mile of the station) were found to have an 18.7% lower value. Properties that are situated between one and three miles from the station, however, are more valuable than those further away. Though this study provides an important contribution, unexplained variations still remain.

Heterogeneity between stations is another important characteristic that specifies differences between study results. Stations differ from each other in railway technology, service frequency and service catchment areas. We can identify four types of railways in the studies, namely Light railways (LRT[1]), heavy (rapid) railways (HRT/Metro[2]), commuter railways (CRT[3]) and rapid bus transits (BRT[4]). There are indications that commuter railways have a higher impact on property value than other stations (Cervero 1984; Cervero and Duncan 2001; NEORail II 2001). The number of parking lots in or near the station and the proximity of the railway station to the CBD also increase the impact of the station on property value (Bowes and Ihlanfeldt 2001). In addition Gatzlaff and Smith (1993) claim that the variation in the findings of the empirical work is attributed to local factors in each city.

Some empirical studies on a railway station's impact on property value also focused on demographic characteristic differences in the population of various city quarters. Income and social (racial) divisions are common in the literature. Proximity to a railway station is of higher value to low-income residential neighbourhoods than to high-income residential neighbourhoods (Nelson 1998; Bowes and Ihlanfeldt 2001). The reason is that low-income residents tend to rely on public transit and thus attach higher value to living close to the station.

5. META-ANALYSIS OF THE STUDIES

In the previous section we briefly reviewed empirical work on the effects of station proximity on property value. Other reviews can be found in Vessali (1996), Smith 2001, NEORail (2001), CIP annual conference (2002) and RICS (2002). These studies also summarized empirical work in this area, but did not look for a systematic explanation of the variation in the findings. Our study not only summarizes earlier work, but also looks for a systematic explanation of differences in the results. Meta-analysis serves as an important tool for this purpose (Smith and Huang 1995; Cook et al, 1992).

It provides statistical synthesis of empirical research focused on a common research question. It includes the differences in study settings that are expected to explain the variation in the findings of the studies. In our case, the summarized studies focus on the impact of railway station proximity relative to property value. Different approaches towards the analysing of property value in areas surrounding railway stations are encountered in the literature. For the comparison of results to be meaningful, it is required that the studies have comparable effect sizes (in our case the change in property value at various distances from the railway station). Different measurement units are encountered in the literature, although these all aim to measure a similar effect. However, for meta-analysis it is important that the findings are in the same measurement unit. Meta-analysis models are basically hedonic in nature and the results of the studies are treated as a dependent variable explained by implicit or explicit characteristics of the underlying studies. A basic meta-analysis equation can be given as follows (Florax et al, 2002).

$$Y = f(P, X, R, T, L) + \varepsilon \tag{1}$$

Where *Y*= the variable under study

P= set of causes of the out come Y

X= characteristics of the set of objects under examination affected by P in order to determine the outcome Y

R= characteristics of research method

T= time period covered by the study

L= the location of each study conducted

ε = the error term

The number and nature of the studies on railway station impact on property value enable the use of meta-analysis. The studies included in this study all quantify the impact of railway station proximity on property values. A matching process was necessary to transform the study results into a variable with a common unit of measurement.

5.1 Model specification

The literature on property value estimation is dominated by a hedonic price approach. This approach treats a certain property as a composite of characteristics to which value is attached. The value of the characteristics explains the value of the property as a whole. Meta-analysis is also hedonic in nature, since it starts by identifying the characteristics of the underlying studies that could explain the variations in effect size. The underlying studies usually include the proximity of the property to the station. However, we observe that not all studies use the same set of (explanatory) variables. The studies also differ in methodology. A railway station variable is mostly treated as an indicator of the degree of accessibility of a certain area. Likewise, other variables serve the same purpose (e.g. presence of highways/freeways in the area under consideration). One can thus expect that these variables "interact". Although they are complementary (one can take a car to the railway station and then take the train), for our purpose it is important to note that they both have an effect on property values. These effects could reinforce each other, but may also be "competitors".

The underlying empirical studies employ different specifications, namely linear, semi logarithmic and log linear. In some studies the analyses are non parametric in nature. Different specifications may also lead to different outcomes. In our analysis we further include type of railway station (light rail, heavy rail/Metro, commuter rail), type of property (commercial, residential), geographical location (Europe versus North America) and time of study. We also examine whether the underlying study includes variables for the quality of a property and demographic features. Thus, our analysis includes eight categories of variables to explain the difference in the findings of the impact of railway station proximity on property values. To account for the variation we specify a standard hedonic model using a simple linear form where bold symbols represent vectors of variables:

$$Y = \alpha_0 + \beta_1 P + \boldsymbol{\beta_2}\mathbf{S} + \boldsymbol{\beta_3}\mathbf{M} + \beta_4 ACCESS + \beta_5 DM + \beta_6 HQ + \boldsymbol{\beta_7}\mathbf{L} + \beta_8 T + \varepsilon \qquad (2)$$

Dependent variable

Y is the percentage impact of railway station on property value (rent).

Explanatory variables[5]

P is a dummy variable that takes on the value 1 when commercial properties are analysed (reference group is residential properties). S is a vector of dummy variables for the station type (heavy rail/ Metro, commuter rail, BRT; light rail is the reference group). M is a vector of dummy variables for the model type (semi log, double log, non parametric; linear is the reference group). ACCESS is a dummy variable indicating the presence of other means of access to the area in the underlying study (usually highways and/or freeways). DM is a dummy variable indicating the presence of a demographic variable in the underlying study (usually income or racial composition of city quarters). HQ is a dummy variable for the presence variables indicating the quality of a property in the underlying model. L is a vector of dummy variables indicating the geographical location of the study (Western US, Central US, Europe; Eastern US is the reference group). T is a dummy for time trend (assume 1 for study data after 1990, study data before 1990 is taken as a reference group).

Some of these variables were used in the models of the underlying studies. However others were not used in these studies, although the study contains enough information to allow these variables to be used in the meta-analysis. Because most variables in the meta-analysis are dummy variables, the estimated coefficients represent the percentage contribution of each attribute on property value in comparison to the reference groups.

5.2 Data and methodology

The database for the analysis of this paper is a pool of studies on the impact of railway station proximity on property value. A wide range of studies is covered. A total of 102 estimation results were obtained from the underlying studies. Different specifications in the same underlying study are treated as separate observations. Thus, the total number of underlying studies is lower than the number of observations in our meta-analysis. However, due to the incompleteness of some of the studies with respect to the requirements of this study, we had to exclude certain observations. We finally made use of 73 observations.

5.2.1 Variation in the presentation of the findings

The dependent variable in our meta-analysis is expressed as the percentage change in property value per some distance measure to the station. The underlying studies are quite diverse in the way the impact of railway station proximity is reported, including pure monetary effects, percentage effects and elasticity measures. However, the larger part of these studies reports the percentage increase or decrease in property value for a certain distance. In addition to the diversity of measurements, the studies also use a variety of methodologies. We summarize them in two categories:

I. Parametric estimation methods

These studies use econometric methods to estimate the impact of railway station proximity on property value. Linear, semi log and log linear (also called double log) specifications are common. Three broad categories of railway station proximity measurement were encountered.

1. Station effect as a continuous measure:

These studies consider the proximity to a railway station as a continuous variable. The variable can be measured in distance, time (walking time) or monetary savings (Dewees 1976;

Nelson and 1990; Nelson 1992; Benjamin and Sirmans 1996; Lewis-Workman and Brod 1997; Chen et al, 1998; Gatzlaff and Smith 1993). The results are given in monetary units (as in linear models) or in percentage units (as in semi log and log linear models). The results of the semi log models are in line with the dependent variable in our meta-analysis. Therefore the monetary changes and elasticity have to be transformed into a percentage change per distance using the average property value and average distance data reported in each underlying study. Coefficients of semi log and double log specifications represent incomparable measures. Thus to bring them into comparable units we divided the elasticity by the average distance of the impact area. The rent curves can have structures similar to (a) in figure 2 below.

Table 1. Sample of railway station effect on property value based on continuous proximity measures

Author	Railway station impact on property value
Dewees (1976)	$2370 premium per hour of travel time saved for sites within 20 minutes travel time (e.g. 1/3 mile walk)
Nelson (1992)	$1.05 per feet distance to the station. premium on property value in low-income areas; $.96 per feet distance to the station.
Allen, et al, (1986)	$443 premium on property value for every dollar saved in daily commute costs (average >$4,500 per house; 7.3% of mean sales price)
Lewis, Workman and Brod (1997)	Elasticity of 0.22 w.r.t property value and distance
Benjamin and Sirmans (1996)	Rent decreased by 2.4 to 2.6% for each one tenth mile distance from the metro station

2. Station effect as a category measures:

These studies treat the proximity variable as a discrete variable (represented by dummy). The area under consideration is segmented into two or more parts, where the outer segment is treated as the reference (McDonald and Osuji 1995; Fejarang et al, 1994; Dueker and Bianco 1999; Weinstein and Clower 1999; Voith 1993; Armstrong 1994; Grass 1992; Bowes and Ihlanfeldt 2001; Cervero and Duncan 2001, 2002; Weinberger 2001). The rent curve for these types can be given by (b) in figure 2 below.

Table 2. Sample of railway station effect on property value based on category measures

Author	Result
Cervero, Robert (1996)	+10- 15% in rent for rental units within 1/ 4 mile of BART
Bowes and Ihlanfeldt (2001)	Property value effect (percentage change)
0-1/4 mile	-18.7%
¼-1/2 mile	2.4 %
½-1 mile	0.9 %
1-2 mile	3.5%
2-3 mile	3.5%
Weinberger (2001)	Rent
0-1/4 mile	+13 cents per square foot
¼-1/2 mile	+7 cent per square foot
½-3/4 mile	+ 1 cent per square foot
¾-1 mile	No effect

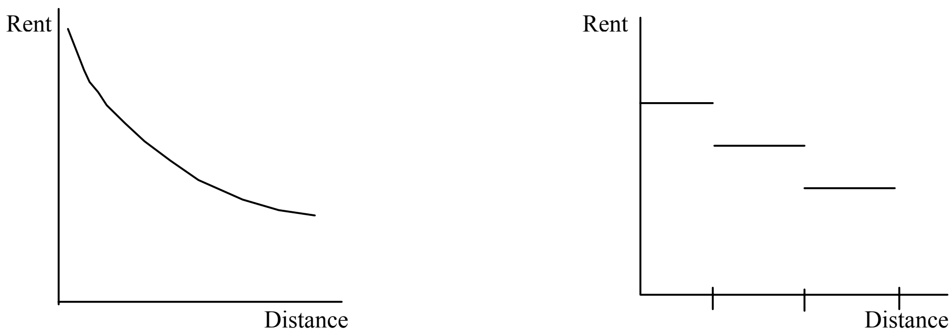

Figure 2. Structure of rent curves. Distance from the station as a continuous measure (left panel) and as category measures (right panel).

II. Non-parametric measures:

These studies do not use econometric methods to estimate the effect of railway stations on property values. They can measure the proximity variable in continuous or discrete terms. The common feature of these studies is that the difference in property value is implicitly attributed to the railway station effect only. Some examples of this sort are given in Table 3.

Table 3. Sample of results presentation for non-parametric cases

Author(s)	Result
Weinstein and Clower (1999)	Effect of station on property vale Within ¼ mile of the station (percentage change)
Retail	36.75%
Office	13.85%
Residential	5.97%
Industrial	7.68%
Dueker and Bianco (1999)	Property value declines $1593 for every 200 feet out of the station
Fejarang (1994)	Properties within ¼ mile of the station enjoy premium of $31 per square foot.

5.2.2 Meta-analysis dependent variable

For meta-analysis it is essential that the dependent variable is measured in comparable units. Due to the large differences between in the underlying studies in reporting the finding some conversion mechanism is required. Three reasonable considerations were necessary for this mechanism:

1. We consider railway station impacts up to a maximum distance of two miles, unless otherwise indicated.
2. The properties under study are evenly distributed in concentric circles around the railway stations. Thus, due to the fact that larger circles lead to an area enlargement, the average distance to the station for each segment is given by a+2/3*(b-a), where a is the distance the border of the inner concentric circle to the station, and b is the distance between the border of the outer segment and the railway station. For the station itself we have a=b=0.
3. The impact of a station in the same segment in a circle is uniform.

For studies that provide the impact for several segments, the continuous railway station impact (see for example Table 2) is estimated by the approach outlined in Appendix 1. However for studies that looked at one (immediate) segment, as compared to the outer segment, we have estimated the continuous station effect per distance by point estimation (under the above assumptions). A final choice is based on the unit of distance. We decided to adopt a unit of measurement equal to 250 metres. Thus, the dependent variable in the meta-analysis is the percentage change in property value (rent) per 250 metres distance to the railway station. In addition we have prepared the effect of the railway station on the immediate segment (within a quarter mile of the station). Therefore, our estimation is based on these two data sets.

5.2.3 Independent Variables

In this context, the impact of railway proximity on station on property value as reported in the underlying studies can be affected by several factors. The type of property value under study may be important, because commercial and residential properties may be affected differently. Different types of railway stations may have different impacts because the frequency of service or the passenger type may be different, etc. The various types of railways are defined in Endnotes 1-4. The type of model used to determine the effect can actually influence the effect (compare e.g. point elasticity estimates to interval estimates). Although most studies were parametric, a few studies used a non-parametric model, as discussed above. Three types of parametric models were encountered: linear, semi-log and log linear. Temporal and spatial characteristics have to be included, because the effects in Los Angeles and London could, for instance, be very different due to inherent characteristics of these cities. We also included a variable for the presence of other accessibility variables (highways and freeways are of interest here), house quality, and demographic features in the underlying studies, as discussed above. As shown in Table 4, these considerations lead to eight categories of dependent variables in our meta- analysis.

Table 4 Independent variables

	Variable	Description	Type
Type of property (*P*)			
	RESIDENTIAL	Residential property	Dummy
	COMMERCIAL	Commercial Property	Dummy
Type of station (**S**)			
	LRT	Light rail transit station	Dummy
	HRT	Heavy (rapid) rail transit station/ Metro	Dummy
	COMMUTER	Commuter rail transit station	Dummy
	BRT	Rapid Bus transit station	Dummy
Type of underlying model (**M**)			
	LINEAR	Model with linear specification	Dummy
	SEMI LOG	Model with semi log specification	Dummy
	LOG LINEAR	Model with log linear specification	Dummy
	NON PARAMETRIC	Non parametric	Dummy
Location of study (**L**)			
	US1	Eastern United States	Dummy
	US2	Central United States	Dummy
	US3	Western United States	Dummy
	EUROPE	Europe	Dummy
Inclusion of Accessibility Variable(s) in the underlying model			
	ACCESSIBILITY (*ACCESS*)		Dummy
Inclusion of Demographic variable(s) in the underlying model: income, racial composition of city quarters			
	DEMOGRAPHIC (*DM*)		Dummy
Inclusion of House quality variable(s) in the underlying model			
	HOUSE quality (*HQ*)		Dummy
Time of data (*T*)			
	TIME Before 1990		Dummy
	TIME After 1990		Dummy

5.3 Descriptive statistics

In Table 5 we display the distribution of the dependent variable. Overall characteristics and characteristics per group (defined by the independent variables) of the dependent variable are given. The mean impact of a station on property value (rent) for every 250 metres close to the station is 2.61%. The Table shows that the range is considerable; it varies from –12.84% to +38.70%.

Table 5: Descriptive summary of Railway station proximity impact on property value

	Effect per 250 metre						Effect within 1/4 mile					
	Min	Mean	t test[a]	Max	Stdev	N	Min	Mean	t test	Max	Stdev	N
Over all	-0.128	0.026		0.387	0.059	73	-0.619	0.089		1.452	0.235	70
Property Type												
Residential[b]	-0.038	0.019		0.099	0.030	52	-0.193	0.062		0.429	**0.109**	49
Commercial	-0.128	**0.043**[c]	1.542	0.387	**0.098**	21	-0.619	**0.152**	1.489	1.452	0.395	21
Residential Properties												
Single Family[b]	-0.031	**0.018**		0.099	0.030	27	-0.149	**0.060**		0.370	0.093	27
Multi Family	0.000	0.002	1.284	0.013	0.005	6	0.000	0.011	1.252	0.065	0.027	6
Condominium	-0.038	0.008	0.661	0.084	**0.041**	6	-0.193	0.043	0.300	0.429	**0.209**	6
Unidentified	-0.012	0.035		0.083	0.024	13	-0.039	0.110		0.291	0.095	10
Type of railway stations												
LRT[b]	-0.014	0.025		0.111	0.036	26	-0.072	0.076		0.368	0.106	23
HRT	-0.128	0.015	1.039	0.099	0.040	28	-0.619	0.053	0.547	0.370	0.172	28
CRT	-0.056	**0.054**	1.292	0.387	**0.104**	15	-0.270	**0.194**	1.288	1.452	**0.421**	15
BRT	-0.031	0.005	1.070	0.041	0.030	4	-0.149	0.025	0.842	0.200	0.144	4
Model												
Non Parametric	0.016	**0.061**	1.565	0.111	0.042	6	0.060	**0.155**	0.673	0.368	0.124	5
Linear[b]	-0.128	0.019		0.387	0.064	53	-0.619	0.073		1.452	**0.268**	51
Semi Log	-0.006	0.039	0.892	0.099	0.038	9	0.000	0.136	0.693	0.370	0.111	9
Log Linear	0.021	0.038	0.666	0.051	0.013	5	0.050	0.103	0.246	0.165	0.048	5
Accessibility [b]	-0.128	0.020		0.387	**0.065**	51	-0.619	0.077		1.452	**0.266**	51
No Accessibility	-0.012	**0.041**	1.432	0.111	0.036	22	-0.039	**0.122**	0.720	0.370	0.115	19
Demographic [b]	-0.128	0.019		0.387	**0.070**	44	-0.619	0.076		1.452	**0.286**	44
No Demographic	-0.012	**0.038**	1.366	0.111	0.032	29	-0.039	**0.111**	0.602	0.370	0.104	26
House quality [b]	-0.128	0.022		0.387	**0.061**	62	-0.619	0.085		1.452	**0.249**	61
No House quality	0.016	**0.052**	1.428	0.111	0.036	9	0.022	**0.137**	0.546	0.368	0.113	7
Study Place												
US1[b]	-0.006	0.031		0.099	0.024	19	0.000	0.102		0.370	0.101	19
US2	0.016	**0.045**	1.076	0.098	0.033	5	0.060	**0.161**	1.105	0.368	0.123	5
US3	-0.128	0.022	0.521	0.387	**0.070**	47	-0.619	0.077	0.378	1.452	**0.283**	45
Europe	0.024	0.025	0.358	0.025	0.001	2	0.022	0.022		0.022	.	1
Time												
Up to 1990[b]	0.000	**0.027**		0.111	0.031	29	0.000	0.066		0.370	0.080	27

[a] The t statistics for pair-wise mean equality test of one group with the reference type within the group. For Example the null hypothesis for property type is H_0: mean change of value for commercial properties = mean change of value for residential properties. The critical values at 5% significance level for d.f. 19, 22, 28, 31, 39, 52, 64, 69, and 71, are 2.093, 2.074, 2.048, 2.040, 2.023, 2.007, 1.998, 1.995 and 1.994 respectively.

[b] Variable reference in the group (category)

[c] Bold figures in the column represent higher mean in each group (category)

From the table above we learn that railway stations have a higher average effect on commercial properties compared to residential properties. However, the corresponding standard deviations are quite high. Commuter railway stations have higher impact on property values than the other three types of railway stations. Non-parametric methods report higher station effects. This is because these analyses attribute the differences in property value solely to station proximity, so that result may be overstated. Contrary to the literature assertion that railway stations have lower impact on multi family or condominium properties as compared to single-family properties, the Table indicates higher impact on single-family properties (Cervero 1997; Cervero and Duncan 2002). Studies in the central part of the US report higher effect of railway stations.

5.4 Estimation Results

To test for the significance of the differences in the findings of the studies, we estimate two functions. The first function explains the impact of station proximity on property value (rent) for every 250 metres distance reduction to the station, using the variables selected above as explanatory variables. The second function explains the impact of station proximity on property value (rent) for properties within ¼ mile of the station, again from the variables above. Weighting is also considered based on the square root of the number of observations in the underlying studies. The output of the model after stepwise elimination of insignificant variables is given in the following tables.

Table 6: Unweighted estimation output for impact of station on property value for every 250 m

Variable	Parameter estimate	Standard error	t test
Constant	0.03312	0.0122	2.723
Commercial	0.02856	0.0141	2.027
Commuter	0.05268	0.0167	3.147
Accessibility	-0.03732	0.0147	-2.544

R^2=0.18, 73 observations

Table 7: Weighted estimation output for impact of station on property value for every 250 m

Variable	parameter estimate	standard error	t test
Constant	0.03175	0.0136	2.318
Commercial	0.02443	0.0135	1.807
Commuter	0.04074	0.0136	2.994
Accessibility	-0.03836	0.0147	-2.606

R^2=0.19, 71 observations

In Tables 6 and 7 we see that the weighted and unweighted estimates of the function for the distance reduction measured in steps of 250 metres are very similar. All coefficients seem to be statistically equal. Each coefficient (apart from the constant) gives the percentage increase compared to the reference group.

Commuter railway stations have a higher impact on property values than light or heavy railway/ Metro stations (light railway is the reference group, heavy railway/ metro is insignificant). This finding is consistent with the expectation, and reflects the fact that commuter railways usually have wider service coverage (i.e. a larger catchment area).

The inclusion of other accessibility factors (highway, freeway) in the underlying studies significantly reduces the level of the reported station impact on property values (reference is "no alternative accessibility variable in underlying study"). This shows that highways and freeways are also important determinants of property value (rent), next to railway station proximity. When both are included in the models (railway station and other modes), the effect on property value is "shared" between the two different modes. Models with highway accessibility on average report 4% lower railway station proximity effects on property value than models excluding highway accessibility. This result becomes insignificant when an alternative the specification is used with discrete railway station distances within a quarter mile of the station areas, as can be seen in Tables 8 and 9. This shows that competition between railway and highway declines in the inner circle areas.

Table 8: Unweighted estimation output for impact on property value for properties within ¼ mile of the station

Variable	Parameter estimate	Standard error	t test
Constant	0.0705	0.0613	1.150
Commercial	0.1064	0.0592	1.798
Commuter	0.1845	0.0701	2.633
Semi log	0.0578	0.0861	0.671
Accessibility	-0.0827	0.0670	-1.235

R^2=0.13, 73 observations

Table 9: Weighted estimation output for impact on property value for properties within ¼ mile of the station

Variable	Parameter estimate	Standard error	t test
Constant	0.0530	0.0663	0.799
Commercial	0.0754	0.0569	1.327
Commuter	0.1639	0.0569	2.878
Semi log	0.1221	0.0729	1.675
Accessibility	-0.0783	0.0674	-1.162

R^2=0.13, 73 observations

In both specifications, it appears that railway station proximity generally has a higher positive impact on commercial property values. It should be noted, however, that the standard errors in Tables 8 and 9 are fairly large. Although from Table 5 it appears that non-parametric studies report larger effects of railway station proximity on property values, we do not find such an effect in the estimations. The estimations suggest that semi log specifications may result, on average, in a 12% increase. Our analysis does not find any temporal or spatial variation effect.

6 CONCLUSION

The impact of railway station proximity on property value has received wide attention in the economic literature. Several empirical studies tried to quantify this effect. However, the conclusions are not uniform. The aim of this paper is to find a systematic explanation for the variation in railway station impact findings. We established that the different features of the study settings could explain these variations. We have tried to relate the variation with eight categories of variables. These are type of property under consideration, type of railway station, type of model used to derive the valuation, the presence of specific variables related to accessibility, demographic features and house quality in the models, place of study and lastly the time of the data. The presence of accessibility and house quality variables is expected to have a negative effect on the magnitude of the impact of the station on the property value reported. However, out of the 14 explanatory variables included, only three variables appeared to be statistically significant in the estimation procedures.

Throughout the analysis, commuter railway stations have had a significantly higher impact on property values compared to light or heavy railway/Metro stations. Their higher service coverage adds to the attraction of the area surrounding the stations. In addition the number of commuter railway stations is (naturally) low compared to light and heavy railway/Metro stations. Thus, the probability that properties are closer to these stations is relatively low compared to the probability that properties are located near light or heavy railway/ Metro stations. This will affect the value of properties around commuter railway stations.

There is some indication that commercial properties enjoy a higher positive impact due to railway station proximity than residential properties do. A given area can be made accessible by a number of modes (railways, car, etc.) Each mode will improve the accessibility of the region independently. All of the studies used in the meta-analysis analyse the (isolated) effect of a railway station on property value. When other accessibility modes are included in the underlying studies, railway stations generally have a lower impact on property value. Although both highways (freeways) and stations may increase property values, there is a negative correlation between the two effects; when one is present, the effect of the other is diminished. Thus, we find an example of omitted variable bias: when highway accessibility is not explicitly addressed, railway impacts on property values tend to be overestimated specially in the continuous space specification.

The research agenda that follows from these findings is as follows. To be able to do a more thorough meta-analysis, a more extensive set of explanatory variables is necessary. Moreover, the number of observations should preferably be increased. As far as the availability of data allows, the share of public transport in the study areas can be included as a weighting factor. Other issues in the design of the meta-analysis include the publication bias (do published studies present "more favourable results") and dependency among observations and studies. But the research agenda is not limited to the meta-analysis. The results already show the effects of, for example, the high accessibility of a location. When railway is the only mode that is included in the analysis, we observe a tendency for the effect of railway stations on property value to be overrated. The results show that when other "modes" are included, these modes also account for some of the effects on property values. This calls for a systematic inclusion of accessibility according to all transport modes in hedonic pricing studies of property values.

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***Appendix 1**: Deducing the continuous railway station effect from discrete measures*

The basic methodology for this was to linearize the impact over the different segments. For this method to work, it is required that the studies used at least three segments, including the reference segment in their analysis. Based on the assumptions described in Section 5.2.2, we can fairly say that the impact of railway station proximity on properties at the average distance of the segment from the station represents the effect of the station on the segment. The average distance of each segment is given by d = a + 2/3*(b-a), where "a" is the distance of the inner circle to the station and "b" is the distance of the outer circle of the segment to the station. The reference segment's (the segment with value 100) outer circle is specified based on assumption one unless otherwise specified in the underlying studies. This gives us two corresponding variables (distance and value) for which we can estimate percentage change in property value per unit of the distance measure using semi log specification:

$\ln(value) = a_0 + b_1 \times D$

Where *value* is the value of properties at distance D from the railway station. The value of the coefficient b_1 measures the percentage change on property value for a unit change of distance.

Endnotes:

[1] **Light Rail Transit**, known as LRT, is a rail-based urban transit system. It has the flexibility to navigate sharp curves, and travel along streets, highways or in exclusive right-of-way. Since the rails are flush with the surface of the street, LRT can be operated in areas with pedestrian, cyclist, or automobile activity. LRT is powered by electricity from overhead wiring which is suspended from poles or buildings

[2] **Heavy Rail** vehicles receive current from an electrified third rail. The system operates along an exclusive guide way and is grade separated from other vehicular or rail modes. Subway or elevated alignments are the common. Heavy rail is appropriate for corridors or alignments with very high demand, as this technology can transport a very high volume of passengers per hour at a high average speed. Operations can be very reliable because of complete grade separation of the alignment.

[3] **Commuter Rail** systems typically operate along existing freight railroad rights-of-way, serving longer-distance trips between central cities, suburban activity centres and outlying areas. Vehicles are configured to provide maximum-seated capacity and comfort due to longer trips. Commuter rail vehicles can operate in mixed traffic with freight trains.

[4] **Bus Rapid transit BRT** combines the quality of rail transit and the flexibility of buses. It can operate on exclusive transit ways, HOV lanes, expressways, or ordinary streets.
(Source: http://www.utahmetro.com/Classroom/heavliterail.htm)

[5] All the dependent variables are discrete variables represented by dummies in the analysis.