Evaluation of Hedonic Price Models that Explain Transit Induced Impact on Housing Prices

Karan Barpete and Arnab Jana

Abstract This review article evaluates housing price models and their configurations across 21 housing projects in different parts of the world that have a transit project being in close vicinity. These projects try to explain the impact of transit projects on the housing prices. The housing projects and their respective hedonic price models are studied to compile all the dependent and explanatory variables used in them. The explanatory variables are then classified into six categories, namely (i) Proximity variables, (ii) Proximity premium, (iii) Land/Structural variables, (iv) Neighborhood variables, (v) Accessibility variables, and (vi) Temporal variables. In most of these studies, the dependent variable is a variation of price (rent price, sale price, land price, etc.). The differences in the dependent variables are noted and highlighted in the evaluation. The comparison of different functional form of HPM is done to establish the difference in results and the applicability of them in appropriate models.

Keywords HPM(Hedonic price Model) · Transit · Housing

1 Introduction

1.1 Effect of Metro Rail on Real Estate in Its Vicinity

Although results are somewhat heterogeneous across study areas, many researchers have identified a positive effect of metro or transit station proximity on housing price [11, 13]. While some results have shown nonsignificant results, no studies were found showing a negative impact of metro rail proximity to housing prices. In research assessing the effect of metro lines on housing prices, a wide range of proximity premiums were found: from as low as 0.3% in Seoul [4] to as high as 75% in London (Banister 2007).

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In Bangalore, the Metro system was found to uplift property values by 10.7% within a 500 m catchment area [38]. Gadziski and Radzimski [15] examined the effect of a new transit line on three variables: travel behavior, housing choices, and property prices. They found a significant influence of the transit line on at least one of the three studied components in every examined region. Metro rail provides quicker and easier access to jobs and can increase housing demand, and thus prices, in a given region. In a Bangkok study, researchers found a significant impact of proximity to mass transit stations, along with proximity to other transportation infrastructure such as arterial roads, on housing prices [2]. Interestingly, it seems that even the announcement of a planned transit line can have an impact on rental prices [17].

Many articles call attention to the positive impacts of land value increase due to metro rail—e.g., opportunities for city governments to earn revenue through land value capture [38]. However, some authors have highlighted the possible negative effects of proximity to transit stations. For example, in the USA, new transit stations (particularly "walk and ride" transit stations) can lead to gentrification or displacement of residents by increasing rent in the catchment area of the station [26]. Additionally, proximity to transit can be a disamenity due to additional noise or crime risk [37]. However, generally speaking, results have indicated positive relationships between access to metro stations and land value.

While many articles have been published quantifying the effect of metro rail on housing prices in urban areas, the present research has much to add to the literature. First, as Mumbai currently has one operational metro line and multiple planned lines, the present study can test the effect of both operational and nonoperational metro lines on housing prices. Second, a majority of published articles assess metro systems in the global north. This article is one of few addressing a metro system in a rapidly developing nation, and one of even fewer addressing an Indian city. The nature of Mumbai, particularly its dynamic and rapidly expanding real estate market, makes this study extremely relevant. Third, this paper features several different data sources and two methodologies. This multiple-methods approach allows for internal validation of results.

Some of the studies [5] that focus on the large-scale operational and established urban rail/metro investments study the impact on property values. However small-scale mode like LRT/trams are not studied as much. There lies a research gap for these modes. Multiple studies [13, 14, 20] have confirmed similar positive effect of having urban rail transit system closer on the property prices. Although there are other studies that undermine the effect and call it marginal or only important when the supporting conditions are favorable. Out of 24 North American cities studied in 19 different studies, 13 tested positive correlation in property prices, while 4 were found to have no effect of LRT infrastructure. However, 7 cities showed signs of decline in property prices. The results are not ambiguous because the negative correlations have an explanation. The cities where increase in socioeconomic inequality was triggered by the LRT infrastructure, the benefits of accessibility and proximity to LRT are outweighed by negative externalities like rise in crime, noise levels.

The conclusions of these studies suggest that the significance of the positive effect of LRT on real estate can be guided by appropriate and supportive policies. This will require context-specific empirical studies because the generalized solution from the case studies of the Anglo-Saxon countries and Western Europe will not be suitable in India. The conclusion of these reviews hangs in the form of three primary questions:

1. How does the proximity to the new transportation infrastructure affect travel behavior in the residents of locality?
2. How does the transportation infrastructure affect the quality of life environment of the locality neighborhoods? How satisfied are the residents with their housing choices?
3. How does the proximity to public transportation network influence the property prices in the study area?

2 Hedonic Price Modeling

"Hedonics" comes from a Greek word hedonikos, which means pleasure, and in economics it refers to the satisfaction one gets from consumption of goods and services, i.e. utility [10]. HPM is extensively used in housing value and real estate research and even though the accuracy of the results may sometime be off the mark, but it continues to be valid for empirical research in the real estate market [10]. HPM analysis does economic analysis with following five assumptions:

- Homogenous land/housing market.
- Perfect competition in the market.
- Consumers and suppliers are free to enter and exit the market.
- Consumers and suppliers are perfectly informed about the products and prices.
- Market is at equilibrium and prices and attributes have no inter-relationship.

HPM applies least squares regression analysis, and there is a linear relationship between the dependent variable and explanatory variables. In case of housing/land market, the observed price (P) is explained using the following parametric land price equation.

$$P_i = f\left(X_j; \beta_j\right) + \varepsilon_i \tag{1}$$

- P_i is the assessed land/residential property price of the ith observation,
- X_j is a vector of quantitative and qualitative attributes of land/residential property,
- β_j is the unknown hedonic hidden price, of the land/residential property for attribute j, and
- ε_i is the stochastic error term.

2.1 Functional Form of Hedonic Price Models

As the association between the explanatory and dependent variables in HPM of Housing markets is mostly nonlinear, there are different configuration of HPM functional form for Housing, land and real-estate models to bypass this lack of linearity, which assume that explanatory variables are continuous, not binary in nature. Hannonen [19] proposes that the methodology choice of the correct functional form for the HPM decides the accuracy of estimation process, and an inappropriate choice can make the subsequent analysis invalid. In parametric research, it is essential to work on a variety of alternative model configuration to decide, which suits the land, housing market or its submarket being analyzed. An incorrect selection of functional form can result in unreliable estimates [6, 10]. And even though, it has been practiced for a long time, the theory lacks guideline on the decision of choosing correct functional form for varying application. Among the variety of hedonic price models, the mostly used ones are (i) Linear HPM, (ii) Log-linear HPM, (iii) Linear-Log HPM, and (iv) Double-Log HPM.

The following tables (Tables 1 and 2) summarize the different forms of hedonic price models used in the 21 projects around the world. They also tell us the degree of success these models had in describing the pricing of these housing projects. Tables 3, 4, 5 and 6 list down the respective independent variables as used in these models. The ID column in the latter tables relates with the Tables 1 and 2.

3 Conclusion and Identified Research Gaps for Further Study

Some of the studies [5] that focus on the large-scale operational and established urban rail/metro investments study the impact on property values. However small-scale modes like LRT/trams are not studied as much. There lies a research gap for these modes. Multiple studies [13, 14, 20) have confirmed similar positive effect of having urban rail transit system closer on the property prices. Although there are other studies that undermine the effect and call it marginal or only important when the supporting conditions are favorable. Out of 24 North American cities studied in 19 different studies, 13 tested positive correlation in property prices, while 4 were found to have no effect of LRT infrastructure. However, 7 cities showed signs of decline in property prices. The results are not ambiguous because the negative correlations have an explanation. The cities where increase in socio-economic inequality was triggered by the LRT infrastructure, the benefits of accessibility and proximity to LRT are outweighed by negative externalities like rise in crime, noise levels.

The conclusions of these studies suggest that the significance of the positive effect of LRT on real estate can be guided by appropriate and supportive policies. This will require context-specific empirical studies because the generalized solution from the

Table 1 Hedonic price models studying impact of BRT and LRT projects

Id.	Author	Location and transit system	HPM form	HPM # Obs. (model R^2)	Dependent variable
BRT1	Rodriguez and Targa [35]	Bogota, Colombia TransMilenio BRT	OLS—linear, log/linear, log/log	494 (0.71)	Linear, log (rental cost)
BRT2	Rodriguez and Mojica [34]	Bogota, Colombia Trans Milenio BRT	OLS WLS—log/linear	3976 (0.694)	Ln (Advert. Sale Price)
BRT3	Perk and Catala (2009)	Pittsburgh, USA, MLK, Jr East Busway	Robust LS—linear	128,717 (0.8)	Praised value (fair market value)
BRT4	Cervero and Kang [7]	Seoul, South Korea, Seoul BRT	Multi-level logit	25,410 (0.992)	Land value
BRT5	Mulley and Tsai [32]	Sydney Australia Liverpool-Parramatta BRT	ANOVA & OLS	1167 (0.67)	Ln (sale price)
LRT1	Golub et al. [17]	Phoenix, USA, Phoenix LRT	OLS—log/log	88,308 (0.533)	Ln (adjusted sale price)
LRT2	Atkinson-Palombo [3]	Phoenix, USA, rezoning around the phoenix LRT	GLS log/linear	9177 (0.76)	Ln (sales price)
LRT3	Du and Mulley [12]	England, UK, tyne & wear light rail	OLS & GWR log/linear	1700 (0.38)	Ln (house price)
LRT4	Cervero and Duncan [8]	San Diego, USA LRT	OLS—linear	14,756 (0.605)	Sale price
LRT5	Garrett (2004)	Missouri, USA St. Louis Metrolink LRT	OLS log/linear	1516 (–)	House price

case studies of the Anglo-Saxon countries and Western Europe will not be suitable in India. The conclusion of these reviews hangs in the form of three primary questions:

(1) How does the proximity to the new transportation infrastructure affect travel behavior in the residents of locality?
(2) How does the transportation infrastructure affect the quality of life environment of the locality neighborhoods? How satisfied are the residents with their housing choices?
(3) How does the proximity to public transportation network influence the property prices in the study area?

Table 2 Hedonic price models studying impact of metro & commuter rail projects

ID.	Author	Location & transit system	HPM form	HPM # Obs. (model R^2)	Dependent variable
Metro 1	Banister (2007)	London, UK, London metro Jubilee line	GWR	–	Land and property valuations
Metro 2	Gatzlaff and Smith [16]	Miami, USA heavy rail/metro	OLS linear log/linear exp. log/log	912 (0.72–0.84)	Sale price
Metro 3	Laakso [28]	Helsinki, Finland Helsinki Metro	OLS log/linear	6732 (0.940)	Ln (sale price)
Metro 4	Bae et al. [4]	Seoul, South Korea Heavy Rail	GLS Log/Linear	956 (0.9542)	Ln (sales price)
Metro 6	Celik and Yankaya [33]	Izmir, Turkey Izmir Metro	OLS Linear Log/linear Log/Log	360 (0.83)	Sale price
Metro 6	Modelewska and Medda [31]	Warsaw, Poland Warsaw Metro	OLS Log/Linear	1130 (0.696)	Sale price
CR1	Cervero and Duncan [8]	San Diego, USA Commuter Rail	OLS	25,923 (0.7)	Sales price
CR2	Sedway Group [36], Mathur and Ferrell [30]	San Francisco USA Bay Area Rapid Transit (BART)	OLS Log/Log	2133 (0.74)	Ln (Sales Price)
CR3	Gruen [18],Chaney [9]	Chicago, USA METRA, Commuter Rail	OLS Log/linear	796	Property value
CR4	Voith [39]	Pennsylvania & New Jersey, USA Commuter Rail	OLS	571 (0.711)	Property value
CR5	Lochl and Axhausen [29]	Zurich, Switzerland, commuter rail	OLS, spatial autoregressive model, GWR, Log/Log	8592 (0.85)	Ln (rent)

Table 3 Explanatory variables in HPM models with BRT

ID	Proximity variable	Proximity premium	Land/structural variables	Neighborhood variables	Accessibility variables	Time-based variables
BRT1	5 min walk	6.8% to 9.3%	Property Area Beds Baths Living Room Age	Socioeconomic Conditions. Population Density Employ. Density % Diff. Land Uses Crime Poverty 400 m Busway	Distance to BRT Ped. time to BRT BRT travel time Distance to CBD	
BRT2	150 m	13% to 15%	House/AptAge Bedroom Bath Garage Area	Socio Economic Conditions. Population Density Employ. Density % Diff. Land Uses Crime	Prox. 150 m BRT 500 m BRT	Year Dummies Interaction terms
BRT3	Distance to BRT	Significant and +ve	Lot Area Living area size Beds Bath 1/2 Bed Age	Income Socio Economic Conditions Population Density	Distance to BRT	
BRT4	90 m to 300 m of BRT stop	5% to 10%	Land use Building coverage ratio floor area ratio % Age Demo. % College degree	Population Density Employment Density Distance to River % Park % Land Developed Road area ratio % Res & Comm. Develop. capacity	Distance to Freeway ramp Distance to BRT Distance to CBD Distance to Subway Distance to Major Rd. Distance to Bus Job Accessibility by Car	

(continued)

Table 3 (continued)

ID	Proximity variable	Proximity premium	Land/structural variables	Neighborhood variables	Accessibility variables	Time-based variables
BRT5	400 m	Up to 3.3%	Bed. Bath Parking House/Apt	% Eng. Language Unemployed Income	Within 50 m of BRT stop	Time dummies & interaction terms;preconstruction during const. & operations

Table 4 Explanatory variables in HPM models with LRT

ID	Proximity variable	Proximity premium	Land/structural variables	Neighborhood variables	Accessibility variables	Time-based variables
LRT1	200ft	25%	Living size, Lot size, Age, #Patios, #Bath, #Floors, Pool, TOD Zoning		Dist. to LRT Stn., Dist. to LRT Alignment, Dist. to CBD, Dist. to Airport	Time dummies Prior NEPA, During NEPA Review, Planning & Design, Construction, Operations
LRT2	1/2 mile	17% Transit 34% Transit + TOD Overlay	Lot Size House size Pool Age	Socio Economic Data TOD Overlay Zoning	LRT Ped Catchment Dist. to Fwy Dist to CBD	Pre and Post dates from the introduction of the TOD overlay
LRT3	200 m	17.1%	House Type, #Bedroom,	Local School Indicator, % unemployed, %Higher Profession Occupation	PT Access (School, College…), Car Access (School College…), Dist. to LRT	
LRT4	400 m	3.8% to 17.3%	Size, #Units #Bath, Bed, Age	Housing Density Income Race Profile %Senior %Vacant Land	½ Mile LRT Dist. to Hwy/Fwy Dist. to Fwy Ramp	Time Dummies Monthly to reflect different sale times
LRT5	700 m	32%	#Bed #Bath #Stories Garage Pool Age Lot Size House size	Dist. to Hwy interchange %Res. With College Education Income Property Tax rate School District Test Scores Does nearest LRT have P&R?	Dist. to nearest LRT Stn Noise impact from LRT by Dist. to LRT	–

Table 5 Explanatory variables in HPM models with metro rail

ID	Proximity variable	Proximity premium	Land/structural variables	Neighborhood variables	Accessibility variables	Time-based variables
Metro 1	2000 m Access to metro	75%		Comm. & environ. amenity Car ownership Socio. economic	Access to shops Dist. to School Access to metro	–
Metro 2	Dist. to metro	Mixed between stations	House area Lot size Age	Est. house price index	Dist. to metro	Construction announcement dummy
Metro 3	250 m	3.5% to 6%	Ln (age) Ln (area) Terrace house Pool Indoor sports Health Stn Library Day care	Ln (%Park) Ln (income quartile) Dist. to Coast Ln (Dist. to CBD)	Metro station dummies Feeder bus dummies Commuter rail dummy Shopping center dummy	Transaction time dummies
Metro 4	400 m	0.3% to 2.6%	Apart. size, Age, #Houses block #Parking Heating Type Dist. to Park	Dist. from Han River School District Pop. Density Job Density	Dist. to Subway Dist. to CBD Dist. to Sub center	Time dummies Sales in 1995 Sales in 1997 Sales in 2000
Metro 5	500 m	0.7% to 13.7%	House size #Apt in Bldg. #Apts. in Floor Age #Bed #Storey of Bldg. Corner location Parking Heating	Location Type of ground	Dist to Subway Dist. to Bus Dist to Shop	
Metro 6	1000 m	6.7%-7.13%	Area #Rooms #Floors in Bldg. Age Parking	School District	Dist to Hospital Dist. to Green Area Metro Catchment dummy	Time Dummy for year of sale

Table 6 Explanatory variables in HPM models with commuter rail projects

ID	Proximity variable	Proximity premium	Land/structural variables	Neighborhood variables	Accessibility variables	Time-based variables
CR1	½ mile	−7.1 to 46.1%	House size Lot size #Bath #Bed Age	Housing Density Income %White Neighbourhood	½ Mile Commuter Rail Dist. to Hwy Ramp Job Access Hwy Job Access Transit	Time Dummies Monthly to reflect different sale times
CR2	½ mile	20% 1.5%	House size Lot size #Bath #Bed Age	Income %Hispanic Neighbourhood	Dist. to BART Dist. to Bus Dist. to Hwy/Fwy	Time Dummies for years 1995–2002
CR3	400 m	14.5 to 20%	House Size Lot Size #Bath Age Furnished Garage Fireplace House Type		Dist. from Station Dist. from Hwy Squared Dist. from Station Squared Dist. from Hwy	
CR4	½ mile	6 to 10%	Size Detached Age #Rooms	%Black Neighbourhood	Auto Commute Station Rail Commute	–
CR5	500 m	4 to 8%	House Size Lift Balcony #Bath Age Furnished Garage Fireplace Single house View	Within 100 m Autobahn Air Noise Job within 1 km Pop. Density per hectare %Foreigners per Hectare Local Tax level Slope	Dist. to CBD Car Access time to employment PT Access to employment Rail stn. catchment	Transaction time dummies

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