ANALYZING THE INFLUENCE OF METRO STATIONS ON COMMERCIAL PROPERTY VALUES IN DELHI: A HEDONIC APPROACH

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Abstract

The effect of proximity to the transit system on property values has become a key issue of discussion on public infrastructure and economic development. This article aims to examine the impact of selected stations on the blue line of Delhi mass rapid transit system (MRTS). The impact was observed on 1256 commercial property sold before and after the commissioning of these stations on the blue line in 2005. Hedonic Price Analysis (HPA) models are used to control other characteristics, such as structural, environmental, locational, neighbourhood and accessibilities in estimating the effects of proximity to metro rail on commercial property values. The method is applied to two time periods from 2000 to 2008 that coincide with the planning and construction (pre-commissioning stage) and operation phase (post-commissioning stage) of the metro rail system. Using sale prices of commercial units near metro rail stations, the study reveals the potential effects on values in the existing commercial property market. The results indicated that the station node shows a negative trend except one during the planning and construction period. The possible reason may be due to traffic, noise, pollution and poor collection of commuters by the existing Delhi bus transportation system. During operation of metro rail system, the results showed that it has produced a significant price premium associated with nearby commercial properties, realised due to improved accessibility, strong collection of users, and a new mass transit system. The coefficients show that the metro rail has induced increase in price premium by 732.7978 ₹ to 246.1906₹ (station-wise) in the vicinity and the impact extends to almost 500 meters away from MRTS stations.

Keywords: MRTS, commercial property value, proximity, hedonic price, panel data regression analysis

1.0 Introduction

Transport infrastructure such as Mass rapid transit (MRT) systems are important means of transportation and play a significant role in urban economic and development of Delhi. Apart from providing accessibility through public transport and solving traffic congestion, the Delhi MRT systems also contribute on the environment front by becoming the first-ever MRTS project in the world to claim carbon credits. The Delhi Metro flagged off its first service in 2002 and has been operating for over 18 years now. The metro consists of nine lines stretched over 389 km and 285 stations. The Delhi MRT system has majorly reduced traffic issues, improved communing problems, and encouraged the increase of neighbourhood property prices. Debrezion et al. (2011), Duncan (2011), Hess and Almeida (2007) examined the influence of rail transit infrastructure on residential property values. Similarly, Tomal M. (2019) examined the impact of macro factors on apartment prices in polish counties. Previous studies produce mixed outcomes, although a positive impact is prevalent in more recent studies, thus, the inferences from current and past studies on urban rail are presented to assess the relationship between urban rail transit and property values. Dziauddin et al. (2013) and Ryan (2005) studied an increase in housing premium near the metro and light rail stations. Bowes and Ihlanfeldt (2001) also examined that metro stations can increase in neighborhood housing prices. Yiu and Wong (2005) examined the effects of changing price expectations over time. Yiu and Wong (2005) analyzed the impact of the MRT system on neighborhood housing prices using a hedonic price model and found that the construction of transport had a significant positive influence on neighborhood housing prices. Forrest et al. (1996) analysed the Metrolink in Greater Manchester before and after completion and find no noticeable impact. Although, the empirical results of before and after a study by McMillen and McDonald (2004) on the MRT line from Chicago to Midway Airport on housing prices showed a positive trend. Cervero and Duncan (2002), Wheaton and Torto (1994), Fuerst (2007), Nelson (1999), Weinberger (2001) observed a positive impact of rail transit on property values, although, few of them such as Ihlanfeldt and Bowes (2001), Ryan (2005) and Cervero and Duncan (2002) found either mixed or insignificant results, while very few showed a negative effect. Ryan (1999) and Landis and Loutzenheiser (1995) examined no effect on any kind for properties within one-fourth mile radius of stations in San Diego, California. While Pan et al. (2013) observed in Houston that immediate proximity to light rail stations and bus stops has significant negative effect on single-family home. Chun-Chang, L., Chi-Ming, L. & Hui-Chuan, H. (2020) examined that housing prices within the 500-meter influence range decreased by 7.9% after the beginning of metro construction and even did not significantly affect housing prices within the 500-meter influence range after the beginning of its operation. This indicates that property prices are influenced by the construction of MRT systems. The increased accessibility of MRT reduces commuting time, which motivates buyers to purchase properties near MRT stations.

Non-residential properties such as commercial, industrial and institutional etc also play an essential role in economies as they are the most important real estate investment area for the investors. Findings from most of the international cases show value appreciation in commercial property benefiting from transit proximity. These international cases vary in location and magnitude with proximity to accessibility and provide lessons to investigate the property price due to the rapidly evolving metro rail in Delhi. This would make a useful contribution to the sustainable integrated rail and property development in Delhi. Inferences are drawn from the literature that most of the studies are conducted a few years after the opening of rail transit because non-residential properties are sold not as frequently as residential. Alonso (1964), Mills (1992), and Muth (1969) makes the assumption that employment is located in the Central Business District (CBD) and focused mainly on the impact of access to the central business district (CBD). In Hiawatha LRT in Minneapolis, Kate Ko and Xinyu Cao (2013) investigated a significant increase in nearby property prices and the impact extends to almost 0.9 miles away from LRT stations. Similar findings were confirmed by Tang et al. (2004) that, urban rail significantly enhances the value of land and property around stations due to improved accessibility. Weinstein and Clower (1999) examined that retail properties in the Dallas and Denver DRAT corridor experienced an increase in value by 29% compared to other areas. Cervero and Duncan (2002) investigated Light Rail Transit (LRT) and commuter rail impact of 23% and 120% respectively in Santa Clara County, California. Cervero (2004) used hedonic models and investigated both positive and negative influence on commercial property for different rail lines in San Diego, California. Kim and Zhang (2005) also reported the Positive impact of transit access on commercial land in Seoul, South Korea but different locations indicated different impacts. In Dallas and Denver, Nelson (2015) found that fifty percent of the positive effect of LRT access on commercial property disappears with an increase of the distance of 0.06 miles and seventy-five with 0.10 miles. In a recent study on Dubai, Mohammad et al. (2017) explored that commercial property witnessed almost 40% in value within a 1000-meter radius from metro station. The results of the studies discussed above are mainly from developed cities which are self-reliant commuting systems and results may vary from case to case

Weinberger (2001) and Ryan (2005) have addressed that in non-residential property values, the data are the major barrier. Ryan (2005), Fuerst (2007), Landis and Loutzenheiser (1995) Bollinger et al. (1998) used asking rents to measure property values due to paucity of sales data of non-residential property disposal. Sales data may also present some challenges to researchers because non-residential such as commercial properties are sold not as frequently as residential. Nelson (1999) used only 30 properties in his model while analyzing the impact of the Metropolitan Atlanta Rapid Transit Authority (MARTA) on property values. Brennan et al. (1984) used actual transacted office rents as a dependent variable with only 29 cases. Brennan et al. (1984), Sivitanidou (1995), Sivitanidou (1996), Dunse and Jones (1998) included transportation-related factors as explanatory variables and concluded a positive relationship between proximity to rail transit and property values.

International cases indicate that studies have used a cross-sectional or longitudinal data hedonic model to examine the price effect of rail transit in urban areas. Three approaches have been used till date to separate the effects on transit on property values matched pairs, repeat sales and hedonic price models. Hedonic models introduce more rigorous controls and are thus widely considered to be the best method available for ascribing benefits associated with factors like proximity to transportation facilities. In these models, the difference in property values is explained by the integration of physical, accessibility and environmental characteristics of properties. Although, the functional forms can vary from case to case with location and distance from the MRT system. Hedonic price models of commercial property use a variety of dependent variables based on data availability (i.e. Sales transaction data, actual transacted rents or effective rents, asking rents, and assessed property or land values). Mills (1992), Landis and Loutzenheiser (1995), and Bollinger et al. (1998) studied that commercial property sales prices or effective rents are hard to obtain because these data are often not open to public use. Ihlanfeldt and Martinez-Vazquez (1986) stated that actual transacted sales prices are preferred because they capture the real property market behaviours. Alonso (1964) proposed a model to explain the impacts of urban transport on land rents and analyzed that the land rent price decreased with an increase in travel costs. Kelvin Lancaster (1966) was the first to discuss hedonic utility with consumer theory but did not discuss pricing models. Muth (1969) extended the model by combining the consumer behaviour theory proposed by Kelvin Lancaster (1966). Rosen (1974) introduced a hedonic pricing methodology which led to an easier way of attributing effects on the property value to features comprising the properties. He was the first to present a theory of hedonic pricing (HPM) and proposed the hedonic price model as a function of the special combination of its characteristics demonstrated as:

$$Pij = \beta 0 + \beta s\ Sij + \beta l\ Lij + \beta n\ Nij + \varepsilon ij$$

Where βs, is the coefficient vector for the structural attributes (S)which measure the structural effect on the property price (P), while βl and βn are locational (L) and neighborhood (N) coefficient vectors respectively, reflecting the locational and neighbouring effects on the property price, ε is the stochastic disturbance vector.

Many studies rely on longitudinal data after the opening of rail transit or cross-sectional study but it is important to conduct a before-after study to test the effect of the locations. Very few studies seek to combine cross-sectional and time series. Ordinary least squares (OLS) method approach is applied in this study for generating hedonic regression models. Models based on time mainly focus on value changes 'before' and 'after' a particular event. Bartholomew & Ewing (2011) and Debrezion et al. (2007) revealed a wide range of price effects, even with similar methodologies, data tools, and attributes. Ryan (1999) examined the effect of a single factor, time-based, and distance-based accessibility on the estimated change in property prices arising from rail infrastructure schemes. Tyagi and Singhal (2018) analyzed the effect single factor of Delhi Metro ridership on the sale prices of residential group housing dwelling units. Empirical results produced a positive impact in a band of radius from 500 meters to 1.0 km around metro stations for the selected period.

With the advancement in HP models, several recent studies have started using an innovation-based model, the difference-in-differences (DID) estimator e.g. Agostini and Palmucci (2008), Billings (2011), Dewees (1976), and McMillen and McDonald (2004). Although the application of this method varies across cases, it generally depends on different prices for the properties before and after the treatment. Some studies have also compared results obtained from DID to those from conventional HP models. Gibbons and Machin (2005) found that HP models produced statistically larger effects than DID models in newly developed rail stations on dwelling prices in London. In another study of Santiago, Agostini, and Palmucci (2008) investigated that, the DID models delivered higher estimates of the impact of the MRT system on property values as compared to HP models. The difference in the magnitude of effect between the DID and HP models in the two studies may be related to the type of data collected, as Agostini and Palmucci (2008) used repeated cross-sectional data, Gibbons and Machin (2005) used pseudo panel data. The contribution of this study to existing studies is that it provides the effect of Delhi Metro on commercial property values by using panel data analysis with before and after study. HP models are used to estimate the effect of the Delhi Metro on commercial property values on all four identified stations on the metro blue line. Delhi Metro is one of the first metro systems in the rapidly growing South Asia region, and hence this study will not only benefit Delhi but also similar cities in South Asia. We estimate the effect of the metro on property values using actual walking distance within 500 meters of radius around each station to examine the influence of increased distance from the station.

The main objective of this study is to address the impact of proximity to transit stations on commercial property values in the growing metropolitan city of Delhi. A literature study addresses the theoretical foundation of international cases of urban rail transit systems influencing residential and commercial properties. The hedonic model with before and after study is used for highlighting the effect of proximity to transit on property values. In addition to the above objectives, this study was also carried out in hopes of filling research gaps and increasing our understanding of the influences of metro rail investments on real estate values. This study presents the hedonic models estimated for predicting commercial property value in New Delhi from 2000-2008. This specific period is selected due to its unique feature of rapid growth and availability of data set. Inferring from select stations of the blue line of metro rail in Delhi, there is the substantial scope of benefiting from enhanced commercial property value on the establishment of metro rail infrastructure. The results indicate that the metro rail in Delhi has induced a noticeable increase in price for commercial properties within 500 meters from the metro rail station. Planning efforts in progress to include heavy and light rail transit system in tier 1 and tier 2 cities in India will be better informed by this study of Delhi. With the surge in the development travellers may save time by increased accessibility through MRT systems. Policymakers and planners will be able to address the implications of these rail transit development and investments.

3.0 Methodological Approach

The panel data analysis is applied to examine the difference in impact before and after an event of commissioning of each station on the blue line. Hedonic regression modelling was used for examining price determinants and applied to test the relative importance of various factors particularly the distance from commercial property to the metro station. In this study the beginning of metro operation/commissioning was set as an event that influenced neighbourhood commercial prices and the changes before and after this event were measured. An influence zone of 500 meters was considered from the metro each metro station. A panel with before and after data of each station is regressed and the hedonic model is established. The initial results of empirical analysis show some basic descriptive measures which are used to investigate volatility and cross-sectional variability of property prices. For this study, two hedonic models are specified. Model-I capture the influence of metro station node for pre-commissioning stage and Model-II contains the influence of accessibility effect of the metro station of the MRT system for the post-commissioning stage.

The general form of function used to explain the hedonic model is:

$$PRICE = f(S, N, E) + \varepsilon$$

PRICE= The sales price per square meter of the commercial building is a function of the structural or physical characteristics (number of bedrooms, size in square meters, etc.), neighbourhood or location characteristics (access to transport routes, etc.) and environmental characteristics (such as proximity to green spaces. ε is an error term. Rosen (1974) observed that the hedonic weights assigned to each variable are equivalent to this characteristic overall contribution to the property price. Wen, Gui, et al. (2018) examined that the ordinary least squares (OLS) regression model can only analyse the average implicit prices of housing attributes and may ignore the other effects and dynamic time-series aspect of the data. Mourouzi-Sivitanidou (2002) examined the combined effect of both cross-sectional and time-series data. Glascock, Kim, and Sirmans (1993) observed that the coefficients vary across time, location, and a class of building and also conclude that random-effects models are superior over fixed-effects methodologies. Thus, for commercial real estate analysis methods need to be devised that are capable of capturing the cross-sectional and time-series dynamics. In this context, panel data analysis along with OLS hedonic regression models can produce significant results. The present study applies a random-effects model and compares the results to the OLS regression analysis.

The model is applied to all sales of commercial spaces during the Study Period. The set of data used in this analysis comprises of a commercial property price and its characteristics dataset, which was then related to information on the location of transport and environmental amenities. The commercial property price data were provided by Delhi development authority and other local bodies such as North DMC and South DMC. The dataset consists of a representative sample of commercial space sales on the metro blue line in the north and south districts of Delhi between January 2000 and December 2008. Data were used from several sources. Properties selected were from period the property was built (pre-commissioning:2000-2004 and post-commissioning stage: 2005-2008). The data chosen was from variables such as floor area and lot area measured in square meters, presence of parking as per Mater plan, distance from master plan green, distance from master plan road, population density, floor level and the age of the structure. The space within the commercial centers such as DC, CC, LSC, and CSC were mainly developed and maintained by DDA and other local bodies. The environmental variables included the distance to the nearest master plan green. The data were extracted from MPD, zonal plans, and area-level plans provided by the MPD wing of DDA. Distance/locational variables include two types of variables; proximity to metro stations and distance from MPD road. Variables such as structure age & parking are collected from sanctioned, completion drawings and details provided by local bodies such as DDA, North DMC, and South DMC. Socio-economic data are collected from the census of India and the economic survey of Delhi. The property data set is the individual parcel's data and the study variables include variables describing characteristics of space, structural, environmental, location, and socio-economic. These are explained as dependent and independent variables.

Dependent variable:
PRICE=The sales price per square meter of commercial space
Independent variables:
FLOOR-AREA=The enclosed floor space in square meters. Because of economies of scale that relate to pricing per unit of space, a negative relationship may be expected between price and building area.
LOT AREA= The total area of the lot in which space is existing. A positive association is expected between the number of floors and the price per square meter.
FLOOR LVL= The number of floors of a subject building space. This variable helps to account for the lower price per unit of construction. A low premium is attracted in the market especially for offices on the higher levels. A negative association is expected between the number of floors and the price per square meter.
PARKING=The parking provided as per MPD. Because commercial buildings usually require parking to satisfy the need of customers and employees, a positive association is expected between parking and price per square meter.
STRUCTURE AGE = Building or structure age is expressed as the age of built structure; more recent construction date has a positive impact on property prices.
METRO-STATION-DISTANCE=The distance in meters from the nearest METRO station. If the commercial space is in close proximity to rail transit stations as an improvement in accessibility for its employees and customers, it should capture this value. Distance from transit stations should be positively associated with price.
MP ROAD-DISTANCE=The distance in meters from the nearest MP ROAD. If the commercial space is in close proximity to MPD road, it may or may not capitalise the value depending on the local transport system. Distance from transit stations may or may not be positively associated with price.
MP GREEN-DISTANCE=The distance in meters from the nearest MP GREEN. If the commercial space is near to MP green, it is expected to capture the value. In most cases, distance from MP green is expected positively associated with price.
POPULATION-DENSITY=The population density per 500 meters radius is in numbers. If the density is more near commercial space, it is expected to capture its value. It is expected positively associated with price.

The Delhi MRTS blue line is significant as it covers three districts and commercial development of a similar nature. The selection of the Methodological approach is driven by the data constraints as encountered in previous studies. To estimate the effect of proximity of a metro rail transit system on commercial property, 500 meters buffer all around the selected stations is specified. Here, the hedonic model with both cross-sectional and time-series approaches for individually selected stations are employed to capture the effect of access to the Delhi MRTS on commercial properties, while controlling other factors. This study used an explanatory hedonic model, developed with a dataset of around 1256 commercial property records. Basic descriptive measures are used to investigate volatility and cross-sectional variability of property prices. In addition to usual tests of the parameter of significance, explanatory power as shown by R^2 as a goodness of fit, reflected by F-statistic and correlations. To explore the impact of proximity to the metro station on commercial property multiple linear regression analysis is conducted on sales prices as independent variables and other dependent variables such as location and structural attributes. The analytical data has been collected from several sources, primarily: (i) DDA, the Delhi Development Authority keeps all records of space transactions (ii) Google Maps and approved layout plans to locate each of the stations and distances to specific properties and other facilities; and (iii) the census of India information on community economic profiles. Theoretical approach and past international cases of residential and commercial property are studied in the first part of the paper. In most of the cases, HP models defend the impact of property characteristics in a cross-sectional approach but did not explain a relationship between rail access and property value change over time. For this reason, this paper uses a "pre-post" methodology, which allows comparing changes in property costs before and after a public transit was added or expanded.

Duncan (2011) analyses that pre-post methodology is less common due to the paucity of data over a much longer period. Previous studies involved various techniques such as; a meta-analysis of transit premium, benefit-cost analysis etc to investigate the economic impact of transportation investment. Iacono and Levinson (2009) observed that the hedonic pricing model is the most prevalent in capturing its impact on property values. Here hedonic model with both cross-sectional and time-series approaches for individually selected stations are employed to capture the effect of access to the Delhi MRTS on commercial properties while controlling other factors. Multivariate regression analytical estimators in STATA is used to compare the change in values of commercial property sale prices before and after the operations of the metro stations. In the past, a cross-sectional study used data only for a single year thus rendering it impossible for the researcher to draw meaningful conclusions concerning transportation improvement's effect. The study design used in this research attempts to reconcile before and after effect. The study variable is the distance of the commercial parcel's distance to nearby MRTS station. Network analysis of Google maps, zonal plans, area plans, and layouts are used to measure the transportation network distance from a property to the closest MRTS station.

3. Study area and Data description

3.1. Study area

Delhi is one of the most populated metropolitan cities of India with a growth rate of 21.2 percent and area of 1483 square kilometre. To control traffic load, Delhi Metro Rail Corporation (DMRC) was established in May 1995 with an objective to reduce transport congestion in Delhi and National Capital Region (NCR). Delhi's metro rail system is planned to be constructed in four phases by 2021. Construction of the first phase started in October 1998 and the blue metro line was operational in December 2005. Two phases of the metro rail network were completed in 2011 (DMRC, 2011). Phase-III (140 km, 69 stations) has been completed in 2016 and Phase IV (100 km) is planned to be completed by 2021 respectively. The metro rail corridors namely; Red, Yellow, Blue, Green and Violet lines, etc are covering different jurisdictional and municipal areas of Delhi. To achieve integrated and sustainable growth of metro rail and property development, commercial properties developed by Delhi development authority (DDA) and local bodies in three jurisdictional areas of Delhi are examined having different socio-economic status and development patterns. It has been realized that the property prices have changed significantly after the approval and implementation of the metro rail in Delhi. Limited studies have investigated the relationship between metro rail infrastructure and property prices. This study investigates the influence of proximity to select metro stations on commercial property prices using hedonic price modelling. Based on the master plan of Delhi, literature and identified local factors a survey was conducted with experienced professionals and academicians for finalization of factors. Table (2) reflects different districts, Master Plan zones, and the parameters for selection criteria of the metro rail line and station. The method was chosen to achieve heterogeneity of the property samples collected from three districts and two municipal corporations with a wide range of socio-economic conditions. The analysis is conducted within a 0.5 km radius of a select metro rail station to investigate the effect of proximity to the metro rail station on property prices of commercial development by DDA and other local bodies.

Table 1. Selection criteria for metro stations on MRTS blue line of Delhi.

District/Municipal corporation of Delhi	*Zone as per Master plan of Delhi	Stations on metro blue line-3 commissioned in year 2005	**Total population (zone-wise)	***Percentage of the mix of land use development In the specified master plan zone	Period for which data of different indicators collected
Central District /North Delhi Municipal Corporation (NDMC)	D	Rajendra place	7,03,510	R: 35.65 C: 3.15 Re:33.43 T: 11.39 I: 0.42, U: 1.60	2000 to 2008
West District / North Delhi Municipal Corporation (NDMC)	G	Rajouri garden	14,89,570	R: 57.72, C: 2.58 Re: 10.76 T: 10.87 I: 6.86, U: 1.53	2000 to 2008
West District / North Delhi Municipal Corporation (NDMC)	G	Janakpuriwest	14,89,570	R: 57.72, C: 2.58 Re: 10.76 T: 10.87 I: 6.86, U: 1.53	2000 to 2008
South West/SDMC (South Delhi Municipal Corporation)	K-II	Dwarka	780000	R: 51.56 C: 6.24, Re:17.81 T: 13.76, I:0.0, U: 2.46	2000 to 2008

Source: *Zonal Plans as per Mater Plan Delhi, 2021, DDA ** Census of India and provisional census 2011, ***R: Residential C: Commercial Re: Recreational T: Transportation
I: Industrial U: utility

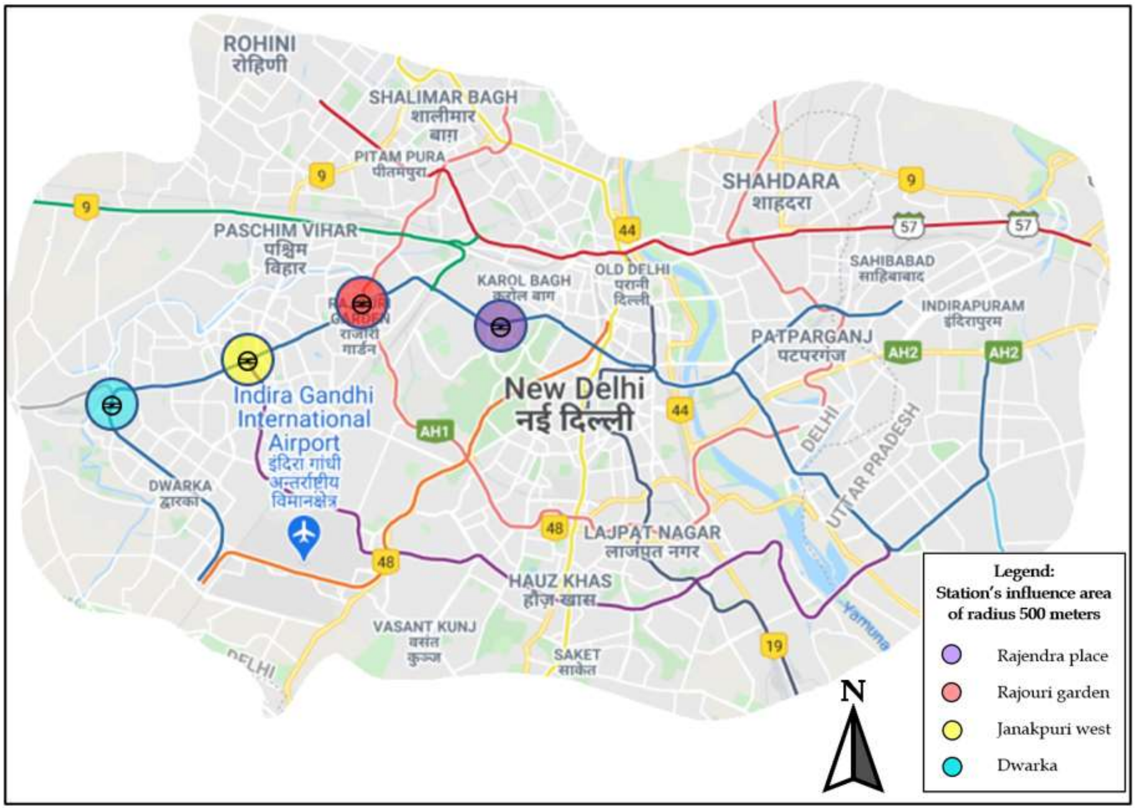

Fig. 1. Study area: Delhi map showing blue line (line no-3) and four nos. selected stations with a circle of radius 500 meters as an influence area. *Source*: Adapted from www.mapdevelopers.com

3.2. Data Description

This section summarizes the data source of its collection and cleaning which includes the significance of data for analysis.

Data collection: The property data set are the individual parcel's data, structural and locational characteristics from DDA, other local bodies Delhi such as; North DMC and South DMC. Based on conditional access for study purposes only, property prices per square meter of commercial units are collected from commercial land /estate branch of DDA and local bodies. Since the study is focused on the impact of access to the MRTS before and after its opening, properties that are sold between 2000 and 2008 are included. The sale prices of properties are collected from auction, resale transaction and space buyer's price details before and after commissioning of the select metro station of the blue line.

Data review and cleaning: The data is grouped into two categories; dependent variable as the sale price of commercial spaces and independent variables as transit rail proximity, accessibility, socio-economic, locational and structural property characteristics, etc. Out of 1600 database, the final property records were used for analysis after verifying their details from commercial land (CL) and commercial estate (CE) branch. Ultimately commercial land and commercial estate branches were able to successfully match 1256 datasets used in this research. Once the records were properly verified, street or network distance from the property to the nearest metro station was measured, as it is more realistic, although it was expected that the number of property samples will decrease in the station area. Finally, layout plans of commercial centers are studied for accurate measurement of the distance to the metro station. The distance variable represents the walkable distance from these verified commercial property units to the nearest metro station when the blue line was opened. Data for locational, structural, and neighbourhood variables were also collected on a yearly basis from 2000 to 2008.

Table 2. Property sales volume.

Area	Sold between 2000-2000 (within 500 meters) (pre-commissioning stage)	Sold between 2005-2008 (within 500 meters) (post-commissioning stage)
Rajendra place	195	156
Rajouri garden	170	136
Janakpuri	255	204
Dwarka	165	132

4. Empirical analysis and results

Findings present the results of ordinary least squares regression (OLS) of the panel data regression random effect model for all the cases present below from table 3-7. Table 3 presents the Significance level of hedonic models developed out of panel data for pre-commissioning stage (2000-2004) and post-commissioning stage (2005-2008) estimated for predicting commercial property value in New Delhi from 2000-2008. Table 4 and 5 provides statistics for the transaction data sample for the pre-commissioning stage and post-commissioning stage. A vector of ten predictors with data set is linearly regressed on STATA to predict the value of a commercial property. In each model random effect regression of panel data sample is used for before-after analysis. The correlation coefficient analysis or goodness of fit test for all models is analysed based on R^2, P-value, F-test value, and VIF (variance inflation factor). P-value tests shows significant influence on dependent variable as its value in each case is less than 0.05. The correlation matrix reveals no problematic collinearities, although careful attention was paid to remove highly correlated variables to reduce multicollinearity. VIF is used to eliminate variables with large variances due to the dependency of other variables. The random effect model is more robust than the fixed effect model, used by keeping the level of significance at 5%, the overall performance of the model analyzed as good with adjusted R^2 value. After passing the R^2 value test, F-value is checked to pass the critical value test.

Observations of each model are not constant but the predictive power of the regression analysis is roughly equal from lower levels of x-values to higher levels of x-value. All the models have explanatory power (R^2) in a very close range varying from 75.98% to 99.10 % in the pre-commissioning stage and 75.98% to 99.42% in post-commissioning stage which proves the 'goodness of fit" is highly significant for all the models.

Table 3. Significance level (goodness of fit) of hedonic models of selected metro stations:

Metro Line	Selected Station	R-square value (%age), (pre-commissioning stage within 500 meters) before year 2005	R-square value (%age),(post-commissioning stage within 500 meters) after year 2005
Blue	Rajendra Place	0.9089	0.7598
Blue	Rajouri Garden	0.9910	0.9940
Blue	Janakpuri	0.9143	0.8825
Blue	Dwarka	0.9457	0.8170

Table 4. Descriptive statistics for dependent and explanatory variables: Pre-commissioning (2000-2004) stage of all select stations (N=785)

Variables	Rajendra Place		Rajouri Garden		Janakpuri		Dwarka	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PROPER~D	20	11.2836	17.5	9.839691	26	14.74855	17	9.550891
YEAR	2002	1.417854	2002	1.418391	2002	1.416995	2002	1.418519
PX_MET~S	283.7821	101.2665	212.4706	13.16989	317.098	95.85961	463.242	26.30384
PRICE_~M	51814.05	37910.16	78699.67	15016.61	81015.6	9293.599	88147.0	12629.69
FLOOR_~A	18.47923	19.23331	590.2126	439.0691	39.91608	17.17311	30.4381	44.49707
LOT_AREA	2935.641	352.6833	4703.118	890.9879	2582.603	459.3531	2247.13	906.4182
STRUCT~E	5.379487	1.566265	4.088235	1.583339	5.137255	1.872087	3.57575	1.562329
PX_MPR	166.6923	50.32889	253.5882	131.0452	147.4333	29.93635	72.6060	50.62412
PX_CG	38.62179	14.88366	203.8824	32.89464	170.6655	12.2764	88.0606	58.22891
POP_~500	20430.25	260.3295	13452.08	354.1441	13415.82	408.4138	3440.8	152.244
FLOOR_~L	1.692308	0.7582483	2.117647	.8343479	1.235294	.4250167	1.78787	.8819869
PARKIN~S	.5128205	.5011222	.7058824	.4569912	.5294118	.5001158	.727272	.4467175

Table 5. Descriptive statistics for dependent and explanatory variables: post-commissioning (2005-2008) stage of all select stations (N=628)

Variables	Rajendra Place		Rajouri Garden		Janakpuri		Dwarka	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PROPER~D	20	11.29088	17.5	9.846977	26	14.75581	17	9.558179
YEAR	2006.5	1.121635	2006.5	1.122167	2006.5	1.120784	2006.5	1.122293
PX_MET~S	283.7821	101.3318	212.4706	13.17964	317.098	95.90682	463.2424	26.32391
PRICE_~M	129764	66502.35	171877.3	15516.47	89202.65	31480	159240	38224.25
FLOOR_~A	18.47923	19.24572	590.2126	439.3942	39.91608	17.18157	30.43818	44.53103
LOT_AREA	2935.641	352.9108	4703.118	891.6476	2582.603	459.5794	2247.138	907.1099
STRUCT~E	9.858974	1.341394	8.588235	1.324809	9.637255	1.659659	8.075758	1.299567
PX_MPR	166.6923	50.36135	253.5882	131.1422	147.4333	29.95109	72.60606	50.66275
PX_CG	38.62179	14.89326	203.8824	32.91899	170.6655	12.28245	88.06061	58.27334
POP_~500	19491.6	243.1706	14575.64	280.1828	14575.64	279.8375	3905	114.4739
FLOOR_~L	1.692308	.7587374	2.117647	.8349657	1.235294	.425226	1.787879	.88266
PARKIN~S	.5128205	.5014454	.7058824	.4573296	.5294118	.5003621	.7272727	.4470584

Table 6. Analysis of empirical results (pre-commissioning: 2000-2004)

Variables	Rajendra Place	Rajouri Garden	Janakpuri	Dwarka
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
CONSTANT	122726.4	170070.9	106904.7	147628.2
PX_MET~S	**-75.35265**	**156.5153**	**39.67771**	**58.45889**
FLOOR_~A	2.016266	9.72	-3.160896	26.47488
LOT_AREA	-.8554379	-7.95	4.372367	-1.193333
STRUCT~E	-2603.346	-.000078	2320.83	8422.305
PX_MPR	-21.46697	-7.00	9.236581	-33.39185
PX_CG	68.38015	4.95	5.310691	13.87800
POP_~500	-104.5821	41.81158	11.255	-2.805788
FLOOR_~L	-446.7511	.0002591	216.0634	-2641.493
PARKIN~S	1453.58	-.0006571	1005.986	1043.7

Table 7. Analysis of empirical results (post-commissioning: 2005-2008)

Variables	Rajendra Place	Rajouri Garden	Janakpuri	Dwarka
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
CONSTANT	170284.9	302306.4	203987.5	288213.8
PX_MET~S	**-627.4313**	**-732.7978**	**-322.1453**	**-246.1906**
FLOOR_~A	-76.23403	.0000118	.0001714	-.000018
LOT_AREA	3.489039	-1.80	-6.53	-.000035
STRUCT~E	293.2394	-.0000989	-.0014266	.0133361
PX_MPR	6.888914	-.0000823	.0000731	-.0011588
PX_CG	2.744962	.0000304	.0000149	.0008051
POP_~500	-72.23486	43.21469	20.2627	297.4391
FLOOR_~L	-423.098	-.0014341	.0046463	.0038609
PARKIN~S	1736.233	-.0357709	-.0014741	-.0884603

Histogram of residuals associated with the dependent variable and normal probability plot shows linear effect across the two axes. Z-residuals (ZRESID) as Y and Z-predictors (ZPRED) as X, create a scatter plot which is like a bird's nest and shows dataset is randomly distributed. The histogram is roughly normal in each case with normal P-P plot and values are roughly hovering or shouldering the regression line. The Coefficients in annexure are explaining the influence of predictors in each model with a confidence level of 95% and significance at 5% level. Hedonic regression models (hedonic price models) developed out of panel data analysis indicated that commercial property value is a function of structure age, floor level, proximity to metro station, floor area, lot area, parking, central green, distance to MP road, structure age and density population of that area. Results from this study reveal that before the rail system began operating, proximity to the future rail corridor does not show a significant influence on commercial prices. This is likely due to the presence of other land use zones around future stations. After opening, the regression coefficient of each model suggests a significant accessibility effect of the MRTS on sale prices after its opening. Model after commissioning showing benefits associated with access to MRTS declines with distance. Results show that in panel data analysis, there is an increase in commercial property price varying from 732.7978 ₹ to 246.1906₹ per meter with decrease of distance from existing metro stations in post-commissioning stage. Although in pre-commissioning stage it shows negative effect and increases in the range varying from 156.5153 ₹ to 39.67771 ₹ per meter increase in distance from metro station node, except in case Rajendra place station where the results indicated the presence of positive trend. In this case it increases with decrease in distance from metro station. The finding suggests that the benefits associated with access to MRTS decline with distance.

5. Discussion and conclusions

In this paper, panel data analysis along with OLS hedonic regression models was applied with random-effects to evaluate the impact of the MRTS system on commercial property values in New Delhi. The empirical results show that the MRT system had a varying influence on neighbourhood commercial property prices in these two phases. Most research efforts have been cross-sectional, although this study takes a longitudinal approach by repeating the same hedonic regression analysis at two different periods, coinciding with before and after the commissioning of the Metro rail system.

Results from this study reveal that before the rail system began operation, proximity to the future rail corridor does not show a significant effect on property prices. This is likely due to other land use around existing stations. However, when compared across the two time periods, commercial property prices have started to react positively to metro rail investment during the operational phase. This may suggest that accessibility to reliable transportation has improved the attractiveness of commercial property in the vicinity of metro rail stations and investment has improved the image of the area. Another reason is that, due to the concept of transit-oriented development, it is likely that commercial properties have started to concentrate in the vicinity of metro rail stations.

In this paper, we have used a distance of 500 meters (0.3 miles) around metro rail stations to extract those properties for which sale prices would potentially be influenced by the proximity to transit. As future research, the distance buffer can be modified to be station-specific, better reflecting the type and complexity of surroundings. This study was limited mainly to analysing the impact of metro stations on neighborhood commercial property prices before and after the commencement of metro operation. The effects of the metro stations on neighborhood property prices in the planning, announcement, and construction completion phases were not discussed. Moreover, the data used in this study only included commercial transactions. Therefore, the influence of the blue line on prices of other real estate types, for example, residential, institutional, and industrial real estate, was not explored. As a future study, we would like to extend our analysis over a wider distance and period after the rail entered its planning, construction, and operational phase. Spatially explicit regression methods exist to test whether the price premium associated with rail proximity will fluctuate from station to station, especially with varying distance.

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