Study of the Effect of the TransMilenio Mass Transit Project on the Value of Properties in Bogotá, Colombia

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Abstract

The new commercial and housing developments around the TransMilenio Bus-Rapid-Transit System (BRT) of Bogotá indicate that accessible to the system generates benefits for adjacent properties that must be reflected in the prices of land and buildings. This paper contributes to an understanding of the impact of TransMilenio on the price of adjacent properties. It uses Propensity Score Matching (PSM) to compare selling prices of buildings in two areas of Bogotá that are homogeneous with respect to their urban and socio-economic characteristics except that one of them has access to TransMilenio and the other does not. We find that properties located in the TransMilenio area of influence enjoy a "premium" that is reflected in their value of between 5.8% and 17% for residential buildings. We believe that determining and quantifying these impacts will enable the national and local authorities to design mechanisms to help them to obtain additional resources for the expansion of TransMilenio.

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1. Introduction

1.1. The Problem of Urban Transport in Bogotá, Colombia

The problems faced by public transport in Bogotá (and other cities of Colombia) during the decade of the 1990s were no different from those of other developing countries. Diagnoses sponsored by the national government and cited in various national policy documents (CONPES[1] Documents) revealed the inefficiency in the operation of the system and its direct responsibility for the high accident rates and the worse air quality of the cities, among other problems. The solution proposed by the national and local governments for the particular problem of Bogotá consists of establishing an integrated mass transit system based on BRT-type buses (from its name in English: Bus Rapid Transit), to be developed over 388 kilometers of trunk routes in order to handle 80% of the demand for public transport in the city. The system, known as the "TransMilenio," is to be developed in installation phases or stages over a period of 16 years.

1.2. The Mass Transit System of Bogotá –The TransMilenio System

The establishment of the TransMilenio system has been under way in Bogotá since the end of 1999. It has become the principal infrastructure project of the city, not only because of its size but also because the local government has taken advantage of the investments in the system to promote the construction or recovery of public space and also to promote urban renewal and recycling.

The TransMilenio system is a mass transit passenger system based on high-capacity buses and designed according to criteria of operating efficiency and environmental and financial sustainability.[2] Its components include: (i) an infrastructure specially created for the operation of high-capacity buses and the handling of large numbers of passengers; (ii) trunk fleets of high-capacity buses (160 passengers each) and medium- and low-capacity feeder fleets (80 passengers each); (iii) A centralized fare collection and access control system for large numbers of passengers; and (iv) an operations monitoring system to permit real-time operation with the support of Global Positioning Systems (GPS) and two-way communications systems.

The TransMilenio infrastructure has exclusive bus lanes that are physically segregated from the general traffic (known locally as trunk routes), bus stops,[3] access facilities for

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[1] It is recommended that the reader consult CONPES Document No. 3167 of 2002 and No. 3260 of 2003. They can be downloaded from http://www.dnp.gov.co/paginas_detalle.aspx?idp=19.

[2] In this paper, financial sustainability is understood to mean fare revenues and other system revenues. These cover, as a minimum, all the costs of investment, operation, and replacement of the collection system.

[3] In this paper the terms "bus stops" and "stations" are used interchangeably. There are two types of stations in TransMilenio: regular station or stops and transfer stations, these are generally simply referred to as station. The term "portal" refers to terminal or end-of-line stations.

pedestrians, terminals (end-of-line stations), yards and shops for equipment parking and maintenance, and a centralized operations monitoring system (Sandoval & Hidalgo 2001). The bus stations are located every 700 meters on average, and are between 50 meters and 200 meters long (TransMilenio S.A. and IDU 2003). Figure 1 shows some of the elements that compose the TransMilenio system. Supplementing the trunk system are feeder lines that feed into the transfer and terminal stations and also some intermediate stations.

Figure 1. Infrastructure of the TransMilenio System

Source: TransMilenio S.A.

A mixed financing plan was used for the development of TransMilenio. The preparation of the routes and the construction of the stations, control center, and yards and shops were financed with non-reimbursable public funds supplied by the national and the local governments. The purchasing, operation, and replacement of the buses and the installation and operation of the collection system are left to the private sector, which recovers its investment by sharing in the revenues from passenger fare collections. Thanks to the success of the system established under these parameters, TransMilenio is recognized as an international example of implementation of urban public transport solutions that offer large capacity at low cost.[4]

Some 84 kilometers of trunk routes, built in two 42-kilometer phases, are now in operation. At the present time the local government is working on the development of the Phase 3

[4] Cf. "Cities on the Move: A World Bank Urban Transport Strategy Review". Additionally, because of the success of the project, the National Government of Colombia decided to implement and co-finance similar systems in the six largest cities and metropolitan areas of the country. TransMilenio has served as a model for mass transit systems in various cities around the world, including cities in Chile, Mexico, Panama, Indonesia, Tanzania, and other countries.

which will add 47 kilometers[5] of trunk routes to the system. A major advance in the development of this new phase occurred in December 2007, when the local government awarded five contracts for work on 19.4 kilometers of trunk routes along Avenida Calle 26 and Avenida Carrera 10.

Various statistics demonstrate the benefits of TransMilenio, including a decrease in the number of accidents and crimes along the system routes.[6] The average operating speed for the route increased, reducing travel time for passengers. The "*Guerra del centavo*" [penny war][7] has been eliminated on trunk routes, and the effect of noise and emissions was reduced on roads on which the BRT has been installed.

Notwithstanding these benefits, the true costs of the construction of the infrastructure for Phases 1 and 2 have been higher than anticipated. This means that in order to achieve the original goal of 388 kilometers of trunk routes, it will be necessary to obtain funding in addition to the US$1,970 million in constant 2000 dollars committed to the project by the national and local governments.

Effect of Mass Transit System on property prices and land use

Theoretically, one of the greatest indirect benefits of a mass transit project is to optimize the use of land resources and the consequent development of land (Scheurer et al, 2000). Areas adjacent to the new mass transit infrastructure should become more attractive, with consequential increase in property prices (cf. Weinberger, 2000; Mendoza, 2005). The construction of stores and shopping centers and increased density of housing around the TransMilenio routes and stations are activities that can be associated with the reproduction of these phenomena in the context of Bogotá.

However, there has been little study of the effect of TransMilenio on the price of nearby properties, notwithstanding the fact that research in this area would make it possible to develop value-capture mechanisms or real estate development projects that could be used to finance the implementation of future phases of the system. This paper seeks to contribute to the understanding of this phenomenon and to support the creation of a research agenda on the topic.

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[5] In conformity with the TransMilenio System Basic Plan (TransMilenio & IDU 2003), Phase 3 of the system is composed of the trunk routes (bus-only lanes) of Carreras 7 and 10 (18.8km), Calle 26 (8.8km), and Avenida Boyacá (19.5km).

[6] Cf. "Evaluación Expost del sistema TransMilenio" at http://www.dnp.gov.co/archivos/documentos/DIFP_Bpin/Evaluaci%C3%B3n_Expost_Sistema_TransMilenio.pdf.

[7] In the traditional public passenger transport system in the city (and in the country), bus drivers and owners receive their revenues according to the number of passengers who use their buses. This leads to aggressive driving practices and competition among buses on the route to pick up the largest possible number of passengers. The name given to this phenomenon in Colombia is "Guerra del centavo," or "Penny war."

2. Objectives and Hypotheses

2.1. Objectives

The **general objective** of the study is *to determine if, in homogeneous areas, the value of properties with access to TransMilenio is higher than the value of properties without access.*

In this context, the specific objectives, based on the theoretical framework and the method of analysis selected, are:

1. To determine if there is a difference in the price of properties in two areas having similar socio-economic and urban characteristics, with properties in one group having direct access to TransMilenio[8] and the others lacking access;

2. Based on the result of point one, to estimate the price differences between one area and the other;

3. Lastly, to determine if the price differences vary according to the use of the property, according to availability of data for each use.

2.2. Hypotheses

The principal hypothesis of the study, associated with objectives Nos. 1 and 2 above, is that *when two homogeneous areas are compared, the properties with access to TransMilenio are more expensive than properties that do not have access to the system.*

The complementary hypothesis, which corresponds to objective No. 3 above, is that *when homogeneous areas are compared, the difference between the value of commercial properties that have access to TransMilenio and commercial properties that do not have access to the system is relatively greater than the difference between properties having other uses. That is, in terms of its effect on property values, the TransMilenio system favors commercial uses.*

2.3. Use of the results

As mentioned in Section 1.2, the true costs of the construction of Phases 1 and 2 of the TransMilenio system have been higher than anticipated.[9] In addition, according to TransMilenio S.A. and IDU (2003), the public funds available will be sufficient only for the construction of about 56 more kilometers, which means that of the 388 kilometers initially planned, only 140 kilometers would be implemented.

According to what has been said above, the hope is that this study will show the direct effect of the TransMilenio on land values and the indirectly effect on land use (cf. section 3). If the hypotheses are confirmed, this study will provide new evidence that could be used

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[8] "Direct access" refers to properties located within a radius of 500 meters from the closest stop or terminal.

[9] The estimated initial investment was US$5 million per kilometer (including costs of financing). In fact, the average cost per kilometer has been US$13.5 million, excluding the costs of financing.

by the local government to design value capture mechanisms or mechanisms for the development of system infrastructure as part of large-scale real estate and business developments in order to finance the future expansion of the system.

Additionally, it is hoped that this study will serve as source material for complementary studies for the city of Bogotá or as reference material for other cities that are developing similar public transportation systems and which are seeking alternatives to public funding to finance such systems. Consequently, it is hoped that the results of this study will serve as a basis for the formulation of policies and mechanisms that will not only make it possible to obtain additional funds for the expansion of this type of systems but will also support and increase the probability of success of the urban renewal programs associated with the development of the TransMilenio system.

3. Review of the Literature

Rybeck (2004) argues that the value of land reflects the availability and quality of the public services and goods in a given area. Batt (2001) is more categorical in stating that land has economic value solely on account of its location; that is, more and better conditions of accessibility are capitalized in the property values. For this reason, investments in mass transit generate increases in property values (Mendoza, 2005).

Batt (2001) and Benjamin & Sirmans (1996) argue that mass transit projects tend to increase density. Proximity to a station has a positive effect on rents, as a consequence of greater demand. Consequently, real estate developers will try to build taller and denser structures in order to make more intensive use of the land and to obtain higher profits (Benjamin & Sirmans 1996). However, the effects of such closeness are not always positive, since, as Cervero & Duncan (2001) and Targa (2003) point out, proximity to the right-of-way can be prejudicial to property values.

Because of greater flow of pedestrians, and the interest of urban developers in promoting more intense land use, it can thus be predicted that profits will differ depending on the use made of the properties. Along these lines, some authors, for example Cervero & Duncan (2001), state that profits are higher for business and office uses. Weinberger (2000), for example, found evidence of an increase in value of commercial properties after the installation of a light-rail type of system in Santa Clara County. He also found that the positive effects diminish with distance, and vary according to use. The benefit is greater for commercial uses very close to stations, while residential uses acquire their greatest premium when they are a few blocks away.

This theory is consistent with the urban structure models proposed by Von Thünen (1826) and Alonso (1964), who state that the use made of the land will be in accordance with the activity that pays the best rent on its use and that this rent will be determined by the individual preferences and budget restrictions of the agents who are participating in this "auction" for land. For example, commercial activity benefits greatly from being located in areas with good accessibility and high passenger traffic, or in which there are external economies that benefit them (Fujita, Krugman, and Venables 1999: chapter 2), and for this

reason this type of business is willing to pay whatever rent is necessary in order to be located in these preferred areas (Cervero & Duncan 2001 and Weinberger 2000).

Individuals in turn prefer to live in areas that combine in the best way possible their preferences for space, peace and quiet, safety, and local amenities, among other factors, and which fit their budget. These differences of criteria among activities mean (at least theoretically) that commercial and office benefit more than other uses from the development of mass transit systems (Cervero & Duncan 2001, Weinberger 2000).

Lastly, consideration must be given to the fact that the real dynamics and the imperfects that exist in the real estate market mean that clear and complementary land use policies are needed to promote an active real estate markets and a healthy economy that maximize the positive effects (or, of course, minimize the negative effects) of mass transit systems. (Offermans 2003).

3.1. Some Specific Studies

On the international level there are several studies of the effect of mass transit projects on the value of the properties affected by the project. The results vary from study to study, with evidence both for and against increases in land value. Cervero (2004) states that for every two studies that show an increase in land prices, there is one study that states the opposite. In addition, the magnitude and extension of the positive effects vary from project to project (Targa, 2003).

Batt (2001) uses the value-capture focus in order to evaluate the benefits from the change in property values as the result of the construction of various sections of the Interstate Highway System in the State of New York. The principal outcome shown by his study is that although construction cost is about US$128 million, the increase in the value of the land within two miles of the interstate is US$3.73 billion.

Another study, considered seminal with respect to the effect of the transportation infrastructure on land values, is the study by Spengler (1930) analyzing the effect of the construction of a railroad track on the value of adjacent properties at the beginning of the twentieth century. He arrives at the following conclusions:

- New transportation routes generate value. The owners of land near the route benefit, those outside its area of influence do not benefit;

- Transportation routes are not the only way to create property values and other factors that may lead to a decrease in the value of the properties must be taken into account. Limited availability of access sites, even when there is good mobility, can be one cause of loss in property values;

- The increase in value occurs in areas with a highly concentrated population, at the expense of less populated areas;

- Highly developed sectors do not increase in value when new transportation routes are opened;

- The value of areas with several transportation routes increases less with the addition of another route than is the case in areas where there were no routes initially;

- In areas that are developing with a transportation system, the increase in property value is ascribable to the process of sub-division of the properties, not to the availability of transportation services.

Another study that explores the subject of investments in urban transport projects and changes in property values is that of Damm et al. (1980). The study argues that "the provision of public infrastructure has a strong impact on urban development and the spatial distribution of urban properties." That is, the benefits from highways, efficient public transport systems, sewers, and other public structures are capitalized in part or totally into urban property values. The model developed by Damm et al. is based on the choice by means of statistical methods (goodness of fit and significance of the parameters) and analysis of functional form (Box-Cox models), with a warning that obtaining reliable data on urban property transactions is always problematic.

To analyze the effect of a metro-type transport system on the price of adjacent properties, Damm et al. use cross-sectional data for the period from 1969 to 1976 for Washington D.C., dividing them into three groups: (i) Single-family dwellings; (ii) Multi-family dwellings; and (iii) Commercial properties. In all cases, the distance of a parcel of land from the closest metro station was statistically significant in the determination of its price; in this order of ideas, the closer the property is to the station, the higher its price will be. The principal results are:

- The metro has a stronger effect on the retail sales sector than on residential units (the elasticity is greater for the commercial sector);

- The inauguration date of the metro has a significant effect on property values. The construction years have a greater effect on the business sector (retail sales);

- It is not completely certain that above-ground location of a station, presence of a parking lot at the station, and a dummy variable indicating proximity to a station based on the level of significance has a positive influence on the price;

- Variables related to the parcel (distance from the nearest metro station and size of the lot) and demographic variables (income, employment density and quality of the house) have a strong influence on the value of the property in residential areas (single-family and multi-family dwellings);

- The presence of parking lots has a positive effect on the retail sales sector;

- There are strong agglomeration effects on the value of retail commercial properties in central business districts (CBDs).

3.2. The case of Bogotá

A study by Rodríguez and Targa (2004) analyzes the effect of the change in the value of urban land in Bogotá associated with the implementation of the TransMilenio. The authors estimate several spatial hedonic price functions,[10] aiming to determine the point at which access to the TransMilenio stations increases land values.[11] In particular, Rodríguez and Targa concentrated on the effect of TransMilenio on the price of rental housing,[12] carrying out their analysis in a 1.5 kilometer area of influence around two Phase 1 routes (Avenida Caracas and Calle 80).

The results suggest that after controlling for structural characteristics, neighborhood attributes, and proximity to the TransMilenio route, the rental value of properties decreases by between 6.8% and 9.3% for every additional five minutes of walking to a station. The average elasticity of walking time to a station was estimated at between -0.16 and -0.22.

Although rental prices seem to be related to TransMilenio, the "premiums" are not necessarily ascribable exclusively to the system, and Rodríguez and Targa (2004) recommend that a new study be made using information from before and after the construction of the infrastructure. Another aspect to be kept in mind is that in order to quantify the true effect on land prices, information must also be available on the selling price of the properties, including identification of their use, so that price differences related to the activity carried on in the buildings can be determined (Mendoza 2005).

The review of the literature also revealed a study by Moreno (2004) that uses the start-up of the Avenida Caracas TransMilenio route as a natural experiment in the application of crime-fighting policies. It measures the effect of TransMilenio on the transformation of this route and the neighborhood. Using spatial econometric methods, the study found that criminal activity on Avenida Caracas decreased markedly, and that for the rest of the area studied, the results varied according to type of crime and proximity to Avenida Caracas. There is evidence that some types of crime have moved out of the area, and that the route has acted as a factor of dissuasion for other types (Moreno 2004, page 10).

Another study related to the effect of TransMilenio on neighboring areas is that of Fernández (2005), who studied the effect of the shifting of traffic (municipal buses) from Avenida Caracas and Autopista Norte to Carrera Séptima.[13] In this study, a survey was sent to some 200 Carrera Séptima residents concerning their perception of the increases in

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[10] The price of a property is composed of a group of attributes that differ in values and characteristics. These attributes include characteristics of the environment, such as access to mass transit, and individual characteristics, among others. The hedonic models break down the prices of each of the attributes that form the value of a given property (Cervero & Duncan 2001).

[11] This study by Rodríguez and Targa was one of the first to analyze the impact of BRT-bus-based systems on property values.

[12] Some authors argue that this type of estimate of rental prices can be problematic, since "leases do not always reflect all the concessions received by the lessees" (Cervero & Duncan 2001).

[13] Carrera Séptima is one of the main streets of Bogotá. It crosses the city from north to south, running parallel to Avenida Caracas and the Autopista Norte. When the TransMilenio System went into operation, many buses of the traditional system that served Avenida Caracas were "displaced" to Carrera Séptima.

selling prices of residential and commercial buildings. Fernández concluded that in general the persons surveyed felt that the value of their properties had not decreased (had remained stable). Despite the over-supply of buses, which led to slower speeds in Carrera Séptima and increased congestion and pollution levels, the persons surveyed felt that these disadvantages could be offset by the increase in passengers and commerce in Carrera Séptima. Nevertheless, people who felt that their properties had increased in value justified it in terms of location and the economic renewal of the city and the country.

As is evident, various studies carried out internationally show that improvements in the transportation infrastructure have a positive effect on land prices. In the case of Bogotá, there have been very few studies of the subject, and notwithstanding the various analyses of TransMilenio and its benefits (or disadvantages) in terms of various aspects (safety, congestion, etc.), only one analysis has concentrated on the impact on the rental value of properties. In this study we wish to increase the knowledge of the effects of TransMilenio on the sales value of properties in Bogotá. In the next section we provide a description of the model that we use to estimate these effects.

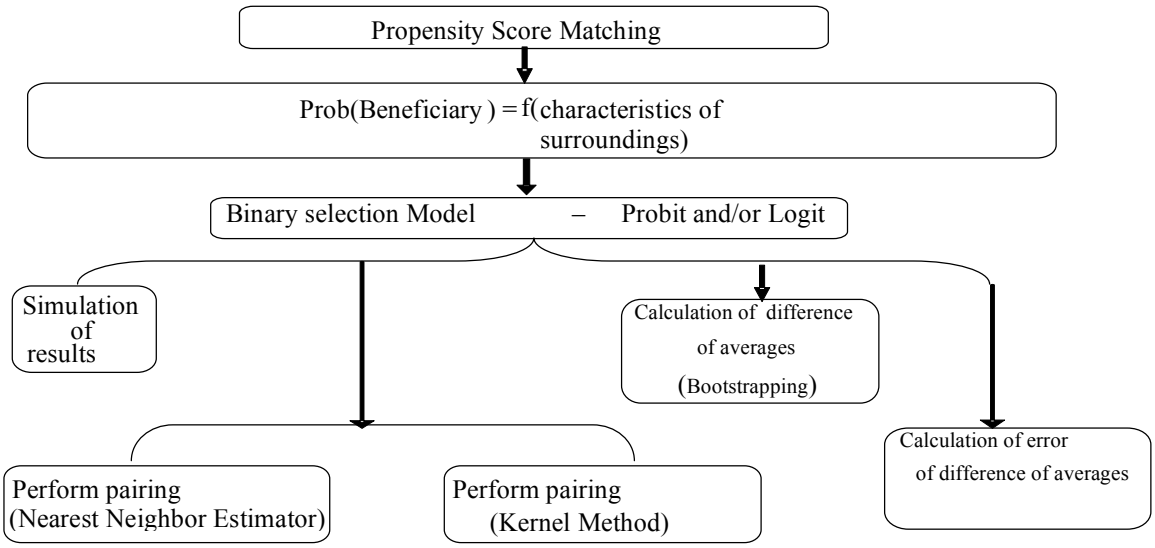
4. Methods

We are using in this study the "Propensity Score Matching" (PSM) method, a non-parametric method of comparison, classified as an experimental evaluation technique, that makes it possible to compare the effects generated by a project or a policy on one individual compared to another individual with homogeneous socio-economic or socio-demographic characteristics who has not been affected by the project or policy (Aedo & González 2002). The PSM has applications in various fields, including health, the labor market, and public services, among others.

Using PSM we estimate the effect caused by the construction of the TransMilenio system on the average prices of properties that have access to the system. We compare property prices in two areas of Bogotá, with homogeneous land uses and characteristics, except that one area has a TransMilenio route and terminal, i.e. has direct access to the system, while the other area is served by feeder roads and lacks direct access to the system. Under these conditions, we believe that the differences in average property prices in the two areas are related to access to the infrastructure of the mass transit system.

Following is a diagram of the strategy and method of modeling used for this analysis (Figure 2).

Figure 2. Diagram of the Propensity Score Matching Model



Source: Prepared by the authors.

4.1. The Logit and Probit Models

The probit and logit models are the starting point for the use of the Propensity Score Matching (PSM) technique. For this technique, access of a property to mass transit service will depend on a series of characteristics or attributes of its environment. When the environment meets certain conditions (for example, socio-economic aspects, location on outskirts or in the center, and access routes, among other factors), properties located in that area will have a greater or lesser probability of having access to the TransMilenio system.[14] Application of these probit and logit models makes it possible to determine the probability that a property will have access to the TransMilenio system.

The probit and logit models are probabilistic, and are characterized by the fact that their dependent variable, *y*, is a discrete (binary) dummy variable in the equation (1), depending in this case on whether the property has access to the TransMilenio system, in which case it has the value of one (1), otherwise zero (0). As mentioned, this choice depends on variables that describe characteristics of the environment on the properties.

$$\Pr ob(y = 1) = F(\mathbf{X}, \hat{\mathbf{a}}),\ \Pr ob(y = 0) = 1 - F(\mathbf{X}, \hat{\mathbf{a}}) \quad (1)$$

In the equation (1), the vector of coefficients $\hat{\mathbf{a}}$ reflects the impact of the independent variables $\mathbf{X}$, in this case characteristics of the surroundings, on the probability. Given this

[14] For purposes of this study, the properties with access are those that are within 500 meters or less of a TransMilenio station or terminal.

relationship, the logistics function equation (2) opens the way for the logit and probit models, which use normal distribution and are described in equation (3).

$$\Pr ob(y=1)=\frac{1}{1+e^{\hat{a}'\mathbf{X}}} \quad (2), \text{ and}$$

$$\Pr ob(y=1)=\int_{-\infty}^{\hat{a}'\mathbf{X}}\phi(t)dt = \ddot{o}(\hat{a}'\mathbf{X}) \quad (3)$$

In the equation (2), *e* is the Euler number, and for (3) **ö** represents the standard normal distribution function. In these equations it can be seen that the parameters to be estimated are not linear, which is why they are obtained with the maximum probability method. This means that the coefficients lack any interpretation, and the accompanying sign is the only thing noted in order to determine if the effect is positive or negative. If a numerical interpretation of the influence of each independent variable with the change in probability is desired, it is necessary to calculate the marginal effects for each model:

$$\frac{\partial y}{\partial x_i}=\hat{\beta}_i(1-\hat{p})\hat{p} \quad (4)^{15}, \text{ y}$$

$$\frac{\partial y}{\partial x_i}=f(\alpha+\beta_i x_i)\beta_i \quad (5)^{16}$$

In equation (5), α se refers to the intercept.

4.2. Propensity Score Matching

Once we have estimated the probability that each property will have access to the TransMilenio system by means of the probit and logit models, we continue the analysis by applying the Propensity Score Matching technique. Using the approach proposed by Heckman, Ichimura & Todd (1997), the principal authors of the PSM method, the value of the properties that actually have access to TransMilenio is compared with the value of the properties that do not have access, the criterion for comparison is that the properties have a similar probability of having access to TransMilenio, calculated on the basis of the characteristics or attributes of the environment.

If using the PSM we find statistically significant differences between the value of properties with and without access to TransMilenio, it will be possible to conclude that the system has an effect on property prices. Whether the impact is positive (increase in price) or negative (decrease in price) will be determined by the sign of the calculated difference between the prices of each group.

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[15] For the Logit model.
[16] For the Probit model.

For this purpose, in each zone we estimate the price Y_i^1 for dwellings, establishments, or lots with access to the TransMilenio system, and the price Y_i^0 for those that do not have access. Accordingly, properties with access to mass transit can be defined as *D=1*, and properties without access as *D=0*.

The increase in the value of the property is indicated by $\Delta = Y_i^1 - Y_i^0$, where Δ is not known, because it is impossible to observe the two situations simultaneously (Y_i^1 y Y_i^0, with and without project) for the same property. The property price is represented by Y_i^j, which describes the situation where is it located, for each scenario *j* in zone *i*. Y_i^j can be expressed by means of functions of observable characteristics $\mathbf{X}_i$ of the property (characteristics of the environment) and other non-observable characteristics (e_i^1, e_i^0), represented in equations (6) and (7).

$$Y_i^1 = \mathbf{B}^1\mathbf{X}_i + e_1^1 \quad (6)$$
$$Y_i^0 = \mathbf{B}^0\mathbf{X}_i + e_1^0 \quad (7)$$

In equation (7), Y_i^0 stands for the value of the property in zone *i* without the presence of TransMilenio (*D*=0, situation without project), $\mathbf{B}^0$ is the vector of coefficients associated with observable characteristics $\mathbf{X}_i$, and e_i^0 is the error term. The elements of equation (6) correspond to the same elements of equation (7), but with the presence of TransMilenio (*D*=1).

To evaluate the effect of the TransMilenio infrastructure on property values we treat statistical averages, the usual method in the literature of PSM, conventionally called "Average Treatment on the Treated" (*ATT*). This parameter can be represented in two ways, as expressed in equations (8) and (9).

$$ATT = E\left(Y_i^1 - Y_i^0 \mid \mathbf{X}_i, D=1\right) = E\left(Y_i^1 \mid \mathbf{X}_i, D=1\right) - E\left(Y_i^0 \mid \mathbf{X}_i, D=0\right) \quad (8)$$

$$ATT = \frac{\int_S E\left(Y_i^1 - Y_i^0 \mid \mathbf{X}_i, D=1\right) dF\left(\mathbf{X}_i \mid D=1\right)}{\int_S dF\left(\mathbf{X}_i \mid D=1\right)} \quad (9)$$

The conditional density function of $\mathbf{X}_i$ is *dF(X_i | D=1)* in equation (9), and *S* is the subset to determine $\mathbf{X}_i$, with *D=1*.[17] *ATT* is the coefficient that represents the greatest increase in value experienced by properties with access to TransMilenio, compared to the increase experienced if they did not have this attribute.

[17] It is a subset of properties for which the difference in their average price is estimated.

4.3. Assumptions of Average Treatment on the Treated (ATT)

ATT uses information about properties that belong to a control group (properties that do not have access to TransMilenio), in an effort to simulate counterfactuals of treated properties (those close to or with access to TransMilenio). The PSM makes it possible to obtain the difference in the increase in property value, using information for the control group in accordance with the characteristics $\mathbf{X}_i$ of the properties; if the increase in value is independent of the influence of TransMilenio, it has the expression of Rosenbaum and Rubin (1983), presented in equation (10).

$$\left(Y_i^1, Y_i^0\right) \perp D \,|\, \mathbf{X}_i, \Rightarrow E\left(Y_i^0 \,|\, \mathbf{X}_i, D=1\right) = E\left(Y_i^0 \,|\, \mathbf{X}_i, D=0\right) \quad (10)$$

If the condition of equation (10) is met, the increase in value obtained for land or properties is equal to the ease of access to TransMilenio or lack thereof. The last requirement is that $0 < \Pr\left(D=1|\mathbf{X}_i\right) < 1$ be met, to ensure the existence of a common support for the group of properties compared (that is, properties that would have the same probability of having easy access to TransMilenio).

4.4. Steps for preparation of the model

Figure 2 above shows the form in which the PSM model is developed. In general terms, the steps are as follows:

1. The logit and probit models are estimated, for the purpose of calculating the probability that a property has access to the TransMilenio system, according to the characteristics of its environment. The parameters for the probability equation are estimated using the probit or logit model.

2. Given the results, we obtain the probability that, based on the characteristics of the environment, a property has easy access to TransMilenio and the sample is restricted to the common support. That is, only properties that meet $0 < \Pr\left(D=1|\mathbf{X}_i\right) < 1$ are include in the sample.

3. For each property with access to TransMilenio, we select a property in the control group (without access to TransMilenio) that has a similar probability of having access to the system, and their average values are compared. To do the matching of the properties we can use the Nearest-Neighbors [18] and the Kernel methods:

- The nearest-neighbor method is used to estimate the probability of access TransMilenio for each property, and we calculate the difference of probabilities between the properties that actually have access to TransMilenio and those that do not. Using the difference, we build a vector of distances and rank that in ascending order. Subsequently we compare the average value of the property with the TransMilenio

[18] "Nearest-neighbor estimator"

attribute with the N properties with the closest probability to the control group of properties that lack access to mass transit.

- The Kernel method is similar to the nearest-neighbor method, but differs in the weighting given to the control group with the factor $\omega(i) = \frac{1}{n_1}$ in which n_1 is equal to the number of observations with $\omega(i) \neq 0$.

4. We then test the statistical significance of the results by means of the bootstrapping technique, which consists of random generation of K samples with replacement. For each sample we obtain the difference in property values using each of the matching methods explained in step 3 above.

5. We calculate the prediction error of the differential of values in each sample and the average of all the standard errors of prediction.

We then apply the PSM method to determine if the owners of the properties are actually experiencing an increase in the value of their property when it has access to the TransMilenio mass transit system.

5. Selection of zones to be studied

According to the methodology chosen for this analysis, we searched for two areas of Bogotá having similar socio-economic and urban characteristics, one of which was served by TransMilenio while the other was not. Taking into account the fact that the main commercial developments associated with TransMilenio occurred near the terminals of the system, we determined that the area of study influenced by TransMilenio would have to include a system terminal. For this first zone, the area near the Portal de Suba[19] terminal was selected. This terminal was opened in April 2006, when the Avenida Suba trunk of TransMilenio Phase 2 went into operation. For the other zone, not affected by TransMilenio, we chose the intersection of Avenida Boyacá and Avenida Primero de Mayo.

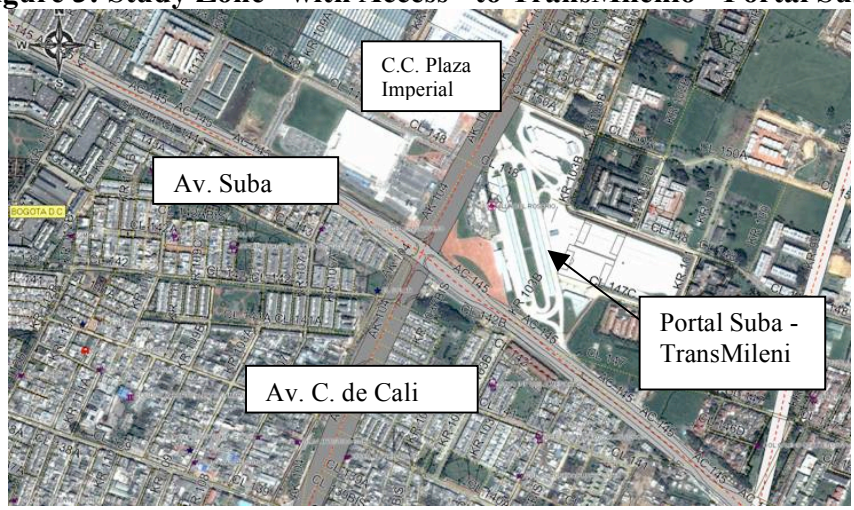
5.1. Socio-economic characteristics of the zones to be studied

5.1.1. Zone adjacent to Portal de Suba

The Portal de Suba study area is located in Suba, northwest of the city, and more specifically in "El Rincón" Zone Planning Unit (*Unidad de Planeamiento Zonal*—UPZ) (Figure 3).

[19] The term "Portal" refers to a terminal or end-of-line station; while the term "station" or stop is normally used to mean a regular station as well as a transfer station.

Figure 3: Study Zone "with Access" to TransMilenio - Portal Suba



Source: http://mapas.idu.gov/internet/

According to the Document "*Recorriendo Suba: Diagnóstico Físico y Económico de las Localidades de Bogotá* – 2004"[20] the population of this UPZ is approximately 187,000 inhabitants and it contains 296 urban facilities.[21] According to Decree No. 200 of 2004, the properties in this area are classified in strata 2, 3, and 4.[22]

The effect of the TransMilenio system on the zone is determined by the presence of a trunk route that runs along Avenida Suba and ends at the intersection of Avenida Ciudad de Cali, where the Portal de Suba terminal is located. According to the Bogotá Master Plan (*Plan de Ordenamiento Territorial de Bogotá*—POT), Avenida Ciudad de Cali is a Class V-1road, [23] while Avenida Suba is a Class V-2 road.

In addition to the TransMilenio terminal, this zone has other activities that draw people to the area, including a supermarket, two shopping centers (a third shopping center is under

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[20] Departamento Administrativo de Planeación Distrital – DAPD 2004a.

[21] Urban facilities consist of the spaces and buildings designed to provide the citizens with social services that are formative, cultural, educational, medical, religious, social-benefit, sports, and recreational in nature. They also provide functional support for the public administration and the basic urban services of the city. Depending on the nature of their functions, the facilities are classified in three groups: community installations, sports and recreational installations, and basic urban services.

[22] Stratification is a process for classifying residential properties on the basis of the characteristics of the housing and according to the socio-economic level of the population living there, for purposes of tax collection, billing and subsidizing of public services, and for the development of social welfare programs. Presumably, the higher the stratum the higher the socio-economic level of the area. (Obtained from http://redbogota.com/endatos/0200/02-030-vivienda/02.03.01.htm.)

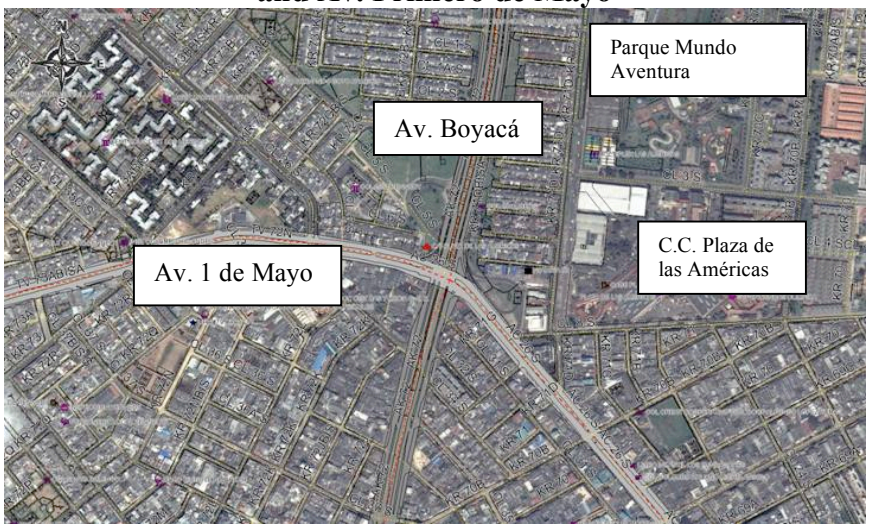
[23] The road classification information was obtained from the Bogotá Geographical Information System (GIS), available at IDU web page http://mapas.idu.gov.co. This GIS is based on the POT of the city. Classes V-0, V-1, V-2, and subsequent classifications of the road are associated with the width and characteristics that a section must have in order to handle the pedestrian and vehicular traffic it carries. Class V-0 corresponds to the section with the highest standards, and subsequent classifications will have increasingly lower standards, depending on the priority of the road network of the city.

construction), and a Specialized District Service Center (*Centro de Atención Distrital Especializado*—CADE). It should be emphasized that these facilities were constructed after the announcement of the location and construction of the TransMilenio system terminal in this sector of Suba.

5.1.2. Zone adjacent to the intersection of Avenida Boyacá and Avenida Primero de Mayo

The study area of the zone adjacent to the intersection of Avenida Boyacá and Avenida Primero de Mayo is located at the Kennedy locality, southwest of Bogotá (Figure 4). Avenida Primero de Mayo is the boundary between two UPZs in this locality, so the study area covers two UPZs: Américas and Carvajal. The total population of these two UPZs in 2002 was 244,000 inhabitants, and the area had a total of 252 urban facilities at that time, or one facility for every 970 inhabitants (DAPD, 2004b), compared to one facility for every 631 inhabitants in the Suba UPZ. According to Decree No. 200 of 2004, properties in this study zone are for the most part classified as stratum 3, although there are several blocks of strata 2 and 4.

Figure 4 4: Study Zone "without access" to TransMilenio – Intersection of Av. Boyacá and Av. Primero de Mayo



Source: http://mapas.idu.gov/internet/

This zone does not have any TransMilenio system infrastructure, although some neighborhoods to the west of Avenida Boyacá are served by feeder routes from the intermediate station of Banderas. Avenida Boyaca and Avenida Primero de Mayo are classified in the Bogotá POT as Class V-1 and V-2 roads, respectively.

Other activities that draw people to this study zone are the Plaza de las Américas Shopping Center, the Mundo Aventura Park, the Plaza de las Américas CADE, and an area with nighttime activities that is very close to the intersection of the two avenues.

When we compare the information for the two study zones, we note that the hierarchy of the main roads that cross them is the same, the socio-economic characteristics of the properties are similar, and, with the exception of the TransMilenio infrastructure, the two areas have other activities that draw people. From the socio-economic and urban points of

view, we believe that the similarities between the two areas justify their being considered homogeneous. Thus, we believe the similarities between the zones permit us to the analysis to determine the effect of the TransMilenio system on property values.

5.2. Information collected

In two months of field work and research on the asking-prices of properties,[24] we created a preliminary database containing some 400 properties, 200 for each study zone.

After cleaning the data and removing incorrect information such as properties located outside the study zones, and/or incomplete information, we built the final database of 350 observations. Of these, 186 observations are in the zone of the intersection of Avenida Boyacá and Avenida Primero de Mayo and 164 are located in the Suba zone. The distribution of the sample of properties in the two zones is presented in Table 1 according to distance to the TransMilenio infrastructure and land use.

Table 1: Distribution of the Sample of Properties by Zone, Distance to TransMilenio Infrastructure and by Land Use

Distance to a TransMilenio Station	Suba Zone	Av. Boyacá/ Av. Primero de Mayo
500 meters	89	5
500-1000 meters	49	13
More than 1000 meters	26	168
Total	164	186
Land Use	Suba Zone	Av. Boyacá/ Av. Primero de Mayo
Residential	152	152
Commercial	10	30
Other*	1	1
Mixed-use	1	3
Total	164	186

(*) Includes vacant parcels, grocery stores and/or shacks (*casa-lote*).

Information was collected on the characteristics of each property, including the asking-price (as already stated), usable area, socio-economic use, socio-economic stratum, address, age, and other characteristics that are not mentioned since they are not relevant for the analysis. In addition it was possible to obtain information from secondary sources regarding the environment in each of these zones, including the location of urban facilities such as hospitals, schools, libraries, pharmacies, police stations and fire houses, shopping centers, banks, highway infrastructure, and TransMilenio stations, among others.

We used a Geographical Information System (GIS) to determine the accessibility of each property to a TransMilenio station and to other urban facilities. Accessibility was measured as the Euclidean distance in meters from the property to the individual facility. The

[24] The property asking-price data included data published in the local newspapers and on Internet pages, including http://www.metrocuadrado.com.

properties were loaded in the GIS using as a parameter their respective addresses and cadastre-map information.

6. The Estimated PSM Model

In this exercise we made an effort to quantify the change in benefits resulting from the increase in the value of the properties directly influenced by TransMilenio.[25] To capture the difference in the prices for residential and commercial properties with and without access to the TransMilenio system, the method selected for this study helps to provide an approximation answer to this question.[26]

The dependent variable "within the TransMilenio area of influence" or DTM (for the Spanish name "*Dentro de Influencia de TransMilenio"*) to be estimated by means of the probit or logit model is binary dummy which takes on the value of 1 when the property has access to TransMilenio (i.e. is located not more than 500 meters from the nearest TransMilenio station), and the value of 0 when the property does not have access to TransMilenio (i.e. is located more than 500 meters from the nearest TransMilenio station). The behavior of the dependent variable is related to environment variables.

Properties with access to the TransMilenio system, selected at random, comprise the treatment group (participants in the project), while the control group is represented by the properties that are more than 500 meters from the system.[27] Once the treatment and control groups have been defined, we made an effort to match the properties using PSM, according to the probability of access to the system obtained with the probit model. Using this procedure, we were able to find the control group observation that is most similar to the observation of the treatment group.

Once the specification of the logit and probit models has been explained, all that needs to be done is to describe the specification and the variables of the PSM model, as follows:

$$\Pr ob(\Pr edio\ \ Beneficiario\ por\ TM) = f(características\ del\ entorno) \qquad (11)$$

(Property Benefitting from the TM) (characteristics of the environment)

$$\Pr ob(DTM = 1) = \int_{-\infty}^{\hat{\alpha}' \mathbf{X}} \phi(t)dt = \ddot{\mathbf{o}}(\hat{\alpha}' \mathbf{X}) \qquad (12)$$

Equation (12) represents the function of the probit model estimated earlier (as in equation (3) of section 4). The dependent variable DTM and the independent variables **X** are shown in Table 2.

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[25] This is the first application of PSM in the field of urban economics in Colombia.

[26] The Stata 9.0 software program was used to prepare the PSM estimates for this project, with robust estimates, for the purpose of removing the problems of residual autocorrelation and heterscedasticity with unknown structure.

[27] According to National Urban Transport Policy Document No. CONPES 3185, 500 meters or less is considered to be the distance directly influenced by a BRT system such as the TransMilenio.

Table 2: Variables of the Study

Type	Variable	Description
Property Characteristics	Address	Address of the observed property
	Zone	0: Primero de Mayo 1: Suba
	Area	Built area in m2 of the observed property
	Price/m2	Asking-sales-price or asking-monthly-rent by m2 = price/m2
	Use	1: Residential
		2: Commercial
		3: Other (vacant lot, grocery store, shack)
		4: Mixed-use (combination of the above uses)
	Age	Approximate age of the observed property
		0: new or under construction
	Stratum	Stratum corresponding to the observed property
Environmental Characteristics	dbancos	Minimum distance between the observed property and the closest bank
	dbomberos	Minimum distance between the observed property and the closest fire station
	dcais	Minimum distance between the observed property and the closest CAI
	dccomercial	Minimum distance between the observed property and the closest commercial center
	dclinic	Minimum distance between the observed property and the closest clinic
	dcoleg	Minimum distance between the observed property and the closest school
	ddrogue	Minimum distance between the observed property and the closest pharmacy
	dembajadas	Minimum distance between the observed property and the closest embassy
	destpoli	Minimum distance between the observed property and the closest police station
	dgasolineras	Minimum distance between the observed property and the closest gas station
	dhotel	Minimum distance between the observed property and the closest hotel
	diglesias	Minimum distance between the observed property and the closest church
	dmuseos	Minimum distance between the observed property and the closest museum
	dnotarias	Minimum distance between the observed property and the closest notary public
	dparques	Minimum distance between the observed property and the closest park
	dparquead	Minimum distance between the observed property and the closest parking lot
	drestaurant	Minimum distance between the observed property and the closest restaurant
	dsupermerc	Minimum distance between the observed property and the closest supermarket
	dteatros	Minimum distance between the observed property and the closest theatre
	dtransp	Minimum distance between the observed property and the closest inter-urban transport terminal
	duniversi	Minimum distance between the observed property and the closest university
Dependent	DTM	0: If the property is more than 500m from a TransMilenio station or terminal
		1: If the property is less than 500m from a TransMilenio station or terminal
	dtransmil	Minimum distance between the observed property and the closest TransMilenio station or terminal
Comparison	PRECIO	Asking-sales-price or asking-monthly-rental price, as appropriate

Source: Authors.

Table 2 describes the information collected for this study, using the environment variables to estimate, by means of the logit or probit model, the probability that, based on the environment characteristics, the property does or does not have access to a TransMilenio station or terminal in the zones of selected. The variables that represent characteristics of the property, different from those mentioned in Table 2, are not considered for purposes of the PSM analysis, although they too will have an effect on the intrinsic price of housing. By means of this research we aim to estimate the change in property prices caused by the construction of the TransMilenio system. For this reason, we calculate the probability of easy access to the system, *ceteris paribus*.

6.1.1. PSM of Residential Properties

The estimated results, marginal effects, and elasticity of the probit model are shown in Table 3 for residential properties in the zones selected. As can be seen, we find a probability of 0.05%, with the environment variables selected statistically,[28] that a property has easy access to a TransMilenio station or terminal.

Table 3: Probit Model, Marginality and Flexibility, Residential Properties

Residential			
Variables Dependent	DTM	Probability	0.00545115
Variables Independent:	Coefficients	Margin Effects	Elasticity
dbancos	(-0.0026334)***	-0.00004110	-3.468718
Dccomercial	0.0008123***	0.00001270	4.924106
Dclinic	(-0.0056576)***	-0.00008830	-12.226750
destpoli	(-0.0019257)***	-0.00003010	-10.676880
Dgasolineras	0.0057135***	10.66456000	10.664560
Constant	1.218743***	-	-
No. Observations	350		
Variables statistically significant at (8) 10%, (**) 5% and (***) 1 percent.			

Source: Authors.

The selected variables are significant at 1%. In Table 3, the elasticities for each independent variable with respect to the dependent variable (probability that the property has access to TransMilenio) are evaluated. We interpret the observed elasticities depending on the direct and inverse relationships, and given the sign (plus or minus) of the coefficient as follows: When the property is 1% farther from banks, clinics, and police stations, the probability (0.05%) of being near a TransMilenio station or terminal, based on environment characteristics, decreases by 3.4%, 12.2%, and 10.67%, respectively. In contrast, with a 1% increase in the distance of the property from a gas station and shopping center, this 0.05% probability increases by 10.6% and 4.9%, respectively.[29] This allows us to infer from the sample that residential properties far from shopping centers have the possibility of being closer to a station because travel to these locations. Most of the stations are starting places for buses going to such destinations as shopping centers, universities, schools, and workplaces.

It should also be noted that implementation of the TransMilenio system, and specifically the construction of terminals, has promoted a change in land use, with large shopping centers being built near TransMilenio terminals, giving residential properties easy access simultaneously to shopping centers and TransMilenio terminals, as is now the case in Suba. It is also pertinent to note that the model was applied without taking into account the new shopping centers in the Suba sector, since they were developed after the implementation of the TransMilenio system in the area, and they are considered a consequence rather than a cause of the system. If the model were estimated taking into account this new phenomenon, sampling these new points on the map of Bogotá, the results would have been the opposite

[28] The table shows only environment variables that are statistically significant.
[29] This description of the variables is on a partial level, leaving constant the influence of the other variables on the model.

of those found; that is, the closer a property is to shopping center, the higher would be the probability of easy access to a TransMilenio terminal.

Another phenomenon that seems to be related to the construction of the mass transit infrastructure in Bogotá is the increase in safety (decrease in thefts, robberies, and rapes, among other crimes). Many stations and terminals of the system are near police posts and security stations. This helps to explain the minus sign found in the parameter for police stations, indicating that if a property is far from a police station it is also far from a TransMilenio station or terminal.

Based on these results, the probabilities were matched by means of the PSM technique in order to find the difference in square-meter sales-asking-price of housing with and without access to the TransMilenio. The use of the standardized square-meter price indicator eliminates distortions related to the size of the properties and the consequent differences in price. The results of the PSM in Table 4 indicate the square-meter price differential in the zones analyzed.

Table 4: Comparison of PSM Residential Averages[30]

Method	Properties	Variable	Sample	Treatment Group	Control Group	Difference
Nearest Neighbors	1	House Price	Non-Matched	$990,361.84	$935,685.72	$54,676.12
			EPPP (ATT)	$990,361.84	$1,065,276.74	($74,914.91)
	5	House Price	Non-Matched	$990,361.84	$935,685.72	$54,676.1184**
			EPPP (ATT)	$990,361.84	$861,977.16	$128,384.678***
	10	House Price	Non-Matched	$990,361.84	$935,685.72	$54,676.1184*
			EPPP (ATT)	$990,361.84	$894,315.06	$96,046.7763***
Kernel	0.01	House Price	Non-Matched	$990,361.84	$935,685.72	$54,676.1184*
			EPPP (ATT)	$1,051,654.06	$898,722.84	$152,931.214*
	0.05	House Price	Non-Matched	$990,361.84	$935,685.72	$54,676.1184*
			EPPP (ATT)	$980,709.08	$947,211.27	$33,487.81
	0.86	House Price	Non-Matched	$990,361.84	$935,685.72	$54,676.1184*
			EPPP (ATT)	$980,709.08	$933,168.68	$47,540.40
Level of significant at (*) 10 percent, (**) 5 percent and (***) 1 percent.						

Source: Authors.

Table 4 shows the average price differences per square-meter prices for houses to be statistically significant for the five closest neighbors and for probabilities close to 1% (Kernel). Considering only those values that are statistically significant at 10% or less, properties that have easy access to TransMilenio are found to have an average price per square-meter of between Peso$990,362 and Peso$1,051,654.[31] The price for those that do not have easy access to TransMilenio is between Peso$861,977 and Peso$935,686. The difference in average prices of residential properties with and without access to

[30] EPPP: Average effect of program for participants. Properties: numbers of nearby neighbors by the N-Neighbors method and by probability for Kernel.

[31] At the time of preparation of the study, and for purposes of better understanding, we note that one dollar is equal to approximately Colombian Peso$2,000.

TransMilenio is statistically significant and varied between Peso$54,676 (without access) and Peso$152,931 (with access) in 2007.

In conclusion, the location in the radius influence of the TransMilenio (less than 500 meters) is capitalized in the square-meter price of residential properties as their value increases within a range of 5.8% and 17%, with the first figure prevailing.

This difference in square-meter (asking) price for residential properties, obtained with PSM, is the incremental value generated for properties that are near and have benefitted from the TransMilenio system in Bogotá. That is, the system has a positive and significant effect on the square-meter price of residential properties that have easy access to it, at least in the Suba sector.

6.1.2. PSM Commercial Properties

Table 5 presents the estimates, marginal effects, and elasticities of the probit model for commercial properties in the zones studied, showing a 2% probability that a commercial property has easy access to a TransMilenio station or terminal.

Table 5: Probit Model Estimates, Marginal Effects and Elasticity for Commercial Properties

Commercial Properties			
Dependent Variable	DTM	Probability	0.0218637
Independent Variables:	Coefficients	Marginal Effect	Elasticity
dcoleg	0.0244357***	0.0002190	3.008109
destpoli	(-0.004343)***	-0.0001091	-11.027810
Age	(-0.4381234)***	-0.0031550	-2.484612
Constant	2.034440	-	-
No. of Observations	40		
Level of significant at (*) 10 percent, (**) 5 percent and (***) 1 percent.			

Source: Authors

The results of the probit model indicate that the variables selected are significant at 1%. According to the direct and inverse relations, for the plus or minus sign in the parameter (Table 5), the elasticity is interpreted as follows: For every 1% increase in distance from a police station, the probability that the property has easy access to TransMilenio, based on the characteristics and attributes of the environment, decreases by 11%. In contrast, for every 1% increase in distance from a school, the probability that the property has easy access to TransMilenio increases by 3%. Lastly, for every 1% increase in the age of the property, the probability of easy access to TransMilenio decreases by 2.48%.

Table 6: Comparison of PSM Commercial Averages[32]

Method	Properties	Variable	Sample	Treatment Group	Control Group	Difference
Nearest Neighbors	1	House Price	Non-Matched	$4,451,511.06	$1,247,892.99	$3,203,618.07***
			EPPP (ATT)	$4,451,511.06	$955,443.88	$3,496,067.18***
	5	House Price	Non-Matched	$4,451,511.06	$1,247,892.99	$3,203,618.07***
			EPPP (ATT)	$4,451,511.06	$1,222,628.86	$3,228,882.2***
	10	House Price	Non-Matched	$4,451,511.06	$1,247,892.99	$3,203,618.07***
			EPPP (ATT)	$4,451,511.06	!,292,090.37	$3,249,420.69***
Kernel	0.01	House Price	Non-Matched	$4,451,511.06	$1,247,892.99	$3,203,618.07***
			EPPP (ATT)	-	-	-
	0.05	House Price	Non-Matched	$4,451,511.06	$1,247,892.99	$3,203,618.07***
			EPPP (ATT)	-	-	-
	0.86		Non-Matched	$4,451,511.06	$1,247,892.99	$3,203,618.07***
			EPPP (ATT)	$4,098,808.38	$1,251,783.11	$2,847,025.26
Level of significant at (*) 10 percent, (**) 5 percent and (***) 1 percent.						

Source: Authors.

With respect to the average differences found for commercial properties, Table 6 shows that for differences significant at 10% or less, properties with easy access to TransMilenio have an average square-meter price of Peso$4.45 million, while for properties without access this figure is between Peso$955 thousand and Peso$1.25 million. Based on these results, the approximate difference between the average square-meter value of commercial properties with easy access to TransMilenio and properties that do not have such access in the zones analyzed varied between Peso$3.2 million and Peso$3.5 million in 2007. In any case it is pertinent to clarify that the sample has only 40 observations of commercial properties and of these only 10 are located within the area of influence of the TransMilenio (within 500 meters of its infrastructure), thus caution must be exercised in using these results.

Notwithstanding this clarification, the analysis indicates that the average price per square-meter of commercial properties with access to TransMilenio is between 257% and 365% higher than for commercial properties without access to the system. The simple average of these differences shows an increase of 268.7% in the value of the properties in the zone of influence over those that do not have access to the system.

[32] EPPP: Average effect of the program of participants, Properties: Numbers of nearby neighbors according to the N-Neighbors method and the probability for Kernel.

7. Conclusions and Recommendations

7.1. Conclusions

As proposed, the principal objective of this study consists in determining if properties with access to TransMilenio, the BRT-type mass transit system of the city of Bogotá, have a greater commercial value than properties that do not have such access, quantifying the difference (if any) and identifying variations depending on land use.

The Propensity Score Matching (PSM) method was used for the analysis. This method is commonly used for ex-post facto evaluations of a project or policy, determining its effect on the group of individuals included or benefiting from it. In this study, this group consists of properties that have easy access to the TransMilenio system. Using the PSM, we determined the increase in the square-meter market price experienced by properties that benefitted from the TransMilenio, comparing two homogeneous zones of the city differentiated by the fact that one zone is served by the system and the other is not.

The results obtained with the PSM technique, with differences significant at 10% or less, show that residential properties with easy access to TransMilenio have an average price per square-meter of between Peso$990,362 and Peso$1,051,655, while properties that do not have such access have an average price per square-meter of between Peso$861,977 and Peso$935,686. From the foregoing we concluded that the average square-meter price differential for residential properties varies between Peso$54,676 and Peso$152,931. That is, ease of access to TransMilenio is capitalized in the prices of residential properties at a rate of between 5.8% and 17%.

This difference is the incremental value generated for properties that benefit from access to TransMilenio. From our analysis we conclude that, at least in the zone studied, the TransMilenio may in fact have a positive effect on the prices (or, more specifically, sale asking prices) of residential properties.

On the other hand, the results of the logit model show that TransMilenio stations have been installed in the zones analyzed in areas near police stations, clinics, and financial centers. The closer a residential property is to this type of facility, the greater the probability that it has access to TransMilenio. This is important to highlight the integration of the TransMilenio system with the employment, financial, commercial and services markets in the city.

With respect to commercial uses, properties with access to TransMilenio have an average price per square-meter of Peso$4,451,511 million, while for properties without access to the service have an average price per square-meter price between Peso$955,444 and Peso$1,247,893. The approximate difference between the average square-meter price of commercial properties with easy access to TransMilenio and properties without such access, in the zones analyzed, ranges between Peso$3.2 and Peso$3.5 million. This shows that the incremental value capitalized into the value of commercial properties is greater than that for residential properties. Despite the fact that these findings correspond to differences statistically significant at 10% or less, it is appropriate to keep in mind that the

sample of properties includes only 40 observations of commercial properties, and of these 40, only 10 are properties with access to the system. Therefore, we recommend that these results be used with caution until more observations of commercial properties have been compiled and a new analysis of the information has been made.

7.2. Recommendations

The Colombian Government has embarked on an aggressive policy to improve public transport services in several cities. The principal component of this policy consists in supporting the implementation of BRT-type Integrated Mass Transit systems in the principal cities of the country. This is the result of the success of the Bogotá TransMilenio system.

The implementation of BRT-type systems is less expensive than that of other, rail-based public transport systems. However, public funding is insufficient for the implementation of BRT providing full-coverage. To do that requires major financial, administrative, and political efforts by the national and local authorities, which frequently turn to outside financing (from multilateral agencies or commercial banks) to ensure that resources match project execution schedules.

Traditionally, implementation of BRTs, not only in Bogotá but in all Colombian cities (and, we dare to say, in other Latin American cities as well) has been financed with public funds obtained from taxes or sovereign debt operations. No effort has been made to capture the benefits deriving from these systems in order to leverage their development. Studies like the present one show that the benefits from the development of mass transit systems are capitalized by landowners and there are real opportunities for the state to participate in these capital gains from land appreciation to finance the infrastructure. There are also opportunities for the introduction of programs or mechanisms that will permit development infrastructure components of mass transit systems by the private sector.

The results of this study are consistent with residential and commercial developments observed around the terminals of the TransMilenio. To the extent that commercial demand for these locations increases, properties and land prices increase. Once the incremental amount in the land price associated with the benefits accruing from proximity to the TransMilenio is quantified, it is possible to design mechanisms that will enable the public-sector to capture some of these benefits and use that to finance additional infrastructure. In this paper we show that investments in new and better passenger mass transit systems can have a positive effect on property values.

This study indicates that there are benefits that can be shared with local governments and be used to finance urban infrastructure development. However, we believe that the results reported are not sufficient to warrant development of public value-capture policies or to incorporate the construction of mass transit system components in private real estate development projects. For one thing, the PSM technique uses only the characteristics of the environment to estimate price differences, ignoring the potential effect of the characteristics of the property itself on the price. Also, our analysis of the commercial properties was based on a small number of observations and therefore the results should be used with

caution, even though they are statistically significant. An alternative to be considered is to modify the PSM analysis in such a way as to make it possible to incorporate hedonic models in the analysis and thus base the estimate of the differential property prices on the characteristics of the property as well as on the characteristics of the environment.
This study complements the existing evidence of the effect of TransMilenio on properties within the area of influence of the system, and reveals the opportunity available to local authorities for designing mechanisms that will allow them to share these benefits in order to finance or promote the development of the mass transit infrastructure.

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Attachments – Print-outs of the Model[33]

```
Probit regression                                 Number of obs   =        304
                                                  LR chi2(6)      =     244.28
                                                  Prob > chi2     =     0.0000
Log likelihood = -57.049651                       Pseudo R2       =     0.6816

------------------------------------------------------------------------------
         dtm |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     dbancos |  -.0037076    .001078    -3.44   0.001    -.0058205   -.0015946
 dccomercial |   .0007246   .0001686     4.30   0.000     .0003941    .0010552
     dclinic |  -.0058239   .0009578    -6.08   0.000    -.0077012   -.0039467
    destpoli |  -.0015652   .0003133    -5.00   0.000    -.0021793   -.0009512
dgasolineras |    .005387   .0009885     5.45   0.000     .0034496    .0073243
   valoradmi |   .0000205   5.60e-06     3.66   0.000     9.54e-06    .0000315
       _cons |   .7101128   .5918279     1.20   0.230    -.4498486    1.870074
------------------------------------------------------------------------------
Note: 29 failures and 0 successes completely determined.

There are observations with identical propensity score values.

The sort order of the data could affect your results.
```

psmatch2 dtm dbancos dccomercial dclinic destpoli dgasolineras valoradmi if duso1==1, n(1) out(precio)

```
Make sure that the sort order is random before calling psmatch2.

        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
```

[33] The tables in this attachment are In English, with exception of the following words and abbreviations: *precio* = price; *coleg* = school; *antiguedad* = age; *banco* = bank; *gasolinera* = gas station; *dest* = distance = *poli* = police station]; psmatch2 dtm dbancos dccomercial dclinic destpoli dgasolineras valoradmi if duso1==1, n(10) out(precio).

```
          precio  Unmatched | 77004107.1   68971301.8   8032805.32   4854277.81     1.65
                         ATT | 77004107.1   84505238.1  -7501130.95   14016294.7    -0.54
```

psmatch2 dtm dbancos dccomercial dclinic destpoli dgasolineras valoradmi if duso1==1, n(5) out(precio)

```
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 77004107.1   68971301.8   8032805.32   4854277.81     1.65
                         ATT | 77004107.1   65732714.3   11271392.9   7735509.02     1.46


    Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 77004107.1   68971301.8   8032805.32   4854277.81     1.65
                         ATT | 77004107.1   63022357.1     13981750   6815274.24     2.05
-----------------------------+------------------------------------------------------------
Note: S.E. for ATT does not take into account that the propensity score is estimated.


           | psmatch2:
 psmatch2: |   Common
 Treatment |  support
assignment | On suppor |     Total
-----------+-----------+----------
 Untreated |       220 |       220
   Treated |        84 |        84
-----------+-----------+----------
     Total |       304 |       304
. psmatch2 dtm dbancos dccomercial dclinic destpoli dgasolineras valoradmi if duso1==1,
out(precio) kernel kerneltype(epan) bwidth(
> 0.01) common nowarnings quietly
------------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
```

```
-----------------------------+------------------------------------------------------------

          precio  Unmatched | 77004107.1   68971301.8   8032805.32   4854277.81     1.65

                          ATT | 73958333.3   65354907.2   8603426.15   11672984.5     0.74

-----------------------------+------------------------------------------------------------

Note: S.E. for ATT does not take into account that the propensity score is estimated.

        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat

-----------------------------+------------------------------------------------------------

          precio  Unmatched | 77004107.1   68971301.8   8032805.32   4854277.81     1.65

                          ATT | 78021533.3   65870677.5   12150855.9   11894981.4     1.02


. psmatch2 dtm dbancos dccomercial dclinic destpoli dgasolineras valoradmi if duso1==1,
out(precio) kernel kerneltype(epan) bwidth(0.86) common nowarnings quietly

-------------------------------------------------------------------------------------

        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat

-----------------------------+------------------------------------------------------------

          precio  Unmatched | 77004107.1   68971301.8   8032805.32   4854277.81     1.65

                          ATT | 79508849.1     67360984   12147865.1   6984067.65     1.74

-----------------------------+------------------------------------------------------------

Note: S.E. for ATT does not take into account that the propensity score is estimated.


 psmatch2: |   psmatch2: Common

 Treatment |        support

assignment | Off suppo  On suppor |     Total

-----------+----------------------+----------

 Untreated |         0        220 |       220

   Treated |        31         53 |        84

-----------+----------------------+----------

     Total |        31        273 |       304

. psmatch2 dtm dbancos dccomercial dclinic destpoli dgasolineras valoradmi if duso1==1,
out(precio) kernel k(biweight)


Probit regression                                 Number of obs   =        304
```

```
                                                  LR chi2(6)      =     244.28
                                                  Prob > chi2     =     0.0000
Log likelihood = -57.049651                       Pseudo R2       =     0.6816

------------------------------------------------------------------------------
         dtm |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     dbancos |  -.0037076    .001078    -3.44   0.001    -.0058205   -.0015946
 dccomercial |   .0007246   .0001686     4.30   0.000     .0003941    .0010552
     dclinic |  -.0058239   .0009578    -6.08   0.000    -.0077012   -.0039467
    destpoli |  -.0015652   .0003133    -5.00   0.000    -.0021793   -.0009512
dgasolineras |    .005387   .0009885     5.45   0.000     .0034496    .0073243
   valoradmi |   .0000205   5.60e-06     3.66   0.000     9.54e-06    .0000315
       _cons |   .7101128   .5918279     1.20   0.230    -.4498486    1.870074
------------------------------------------------------------------------------
Note: 29 failures and 0 successes completely determined.

-------------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+-------------------------------------------------------------
          precio  Unmatched | 77004107.1   68971301.8   8032805.32   4854277.81     1.65
                        ATT | 75757727.3   89103914.9  -13346187.6   20166928.5    -0.66
-----------------------------+-------------------------------------------------------------
Note: S.E. for ATT does not take into account that the propensity score is estimated.


 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |         0        220 |       220
   Treated |         7         77 |        84
-----------+----------------------+----------
```

```
     Total |         7        297 |       304

. probit dtm  dcoleg destpoli antiguedad if duso2==1, robust

Iteration 0:   log pseudolikelihood = -21.326554
Iteration 1:   log pseudolikelihood =  -7.136953
Iteration 2:   log pseudolikelihood = -4.5252478
Iteration 3:   log pseudolikelihood =  -3.015847
Iteration 4:   log pseudolikelihood = -2.2579721
Iteration 5:   log pseudolikelihood = -1.9723014
Iteration 6:   log pseudolikelihood = -1.8463215
Iteration 7:   log pseudolikelihood = -1.7800972
Iteration 8:   log pseudolikelihood = -1.7610357
Iteration 9:   log pseudolikelihood = -1.7573684
Iteration 10:  log pseudolikelihood = -1.7570025
Iteration 11:  log pseudolikelihood = -1.7569952
Iteration 12:  log pseudolikelihood = -1.7569952

Probit regression                                 Number of obs   =         40
                                                  Wald chi2(3)    =      15.40
                                                  Prob > chi2     =     0.0015
Log pseudolikelihood = -1.7569952                 Pseudo R2       =     0.9176

------------------------------------------------------------------------------
             |               Robust
         dtm |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      dcoleg |   .0244357   .0095169     2.57   0.010     .0057829    .0430885
    destpoli |   -.004343   .0012855    -3.38   0.001    -.0068626   -.0018234
  antiguedad |  -.4381234   .1496431    -2.93   0.003    -.7314185   -.1448282
       _cons |    2.03444   1.375972     1.48   0.139     -.662415    4.731296
```

```
. mfx compute, dydx at(mean)

Marginal effects after probit
      y  = Pr(dtm) (predict)
         =  3.570e-12
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
  dcoleg |   6.10e-13      .00000    0.09   0.932  -1.3e-11  1.5e-11   291.531
destpoli |  -1.08e-13      .00000   -0.09   0.932  -2.6e-12  2.4e-12   2168.86
antigu~d |  -1.09e-11      .00000   -0.09   0.932  -2.6e-10  2.4e-10     15.05
------------------------------------------------------------------------------

. mfx compute, eyex at(mean)

Elasticities after probit
      y  = Pr(dtm) (predict)
         =  3.570e-12
------------------------------------------------------------------------------
variable |      ey/ex    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
  dcoleg |    49.8312      30.013    1.66   0.097  -8.99244  108.655   291.531
destpoli |  -65.88856      33.012   -2.00   0.046  -130.591 -1.18639   2168.86
antigu~d |  -46.12389      25.533   -1.81   0.071  -96.1682  3.92045     15.05
------------------------------------------------------------------------------

. psmatch2 dtm  dcoleg destpoli antiguedad if duso2==1, n(1) out(precio)
-------------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+-------------------------------------------------------------
          precio  Unmatched | 99222222.2    174387097  -75164874.6     59577995    -1.26
                         ATT | 99222222.2     48000000   51222222.2            .        .
```

```
. psmatch2 dtm  dcoleg destpoli antiguedad if duso2==1, n(5) out(precio)

-----------------------------+------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 99222222.2    174387097  -75164874.6     59577995    -1.26
                         ATT | 99222222.2     90400000   8822222.22   60136266.1     0.15


. psmatch2 dtm  dcoleg destpoli antiguedad if duso2==1, n(10) out(precio)
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 99222222.2    174387097  -75164874.6     59577995    -1.26
                         ATT | 99222222.2    214200000   -114977778     76295518    -1.51


. psmatch2 dtm  dcoleg destpoli antiguedad if duso2==1, out(precio) kernel kerneltype(epan)
bwidth(0.01) common nowarnings quie

> tly

-------------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 99222222.2    174387097  -75164874.6     59577995    -1.26
                         ATT |          .            .            .            .        .
-----------------------------+------------------------------------------------------------


. psmatch2 dtm  dcoleg destpoli antiguedad if duso2==1, out(precio) kernel kerneltype(epan)
bwidth(0.01) common nowarnings quie

> tly

-------------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 99222222.2    174387097  -75164874.6     59577995    -1.26
```

```
                        ATT |          .           .           .           .       .
----------------------------+------------------------------------------------------------
Note: S.E. for ATT does not take into account that the propensity score is estimated.


 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |         0         31 |        31
   Treated |         9          0 |         9
-----------+----------------------+----------
     Total |         9         31 |        40



. psmatch2 dtm  dcoleg destpoli antiguedad if duso2==1, out(precio) kernel kerneltype(epan)
bwidth(0.05) common nowarnings quie

> tly

------------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 99222222.2    174387097  -75164874.6     59577995    -1.26
                        ATT |          .           .           .           .       .
-----------------------------+------------------------------------------------------------


. psmatch2 dtm  dcoleg destpoli antiguedad if duso2==1, out(precio) kernel kerneltype(epan)
bwidth(0.86) common nowarnings quie

> tly

------------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
-----------------------------+------------------------------------------------------------
          precio  Unmatched | 99222222.2    174387097  -75164874.6     59577995    -1.26
                        ATT |  290000000    173910163    116089837           .       .
```