



# Four essays about the link between improvements of urban transports and criminality in big cities : the case of Bogota

Carlos Augusto Olarte Bacares Olarte Bacares

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Université de Paris 1 PANTHEON SORBONNE  
Centre d'Economie de la Sorbonne, CES

## Four Essays about the link between Improvements of Urban Transports and Criminality in Big Cities: The case of Bogota

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## Four Essays about the link between Improvements of Urban Transports and Criminality in Big Cities: The case of Bogota

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**DOCTOR OF ECONOMICS**

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# Foreword

This Ph.D. dissertation, entitled “**Fours essays about the link between Improvements of Urban Transports and Criminality on Big Cities: the Case o Bogota**”, is composed of four essays in the field of Urban Economics, Transport Economics and Criminology. Each essay corresponds to one chapter. The links between those different chapters and the underlying logic of the whole dissertation is explained in the General Introduction and in Figure 1 and Table 1. This General Introduction also provides a review of the related literature as well as the research question . Since each chapter of this PhD disseration corresponds to an independent essay, chapters can be read separately. This implies the presence of redundant data and information across chapters.

# Abstract

The aim of this PhD dissertation is to study and reveal the impact of public transports' improvements on the configuration of the crime on a big city like Bogota. First, this research focuses on a calculation of the number of reachable jobs of bogotanians on three different time intervals from 30 minutes to 60 minutes. The effective size of labor market is computed in order to establish if inhabitants have the same degree of accessibility to jobs with respect to their socio-economic situation and with respect to the presence of enhancements of public transports in zones where they live. The presence of improvements of public transports is defined by the presence of Transmilenio system in each zone of the city. Following the same intuition, this research also study, in a second time, the possible endogeneity of the presence of Transmilenio (TM) on the concentration of jobs and on the income of inhabitants of each zone. More precisely, the aim of this analysis is to determine if improvements of public transports may have a causal relation on the localization of jobs and the concentration of highest incomes in the city. The objective of this investigation is to establish that high incomes and jobs centers may be localized, in a big proportion, because of the presence of TM. Following the hypothesis suggested on several studies regarding the fact that criminals prefer to commit their crimes in zones with high density of jobs and in zones with highest incomes (regardless housing zones localization), this dissertation follow, in a thirdly, with an *ex-ante* and *ex-post* study of the evolution of crime with respect to the opening of Transmilenio in each zone. The goal of this analysis is to establish a causal relation of enhancements of public transports on the evolution of five different types of crimes in each zone. Because of the weakness of available data, results are unfortunately not conclusive but give us an appropriate approximation of the impact that Transmilenio system may have on crime configuration. These results lead to make, on a final instance, a causal analysis for the year on which we have whole data. Results are conclusive: a causal relationship of Transmilenio on three of five types of crime object of this study is confirmed. In addition, a spatial dependence on the concentration of crimes is also

confirmed. It appears that, regardless the positive impacts that it could have, the presence of Transmilenio and hence, the enhancements of public transports in different zones of Bogotá make raise some kinds of crimes. Even if this research presents some limitations that should be solved on future studies, results as well as the way how the issue is analyzed provides new perspectives for the comprehension of some negative consequences that can thwart positive objectives of urban transport policies on big cities. We believe that this PhD dissertation contributes to complement the studies about the effect of urban transports.

*Keywords: Big cities, Bogota, Enhancements of Urban Transports, Accessibility to Jobs Centers, Income Concentration, Endogeneity, Causal Relation, Criminality, Spatial Dependence.*

# Résumé

Cette thèse cherche à étudier et à déterminer l'impact des améliorations des transports publics sur la configuration de la criminalité dans une grande ville qu'est Bogota. Dans une première étape, cette recherche a pour objectif de préciser le nombre d'emplois accessibles par les habitants de la ville de Bogota selon la durée de transport. La taille effective du marché du travail doit être définie dans le but de déterminer si les habitants des différentes zones qui composent la ville ont le même degré d'accessibilité aux emplois. Une fois définie l'accessibilité, cette recherche procède à une étude comparative des caractéristiques socio-économiques des habitants, par zone, ainsi que par rapport à la présence ou au manque d'améliorations du système de transport dans chaque zone qui compose la ville de Bogota. La présence des améliorations du système de transport se caractérise par l'adoption du système de transport Transmilenio (TM) dans chaque zone. Dans une deuxième étape, afin d'approfondir l'étude du lien entre les caractéristiques socio-économiques des habitants et la présence de TM dans chaque zone de la ville, nous nous concentrons, sur l'existence d'une possible relation endogène de la présence de TM dans la concentration des emplois et des hauts revenus à Bogota. L'objectif de cette analyse est de déterminer si les améliorations des transports publics admettent une relation causale dans la localisation des emplois et des hauts revenus au sein des zones de la ville. Nous adoptons ensuite l'hypothèse que les criminels préfèrent commettre leurs crimes dans les bassins d'emplois et dans les zones à forte concentration des hauts revenus (indépendamment de la localisation des zones résidentielles). De plus, afin d'établir une relation causale quant à l'évolution de cinq différents types de crimes dans chaque zone de la ville, cette étude réalise une analyse *ex-ante* et *ex-post* de la mise en place de TM. Cependant, en raison de la faiblesse de la base de données sur l'ensemble des périodes, les résultats de cette étape ne sont pas homogènes, ce qui les rend peu convaincants. Toutefois, ces résultats nous fournissent une approximation pertinente de l'impact que TM peut avoir dans la configuration de la criminalité à Bogota. Dans une dernière étape, nous effectuons une analyse de

causalité pour la période au cours de laquelle les données disponibles sont complètes pour l'ensemble des zones de la ville et ne montrent pas de problèmes de fiabilité. À l'issue de cette étape d'analyse, les résultats sont robustes. Ils suggèrent l'existence d'une relation causale de la présence de TM sur l'évolution de trois des cinq types de crimes considérés dans notre étude. Les résultats permettent également d'identifier une nette dépendance spatiale de la concentration des crimes à Bogota. Malgré les multiples effets positifs de l'amélioration des transports publics pour les habitants de Bogota, la hausse de certains types de crimes peut aussi s'en trouver accrue dans les zones desservies par TM. En dépit des limites de cette étude qui devront être résolues dans des recherches futures, les résultats obtenus, ainsi que l'angle d'analyse du sujet, représentent une perspective innovante en vue d'une meilleure compréhension des potentielles conséquences négatives qui peuvent entrer en conflit avec les objectifs des politiques des transports urbains dans les grandes villes. Nous pensons que cette thèse contribue à la complémentarité des études sur les effets des transports urbains.

*Mots clés : Grandes Villes, Bogota, Améliorations des Transports Urbains, Accessibilité au Bassins d'emplois, Concentration des Revenus, Relation Endogène, Criminalité, Relation Causale, Dépendance Spatiale*

# Contents

<b>Acknowledgments</b> .....	<b>1</b>
<b>Foreword</b> .....	<b>4</b>
<b>Abstract</b> .....	<b>5</b>
<b>Résumé</b> .....	<b>7</b>
<b>General Introduction</b> .....	<b>13</b>
Big cities and Criminality .....	14
Urban structure and urban transports .....	18
Urban transport and crime .....	25
Bogota: a very interesting case of study .....	28
Plan of the Thesis .....	34
Data and Methodology .....	40
<b>1 Heterogeneity of Social Classes and Job Accessibility: Implications of Transports Policies in Bogota</b> .....	<b>47</b>
1.1 Introduction .....	47
1.2 Research question .....	50
1.3 Research methodology .....	52
1.3.1 The “Effective Size of the Labor Market” (ESLM) approach ....	52
1.3.2 Social class and grouping of zones .....	54

1.4	Analysis of the data .....	56
1.4.1	The dataset .....	56
1.4.2	Descriptive statistics .....	59
1.5	Results .....	64
1.5.1	Travel from a UPZ with a direct connection to TM to another UPZ with a direct connection to TM. ....	64
1.5.2	Travels from a UPZ without any connection to TM to another UPZ without any connection to TM. ....	66
1.5.3	Travels from UPZ with a direct connection to TM to another UPZ without any connection to TM, and reciprocally .....	67
1.6	Conclusion.....	69
1.A	Annexes .....	72
<b>2</b>	<b>Are public transport improvements endogenous with respect to employment and income location in a city? .....</b>	<b>74</b>
2.1	Introduction.....	74
2.1.1	A brief theoretical contextualization .....	74
2.1.2	Some characteristics of Bogota .....	76
2.2	Conceptual framework and research methodology .....	80
2.2.1	How to mediate with endogeneity .....	80
2.2.2	Models and variables structure .....	82
2.3	Descriptive statistics and data available .....	86

2.4	Results and discution .....	91
2.4.1	OLS Results.....	93
2.4.2	2SLS Results.....	101
2.5	Conclusion.....	111
2.A	Annexes .....	115
<b>3</b>	<b>Impact of urban public transport enhancements on crime rate: a diff-diff analysis for the case of Transmilenio.....</b>	<b>120</b>
3.1	Introduction.....	120
3.1.1	Literature review and research question .....	120
3.1.2	Contextualization of the case of study .....	122
3.2	Available data and descriptive analysis of data .....	124
3.3	Methodology.....	131
3.4	Results .....	134
3.5	Conclusion.....	138
3.A	Annexes .....	140
<b>4</b>	<b>Criminality spread: a “Boomerang effect” of public transport improvements? .....</b>	<b>143</b>
4.1	Introduction.....	143
4.2	Social interaction, criminality and mobility .....	146
4.2.1	Criminality and social interaction.....	146
4.2.2	Criminals’ mobility and jobs’ centers .....	149



4.2.3	Some studies about BRT system and its effects in Bogota . . . . .	151
4.3	Bogotá: Public transports development . . . . .	152
4.4	Data and methodology . . . . .	154
4.4.1	Descriptive statistics and available data . . . . .	154
4.4.2	Models and methodology . . . . .	156
4.5	Results . . . . .	164
4.5.1	Results from PSM methodology . . . . .	164
4.5.2	Results from Spatial econometric methodology . . . . .	168
4.6	Conclusion . . . . .	173
	<b>General Conclusion . . . . .</b>	<b>177</b>
	<b>References . . . . .</b>	<b>181</b>
	<b>List of tables . . . . .</b>	<b>194</b>
	<b>List of figures . . . . .</b>	<b>197</b>

# General Introduction

This PhD dissertation focuses on the link between urban transport networks improvements and their impact on urban crime in big cities like the capital of Colombia: Bogota.

In order to overview how the main subject will be treated, this introduction defines and describes the evolution of crime approaches accentuating on the presence of crime in big cities. Crime is supposed to be higher in big cities because of a bigger density, a high degree of social interactions which infers a greatest heterogeneity and makes allusion to the social multiplier approach developed by Glaeser and Sacerdote (1999).

The link between the structure of a big city and its relation with urban transports is then described. Subjects like the cost of travels, the commuting time and the development of urban transports among others can define urban structures.

The third part of this introduction associates the link between urban transports and the configuration of crime in a city. It shows that the enhancements of urban transports have a direct effect on the urban structure and the social heterogeneity of inhabitants of a same city. These consequences may manifest as social tensions that can lead to an increasing or a decreasing of the criminality.

Those precedent parts of this introduction represent a brief literature review on which is based the theoretical perspective of this research. It leads to the definition of the aim of this research.

The subsequent part reveals the real interest to develop this subject for a big city of a developing country as is the case of Bogota. The plan of the Thesis and the data and the methodology used on this research close the introduction of this dissertation.

## **Big cities and Criminality**

Criminality is highly most developed in big cities than in small ones. It permits to infer that the possible consequences are more important in big agglomerations than in small ones. As demonstrated by Glaeser E. and Sacerdote B. (1999), *crimes rates are much higher on big cities than in either small cities or rural areas*. In order to understand why it is like that, an analysis of the evolution of crime approaches as well as the importance of social interactions and social heterogeneity with respect to crime should be done.

## **Definition and evolution of crime approaches**

From Antiquity, several theories about crime and punishment have been developed. Philosophers like Aristotle, Socrates, Plato and Pythagoras suggested that delinquency, which is generally defined as a harmful act to people or to a society forbidden by the law and by society, was a consequence of some physical and mental deficiencies. Long time after, in the Middle Age and during the Age of Enlightenment, the study of the crime and its foundations have been explored in a deepen way. Several theories appeared in this period and some of them continue to influence current theories. It is the case of the studies of Thomas Aquinas, William of Ockham and Bonaventure, among others, and their works about the scholasticism that constitute in some aspects the basis of a first theory of the philosophy of law. From these studies, other approaches emerged from other disciplines like sociology, criminology and economics. One of the most used theories that study the causes of the propagation of crime is the deviance theory.

The deviance theory encompasses different types of sociological approaches from the “macro level” and from the “micro level”. With respect to the macro level there are three main theories regarding the study of crime: *the functionalist theory, the marxist theory and the theory of the subculture*. Since the study of those theories does not enrich this research, they will not be presented here. Nonetheless, the theories of deviance that fall within the

micro level are of great interest for our subject. Indeed, the labeling theory developed by Howard Becker (1963) and the theory of rational choice proposed by Gary Becker (1976) constitute the basis of the approach followed on this dissertation.

From the 60's, the labeling theory centered its hypothesis on the fact that the deviations of individuals are a result of the rules of society to control their behaviors and a result on the way that individuals interact. According to Becker H. (1963), "deviance is not a quality of the act the person commits, but rather a consequence of the application by others of rules and sanctions to an "offender". The deviant is one to whom the label has successfully been applied; deviant behavior is behavior that people so label". In other words, labeling theory suggests that crime is a social construct and it is not always a deviant act committed by a person but a result of the society if it defines the act as a crime. Therefore, definition of those acts as deviant depends on social interactions. Some groups of persons who compose a society may consider an act as crime but other ones may consider those acts as legal. Social interactions are hence in the core of the debate.

On the other hand, the rational choice theory suggests that deviant acts are the result of a cost-benefit calculus and hence, by highly rational individuals. Several studies have attempted to identify the benefits and the costs from this deviance. These benefits may be monetary or subjective, like the feeling of power, recognition among their peers, etc. Costs are generally translated in social sanctions, law sanctions, guilty feelings and monetary costs. This theory also focuses on the efficiency of sanctions finding that a way to reduce crimes could pass by the increase of their costs with higher sanctions. Nevertheless, if travels of criminals make part of their costs, the fact that public policies look to decrease these costs, it may thwart positive effects.

### **How social multiplier, social interactions and social heterogeneity have an influence on urban crime**

The social multiplier approach suggests that, in the presence of social interactions, individual actions may influence and infer the actions of other people. The sum of these social interactions may have at their turn, an effect on individual decisions and individual actions. This research considers works from Becker and Murphy (2000), Ludwig and King (2006), and mainly Glaeser, Sacerdote and Sheinkman (2002), about this approach which implies that crime and their possible effects may be significant. The construction and the mathematical explanation of this multiplier are well explained in Glaeser, Sacerdote and Scheinkman (2002); this dissertation assumes the interpretation and the construction of the multiplier.

From the point of view of criminals, this social multiplier could create positive externalities for them but negative ones for society. In fact, the spread of the city decrease the probability to be arrested. It means that criminals could enjoy from this fact but it could also have a negative externality for criminals that could discourage them to commit crimes: their earnings decrease because of the entry of more competitors in the market (more criminals). Therefore, crime market could be reduced as well as commuting cost fall down.

This suggestion implies that the size of the crime market depends on the size and on the population of each city. By consequence, in order to have a better sample for the study of crime, big cities represent an ideal “laboratory” because of their highest density and also because of the existence of several “sub-centers” of jobs or housing zones; those concepts will be analyzed later.

With this respect the impact of the distance traveled by offenders to commit their crimes on their earnings was studied by some authors. However, in the purpose to avoid a repetition with the literature review that was done in chapter 4 of the dissertation, a brief summary about criminals mobility will be evoked on this introduction.

Morselli and Royer (2008) show that there is a strong relationship between the earnings of criminals and their offending perimeter. It suggests that the higher their offending perimeter is, the higher are their earnings. In the other hand, other characteristics like the age of offenders have also a direct relationship with crime behavior. It means that their earnings will decrease with their age. Another important aspect to take in consideration is that the type of crime is essential to establish the degree of the relationship between gains and offending perimeter. Actually, offenders are highly motivated to commute and travel long distances for the sake of higher earnings but higher earnings are placed on job centers. It supposes that criminals will have the same behavior than employees which means that they will follow job-centers for crimes against people.

Zenou (2003) shows that, if delinquents decide to go to job centers, they will also have an advantage because of the density. In effect the denser is the zone, the lower are the travel costs and the lower is the probability to be caught.

This dissertation underlines also the role of infrastructure on social interactions and hence, on crime. Results from Holtz-Eakin, Schwartz (1995), Barr (2000), Zenou (2000), and Donzelot (2004), among others, are taken in consideration. Public transportation networks and transports infrastructures are essential to boost the insertion of the inhabitants into the job market. According to those studies, this fact has positive externalities like the reduction of commuting time between homes and jobs, the embellishment and the rehabilitation of neighborhoods and zones along new infrastructures which encourage social interactions and that increase the price of houses alongside the transport network. In addition, the best is the accessibility to the job centers, the higher the productivity of the city will be and the less the social inequalities may be (Hipp 2007, Putman 2000). This point suggests that improvements of accessibility in a city may be a solution to the spatial mismatch evoked by Kain (1968, 1993), Ihlandfeldt, Sjoquist (1991). In parallel, it may have a positive effect on the reduction of social tensions in the city like criminality like it was proposed by (Zenou 2003, Putman 2000, Donzelot 2007 among others). Putman (2000)

suggests that density is a factor which determines the level of social interaction; a low density reduces social capital and therefore social interactions.

Conversely, Brueckner and Largey (2003) suggest that social interactions could be slowed in zones with high density. In effect, behavior of economics actors is not only in function of their needs but it also depends on the behavior of their entourage as it was suggested by the theory of *broken windows* of Wilson and Kelling (1982). People may be motivated to become criminals if their peers are criminals. In addition, Helsey and Strange (1999) and Mehlum et al (2005), prove that crime has a strong link with economic and social conditions of a zone. Fritz (2008) suggests that delinquency is in a big part, a consequence of the lack of opportunities of people to find a job. As a consequence, urban transports, as equal as amenities of zones of the city, have a core role in the evolution of this behavior (Glaeser and Sacerdote, 1999). On the other hand, Zenou (2003) suggests that almost 70% of criminality could be associated to social interactions.

As stated above, urban infrastructure has a possible impact of social relations and social interactions that may be boosted by the social multiplier. Indeed, the evolution of the crime phenomenon may be related to the development of urban infrastructures. However, infrastructure depends, among several other reasons, on the needs of each city and those needs may depend on the structure of the city. The next sub-section treats the relationship between urban structure and urban one kind of urban infrastructure: the urban transportation.

## **Urban structure and urban transports**

In order to better understand the reasoning of this dissertation, a brief theoretical review of urban structure, its link to the evolution of urban transport and its importance on the delineation of urban structures will be also done. It first treats the evolution on literature regarding two different concepts of cities: monocentric and polycentric cities. This brief

literature review is then completed by another some literature example that exposes the impact of urban transports on the concentration of jobs and how commuting costs and travel times have an important incidence on urban structure.

### **Evolution of the concept of urban structure: monocentrism and polycentrism**

From the half of XIX century, urban structure, urban transports and the evolution of their costs are well studied by several researches. In parallel, changes in transport costs as well as the metamorphosis of cities are still subjects of research that does not cease to unveil new theories and new models seeking to explain or to predict the development of current and future urban structures.

But it was from the second half of XX century that a modeling was proposed. The research of Alonso (1964), based on the research of Von Thünen (1826) are the starting point of this topic for economists. These studies were the first ones that formalized the models of urbanization. The existence of a Central Business District (CBD) in the city was the core of these models. It supposes that every economic activity of production, consumption and even the jobs are situated at this same place.

J.H. Von Thünen developed a model of the use of agricultural land that surround a city. In 1964, W. Alonso used this model in order to explain the urban structure. Von Thünen suggests that, in order to commercialize the agricultural products in the city, the city has one center which supposes that there were a tendency to the concentration of population at this center . Alonso said that the use of the land and the space was efficient on the context of a monocentric city. Actually, the use of the land was determined by the tradeoff of people between the willingness to live and to occupy more space in the city and the resulting costs if they decide to live out of the city.

In parallel of this trade off of the people, it is equally observed that relation between enterprises changed. Enterprises can make their production costs decrease even if they are



not placed at the center of the city. The downtown is not the only zone of the city when all the enterprises minimize their costs (Rosenthal, Strange, 2009; Glaeser, Rosenthal, Stuart and Strange, 2010).

The beginning of XX century marked a change of the urban dynamism. Technological changes as well as the evolution of urban transports have meant that the city becomes increasingly spread out. This constantly sprawl of the city leads to a decentralization or a “polycentrism” of cities. Since the 80’s, a new concept developed by some authors like Ogawa and Fujita (1982), joins and completes the concept of “monocentric” city: the “polycentric” city. The periphery of cities has become more attractive offering bigger spaces to people. New cities became attractive and their “sub-centers” attract inhabitants. In parallel, the “easy” access to private cars for high-income people has induced to take in consideration a new concept that was not treated before with great attention: the time and its value.

A description of spatial structures and its evolution are well studied by Anas and Arnott (1998), Brueckner (2000, 2001), Cervero (1997), Glaeser, Khan (2003). The new concept of “polycentric” cities is most adapted for most of the big cities: Los Angeles is one of the most known example (Giuliano, Small 1991). The next subsection of this introduction offers a more deep analysis of “monocentric” and “polycentric” cities.

Assuming the existence of a CBD, the monocentric model had a lot of success which made a lot of contributions to the study of urban structures. Nonetheless, cities have changed and evolved. Consumption activities and production activities were dispersed to all direction. In the last forty years, cities were spread in a “disordered” way and the concept of “monocentric” city was reevaluated and complemented. It influenced in the formalization of the theory of spatial mismatch evoked by Kain (1968) and complemented by Holzer (1991), Ihlandfet and Sjoquist (1998) and Brueckener and Zenou (2003), among several others.

The positive externalities for economic agents that result from this “polycentrism” tend to position themselves closer creating the phenomenon of “knowledge spillovers” and

therefore, a formation of spatial networks (Audretsch and Feldman, 1996; Kung and Wang 2007). Because of this “surplus” of knowledge and thus, due to the economies of scale, people and entrepreneurial activities tend to be in the same place (Krugman, 1991). The concentration of job in big cities results from this evolution. Infrastructure of the city and more precisely for the subject of this research, urban transports, may have an impact on the concentration of jobs or vice versa.

### **Urban transports and job centers**

Among the principal reasons to migrate to cities, the most common reason is the fact that people perceive that there are more and better opportunities to find a job and to find a school for their children in cities than in rural zones (Blomqvist A.G, 1978). Urban population have two ways to commute: or they carry in private cars or they use public transports. As a consequence, the questions of urban transportation, the accessibility to jobs and the capabilities of the city to offer to people good conditions to reach their jobs represent a vital element to take in consideration at the moment to settled in a zone and the amplitude of urban sprawl (Prud’homme R., Lee C 1999; Orfeuil J.P., Wenglenski S 2004). Said conditions depend, in an important degree, on the quality of transport infrastructures which means that municipality has the big challenge to improve continually the provision and the construction of public transports.

Miezkouski and Mills (1993) suggest that jobs, and hence, enterprises and companies, try to follow people. The individual stays to be the principal actor of the behavior of the economy of the city. The concentration of jobs and people in some zones of the city is what define a sub-center. As stated above, some examples have proved that the price for inhabitants or to companies to be in downtown could be very high. It generally motivates the economics agents to look for other zones of the city that may offer them better conditions leading to the creation of “edge cities” and transforming the city in a polycentric one giving rise to the existence of an interdependence of productive factors.

The interdependence of productive factors and its negative relation with their costs with respect to the distance, give a particular attention to transports costs and hence, to the transaction costs which represents a not negligible subject. The existence of several CBD is hence possible.

Several economists like Krugman (1995) and Henderson and Mytra (1996) among others, have also developed this concept. The interactions of economics agents, their preferences, the transport costs and the transaction costs are taken in consideration with a greater importance in order to study the structure and the evolution of cities.

On this respect, several theorists have tried to explain the increasing "sub-urbanization" of cities. This seems to be in contradiction with the fact that time has a value. In fact, when time has a value, which seems to be important to economic agents, it can be suggested that people may prefer to live near the CBD. Nevertheless, some studies like from Giuliano, Small (1991) have shown that this was not always the case. The cities have spread and "edge cities" have developed. In addition, like Gaspar and Glaeser (1998) suggest, technological changes in communications have also pushed a change on social interactions which has also a consequence on the configuration of the cities. This point is studied most profoundly in the next section of this introduction.

The creation of new agglomeration economies is also an explanation of the sprawl of enterprises and inhabitants and therefore, a sprawl effect of the city. In order to control this spread of the city, the development of an efficient transport network in the city is necessary. In effect, the development of this kind of infrastructure as a direct influence on travel costs of population. Anas, Arnott and Small (1998) suggest that if these costs are high, the concentration of population and companies on some specifics zones of the city may be waited.

On the other hand, if travel costs are neither too high nor too low but if they still represent a non-negligible part of the budget of the people, it can be expected to see a development of a polycentric city. Finally, Glaeser and Khan (2003) proved that if travel

costs are too low it may encourage the creation of some clusters in the city which will lead to a bigger sprawl of the city.

Those reasons lead to confirm that transports networks and the development of transport infrastructure is at the core of the subject. The transport infrastructure on the configuration and the development of the city is a determining factor. The relation between transports and the creation of sub-centers in the city is essential.

Nonetheless, people cannot always be near their jobs. In some cases, house' prices in downtown may be very high like it can be observed on the studies of Brueckner, Thisse and Zenou (1999), and Glaeser, Gyourko and Saks (2005). Because of this reason and also looking for economies of scale, enterprises are now more flexible to go closer their potential employees (McMillen and McDonald, 1998; Zenou, 2000). This decentralization of the production activity entails an increasing of the area of the city which, at its turn, conduces to the creation of more agglomeration economies. Nevertheless, generally, in order to be closer to their potential employees but also looking to have fiscal advantages, enterprises decide to settle on some small cities belonging to the periphery. These advantages attract also more enterprises leading to new agglomeration economies outside downtown. Duranton and Puga (2003) illustrate that this phenomenon lead to a "sharing" effect which is the origin of the "edge cities" or the "specialized cities". In parallel, Abdel and Fujita (1993) suggest that economies of scale between enterprises belonging to different kind of industries generate urbanization economies that engender diversified cities or a "matching" effect creating clusters as it was suggested by Duranton and Puga (2003). The precedent examples represent external scale economies where we can also distinguish other examples as the concentration of information or education called by the same authors as the "learning" effect.

Garcia and Muniz (2005) said that the "intensification of the use of the land" and in the "employment density" are the principal elements to identify a center. This definition is adaptable to the cities of the USA. Nevertheless, regarding European cities the center should be defined with respect to the "economic activity" of the zone. However, regardless

which definition is adopted, studies proved that “ancient cities” and “young cities” may count several center and it is always related to the concentration of employments and density. Giuliano and Small (1991) have found 29 centers in Los Angeles city while McMillen and McDonald (1998b) and Cervero and Whu (1997) talk about 15 and 22 centers for Chicago and San Francisco respectively.

On the other hand and as it was suggested above, sub-centers of a city are in zones well deserved by public transports and by transport infrastructures. Edge cities are generally placed along an important transports corridor or near an important train station. This tendency contributes to a better mobility and a better accessibility of people which represents one of the most important elements of attractiveness of new centers. With a better transportation network, inhabitants have the option to minimize their travel time but they have to arbitrage it with respect to their travel costs in terms of time and distance. Even if their jobs are still far from their houses when they decide to live in edge cities, and even if it may represent a loss of time and an increase of distance, it can be supposed that their benefits in terms of amenities offered by the zones where they decide to live are higher than their costs. Brueckner J.K., Thisse J.F., Zenou Y. (1999) shown that amenities and wages are decisive. It means that it will always be costs linked to their travels; they have to arbitrate between the cost of transportation, their loss of time, their gains from amenities and their preferences to live in a zone of the city. As it is shown by Anas A. (1990), the heterogeneity of their preferences and the opportunities to find a job explain their choice to live in a specific zone of the city.

In addition, edge cities have therefore a big heterogeneity of population which leads enterprises to settle there but it has another effect on social interaction. Indeed, social tensions increase with social heterogeneity. Crime rates used to be higher on neighborhoods with a big diversity of social population (Glaeser and Sacerdote; 1999) and it may rise with the social multiplier already foregoing (Ludwig and King; 2006, Glaeser, Sacerdote and Sheinkman, 2002). It introduces to the next subsection which examines, from a theoretical point of view, the possible link between urban transports and urban crime.

## **Urban transport and crime**

As stated above, the goal of the enhancement of transport networks is to connect residential zones to the job centers in order to give to inhabitants more opportunities to reach the job market and has a direct and a positive effect on social interactions. Positive externalities of this enhancements have been demonstrated along the last three decades. Nonetheless, the constantly improvement and the construction of new transports systems also create negative externalities that this thesis considers pertinent to analyze. This sub-section emphasizes on the role played by transport networks as a stressing on social interactions.

This dissertation considers that, even if the total urban crime rates decrease after the development of public transports, not every crime rates of every kind of crimes decreases. Actually, there are some kind of crimes that could be boosted by public transports systems. In order to better understand this point and with the intention to avoid some repetitions between the introduction of this thesis and the content of some chapters that compose this thesis, the following sub-section of this introduction delves on a summary of the literature about the crime from a social interaction perspective and its relationship with urban transports.

### **Urban transports as a determinant of social interactions**

Social interactions in cities constitute an important subject on which several researchers have contributed. Krugman (1991a), Glaeser (1996), Freedman (1996), Putman (2000) and Brueckner and Largey (2006) demonstrated that social interactions are crucial in the economic and social behavior in cities. These authors developed this concept of interaction “off-market” and presented it as a possible cause but also as a possible consequence of modern urban structures. The increasing accessibility of individuals and of enterprises makes from social interactions, an important element to take in consideration on the study of urban structures. The reduction of travel costs can benefit the social interaction of economics agents. Nevertheless, the increase of the interaction of economic actors creates

interdependences between themselves which can be traduced in positive or negative externalities. Among negative externalities, this study focuses on crime.

As stated above, considering literature from Becker and Murphy (2000), Glaeser, Sacerdote and Sheinkman, (2002), Ludwig and King (2006) about the social multiplier, implies that crime and its effects may be significant. From the point of view of criminals, this social multiplier could create positive externalities for them but negative ones for society. In fact, the spread of the city decreases to criminals the probability to be arrested. It means that criminals could enjoy from this fact but it could also have a negative externality for criminals that could discourage them to commit crimes: their earnings decrease because of the entry of more competitors in the market (more criminals). Therefore, crime market could be reduced as well as commuting cost fall down.

On this respect, the impact of the distance traveled by offenders to commit their crimes on their earnings was studied by some authors. However, in in the purpose to avoid a repetition with the literature review that it was done on chapter 4, a brief summary about criminals mobility will be evoked later.

Conclusions from Morselli and Royer (2008) were that there is positive and strong relationship between criminal earnings and offending perimeter: the age of offenders is important which means that their earnings will decrease with their age. Another important aspect to take in consideration is that the type of the crime is essential to establish the degree of the relationship between gains and offending perimeter. Actually, offender are high motivated to commute and travel long distances for the sake of higher earnings but higher earnings are placed on job centers. It supposes that criminals will have the same behavior than employees which means that they will reach job-centers in order to commit crimes against people.

Furthermore, as Zenou (2003) showed that, if delinquents decide to go to job centers, they will also have an advantage because of the density. In effect the denser the area, the lower the travel costs and the lower the probability to be arrested.

## **Social interactions: an explanation of the evolution of urban crime**

From a sociological point of view, Hipp (2007) suggests that, thanks to a better accessibility provided by an improvement of urban transports, people may have a bigger feeling of exclusion and of injustice which could lead to more social tensions. In effect, the fact that people have the opportunity to travel to other zones on the city and look that there are people that live in much better conditions than them make them feel excluded. In consequence, looking to pronounce their displeasure, people could find in criminality an instrument to “compensate” this exclusion. Following this same line of perspective, Hipp (2007) propose six theories of crime which take in consideration inequalities and ethnic heterogeneity. This study considers four of those as pertinent to take in consideration and that have a direct relation to social interaction perspective<sup>1</sup>.

The travel distance is perceived as an important factor for criminals but moreover, for the different types of crimes. Criminals that commute to commit their crimes have higher earnings than those who stay on their zones. Crimes with aggressions to people do not required long distance to be done. Conversely, property crimes require long distance to be done.

In parallel, as part of a cost-benefit analysis and adopting a Gary Becker’s point of view, criminals prefer to travel long distances for the sake of decrease the probability to be arrested. With better infrastructures and better transport networks, offenders decrease their commuting costs: the time that they will spend on public transport will be reduced and it gives them more choices and more places to perpetrate their crimes.

The evolution of public transports can stimulate a big heterogeneity of inhabitants in a same zone of the city. This fact could have a very important impact, negative or positive, on social interactions that can boost or decrease crime on cities. The effect may be positive or negative depending on the type of crime.

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<sup>1</sup> Social distance theory, social disorganization theory, the relative deprivation theory and routine activity theory



This dissertation aims to shed light on the link between the development of public transport system in Bogotá and the evolution of the crime rate in the city. As it was said on precedent sub-section, public transports are supposed to help population to find their jobs and hence, be adapted to the city. It supposes to decrease social tensions and thus, to decrease crime rates in cities. Why study this subject in Bogotá?

### **Bogota: a very interesting case of study**

One of the biggest questions of agglomerations today is focuses on the problem of the public transport supply. To deal with, Bogota has been developing a new urban transports system with a worldwide recognition since 2000: Transmilenio.

### **Colombian internal conflict and its influence on crime rate in Bogota**

On the last five decades, Colombia has been suffere one of the oldest intern conflict in the world between the State and some groups of rebels that constitute several groups of left-wing guerrillas<sup>2</sup>. Because of the incapacity of the State to defeat those groups and to solve the problems on where those leftist guerrillas based their fight, several armed groups of right-wing, were formed to combat these left-wing groups<sup>3</sup>. Since 30 years these two groups have waged a war that focused mainly in the countryside of Colombia. Aside from the fact that from this conflict, the country have had a lot of economic and social consequences, one of the highest and most cruel impact is that peasants have been the main victims of this conflict. In effect, according to the United Nations High Commissioner for Refugees (UNHCR), on the last 15 years Colombia has been part of the three countries with the largest number of internal refugees<sup>4</sup> in the world. Looking for to escape from violence

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<sup>2</sup> The most important groups were FARC, M-19, ELN and EPL whit extreme left-wing ideology. They had almost 25.000 men.

<sup>3</sup> Several groups of paramilitaries unified on what it was called “Autodefensas Unidas de Colombia” AUC.

<sup>4</sup> More than 2 million of persons are considered as refugies in Colombia. See on <http://www.unhcr.org/50a9f81a0.html>.

on countryside, the majority of these refugees do not find another solution than reaching cities.

The arrival of “new people” is generally not very well “absorbed” by urban structures from different points of view. Indeed, it has several consequences from sociological, geographical, demographical, economic, political and anthropological perspective. Bogota is not the exception.

One consequence of this phenomenon is the growing “overpopulation” on urban space. It represents one of the principal causes of the sprawl of urban spaces. In effect, because of the constantly arrival of people from other regions the number of available houses become increasingly rare. In some cases, this fact creates a generalized lack of housing on cities which may lead another kind of evils within population.

Other costs caused by this migration are that not all of those who arrive to settle in cities have the same culture, the same customs and do not make part from the same social class. Hence, this migration has an increasing effect on the gap between social classes; this consequence also modifies and gives birth to social tensions in the city which also influences the sprawl of the city and that have to be solved by public administrations.

Indeed, these kind of problems, among several others, make part of a big list of consequences because of the constant arrival of refugees and therefore, the growth of urban population. As stated above, as a result, Bogota has to sprawl its frontiers in order to gain more space to receive its new “guests”.

New challenges arise in order to deal with these consequences. The increase of the population and hence, the sprawl of the city forces public managers to improve urban infrastructures. Enabling more space in the city in order to build more houses for the people arrival represents the most important task of public managers. Nevertheless, this task has to be complemented by ensuring the provision of public services. The construction of new places to live is just the “tip of the iceberg”. In parallel to new houses, public administra-

tions have to ensure access to public goods and public services. The construction of that kind of infrastructure is mandatory to the welfare of the population.

The provision of potable water, the access to sewer services and to electricity services make part of the imperative public services to provide by city hall to people. In addition, this provision of public services allow city hall to tax and to increase its accounting ( De Soto, 2006). Nonetheless, other characteristics are almost equally important for people' welfare: the access to education, the access to wealth services and the access to employment are also very important aspects that people hope and claim to find on cities. By providing these public services, local government may reduce radically the probability of social problems that can lead to disturbances, strikes, riots and even worst, on a rising of criminality.

Nonetheless, with the purpose to give to new and old inhabitants the opportunity to integrate into society and in order to avoid that people remain embedded in their neighborhoods, an efficient system of public transports must be developed.

The question of the development of urban transports is placed today on the core of the “bogotanian” debate with a main emphasis on consequences of its positive and negative externalities. The encouragement to improve and to use the public transport systems seem to take the debate with respect to the use of private cars on cities. Environmental reasons, cost and benefits analyses, decongestion of urban roads, less commuting times among other reasons, are the principal causes of Bogota's decision to adopt policies that promote the use of public transports. Their benefits and their positive externalities seem to be more appreciated than their negative externalities. Nevertheless, excluding the environmental subject, this research considers that the negatives externalities that public transports, like the different types of criminality in the city, may cause were not deep analyzed, hence the necessity to make a point on this subject.

Regarding the case of the capital of Colombia (Bogotá), overall criminality dropped constantly from the last 15 years. Nevertheless, after 2000 when the first line of a new Bus

Rapid Transit system (BRT) called Transmilenio was opened, some types of crime did not fall. The interest of this research is to find the impact that Transmilenio may have on five different kinds of crime on which inhabitants are more sensitive.

### **Transport networks evolution in Bogota**

Bogota is the most populated city of Colombia with more than 7 million of inhabitants. From the 70's until the end of 90's, density grew by more than 50% passing from 100 inhab/ha in 1973 to 150 inhab/ha inhabitants in 1993 and 170inhab/ha in 2005.

The social structure in the city changed at his turn. The gap between rich people and poor people is also bigger than in the 70's. Rich people and poor people live in different zones and different neighborhoods divided on six different socio-economic strata. Those who live in strata 5 and 6 (the richest strata) are placed on the north and north-east of the city and they represent 6% of the population. The south, the center and the west of the city is composed by strata 1, 2 and 3 (the poorest population) which represent 81% of the population; strata 4 represents 13% and characterizes the population of the middle class who live on the west and north-west of the city.

Since the 60's, inhabitants revealed the desire to live close to the "rich" people who, at their turn, decide to settle in the north of the city. Because of this evolution and this transformation of social and urban structure, a spread of population took place. In addition, a degradation of urban transport conditions was inevitable. As a matter of fact, before the 60's Bogota had a tramway system service ensured by public administration. However, because of the spread out of different social classes where "rich people" found in the north and the east of the city a "desirable" place to live, we saw a sprawl of urban structure, and hence, a decline of the efficiency of urban transport system in the city, notably of the tramway. The tramway disappeared because of this loss of efficiency and also because of the lobby of private entrepreneurs who revealed their big intentions to participate in the public transport system in the city as suppliers of the service.

After the subtraction of the tramway, the public administration gave to private entrepreneurs, the task to assure the service with buses: it represents the expansion of public transport system of Bogotá and hence the expansion of public buses until the end of the 90's.

In the 90's, public transport system of the city was composed by private entrepreneurs assembled in about 60 private enterprises assuring the provision of the service in the city. Public administration had not a part on utilities; it only participates as a regulator.

In the beginning of the 90's, as a consequence of the growth of the urban territory, government decides to differentiate and to decentralize the city in 20 different districts (localidades) adopting by this way, a sort of "Parisian mold of decentralization". One of those districts makes part of the rural zone of the city (Sumapaz) and the other ones compose the urban area. Since this reorganization, several planning policies were suggested by the government with the development of urban transport system as the more relevant of those: Transmilenio<sup>5</sup>.

Nowdays, Transmilenio is an integrated Bus Rapid Transit (BRT) system, using busways (84 kms), stations (114) and terminals (7) connected with inter-urban transport system. It is adapted for articulated buses (1080 buses) with capacity to carry 60-120 passengers. The system moves about 1,5 millions of passengers per day at a mean-speed of 27 km/h.

The Transmilenio system (TM) was implemented in 2000 and today is one of the most popular and successful Bus Rapid Transit (BRT) system on the world. After its implementation, mobility in Bogotá has been changed radically. Travel time decreased in 66% (from 1h30 hour to 30 min) and hence, accessibility also increased in a considerable level connecting the north and the south of the city on about 50min per trip<sup>6</sup>. But the implementation of this new transport system also entailed to a reconstruction of the roads of

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<sup>5</sup> [www.transmilenio.com](http://www.transmilenio.com)

<sup>6</sup> Before Transmilenio or today in a private car, this same trip take around 2,5 hours at less. The route is of at least, 20 kilometers

the city and mainly of the parallel roads of Transmilenio corridors where transit just particular vehicles and taxis. These parallel routes and so, cars who transit on these routes, enjoy certain advantages from Transmilenio corridors like the reconstruction of themselves and mainly, traffic light which are priority to Transmilenio. So, after the implementation of Transmilenio not only passengers of BRT are beneficiaries but also vehicles that transit at their sides.

Because of this reorganization of public transport network where public administration participates as manager and as inspector, a change of social and urban structure took place. Rich and poor neighborhoods are now connected directly by a new public transport system which can have a direct effect on social and urban configuration like in the 60's.

Since the opening of TM system, some effects of the new BRT system in Bogota were studied. The most recurrently studies are related to the impact of Transmilenio on the property and land, the accessibility of inhabitants and inequalities. Citywide criminality, but not all the types of crime, decreased in the city. One study from Moreno (2005) made the only spatial econometric analysis of criminality on Bogota related to urban transports. It involves surrounding TM zones one year before and one year after the opening of this new public transportation system in the city.

Through the precedent short literature review it can be noticed that urban structure is deeply influenced by the location of employments that affects the development of urban transport system in a city. In parallel, urban transport networks can also outline the place of job centers. Literature shows that urban transports may have positive and negative impacts. This thesis suggests that one of these negative impacts like crime should be studied in a deepest way for the case of Bogota; the consequences of the link between crime, urban transports and urban structure, have been underestimated.

This dissertation is framed on these two approaches of crime: the rational choice but overall, social interactions are theoretical elements that influence in a big degree this research. Crimes that will be object of this analysis are: Number of homicides, the number

of robberies to people with violent aggressions, the number of thefts to people, the number of burglaries to commercial establishments and the number of house breakings.

According to literature review evoked before, it can be proposed that crime can be associated as a result of the evolution of social interactions that are highly influenced by urban transports of Bogota. Therefore, the decision of economic actors to choose a location to settle in the city is specially correlated to the public transport network. The impacts that the transport networks have on this decision are more important than literature have shown.

In addition, this dissertation also differs from others because it uses different types of econometric methodologies like “Propensity Score Matching” methods as well as “Diff-Diff” models and spatial regressions among others kind of econometric tools that also represent another added value of this study.

The research questions that guide this thesis are undeniable theoretical range respecting urban economics theory and social interactions theory. However, the contributions of our case studies are mainly empirical.

## **Plan of the Thesis**

Even if several studies have already verified that citywide delinquency generally decreases after the improvement or the construction of transport infrastructures, to our knowledge, no research has tried to specify the impact of these public policies with respect to the different types of crimes. With the aim to determine whether all types of crimes have the same respect to improvements of transports infrastructures, this research proposes to evaluate its impact on those different types of crime. Once this evaluation is done, this study verifies if there is a spread of some types of crimes on areas beneficiaries or not from improvements of transport networks.

In this respect, it was well demonstrated that transport infrastructures traduced on roads and highways of a city have a positive impact on employment and economic growth.

Moreno (2005) concluded that for the city of Bogota, citywide criminality is smaller closer the corridor but also that there are some types of crime which are more frequent if the distance to the BRT corridor is shorter.

This PhD dissertation focuses on four essays and each one corresponds to one chapter. They are all linked to the analysis of the impact of improvements of public transports on job accessibility, income, and, above all, on five different kinds of crimes: homicides, robberies to people with violent aggressions, thefts to people without violent aggression, burglaries to commercial establishments and house breakings.

This thesis is based on the theoretical fact that economic agents regardless their nature (individuals or enterprises) react in the same way with respect to the improvements of urban transports in Bogota that are represented by the Transmilenio system. It is divided in two parts and each one is composed by two chapters.

The first part deals with the relationship between Transmilenio system and some socio-economic variables. Those variables are the job accessibility of Bogotans, the location and the distance of job centers, the number and the size of enterprises in each zone and the level of income of inhabitants.

The first two chapters are an evaluation of the impact of the enhancements of public transports on the accessibility of inhabitants to job centers and with respect to the socio-economic situation of each zone of the city. The approach of the Effective Size of Labor Market introduced by Prud'Homme and Lee (1999) is used in the first chapter in order to understand how the job centers and the social classes are placed and distributed with respect to Transmilenio system.

The second part of this research focuses on the impact of transport networks on crime rates adopting three different econometric approaches.



## **Heterogeneity of social classes and job accessibility: implications of transport policies in Bogota**

Transport in Bogota has been the subject of several papers, but no one has treated the impact of the transport network on the disposition of employment in the city.

Improvement of a public transport system such as the Transmilenio is supposed to be beneficial to everyone in the city. However, it might be that only a portion of the inhabitants benefit from this improvement. The aim of this chapter is to demonstrate that improvements in public transport are not necessarily synonymous to benefits to every social class, especially when talking about a city with a great deal of heterogeneity in its social composition. To shed light on the relation between transport accessibility and social classes within the different zones in Bogotá, the definition of the effective size of a labor market in a city will be necessary. We will support this with a study of the existing literature about the effective size of a labor market. The results will give us enough tools to know whether or not an enhancement of the public transport system will have a direct effect on the type of jobs or social classes there are in the different zones of Bogotá. Can enhancements of public transport determine the level of social inclusion within a city like Bogotá?

## **Improvements of urban transports versus income, employment and job' accessibility: an endogenous question?**

Previous research has proved the existence of a causal relationship between the concentration of jobs in a city and the income of inhabitants. Other researchers have studied the close and nearly causal relationship between those variables and the degree of accessibility or of infrastructure such as highways in different zones of a city. Nevertheless, no one study has

taken into account the degree to which each area of a city benefits from the latest improvements to public transport. The aim of this research is to analyse the relationship between the size of the labour market, income and employment concentration in different zones of a city with respect to the degree of improvement to public transport (Transmilenio) in a city in a developing country, like Bogotá. The degree of enhancement of public transport in a zone is suspected to be endogenous to those three variables. Through the use of OLS estimations and then 2SLS estimations for each dependent variable (3), the validation of endogeneity provides sufficient tools to infer positive or negative causality of improvement of public transport. The size of companies, defined by the number of jobs they offer, plays the role of instrumental variable to explain the degree of improvement to public transport in each zone. It suggests three different scenarios that depend on the size of companies established in each zone. In essence, the number of jobs, the size of the labour market and income are largely defined by the level of improvement to urban public transport in each zone of the city and the causality relationship changes depending on the size of companies established in each zone. Results of this empirical research give some robust evidence. In the case of Bogotá, public transport improvements have a causality relationship with the income of inhabitants in each zone and the number of jobs, and this changes with respect to the size of enterprises. In contrast, the size of the labour market, defined as the number of jobs reachable in a specific time, is not determined by the degree of the presence of public transport enhancement.

### **Impact of urban public transport enhancements on crime rate: a diff-diff analysis for the case of Transmilenio**

While most studies have focused on studying the impact of this new public transport system with respect to the environment, hedonic prices, employment and urbanism, among others, none (except one) have studied the question of the evolution of crime linked to the existence of Transmilenio. The aim of this article is to demonstrate that the evolution of urban transport, which is traduced on the construction and on the improvements of Transmilenio,

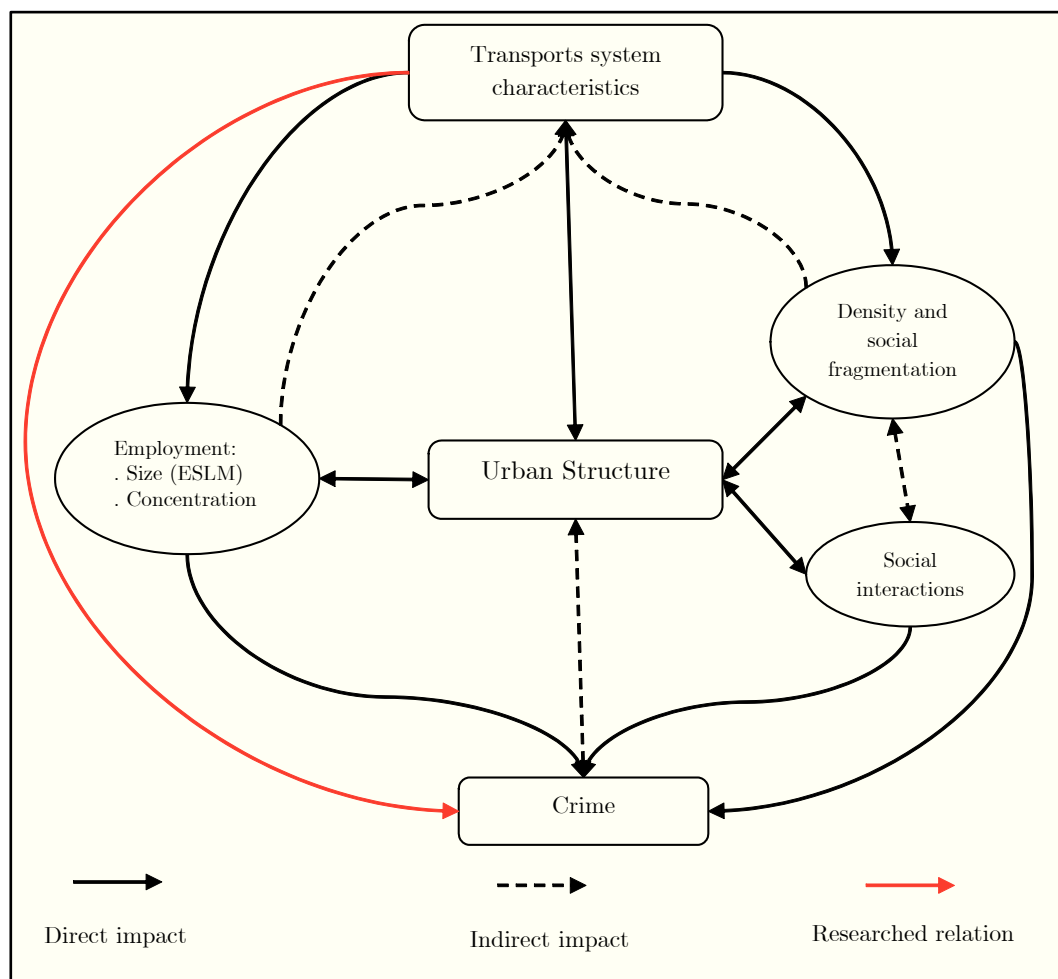
has had a direct impact on the crime rates in the city. By collecting a set of spatially referenced data regarding crimes in 112 of the 117 planning zones that make up the city, this research follows a differences-in-differences methodology to test the causality of the transport system in the evolution of crime rates in each zone for different periods. After a deep descriptive analysis of data and the implementation of the econometric methodology suggested, results indicate that enhancement of the public transport system has had no clear impact on crime rates in all zones of the city. Depending on the zones and on the Transmilenio line in question, the transport system may increase or decrease the number of crimes on each zone beneficiaries or not from the improvement of the system. However, this research gives a non-negligible number of hints to take in consideration on further studies.

### **Criminality spread: a “Boomerang” effect of public transport improvements**

The relationship between accessibility or the degree of improvement of urban transport and criminality has been underestimated and close to forgotten. This paper aims to reveal the importance of public transport policies in the evolution of crime configuration in a city. The hypothesis that the probability of transport improvements in a zone depends on some of its socio-economic characteristics is adopted. The use of the propensity score matching technique reveals that the presence of improvements of public transport in a zone of the city has a direct and significant impact on the increase of some types of crime. Likewise, spatial econometrics results expose that crime tends to be contagious in neighbouring zones. The presence of the Transmilenio system in Bogotá may share out criminality to other zones of the city. Negative externalities like the better mobility of offenders and, then, their possible choice to expand their criminal activities to new zones, can spoil the positive effects of enhancement of public transport. Far from suggesting not developing public transport or isolating some “dangerous” neighbourhoods or inhabitants, this article shows that improvement of public transport may not only generate positive externalities; policy makers should take into consideration the mutation and shift of criminal behaviours in order to identify

possible solutions such as the construction of more establishments providing health, welfare and sporting activities, as is evoked in the results. In this way, the “boomerang effect” of the improvement to transport will be reduced.

Figure-1: Logical enchainment of theoretical analysis of this research



Source: Author' conception

## Data and Methodology

This dissertation is structured on four chapters on four research papers that can be read separately. Even so, those chapters follow a logical order. The content of each chapter is explained on the following sub-section of this introduction. This sub-section gives details about the organization and the sequence of the chapters as well as the methodology and the data set used on each section of the dissertation.

The research starts with an analysis, on a first chapter, of the accessibility of “bogotians” to the different job centers of the city. In order to answer its research question, the first chapter tries to establish the direct relationship of the Transmilenio system and the employment centers and the socio-economic configuration in Bogota.

The methodology used in this section is based on the “Effective Size of Labor Market” approach suggested by Prud’homme and Lee (1999). This approach consists in the calculation of the number of jobs reachable by workers in specific intervals of time<sup>7</sup> from their houses to their job places. After this first calculation, results are contrasted with the level of socio-economic stratum of each zone of the city. This step allows to denote the number of reachable jobs with respect to the socio-economic stratum of each zone and between zones that benefit from Transmilenio system and those that do not. A deeper explanation of methodology and its mathematical concept is presented in chapter one.

The first chapter uses data from the most detailed mobility survey ever made in Bogota called “Mobility Survey 2005”<sup>8</sup>. This survey has information regarding mobility of inhabitants like the distance of trips, the commuting time, the social classes of users, the type of job of users and the starting and the destination points within each 112 planing zones of the city. This research uses this information to make the matrix of transport of Bogota that has information about commuting time between every zones of the city (every possible

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<sup>7</sup> There are 6 interval time for travels. It goes from travels of 10 minutes to travels taking 60 minutes and more.

<sup>8</sup> Mobility Survey 2005 or “Plan Maestro de Movilidad 2005: Encuesta de Movilidad 2005”, in Spanish. Secretaria de Movilidad del Distrito.

itinerary between UPZ<sup>9</sup>). Results from this matrix of transport are completed and linked with information from the survey of quality of life in Bogotá done by the administration on 2007<sup>10</sup>. This second survey has information about socio-economic data of inhabitants and different zones of the city. Variables like the socioeconomic level of inhabitants of each UPZ, the employment and the unemployment rates in each zone, among several others variables, are found on this survey. A most detailed description of dataset used on this chapter can be found on the first subsection of Chapter 1.

This first chapter exposes the levels and the differences of accessibility of inhabitants with respect to the zones where they live and the different social classes that they belong to. Results allow to understand if the urban transport network contributes to the disparities of the accessibility to jobs between social classes and also with respect to the zones benefiting or not from Transmilenio system. People living in zones served by Transmilenio system have a higher probability to find a job. The same relation is observed about the level of income of inhabitants; in effect, people with higher levels of income have a higher probability to find a job corresponding to their skills regardless if they use private or public transports<sup>11</sup>. On this respect, the second chapter was thought with the aim to study the possible causal relation of public transports improvements on the levels of income, of employment and of the accessibility to jobs in Bogotá.

As stated in chapter 2, the relationship between employment, income and job accessibility was already demonstrated. The intention of the second chapter of this thesis is to analyze if the improvement or the construction of a new transportation system in a city has a direct impact and if it causes differences on income and employment levels in Bogotá for the 2007 year.

To demonstrate this causal relation between these variables, this study employs a two stages least square test (2SLS). The idea of the employment of this methodology is to

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<sup>9</sup> Each planning zone is named UPZ

<sup>10</sup> Encuesta de Calidad de Vida para Bogotá (ECV) 2007. Secretaria de Planeación del Distrito de Bogotá. "The Survey of quality of life for Bogotá, 2007".

<sup>11</sup> Magnitudes are presented on the corpus of the chapter

validate or not, the existence of endogeneity and hence, a causal relation of the degree of enhancements of public transports on the income of people, on the accessibility to jobs of inhabitants and on the employment level of each zone of the city.

About the degree of accessibility to jobs, this chapter uses the Effective Size of Labor Market (ESLM) found in the precedent chapter. The number of employments in each zone and the level income of inhabitants in each zone are taken from the “Survey of quality of life for Bogota, 2007”. This chapter focuses on 2007 because of the impossibility to have data for other years.

The variable suspected to be endogenous is the number of Transmilenio stations into each zone and the instrumental variables are the working force on each zone of the city and the number of enterprises on each zone. At this respect, three scenarios are done depending on the number of enterprises regarding their size.

Regardless the fact that this chapter focuses on one period, this cross section analysis exposes interesting results. For the case of Bogota, improvements of urban transports do not have a causal relation on the ESLM. Regarding the level of income, Transmilenio system seems to have a causal relation when instrumental variable is the number of small or big enterprises.

Finally, improvements of urban transport network also have a causal impact on the number of jobs in each zone regardless the size of enterprises.

This second chapter try to prove that improvements of transport networks have a causal relation on the income of people as well as on the quantity or the density of jobs in each zone of Bogota. Once it is proved, next chapters emphasize on the fact that those levels of incomes and the number of jobs in each zone have a direct effect on crime rates in each zone in Bogota. Nevertheless, the analysis is based on the variable that causes the different levels of these two variables which is the number of stations of Transmilenio system.

The hypothesis adopted on the third chapter is that, as well as workers and enterprises, criminals follow high incomes and zones with high concentration of jobs. The goal of this section is to establish that the construction of a new transportation system (Transmilenio) may have an impact on the levels of crime with respect to the specificity of zones that compose Bogota. Criminality in jobs centers and on residential zones may be partly determined by the presence or not of Transmilenio system and thus, by the improvement of urban transport network.

Chapter 3 employs a difference-in-difference methodology (Diff-Diff) that consists to evaluate the change induced by a project or an event on an output or a specific variable in two periods. Some characteristics of each zone are also used on the construction of the model. They play the role of covariates but, due to the lack of information of amenities on each zone, this research assumes that covariates are constant.

Concerning the output or the dependent variable of the model (number of crimes), this chapter takes five types of crime: The number of homicides, the number of robberies to people with violent aggressions, the number of thefts to people, the number of burglaries to commercial establishments and the number of house breakings. The impact on the evolution of each type of crime in each zone of Bogota in order to determine if there is or not a causality relationship will be evaluated.

To carry out this evaluation, it is necessary to have information on crimes rates before and after the opening of Transmilenio<sup>12</sup>. This chapter uses a very rich dataset containing the number of each type of crime committed in each zone of Bogota<sup>13</sup>. Nevertheless, the information about crime rates is available for the period between 2003 and 2008. It means that the impact on crime levels in each zone of the city of the first phase of Transmilenio inaugurated in 2000 cannot be analyzed. However, the available data allow to do a deep

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<sup>12</sup> A most detailed description of this methodology is done on chapter 3

<sup>13</sup> The obtainment of this dataset was possible thanks to the "Conflict Analysis Resource Center (CERAC) and with the permission of the Metropolitan Police Department of Bogota (MEBOG)



examination with respect to the second phase of Transmilenio that counts three different corridors<sup>14</sup> and that was opened between 2003 and 2007.

As it is explained on Chapter 3: Due that the available dataset that this chapter uses has data from January 2003 to December 2008, the analysis takes in consideration crimes committed twelve months before the opening of the corridor called "Americas" (from January 2003 to December the 31th 2003) and twelve months after its initiation (from January the 1st 2004 to 31st of December 2004). Regarding the two other corridors that were opened later (NQS and Suba), this study takes in consideration data of crimes committed 18 months before and 18 months after their opening.

Results of this chapter suggest that, in some cases, there is a causal effect on crime rates from Transmilenio. Nonetheless, results are not always the same. They vary with respect to the corridors and also with respect to the type of crime.

Even if causality is proved for some corridors, conclusions from this section are not conclusive. The evolution of some types of crime on some zones appears to be determined by Transmilenio system. However, the lack of covariates for all periods may be the reason of this ambiguity. Nevertheless, results suggest that this causal relation exists.

Finally, this dissertation suggests that, in order to better understand the evolution of crime and the effect that urban transports may have on its levels, spatial analysis of crime should be done.

The fourth chapter is structured on two different parts: the first part has the same purpose than the precedent section: determine the impact of Transmilenio on crime rates. However, it differs on the methodology used as well as the period studied. The second part emphasizes on a spatial analysis. Data used in this chapter are the same used on the third one.

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<sup>14</sup> Phase 2 is composed by three corridors: "Americas" corridor was opened on December 2003. "NQS" corridor was opened on July 2005 and « Suba » corridor was opened on May 2006.

First of all, this chapter begins with an analysis of the probability that Transmilenio pass or not by a zone of Bogota. This probability is calculated with respect to some characteristics of each zone. Secondly, once this estimation is done (Logit model), a Propensity Score Matching (PSM) methodology is used in order to capture the impact of the presence of Transmilenio on each type of crime in each zone. Those two steps give a clear answer about how crime rates depend on some characteristics of each zone like the presence or not of Transmilenio system. These two first steps allow the comparison of crime rates between zones that benefit from the transport system and those that do not.

With the aim to have comparable results, the same sets of covariates have to be available for each zone. This is an important point that should be clarified in this section: this estimation is done just for the year 2007 because all data that this research has regarding amenities, socio-economic characteristics of each zones and crime rates are available just for this year. Once this first phase of the analysis is done and once the impact of the presence of the transport system on crime is corroborated, Chapter 4 examines if crime rate on a zone has a contagious effect on neighboring zones.

The second part of this chapter is based on a spatial analysis of crime. First and foremost, this chapter proceeds to determine if there is a spatial autocorrelation of each type of crime. Once the spatial autocorrelations are proved with the support of some diagnostics tests, spatial regressions are done in order to determine the spatial dependency in the regression analysis. In effect it provides the spatial relation between dependent variable (crime) and explains spatial relations between some variables among which there is the presence of Transmilenio.

Results suggest that a positive and significant relation of public transports improvements on crime level exists. First phase shows that, excepting homicides and thefts to people with violent aggressions, Transmilenio presence has a causal relation on the rest of crimes level. Second phase suggests that there is a spatial dependence of crime with respect to the presence of transport enhancements on three of the five types of crime as well as other kind of variables.

Table 1: Summary of the dissertation

Chapter	Aim of the Chapter	Methodology	Expected Results
1 -Heterogeneity of social classes and job accessibility: Implications of transport policies	<i>Look to the degree of concentration of jobs in some zones of the city. The idea is to see if Transmilenio benefits everybody in the city at the same degree.</i>	Calculation of the Effective Size of Labor Market (Prud'Homme, Lee 1999) which is the number of the reachable jobs within 112 zones of the city. ( <i>O-D matrix</i> )	We expect to find different degrees of treatment with respect to social classes and with respect to the different sub-center in the city
2- The endogeneity of urban transport improvements on the configuration of the employment and the income: the "bogotanian" case	Evaluate the endogeneity of Transmilenio on the concentration of jobs, the employability and the income in the different zones of Bogota in 2007.	2SLS methodology with a test of endogeneity. ( <i>static analysis</i> )	We expect to find if the presence of TM is endogenous on the three different dependent variables in order to have an approximation of the impact of the system on the configuration of employment and concentration of income in the city.
3- Impact of urban public transport enhancements on crime rate: a diff-diff analysis for the case of Transmilenio	Test the causality effect of Transmilenio on the number of the different types of crimes on three different corridors of Transmilenio. Analysis ex-ante and ex-post for each TM corridor.	Difference in difference methodology with constant covariates. ( <i>dynamic analysis</i> )	According to the hypothesis that criminals follow jobs and high incomes, we expect to find that the presence of TM has a direct impact on crime rates.
4- Criminality spread: a "Boomerang" effect of public transport improvements	Test the causality effect of the presence of TM on each zone on the number of each different type of crime for 2007.	Propensity Score Matching (PSM).	We expect to find that improvements of public transports have a causal relation on the crime rates for 2007. After doing that, we also evaluate the spatial dependence of crime in the city.
	Show if there is a spatial dependence of crime between zones.	Spatial Econometric analysis.	
	Identify the better Spatial model.	Spatial Lag Modeling ( <i>static analysis</i> )	

Source: Author' conception

# **Chapter 1**

## **Heterogeneity of Social Classes and Job Accessibility: Implications of Transports Policies in Bogota**

### **1.1 Introduction**

Over the last twenty years, the question of urban transport policies has been a part of the core of socio-economic debates on developing and developed countries. In fact, the lack of regulation of public and private urban transport, the increasing number of owners of private cars, the increase of the population and hence the increase in the density in cities, along with a multiplicity of other reasons, has produced a rise in the commuting time and travel distance, and are at the origin of the “sprawl” of cities (Glaeser 2003).

The capital of Colombia, Bogotá, is no exception. In the last three decades, it suffered a big increase in its density and its territory. Since this big expansion of population and area and in addition to the absence of an effective urban transport system and appropriate regulatory policies, Bogotá had fallen into a mobility chaos by the end of the 1990s.

Thenceforth, the city was managed by mayors who attached prime importance to the problems of mobility and accessibility. Actually, the core of their plan of government was the planning and the implementation of a suitable transportation system for the city. Between 1998 and 2000, public managers decided to plan and to construct a Bus Rapid Transit System (BRT), called *Transmilenio*, which was rapidly recognized as one of the most successful BRT systems in the world.

The first phase of the system began operations in December 2000, counting 42 km of exclusive lanes for articulated buses. Seven years later (2007), the whole of the two

first phases of *Transmilenio* were in operation. They counted 84 km of exclusive corridors for 1080 articulated buses, 114 stations with off-board fare collection, and seven terminals connected with an inter-urban transport system. The third phase is planned to be finished in May 2012 and it will count 36.3 km more new corridors. In its entirety, the *Transmilenio* is expected to have 388 km of exclusive corridors covering 80% of the daily transit trips in the city.

Several studies explain the different reasons to consider *Transmilenio* as the most successful BRT system in the world. Indeed, the gains in commuting time were remarkable: from 1h30 to 30 minutes (a gain of 66%) in addition to an increase in the average travel speed of the public buses. While the average speed of *Transmilenio* is 25 km/h (similar to a metro system), the average speed of the public service buses is 15 km/h.

Nevertheless, even if gains in travel time and speed continue to be important factors to take into consideration for transport policies, characteristics of a public transport system (PTS), such as affordability, accessibility, and impact on employment and hence, on the productivity of the city, have had more relevance in the last twenty years.

Literature regarding the accessibility of urban transport systems is vast. Some researchers on accessibility have focused their studies on “time accessibility” or “gravity accessibility” (Hansen 1959, Wilson 1970, Wachs 1973 and Koenig 1974). This branch of theory focuses on the reduction of travel time and commuting costs, including both the direct and indirect costs such as the cost in terms of time, the cost of the trip, etc. This suggests that the less the travel time is, the less the global cost is and the better the accessibility is. Thus, the productivity of the inhabitants will be higher. Theorists and policy makers have developed two kinds of solutions: increase the speed of the trips, or reduce the travelling distances involved.

To increase the speed, some authors and policy makers (see Barr 2000, Cervero 1997, Cervero 2002a,c) have suggested the construction or extension of ways and highways and hence the use of cars can be looked upon as a solution (Glaeser 2004, Sheickman and

Glaeser 99, Anas 99, Fujita 2001)<sup>15</sup>, so that commuting times and commuting costs will be lessened. But what researchers have observed is the tradeoff between speed and distance and between work and home. In fact, with such improvements in the infrastructure, individuals realized the possibility of living further away from their jobs in order to live in bigger houses and thus take the same time to go from their houses to their jobs. In other words, they “give up” commuting time per distance in order to have more space or amenities in their living zone. But the only way to have the same commuting time when living in zones of the city which lack public transportation is to have a private car.

Nonetheless, the limited space and budget of cities to improve infrastructural networks, and the exponential increase in the use of cars, reveals the limitations of this kind of strategy. Traffic jams and hence the increase in commuting times and the loss in productivity shows that this kind of policy was not one of the better ones to solve the problems of accessibility and mobility.

For these reasons, another way to reduce commuting times is, according to several researchers (Duranton and Puga 2003, Glaeser 2001?) the “densification” of some city zones. As a result of such a “densification”, there can occur learning and matching effects (Puga-Duranton 2003) which will translate into economies of agglomeration and reductions in the distance between houses and jobs.

The proximity between houses and work places is highly suitable, because the nearer inhabitants are to their jobs, the less time they will expend in commuting, and as a consequence, they will be more efficient. In addition, it will have some other positive effects, such as a reduction of the use of cars and, in turn, a reduction of traffic jams, smog, and all kinds of negative externalities.

Bringing inhabitants and their jobs closer together seems to be the better solution but this zoning would also have as a consequence a cost increase<sup>16</sup> in formal housing, and thus

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<sup>15</sup> Those studies talk about the “Sprawl process” of cities begun decades ago, and show how policies have encouraged car use.

<sup>16</sup> Sometimes artificially

such undesirable effects as the restriction of inhabitants from moving to those zones (in parallel with such other unwanted consequences as squatting) (Duranton 2008). So, people should be pushed to live near their jobs but even if a geographical densification is suitable it is not a hundred per cent affordable because of high costs (Brueckner and Selod 2008).

For those reasons, policy makers and researchers think that the better solution to use, is to mix a densification and a reduction of commuting time with an improvement in the public transport system. Enhancement of the accessibility on the part of a bigger proportion of inhabitants, by the use of an “efficient” public transport system, and not, as before, by increasing incentives to car use, seems to be useful. Jobs and houses are getting closer, which is supposed to lead to higher productivity and less commuting costs. Apparently, policy makers and researchers have found the recipe for enhancing everybody’s accessibility to cities, or at least, this is what theory and some empirical studies say.

Urban mobility usually depends on public transportation. Most people use a PTS to travel within the city from home to work. The statistics gathered by city planning departments confirm that it is often more advantageous to take a bus (BRT) or the metro than it is to use a private car. The encouragement of the use of private cars is rapidly decreasing as a result of the enhancement of the PTSs.

## 1.2 Research question

The accessibility of inhabitants was a relative success of the transport policies implemented in Bogotá. After the construction of the *Transmilenio*, the travel times between work and home decreased in the city. With improvements in PTS travel time had decreased to an important extent: people’s jobs are closer to their homes.

In addition, they also have more opportunities to reach more jobs. In fact, following some researchers (Prud’homme and Lee 1999), the “Effective Size of the Labor Market” (ESLM), which is the average number of jobs reachable in a specific interval of time, will

be higher with the enhancement of the PTS: probability of finding a job can rise with this kind of policy. But the question for this kind of policy is not only to get people closer to jobs but also to get people closer to the type of jobs they are trained to do. There is not the same interest in connecting a working-class neighbourhood to a zone of the city specialized in financial services, for example.

Some studies about Paris show that, even in this city, some transport policies were more useful for managers than for workers. Indeed, managers have a higher range of jobs to access than workers, even if both live in the same zone (Selod et alii 2004; Wenglenski 2005, 2006). Thus, the effective size of the labor market of managers is bigger than that of workers, which could be clearly a flaw of favoritism or exclusion of public policies. This fact has as a consequence a division and a possible segregation that can entail a reduction in social interactions which should be avoidable from the economic and social point of view. (Glaeser and Scheinkman 1999; Brueckner 2003).

As Wenglenski has illustrated in the case of Paris, (Wenglenski 2006) the probability of reaching jobs is not the same for every worker's profile. In effect, people belonging to the highest class (executives, managers) seem to receive more benefits from Parisian PTS policies than people who belong to the lowest class (unskilled workers).

This paper gives us different tools to know if enhancements of a Public Transport System or the transport policies of Bogotá give people belonging to a specific social class the same level of possibilities of reaching a job of their skills as to other classes. The aim of this research is to know if people belonging to different social classes in Bogotá are taking advantage to the same extent of the improvements in accessibility provided by the *Transmilenio*. If this is not the case, we will try to find out how transport policies could alter this conclusion.



## 1.3 Research methodology

To take up the subject and to analyze the research question, we must, firstly, estimate the Effective Size of the Labor Market in Bogotá, as recommended by Prud'homme and Lee (1999). After having the ESLM of the city of Bogotá for some intervals of time, we will suggest an approach to the question of the accessibility of each social class<sup>17</sup> to different zones of the city.

### 1.3.1 The “Effective Size of the Labor Market” (ESLM) approach

To estimate the effective size of the labor market in Bogotá, we follow the methodology suggested by Prud'homme and Lee (1999). This theory is based on the assertion that the labor market is a function of the travel times and zones where employees live and work. The goal of this approach is to know how many jobs are reachable by workers in a specific time from their homes to their jobs. The commuting time intervals we used are from 10 minutes to 120 minutes.

To provide some of the background for this approach, we will merely describe it as the authors did in their paper<sup>18</sup>.

The database we have takes into account 824 different tracts of Bogotá which, in turn, make part of 112 “Zones of planning” (UPZ)<sup>19</sup>. This gives us  $n = 112$  zones of study.

$E_{k_i}$  will represent the number of employees with the  $k$ th type of job located in zone  $i$ , so  $\sum_i E_{k_i} = E$  will denote the total employees in the city.  $J_{k_i}$  represents the number of jobs of type  $k$  placed on zone  $i$ , and  $\sum_i J_{k_i} = J$ , the total jobs in zone  $i$ . Finally,  $T_{ij}$  is the average time needed to reach zone  $j$  from zone  $i$ .

<sup>17</sup> There will be three social classes for the purposes of this study: lowest, medium, and highest

<sup>18</sup> We use the same expressions as the authors.

<sup>19</sup> UPZ is the acronym, which we will use, for the Spanish *Unidades de Planeamiento Zonal*.

For each  $i$ , the ESLM for workers of zone  $i$  will be

$$Li(t) = \sum J_{k_i}$$

in order to have  $T_{ij} \leq t$ , the commuting time to reach  $j$  from  $i$  ( $T_{ij}$ ) will have to be less than or equal to  $t$ : this is the temporal constraint.

For the city, the ESLM will be

$$L(t) = \frac{\sum L_i(t) * E_i}{E} = \frac{\sum_{i=1}^n \sum_j J_j * E_i}{E}.$$

This represents the weighted average of the effective labor size of all zones, weighted with respect to the number of employees who live in the city.

To obtain a more accurate answer to our research question, the estimation of the ESLM was performed for the population belonging to each social class. To realize whether improvements of PTS represent an advantage in terms of ESLM, we took into account the direct access of each UPZ to TM.

The analysis of the ESLM undertaken in this paper took into account three scenarios, depending on possible connections between UPZ where TM skirt or pass within those zones, and UPZ that do not have any connection to TM. As a result, we have three possible scenarios:

- Travel from a UPZ with direct connection to TM to another UPZ with direct connection to TM;
- Travel from a UPZ without any connection to TM to another UPZ without any connection to TM;

- Travels from UPZ with direct connection to TM to another UPZ without any connection to TM and reciprocally.

Besides those possible combinations of connections between UPZ, we also made a distinction in the ESLM with respect to the kind of transportation used by the inhabitants. We calculated the fraction of jobs accessible to inhabitants belonging to a social class with respect to the kind of transport system used (public or private). The results brought some interesting information to light.

### 1.3.2 Social class and grouping of zones

Bogotá is a very big city, composed of 20 subcity urban areas<sup>20</sup> divided in turn into 112 planning zones. The density in Bogotá is approximately 230 people/ha<sup>21</sup>, (one of the densest cities in South America) and the social class heterogeneity is sometimes really appreciable. The city is divided into six socioeconomic strata: from stratum 1, the lowest socioeconomic level, to stratum 6, the highest level. Stratas 3 and 4 often represent the middle class.

As we said above, Bogotá is organized into six socio-economic strata. The analysis we have undertaken took in consideration three types of social classes, which will be made up out of these six socio-economic strata.

Actually, we grouped these strata into what we call three “social classes” composed as follows:

- Strata 1–2: Lowest Social Class

<sup>20</sup> The urban area as a whole is composed of 19 subcity urban areas and one rural one. The urban areas amount to 35,000 hectares (three times the size of Paris).

<sup>21</sup> Adapted from Suarez (2005).

- Strata 3–4: Middle Social Class
- Strata 5–6: Highest Social Class

On the other hand, to make easier the analysis of travels, I suggest a grouping of some zones. I take into consideration the most important “employment centers” of the city. I suggest those “subcenters” because of the number of people working in these zones and also because of the dynamism we perceive in some zones of the city. I defined three different subcenters which are, in turn, composed of a number of UPZ:

- One of those centers is the zone known as “The Center”<sup>22</sup> of the city which is not the geographical center but the historical and the administrative center of the city with the majority of national and regional bureau. This subcenter, “Center”, is composed of 12 UPZ of the city .
- The second subcenter, “Center-North”<sup>23</sup>, includes five UPZ and is defined as a financial subcenter which is 8 km from the historical center. It is these zones which have the highest buildings, belonging to several bank companies.
- The third subcenter, “North”<sup>24</sup>, includes six UPZ and is defined as the commercial subcenter, and is located 14 km from “center” and six kilometers from “Center-

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<sup>22</sup> Subcenter “center” is composed of 12 UPZ: Britalia, Sosiego, Ciudad Jardín, Santa Isabel, Restrepo, Sagrado Corazón, La Macarena, Las Nieves, La Candelaria, Las Cruces, Lourdes, and Teusaquillo.

<sup>23</sup> Subcenter “center-north” is composed of 5 UPZ: Pardo Rubio, Chicó Lago, Los Alcazares, Chapinero, Galerías

<sup>24</sup> Subcenter « north » is composed of 6 UPZ : Usaquén, Country Club, Santa Bárbara, La Alhambra, Los Andes  
El Refugio

North”. This zone has been, for almost ten years now, a new center wherein internationals and also financial companies have their headquarters<sup>25</sup>.

- The rest of the UPZ (84) are called “rest” in our analysis but, even if in this analysis it is considered as a subcenter, it does not represent it.

In this classification, we have made sure that every subcenter is almost served by the same kind of public services, especially by public transport systems. We paid particular attention each subcenter’s being served by *Transmilenio* in similar proportions.

## 1.4 Analysis of the data

### 1.4.1 The dataset

Even if we notice that this analysis is made with data from the matrix of transport of the city of Bogotá, we have to take into account that the information given by this data is not complete. We make the hypothesis that the informal labor market has the same behaviour and characteristics as the formal labor market. Therefore, we can suppose that our results concerning the effective size of the labor market can be very close to reality, which can also be contested, but our objective was mainly the analysis between social classes.

Bogotá is a city where a third part of the population has a formal job. Two parts of the population in age to work is underemployment or unemployment. As is comprehensible, there is no truthful data for the underemployment market but, even if such data is not available, this does not really challenge our results due to our focus on social classes and the formal labor market in the city.

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<sup>25</sup> Analysis of the number of employees of each subcenter as well as the time spent by people commuting from and to these subcenters can be found in appendix 1.

To understand the characteristics of the trips, the public administration decided to make the most detailed mobility survey ever made in the city<sup>26</sup>. The database used for our study was obtained from this survey. It has information about several variables regarding the mobility of the inhabitants: distance of trips, commuting time, social classes of users, type of job of users, and starting and destination points within each of the 112 zones of the city.

The results from this survey were really satisfactory to the city. More than 84,000 persons were asked about their travels or about the time they took to go to their destinations.

Nevertheless, even if this last study is the most detailed mobility survey ever made in the city, it still was a survey. The study was completed by the transport matrix of the city which gives us the time estimation of every trip within the city. In fact, the matrix of transport of Bogotá has information about the commuting time between every zones of the city (every possible itinerary between one UPZ and another).

In addition to this information<sup>27</sup> we judged that we had to take into consideration some of the socio-economic data pertaining to the various zones in order to have better results. In 2007, the administration made another survey in the city<sup>28</sup> with the aim of having some information about the quality of life of “Bogotánians”. This survey takes into account socio-economic data such as the socioeconomic level of the inhabitants of each UPZ, the number of unemployed people in each zone, the number of cars by households, and other variables. It is very interesting to include these variables in our study analysis especially if we are looking to have a greater socio-economic framework of UPZ.

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<sup>26</sup> Mobility Survey 2005 or “Plan Maestro de Movilidad 2005: Encuesta de Movilidad 2005”, in Spanish. Secretaria de Movilidad del Distrito.

<sup>27</sup> The Mobility Survey 2005 and Transport Matrix of Bogotá.

<sup>28</sup> Encuesta de Calidad de Vida para Bogotá (ECV) 2007. Secretaria de Planeación del Distrito de Bogotá. The “Survey of quality of life for Bogotá”

With this data, we will be able to make a more refined analysis to answer our research question.

The variables taken in consideration were organized by UPZ of origin and UPZ of destination. The poll of 2005 had the following information for each variable:

- Reason of the trip (8 reasons): return to home, work, study, business, shopping, personal business, change of bus, and other
- Type of vehicle or type of transport used from destination to origin (11 types): foot, bicycle, motorcycle, private car as driver, private car as passenger, taxi, *Transmilenio*, bus of *Transmilenio*, bus, micro bus, other.
- Principal Activity of the person: study, job, house job, retired, independent, searching for job, cannot work, other.
- Type of job of people for which their principal activity is to work: worker or employee, housework employee, independent worker, manager or owner, household worker without salary, other.
- Socio-economic stratum: 1 – people belonging to lowest socio-economic stratum, 6 – people belonging to the highest one.
- Calculated time: walking time to the nearest station plus waiting time inside the station plus time inside the vehicle.

### 1.4.2 Descriptive statistics

Besides the type of work, Table 1 presents us some descriptive statistics resulting from the poll. Among those people for whom their reason for the trip is to work, we can observe that commuting times differ between people with different kinds of jobs.

Table 1.1: Descriptive statistics according to the type of job of those people for whom their reason for the trip is to work

Type of job	Time	Mean	Maximum	Minimum	Standar deviation
Worker of employee	Time of walk	4.37	55	0	4.86
	Time of wait	6.99	105	0	7.64
	Time into the vehicle	58.23	1010	1	39.98
Housework employee	Time of walk	4.78	62	0	4.865
	Time of wait	7.88	80	0	7.64
	Time into the vehicle	62.31	600	1	39.98
Independent worker	Time of walk	3.36	123	0	4.86
	Time of wait	5.51	93	0	7.64
	Time into the vehicle	52.93	910	1	39.98
Manager/owner	Time of walk	1.63	70	0	4.86
	Time of wait	2.28	90	0	7.64
	Time into the vehicle	40.97	240	5	39.98
Household worker w salary	Time of walk	2.81	10	0	4.86
	Time of wait	3.5	20	0	7.64
	Time into the vehicle	46.31	120	10	39.98
Other	Time of walk	3.01	95	0	4.86
	Time of wait	4.69	91	0	7.64
	Time into the vehicle	45.98	900	1	39.98

Source: Author's calculations from "Encuesta de Movilidad 2005"

As expected, managers and owners are those who take less time to commute, to wait, and to walk to the nearest station where they take the vehicle. In contrast, we see that employees, unskilled workers, and housework employees are those who take more time to reach their destinations.



Even if the sample is not negligible (84,000 interviewed) it has to be completed. To do that, we use the Transport Matrix of Bogotá<sup>29</sup>. This matrix includes information about all possible itineraries “from” and “to” every 112<sup>30</sup> zones of the city. This matrix is divided into 824 zones of transport of Bogotá. This gives us a matrix with 678,976 itineraries, which in turn make part of the whole UPZ, so we will bin the data of the transport matrix into the 112 UPZ in order to have just 12,432 itineraries.

Table 1.2: Descriptive statistics according to the socio-economic class of people whose reason for the trip is to work

Socio-Economic Class	Time	Mean	Maximum	Minimum	Standar Deviation
Lowest level (stratus 1-2)	Time of walk	16.46	52.62	7.71	5.77
	Time of wait	2.5	8.05	1.73	0.7
	Time into the vehicle	42.94	63.98	28.59	8.89
Medium level (stratus 3-4)	Time of walk	13.02	41.12	7.1	3.96
	Time of wait	1.71	6.25	1.18	0.5
	Time into the vehicle	41.62	62.74	27.94	8.53
Highest level (stratus 5-6)	Time of walk	11.68	36.23	6.87	3.32
	Time of wait	1.48	2.47	1.08	0.23
	Time into the vehicle	40.95	62.61	27.64	8.32

Source: Author's calculation from “Encuesta de Movilidad 2005” and Transport Matrix of the city of Bogotá

The transport matrix also has information about the time spent in stations waiting for public buses or even the time people spent walking from home or work to the nearest station, as well as the socio-economic classification of the users.

According to the socio-economic class of the people whose reason for the trip is to work, we observe that people from the lowest socio-economic (strata 1 and 2) take more time to walk to the next station than do people of the other socio-economic stratum (table 2).

<sup>29</sup> This information was obtained from the Secretaria de Movilidad del Distrito and University of Los Andes (Bogotá).

<sup>30</sup> To ensure homogeneity of the data between UPZ and because we do not have the complete socio-economic information of all 112 UPZ, we have to exclude five UPZ from the analysis. This paper will take into account data from 107 UPZ.

Actually, people of the highest socio-economic strata take less time (14.4%) to commute within the city (tables 2 and 3)<sup>31</sup>. Equally, those differences are also revealed between the medium and the lowest classes (9.85%). But the highest differences are observed in walking time to the nearest station or waiting for the vehicle. These differences are substantial, even if they are not really significant compared to the total commuting time. For example, we see that people of the lowest socio-economic strata take 40.92% more time to reach the nearest station than do people of the highest strata. Concerning waiting time, people of the lowest class spent 68.92% more time waiting than did people of the highest class, and 46.20% more than people of the medium class. The same differences between people of the highest class and the medium class are also important but not so much so (Annex 1).

In Bogotá, more than 3.2 million travels have work as their cause. More than half of all trips (59.9%) are made on public transportation and 41.1% of all trips are by private vehicles (table 3). Among the three subcenters, the “Center” is the one who has more trips than the other two (10.5% of the total trips of the city. 6.3% and 3.2 % for “Center-North” and “North”, respectively). We observe that two-thirds of the trips in the “Center” and “North” are made in private vehicles. On the other hand, almost half of the trips in “Center-North” are in public vehicles. This suggests that the modal choice can be heterogeneous across subcenters and UPZ of the city.

Table 1.3: Number of trips with “work” as their reason, by subcenter

Sub-center	Number of trips		By type of transport mode			
	Total	%	PT	%	CO	%
Center	337,970	10.5%	131,155	38.8%	206,815	61.2%
Center-North	204,382	6.3%	109,375	53.5%	95,007	46.5%
North	102,401	3.2%	35,220	34.4%	67,180	65.6%
Rest	2,586,547	80.0%	1,658,627	64.1%	927,921	35.9%
Bogota	3,231,300	100.0%	1,934,377	59.9%	1,296,923	40.1%

Source: Author's calculations from “Encuesta de Movilidad 2005” and Transport Matrix of the city of Bogotá

The attraction and generation of trips (Table 4) from and to subcenters displays the differences between them. In fact, we see that 6.8% of the total trips attracted to Bogotá

<sup>31</sup> Three kinds of times are included: walking time, waiting time, and time inside the vehicle.

(trips to a subcenter) correspond to “Center”, 5.7% are to “Center-North”, and 1.8% to “North”. But what is also interesting to see is that these subcenters generate more trips than they attract. In effect, “Center” generates 15.9% of the trips generated in Bogotá, which is 57.7% more than the trips that it attracts. “North” generates 5.2% of the trips generated in the city (90.7% more trips than it attracts). In contrast, “Center-North” attracted more trips than it generates, and the majority of trips attracted are by private vehicles (84%). Most of the trips attracted and generated from and to “Center” are made by public transportation (two-thirds of the trips) but one-third of the trips attracted to “North” are made by public transportation which suggests that the rest are made in private vehicles. This lets us suggest that two-thirds of the people working and living in “center” use public transportation. In contrast, 84% of the people who work in “Center-North” use private transportation and 96.7% of the trips of people who live and do not work in “Center-North”, use public transportation to reach their jobs. Finally, two-thirds of the trips attracted by “North”, (people who work in “North”) use their cars to go to their jobs; two-thirds of the people living in that zone but working in another one use public transportation to get to their jobs.

The rest of the zones of the city represented by “Rest” attract more trips than they generate (85% attracted vs. 71.5% generated) and more than four-fifths of the trips are made by public transportation.

Table 1.4: Distribution of number of trips generated and attracted by transportation by subcenter

	Zone	Total	%	PT	%	CO	%
Trips attracted	Center	131,155	6.8%	96,705	73.7%	34,451	26.3%
	Center-North	109,375	5.7%	17,488	16.0%	91,887	84.0%
	North	35,220	1.8%	12,909	36.7%	22,311	63.3%
	Rest	1,658,627	85.7%	1,318,957	79.5%	339,670	20.5%
Trips generated	Center	206,815	15.9%	161,763	78.2%	45,052	21.8%
	Center-North	95,007	7.3%	91,887	96.7%	3,121	3.3%
	North	67,180	5.2%	42,048	62.6%	25,132	37.4%
	Rest	927,921	71.5%	733,540	79.1%	194,381	20.9%

Source: Author's calculations from “Encuesta de Movilidad 2005” and Transport Matrix of the city of Bogotá

Concerning the distance traveled by people between their homes and their jobs, we observe that people living or working in “Center” travel lesser distances than people living or working in another subcenter (Annex 2). We can suggest that there is a greater willingness to be closer to “Center”. This can confirm that the fact of being closer to the zone

considered as “the center” of the city, where the historical and the administrative center is located, may be more advantageous for workers. In contrast, we can observe that the distances people have to travel to “North” are longer than the others. In fact, this could be related to the fact that 84% and 63% of the trips attracted by “Center-North” and “North” are made in private vehicles, which allows people to travel longer distances. In contrast, most of the trips generated in every zone are made by public transportation.

Data from the planning office of the city hall and from the Chamber of Commerce of Bogotá shows us that “Center” attracts 12.6% of the formal jobs of the city and contains 14.5% of the workforce. “Center-North” and “North” have 17% and 8.3% of the formal jobs, respectively, and 13.3% and 8.9% of the workforce of the city (Annex 3). The rest of the zones (“rest”) have similar portions of the formal jobs and workforce.

Having information about all the kinds of jobs in each subcenter may be the most desirable, but because of the lack of accurate information we opted to make an analysis with respect to social classes in order to have a better estimation of the influence of transport policies in Bogotá on the effective size of the labor market.

As we have said before, every subcenter has a direct connection with the *Transmilenio* (TM), but each subcenter is composed of several UPZ. Each UPZ makes part of a subcenter but might not have direct access to TM.

The level of concentration of jobs and workforce in UPZ with direct access to TM is as follows: (Annexes 4–5)

- 10.6% of the formal jobs are directly connected to TM and make part of “Center”.

Only 2% of the formal jobs of the city, which represents 15.9% of the formal jobs of “center” subcenter”, do not have a direct connection to TM.

- 16.4% of the formal jobs are directly connected to TM and make part of “Center-North”. No more than 0.6% of the formal jobs of the city, which represents 3.4% of the formal jobs of “zone 72” subcenter”, do not have a direct connection to TM.
- 5.5% of the formal jobs are directly connected to TM and are part of “North”. But 2.8% of the formal jobs of the city, which represents 34.2% of the formal jobs of “center” subcenter”, do not have a direct connection to TM.

Likewise, the concentration of jobs, the level of concentration of the workforce in a UPZ with and without direct access to TM, is rather identical. This gives us a framework for the employment in Bogotá.

Unfortunately, we do not have detailed data of the number of kinds of jobs and underemployment in each UPZ and this does not allow us to make a complete study of the effective size of the labor market in Bogotá. Our results can be criticized, but we believe that our approach will reflect the reality of the labor market in the city. We will suppose that even if we do not have data for underemployment, it has the same behavior as the formal employment market.

## 1.5 Results

### 1.5.1 Travel from a UPZ with a direct connection to TM to another UPZ with a direct connection to TM.

As Table 10 shows, people commuting by public transportation and living in a low-income UPZ with a direct connection to TM, have access to 22.93% of the jobs in the city. Besides, when a UPZ has a direct access to TM, people who belong to strata 3 and 4 (medium class)

have access to 28.98% of the jobs in the city (26.4% more than people of the lowest class) in the same length of time. Finally, when people commute by public transportation and live in a UPZ of the highest class, where a TM passes through or surrounds them, they can reach 29.83% of the jobs of the city in thirty minutes (2.93% more than people of the middle class and 30% more than people of the lowest class).

With an interval of time of thirty minutes, we find that when people use public transportation to reach their jobs from a UPZ where there is a presence of TM with direction to a UPZ where TM passes, the richest people have access to 30% more jobs than people with the lowest income of the city. Such differences are bigger when people would like to reach their jobs in 20 minutes. In fact, while rich people have access to 11.3% of the jobs in twenty minutes of travel, poor people have such access to only 0.8%. The disparity decreases when the commuting time increases. When the commuting time is sixty minutes, the difference between the number of jobs reachable in this time between rich people and people of low income is only 17.5%.

We find the same characteristics when the trips are made in private cars.

Table 1.5: Effective size of labor market for people travelling in public vehicles when neither UPZ has a direct connection to TM

Effective Size of Labor Market							
Type of transport	Time of Travel (minutes)	10	20	30	40	50	60
PUBLIC	Lowest Class	0.00%	0.80%	22.93%	43.28%	58.63%	71.42%
	Medium Class	0.00%	9.49%	28.98%	46.05%	63.44%	79.00%
	Highest Class	0.00%	11.31%	29.83%	49.25%	68.20%	83.82%
PRIVATE	Lowest Class	4.61%	29.20%	53.58%	75.88%	89.98%	96.54%
	Medium Class	9.30%	30.71%	56.19%	77.97%	91.56%	97.16%
	Highest Class	9.93%	32.03%	57.17%	79.41%	92.03%	97.63%

Source: Author's calculations

In fact, when the trips are made in private cars between two UPZ with direct TM, the people belonging to the lowest classes have access to 29.20% of the jobs of the city in twenty minutes, while the number of such jobs of people belonging to the middle (high) class is 30.71% (32.03%) (Table 12). This difference in the accessibility between the high

class and the low class when the trip is made in a private car is 9.7%. When the commuting time increases, this difference decreases.

Our results suggest that in sixty minutes, even people of the lowest social class have accessibility to almost all the jobs of the city when people use private cars to reach their jobs. On the other hand, when people use public transport, they can reach 70% to 84% of the jobs of the city.

The commuting times between UPZ were taken from the transport matrix of Bogotá but we thought that these proportions are higher than they are perceived by the inhabitants. We thought the results might change concerning the number of jobs in each UPZ. In fact, we have to remember that not all jobs were considered in that study. We are focusing only on the formal labor market and we are not taking into account the informal labor market, which represents almost 50% of the employment of the city. But even if we do not have those data, the goal of the paper still has been achieved: the differences between the benefits of the social classes from the enhancement of transport policies such as the *Transmilenio* have been exposed.

### **1.5.2 Travels from a UPZ without any connection to TM to another UPZ without any connection to TM.**

As expected, the accessibility to jobs for people living and working in a UPZ which the TM does not traverse and does not even skirt the boundaries, is fewer for commuting times going from thirty minutes to sixty minutes (Table 13). The differences between social classes in the number of reachable jobs are also less important than in the previous section. (22.38% more jobs are accessible to people of the highest classes than are reachable by people of the lowest social level for a commuting time of thirty minutes and using public transportation).

Table 1.6: Effective size of labor market for people travelling in public vehicles when neither UPZ has a direct connection to TM

Effective Size of Labor Market							
Type of transport	Time of Travel (minutes)	10	20	30	40	50	60
PUBLIC	Lowest Class	0.00%	0.80%	22.93%	43.28%	58.63%	71.42%
	Medium Class	0.00%	9.49%	28.98%	46.05%	63.44%	79.00%
	Highest Class	0.00%	11.31%	29.83%	49.25%	68.20%	83.82%
PRIVATE	Lowest Class	4.61%	29.20%	53.58%	75.88%	89.98%	96.54%
	Medium Class	9.30%	30.71%	56.19%	77.97%	91.56%	97.16%
	Highest Class	9.93%	32.03%	57.17%	79.41%	92.03%	97.63%

Source: Author's calculations

It is interesting to see the magnitude of the differences in labor market size between people living in a UPZ with TM and those who live in zones without TM and who commute by public transportation to reach their jobs. In fact, for intervals of commuting time between ten and twenty minutes, we observe differences but they are not very significant (Table 14). Nevertheless, the differences in labor market size can be seen for trips of thirty, forty, and fifty minutes. In fact, “rich people” have access to 18.07% fewer jobs than people living and working in zones with TM when they travel thirty minutes, 31.92% less when they travel forty minutes, and 25.72% less when they take fifty minutes to reach their jobs.

The disparities in the size of the labor market when trips are made in private cars are also significant. For trips made in twenty minutes we observe a difference of 31.75%, 43.25% for trips made in thirty minutes, 36.97% for trips made in forty minutes, and 22.24% for a commuting time of fifty minutes.

Even if people do not travel in TM, the zones that benefit from its presence have bigger labor markets. The differences for the lowest and medium classes are similar.

### 1.5.3 Travels from UPZ with a direct connection to TM to another UPZ without any connection to TM, and reciprocally

Regarding the effective size of the labor market for people traveling from a UPZ with a direct connection to TM to another UPZ without a connection, we can observe in Table 15



that people commuting in travelling vehicles take twice as much time than if they live and work in a UPZ with TM in the area. This is true for times between ten and thirty minutes. For commuting times between forty and sixty minutes, we see that there still is a difference that tends to disappear; nevertheless, this difference still can be important.

Concerning the comparison between social classes, we observe varying differences in the sizes of the labor markets: 22.16% more reachable jobs for rich people than for poor people who take thirty minutes to go to their jobs. When the trips take forty and fifty minutes, the size of the labor market is 12.07% bigger, respectively, 10.15% bigger, for people belonging to high classes, respectively, for people living in low social level classes.

Table 1.7: Effective size of labor market for people travelling in public vehicles when neither UPZ has a direct connection to TM

		Effective Size of Labor Market					
Type of transport	Time of Travel (minutes)	10	20	30	40	50	60
PUBLIC-3-1	Lowest Class	0.00%	0.30%	9.88%	23.98%	42.34%	57.13%
	Medium Class	0.00%	1.80%	11.85%	25.79%	45.20%	61.98%
	Highest Class	0.00%	2.17%	12.07%	26.89%	46.64%	65.67%
PUBLIC-3-2	Lowest Class	0.00%	0.36%	14.39%	36.29%	57.31%	72.93%
	Medium Class	0.00%	3.43%	18.74%	38.61%	59.64%	75.91%
	Highest Class	0.00%	4.23%	19.68%	40.81%	61.75%	77.79%
PRIVATE-3-1	Lowest Class	0.84%	11.48%	25.92%	48.28%	67.49%	81.83%
	Medium Class	1.90%	11.61%	27.10%	50.14%	69.81%	82.94%
	Highest Class	1.87%	11.47%	27.84%	51.74%	71.61%	84.71%
PRIVATE-3-2	Lowest Class	2.61%	17.12%	38.09%	61.68%	78.01%	90.24%
	Medium Class	4.80%	17.22%	40.09%	63.46%	79.80%	91.89%
	Highest Class	4.75%	17.44%	39.56%	64.00%	81.38%	93.21%

Source: Author's calculations

Furthermore, we might think that the proportions and differences observed on the ESLM for people travelling from UPZ with TM to another UPZ without any connection to TM and the ESLM for people travelling from a UPZ without a direct connection to a UPZ with a direct connection to TM will be the same. Instead, with surprise, we notice that there is a non negligible difference of the ESLM, depending on whether it is a zone from which the individuals are leaving that has TM into their “boundaries” and zones where they are arriving and has no TM to their boundaries. In fact, if we compare the results from Table 17 with those from Table 15, we see that individuals who take public transportation

to leave a UPZ without a direct connection to TM to reach their jobs in a UPZ with TM have 48.7% more jobs which are reachable in an interval of time of twenty minutes. The disparities of the ESLM still are significant for intervals of thirty, forty, and fifty minutes, with, respectively, 38.66%, 34.10% and 24.46% more reachable jobs.

Regarding the differences between social classes, we observe that they are not very significant. For a commuting time of thirty minutes, there is a gap of 33% more reachable jobs for people with higher incomes, but for the intervals of forty or fifty minutes, the differences are not higher than 13%, which is not insignificant but it is not very important.

With respect to trips made in private cars, we see the same kind of differences between social classes, and especially in the case of individuals leaving a UPZ with TM to another one that does not. Actually, Table 18 gives us almost similar information as the preceding table.

## 1.6 Conclusion

Even if we notice that our analysis is made with data from the matrix of transport of the city of Bogotá, we have to take into account that the information given by that data is not complete. We make the hypothesis that the informal labor market has the same behavior and characteristics as the formal labor market. Therefore, we can suppose that our results concerning the effective size of the labor market can be very close to reality, something which could be contested, but our objective was mainly an analysis of differences between social classes, which was done.

The object of this paper was to evaluate the enhancements of the public transport system in Bogotá (the presence of the *Transmilenio* in some zones of the city) and the influence it might have on the accessibility to employment of the inhabitants with respect to their socio-economic status. Our results tend to contribute to the comprehension of some disparities of the accessibility to the labor market between social classes in the city.

With this research, we have confirmed the existence of a significant correlation between the presence of the *Transmilenio* in a specific zone of the city and the effective size of the labor market of the population living or working in that zone. People who live in zones served by the *Transmilenio* have, at least between 18% and 30% higher probability of finding a job than do people who do not live in zones served by the *Transmilenio*. The improvements in public transportation like the *Transmilenio* seem to have had a positive and important impact on accessibility to the labor market.

Besides, when we focus on the comparison of the Effective Size of Labor Market (ESLM), we find that people in the city with less income are those who have less accessibility to the labor market even if they live in the same zone of the city as people with the highest incomes. Their probability of finding a job is, on average, 20% lower than that of those of the upper classes.

In addition, when trips are made in private cars, the results are not dissimilar. We observe the same differences in accessibility to jobs between the high, medium, and low classes and between zones served or not by the *Transmilenio*. At the same time, however, we observe that when the trips are made in private cars, the ESLM increases by 20%, which is not a surprise but it is still more advantageous to rich people.

In general, the improvement of public transportation of Bogotá (*Transmilenio*), gave people the possibility of having a faster commute and increased the accessibility of the labor market. The buses of the *Transmilenio*, besides all the improvements of the road network, seem to have had positive effects not only on the time people spend in public transportation but also on the time spent in private cars alongside the *Transmilenio* corridors; nevertheless, the difference in the accessibility to the labor market between social classes has still been important.

Even if every social class seems to have had an increase in their accessibility to the labor market, those benefits are not equally distributed. People from higher social classes have more advantages from the public transport improvements than do people from the

lowest social classes, and the “poorest” people of the city seem to have received less profit from those enhancements.

When the public administrations decided to upgrade public transit, this was always sought as a way to raise the welfare and social inclusion of the people from the lowest socio-economic level. Whereas the improvement in public transport systems such as the *Transmilenio* entails enhancements of the accessibility, this paper demonstrates that, even if it is an improvement of a public service, it does not benefit all social classes equally. The enhancement of the public transport system seems to benefit more the upper classes than the lower ones.

Our results suggest a lack in the conception of this kind of public policy; social inclusion can be stymied. Why do people belonging to the lowest social classes not profit from the enhancements and the development of new public transportation in the same proportion as people belonging to higher social classes? Have “poor” people enough tools to enjoy those improvements in the same proportion than “rich” people? Are affordability and disposable income the causes of this difference? Those questions could complete our study and could be the subjects of further research. The subject of subsidies in public urban transport to make them more affordable might take on more importance for the conception of transport policies.

## 1.A Annexes

### 1.A.1 Annex 1:

Table 1.8: Differences of times between socio-economic classes

Time	Hi-low	Med-low	Hi-Med
Walk	40.92%	26.42%	11.47%
Wait	68.92%	46.20%	15.54%
Into	4.86%	3.17%	1.64%
Total	14.40%	9.85%	4.14%

Source: Author's calculations from "Encuesta de Movilidad 2005" and Transport Matrix of the city of Bogotá

### 1.A.2 Annex 2:

Table 1.9: Mean distance of trips by subcenter

Sub-center	Mean Distance of trips (km)	Standar Deviation (km)
Center	7.7	5.5
Center-North	8.8	5.6
North	10.7	6.5
Rest	8.7	6.2

Source: Author's calculations from "Encuesta de Movilidad 2005" and Transport Matrix of the city of Bogotá

### 1.A.3 Annex 3:

Table 1.10: Workforce and number of jobs by subcenter

Sub-center	Number formal jobs	%	Workforce	%
Center	188082	12.6%	437795	14.5%
Center-North	253916	17.0%	403891	13.3%
North	124851	8.3%	269424	8.9%
Rest	930888	62.2%	1914483	63.3%
Total	1497737	100.0%	3025593	100.0%

Source: Author's calculations from Secretaria de Planeación del Distrito de Bogotá. "Survey of quality of life for Bogotá 2007"

**1.A.4 Annex 4:****Table 1.11: Jobs and direct access to TM by subcenter**

Sub-center	Number of jobs in UPZ with direct acces to TM	%	Number of jobs in UPZ without direct acces to TM	%
Center	158,186	10.6%	29,896	2.0%
Center-North	245,209	16.4%	8,707	0.6%
North	82,192	5.5%	42,659	2.8%
Rest	595,440	39.8%	335,448	22.4%
Total	1,081,027	72.2%	416,710	27.8%

Source: Author's calculations from Secretaria de Planeación del Distrito de Bogotá. "Survey of quality of life for Bogotá 2007"

**1.A.5 Annex 5:****Table 1.12: Workforce and direct access to TM by subcenter**

Sub-center	Workforce in UPZ with direct acces to TM	%	Workforce in UPZ without direct acces to TM	%
Center	333,938	11.0%	103,857	3.4%
Center-North	388,438	12.8%	15,453	0.5%
North	179,433	5.9%	89,991	3.0%
Rest	1,427,149	47.2%	487,333	16.1%
Total	2,328,958	77.0%	696,635	23.0%

Source: Author's calculations from Secretaria de Planeación del Distrito de Bogotá. "Survey of quality of life for Bogotá 2007"

## **Chapter 2**

# **Are public transport improvements endogenous with respect to employment and income location in a city?**

## **2.1 Introduction**

### **2.1.1 A brief theoretical contextualization**

Connections between commuting time and localization of jobs in urban areas have been widely studied by several researchers (Cervero, 2000; Hansen, 1978; Prud'Homme, 1999). The number of jobs that can be reached in a specific period of time, which can be directly related to the concept of job accessibility (Kay Axhausen, 2008), represents a relevant topic in urban studies and transportation research. Time of urban travel, distance from homes to jobs and urban structure seem to hoard the attention of the majority of researchers involved in urban and urban transport studies.

Inhabitants choose to live in a specific zone of a city taking into account numerous elements of houses and neighbourhoods according to the theory of hedonic price (Rosen 1974). The area of the house in square metres, the comfort of the house, the materials which with houses are built, seem to be very important to buyers. However, in the past decades, due to the increasing congestion in cities, inhabitants have been giving increasing importance to the amenities of the neighbourhood and the zone where their houses are placed (Glaeser, 1999; Brueckner, 2001; Putman, 2000). The better and more amenities the neighbourhood offers, the more expensive the house will be. In other words, the actual configuration of cities and, thus, inhabitants' choices about the zone in which they decide

to live, does not depend just on their desires; more precisely, it depends on the facilities of the zone and hence on the price of the amenities offered in the area.

Therefore, it is not strange to read that disparities of income in a city represent one of the principal causes of the socio-economic gap between different zones in a city (Glaeser and Thyse, 2004; Cao, Morkarian and Handy 2007). Because of their high purchasing power, people and companies with a high level of income used to have more possibilities to choose the zone of the city they want to dwell; they have more flexibility to move and change their place where they live (Brueckner, 2002; Glaeser, Rosenthal and Strange 2010; Anas, Arnott and Small, 1998).

In the 70s and 80s, studies of American cities showed that, because of the widespread usage of the private car, people preferred to live far from all kinds of centres of the city (commercial centre, job centre, government centre, etc.) and inhabited suburbs alongside people with the same level of income and the same level of education. They preferred suburban spaces with less noise from cars, less congestion and better security, which offered big parks and more recreation spaces than zones closer to the centre of the city (Giuliano and Small, 1991; Fujita, 1999). In addition, as noted above, those kinds of suburbs have the most marked homogeneity of social classes. Due to high property prices, people with a low level of income will not be able to live there. This phenomenon was generally perceived in cities both in developed and developing countries. It can be perceived as a phenomenon of cities in general.

This research is focused on the city of Bogotá, the capital of Colombia. As some studies have shown for other cities of developed countries, the city centre of Bogota had a decline from the urban and planning perspective. A spatial mismatch began to settle down in the city (Bureckner and Zenou, 2003).



### 2.1.2 Some characteristics of Bogota

Before the 1960s, provision of public transport was led by the public administration. Buses, taxis and tramway lines composed the urban transport system of the city, with the tramway as the “spinal column”. The city centre was a desirable place to live.

Nevertheless, because of Bogotá’s huge public debt and due to various social factors<sup>32</sup>, tramway took ten years to close and the public administration decided to privatize the public transport system. Since the 60s and due to the destruction of many buildings during several civil manifestations, the centre of Bogotá stopped being a desirable place to live. The management of public transport was given over to private entrepreneurships which were just focused on the development of more lines of buses and not on the urbanization or planning of the city. Public administration was supposed to have a regulatory role but, because of the lobbying power of private entrepreneurships, that role was not assured by the administration.

Today, the city’s public transport system continues to be managed by private entrepreneurships assembled in about 60 private enterprises assuring the provision of the service in the city<sup>33</sup>. The public administration does not participate in utilities. Since the late 1960s, the administration’s regulatory role has involved determining the different lines of buses needed in zones of the city; after a call for tender, it assigns those lines to “winning” enterprises. This mode of management has contributed to the expansion of the public transport system and thereby the major spread of the city in the past 40 years.

In the past decades downtown has become older, not safe, noisy during the day and abandoned and dark during the night. Because of these characteristics, during this period, prices of houses at downtown decreased significantly; people with low income opted to live in the city centre. However, this does not mean that they live only in the centre of the city.

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<sup>32</sup> Public debt and “El Bogotazo”: civil insurrection after the homicide of a very important politician (Jorge Eliecer Gaitan) a future president of Colombia at 1948.

<sup>33</sup> From Secretaria de Movilidad del Distrito

They also live in suburbs, far from the centre of the city, but with characteristics widely different than those of zones that “rich” people used to inhabit.

That type of behaviour encouraged the development of inner cities (Small, 1999; Fujita, 1989; Duranton and Anas, 2001) and also increasing expansion of urban areas. Generally, suburbs where people with a low level of income live do not have good coverage of public services. The water and sewerage services are not provided in the same proportion. Clean water, electricity and even paved roads and, therefore, urban transportation are not offered in the same proportion.

The population continues to grow rapidly in the urban area and, hence, congestion is growing faster than before. Nowadays, people take more time than they are ready to spend from their houses to their jobs. Cities are still to expand its boundaries and “exclusive” suburbs are now too far from the city and, worse, from work. As a consequence of the sprawl and the consistent lack of planning policies for decades, Bogotá has suffered big problems with mobility and its transportation system. Densification of downtown was one of the principal goals of the mayor elected in 2011<sup>34</sup>. The continuous reduction of accessibility, severe congestion on some main roads of the city, long travel times and poor road network conditions became the most relevant problems for the city. These consequences have been called by some researchers the “spatial mismatch” (Kain, 1968, 1993; Ihlandfeldt and Sjoquist, 1991).

At the end of the 1990s, aware of the city’s great need, the mayor of Bogotá decided to improve and innovate public infrastructure of public through the creation of a transport system called “Transmilenio”, which has been the most efficient BRT system ever seen in Bogotá (Chaparro and Irma 2000; Hidalgo and Sandoval 2001).

Reorganization of the transport network and restructuring of planning policies are now at the core of the public debate. Today, the public administration participates in the roles of manager and inspector; changes in the social and urban structure have taken place

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<sup>34</sup> Gustavo Petro was elected for the period 2012-2016

in Bogotá in the past 15 years. Most neighbourhoods (60%) are now connected directly by Transmilenio (TM). Most zones (excluding the suburbs) will be substantially interconnected with downtown areas by TM<sup>35</sup>.

Consequently a shift in decisions to live in the suburbs took place. In the past 15 years, people have shown increasing willingness to inhabit the centre of the city because of proximity to their jobs. In Bogotá, more than 30% of jobs are located downtown. This fact had as a consequence a “redensification” phenomenon in the city centre by people with the highest incomes as well as increased prices in the centre. People prefer to live near to their workplace and not an hour and a half from it<sup>36</sup>. Thus, the connections between income, job accessibility, employment and public transport improvement seem to be very tight.

Some earlier studies (Immerluck, 1998; Gao, 2006; Gao, Mokhtarian and Johnston, 2008), have demonstrated the dependence and even the causal relationships among accessibility to jobs, employment, income and auto ownership. In this study, I propose to demonstrate the differences in these relationships among zones which have benefited from improvements to the transport network and those that have not had enhancements.

Some studies about hedonic prices and their relationship with public transport reveal that the distance between houses and public transport networks can have positive or negative effects on houses’ hedonic prices<sup>37</sup>. Regarding the city of Bogotá, Mendieta and Perdomo proved that “the average elasticity proximity of TM, price of the land are -0.36, -0.55 and -1.13 for the first, second and third stages of TM in the same order”<sup>38</sup>. In parallel, Gutierrez (2011) suggests that amenities of zones, accessibility, economies of scale and other zonal characteristics contribute to explain the configuration of employment centres.

<sup>35</sup> Source: Secretaria de movilidad del Distrito

<sup>36</sup> Time that they normally take if they live in suburbs. Encuesta de movilidad del distrito 2005. Secretaria de movilidad del distrito

<sup>37</sup> In the case of Bogota the distance is measure with respect to the nearest BRT station, Transmilenio.

<sup>38</sup> Mendieta, J. C. y Perdomo, J. A. (2007). “Especificación y estimación de un modelo de precios hedónico espacial para evaluar el impacto de Transmilenio sobre el valor de la propiedad en Bogotá”, Documento CEDE, Centro de Estudios sobre Desarrollo Económico, 22, ISSN 1657-5334

Taking into consideration those studies and following some theoretical and empirical studies (Gao, 2006; Gao, Mokhtarian and Johnston, 2008), this work expects to find that the presence of improvement to public transport in each zone of Bogota has a significant impact on the level of income, the number of jobs and the level of what Prud'Homme and Lee (1999) called "The Effective Size of Labour Market" (ESLM) in each zone. Differences of income, employment and ESLM between zones with improvement to their transport networks and zones without the presence of Transmilenio are expected. This research tends to prove that these three variables are not only deeply related to improvements made to public transport, but there also exists an important endogeneity between the level of enhancement of public transport on these three variables. If endogeneity among improvements and other variables is verified, it will let us infer the existence of a causal relation from improvement to income, employment and ESLM.

This paper is structured in three main sections, as follows: we first explain the research methodology of the conceptual framework of the subject. We define our instrumental variable (IV) and thus the instruments we use in our three models. We then introduce the core phase of our analysis, which focuses on the demonstration of endogeneity. It may show that there is a causal relation between these factors. In fact, from a theoretical point of view, an endogenous variable is a factor which is almost determined by the importance of other variables in a specific model. Generally, factors can be affected directly by other factors presented in the model but also by factors that could not be included in the system. This means that we can find some degrees of endogeneity (partial or total endogeneity).

As previously stated, our purpose is to find and reaffirm the theoretical endogeneity between improvements to the public transport system and job accessibility, income and employment<sup>39</sup>. Finally, in order to better understand the model's results, a discussion takes place in the fourth section. In this way we will be able to conclude whether a causal relationship between these variables is plausible.

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<sup>39</sup> In the model employment will be taken as the total of jobs on each zone of the city.

## 2.2 Conceptual framework and research methodology

Earlier studies (Thompson, 1997; Sanchez, 1999; Shen and Sanchez, 2005) have shown relationships between employment, income, job accessibility and auto ownership. This research assumes these relationships and aims to demonstrate the importance of the enhancement of public transport provided by the construction of TM on the level of income, number of jobs and degree of accessibility to jobs defined by the ESLM.

According to Kawabata (2003), interdependence between these variables can be expected. In effect, the improvement of urban transport directly influences the index of job accessibility. On the other hand, an upgrading of job accessibility will boost the average income because of the gain in time and the reduction of commuting costs, which will also have a direct effect on the number of jobs. Indeed, the reduction in commuting costs and travel times will bring inhabitants closer from their employments (Prud'homme and Lee, 1999)<sup>40</sup>. In our analysis we assume that this proximity and the reduction of commuting time is due to the presence of more Transmilenio stations.

### 2.2.1 How to mediate with endogeneity

To demonstrate whether there is a causal relation, a deep study about the endogeneity of those variables must be done. We will first make an OLS model for each variable with respect to the other control variables, in order to find the degree of relation between those variables when they are dependent or independent factors. This will begin with an examination study of correlations and the variance inflation factors for each variable on each model to determine if the mode could have some multicollinearity problems.

After doing those analyses, the research will proceed with the measurement of possible causal effects. When causality is evoked, the three possible reasons proposed by Kenny (1979) have to be considered:

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<sup>40</sup> See the analysis about the relation between the Speed, the Sprawl and the Spread.

- Factor x must temporally precede the dependent variable (not always)
- Factor x is correlated with the dependent variable
- The relation between the independent and the dependent variable must not be explained by other causes.

Condition 1 can be necessary but is not a sufficient condition to establish causality. Even so, due to our type of data, we will not demonstrate this condition because we are not doing a time series analysis. Our analysis is statistical, hence factor x will not temporally precede the dependent variable. Condition 2 needs, from a statistical point of view, a relationship between the explanatory variable and dependent variable (which is supposed to have been shown before). The third condition supposes the independent variable and dependent variable have a relation that depends on other reasons. Then the independent variable is endogenous and the coefficient of this variable does not reflect a simple correlation. In addition, the dependent variable could also explain the independent variable (reverse causality). To summarize, endogeneity of variables means that there is a presence of functions explanatory variables in the system.

According to Antonakis et al. (2010), independent variables might be endogenous for many reasons. Endogeneity may be caused by the omission of some variables that explain an independent variable. Finally, the fact that independent and dependent variables may be collected from the same rating source could also be a reason of endogeneity among other reason we will not discuss in this issue.

From a mathematical point of view, one or some explanatory variables of a model may be endogenous because they can be correlated with the error term of the system (condition 3). If this is the case, the least square estimator found is not consistent. To have a consistent estimator, researchers have to find valid instruments of the variable suspected to be endogenous. Subsequently, using the appropriate variables, a two-stage least squares (2SLS) model will give a better, consistent estimator that will reflect the “real” influence of the endogenous variable on the explained variable.

After doing the 2SLS analysis, the analysis will continue with a test and correction of the potential endogeneity. Then it is supposed that the results will expose enough tools to conclude if there is endogeneity between variables and, thus, if a causal relationship is verified or not.

### 2.2.2 Models and variables structure

As was noted before, it is assumed that there is a relationship between the enhancement of public transport provided by the construction of TM, the level of income, the number of jobs and the degree of accessibility of jobs. Note that there are three dependent variables (three different models to test) and one variable suspected to be endogenous.

#### Endogenous variable and choice of instrumental variables (*IV*)

Improvement of public transport ( $Improvement_i$ ) will be the “potential” endogenous variable and will be denoted by the number of Transmilenio stations in each zone; ( $Improvement_i$ ) = 0 means that there is no Transmilenio station in the zone.

The choice of the instruments was made after a simple GIS analysis of the configuration of dependent variables and the instruments. Annexes 6 and 7 show that even if the workforce has a “suspected” degree of relationship with employment and income (figure 1 and annex 4), their scattering across the city seems to be randomized and thus, there is not a big correlation between those variables. In effect, it can be seen that there are zones where the employment is condensed but not for working force and vice versa. The same case is perceived concerning the size of enterprises and independent variables. The concentration of enterprises and their size seems to be random and there is not a direct relation with income, the *ESLM* or the number of jobs. Analogically, these remarks could join the conclusions of Wenglenski (2006) with respect to the concentration of jobs and the degree of accessibility equality for people of low income inasmuch as there is not a clear relationship regarding the concentration of these elements in the city.

### The model: three studied scenarios

This research tries to adapt the model presented in some precedent studies (Cao, Mokhtarian and Handy, 2007; Cervero, 2003) with available data collected for the city of Bogotá. It is assumed that the presence of a Transmilenio station in each zone depends on the workforce in each zone  $i$ ,  $WF_i$ , and on the number of enterprises in each zone,  $Enter_{si}$ , with respect to their size  $s$ . Variables such as employment, income, area and others that could be taken into consideration are supposed to be exogenous in order to avoid multicollinearity problems in main models. Remember that IV tries to capture the effects of exogenous variables that are not taken into consideration in the “main” models, and so on dependent variables. But what were the reasons to choose instrumental variables?

Regarding the number of enterprises,  $Enter_{si}$ , because of the data available, I decided to classify them into three different groups according to the number of employees and also taking into consideration some details of methodology from the Colombian government<sup>41</sup>. Enterprises with less than ten employees are named “microenterprises” ( $MiE$ ). Enterprises with more than ten employees and less than 50 employees are called small and middle-sized enterprises ( $SME$ ). Finally, enterprises with more than 50 employees are considered as large enterprises ( $LE$ ). The reason to differentiate companies from each other regarding size is to take into consideration the number of enterprises in each zone, but also the potential jobs that those companies offer. For each model, three different results will be proposed with respect to the number of companies, which are classified into three groups in accordance with the number of employees they have.

Income, employment and job accessibility are the dependent variables to regress.

In this study, job accessibility will be denoted by the Effective Size of Labour Market,  $ESLM$ , which is the number of jobs reachable for people commuting from one zone to another in a specific time frame. The  $ESLM$  was already computed in previous research<sup>42</sup>

<sup>41</sup> DANE, Departamento Administrativo Nacional de Estadística in spanish

<sup>42</sup> Olarte, C. (2012) “Heterogeneity of social classes and job accessibility: implications of transport policies in Bogota” Working paper, Centre d’Economie de la Sorbonne (CES).



following the methodology of Prud'homme and Lee (1999). Results are given on three different intervals of time (40 minutes, 50 minutes and 60 minutes)<sup>43</sup>, so I test three different levels of *ESLM* and hence three different models, one per interval of time. A deeper description of this variable is formulated in section 3.

The variable suspected to be endogenous is defined as follows:

$$impro = \pi_0 + \pi_1 Dens_i + \pi_2 WF_i + \pi_3 Enter_{si} + u \quad (2.1)$$

Models and relationships I propose are:

**Model 1 :**

$$ESLM_{ti} = \beta_0 Cons + \beta_1 impro_i + \beta_2 Y_i + \beta_3 Pop_i + \beta_4 Area_i + \beta_5 Dist_i + \beta_6 Car_i + \beta_7 X_i + e \quad (2.2)$$

where *Cons*, is the constant variable of the model;

*ESLM<sub>ti</sub>*, designates the number of reachable jobs for people commuting from zone *i* in a specific time *t*. It is the “proxy” of job accessibility;

*Impro<sub>i</sub>*, denotes the number of Transmilenio stations in each zone of the city. The more stations the zone has, the better will be the improvement of public transport in these zones; no presence of stations in the zone means that there is no improvement or no presence of TM in *i*;

variable *Y<sub>i</sub>* designates the average level of income for inhabitants living in zone *i*;

*Area<sub>i</sub>*, represents the size in hectares of zone *i*;

*Dist<sub>i</sub>*, denotes the average distance that an inhabitant of zone *i* takes to reach their job in *t* minutes;

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<sup>43</sup> I suppose that when people take less than 30 minutes to reach their jobs, they prefer do it by walk and not by public transports. In fact, as it is shown on annex 1, the average time of trips done on Transmilenio is 40 minutes and the time of trips done by walk or bicycles is 30 minutes.

$Car_i$ , indicates the number of car owners in zone  $i$ ;

$X_i$ , reflects a vector of control variables to complete and fill in the missing information in the model.

What is suggested with this model is that the size of the labour market for people living in zone  $i$  depends largely on the degree of improvement to public transport in the zone, the mean income of inhabitants of each zone, the population and the area of each zone. Other variables could also explain the  $ESLM$ , such as the mean distance from inhabitants' houses to their jobs, the number of car owners in each zone and other control variables represented by vector  $X_i$ .

I decided not to take into consideration the variable  $emplo$  which denotes the number of jobs in each zone because these results ( $ESLM$ ) were made directly with respect to the number of jobs on each zone; therefore a big problem of collinearity was avoided.

As previously clarified, I consider five different intervals of time of  $ESLM$  so, in the first stage of our analysis (OLS estimations), three different results of this model will be presented. For the second stage (2SLS) there are three results for each interval of time in addition to the three different results for each interval of time which will depend on the size of companies on each zone (nine results are expected for this model).

### Model 2 :

$$Y = \beta_0 Cons + \beta_1 impro_i + \beta_2 ESLM_{ti} + \beta_3 Pop_i + \beta_4 Area_i + \beta_7 X_i + e \quad (2.3)$$

Model 2 shows us the dependency of the income factor with respect to  $impro_i$ ,  $ESLM_{ti}$ ,  $Pop_i$ ,  $Area_i$  and  $X_i$ . With respect to the available data, these are the variables that best explain the income. Results of this assumption will be found on section 4 (OLS results).

The hypothesis we follow with this model and the others is that improvements to public transport in each zone have a bigger impact when considered as an *IV* depending on other exogenous variables (see equation 1) than when it just plays the role of an ordinary explanatory variable.

Because Income is explained by *ESLM*, I expect also to have three results for the first stage of the analysis and nine different results of the 2SLS analysis; each with respect to the commuting time and the size of enterprises.

### Model 3 :

$$Emplo_i = \beta_0 Cons_i + \beta_1 impro_i + \beta_2 Y_i + \beta_3 Pop_i + \beta_4 Area_i + \beta_7 X_i + e \quad (2.4)$$

In model 3, we consider that the number of employment on each zone of the city depends on the average income of each zone, the population and the area of that zone and, mainly, the number of Transmilenio stations in each zone; other control variables were taken in consideration as in previous models.

Furthermore, like in previous models, the lack of Transmilenio stations in a zone supposes that it does not benefit from public transport enhancements.

Contrary to previous models, employment in zone *i* is not explained by *ESLM*. It means that one result is expected in the first stage of our analysis (OLS). Three results are expected on 2SLS models which depend on the size of enterprises.

## 2.3 Descriptive statistics and data available

Bogotá is the biggest city in Colombia and also one of the most densely populated cities in Latin America. It counts almost eight million inhabitants and its density is around 230

people/ha<sup>44</sup>. It is organized following the administrative Parisian model, which means it has 20 sub-city urban areas<sup>45</sup> called “Localidades”, each one with its own mayor and an independent budget assigned by the main city hall with respect to the population. Because of their big physical extension, “Localidades” are subdivided in planning zones. In total, there are 112 planning zones in the city. We will develop our research question with respect to each planning zone of the city.

The data we use in our analysis come from various sources.

On 2005, the mobility department of the city decided to make a rather complete study about the mobility behaviour in Bogotá<sup>46</sup> with information about residents’ travel. To estimate the job accessibility index, we use the Transport Matrix of Bogotá<sup>47</sup>. This matrix encloses information about all possible itineraries “from” and “to” each of the 112 planning zones of the city. After some filters of the poll and some estimations, we obtained a summary of the time that people take to get from one zone of the city to any other and the mean distance<sup>48</sup>. In parallel, we established the time of travel when people use public transport or their own cars. This information was compiled by the department of mobility of the city.

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<sup>44</sup> Adapting from Suarez,2005.

<sup>45</sup> Urban area is composed by 19 sub city urban areas and one rural. The urban areas count 35.000 hectares. (three times Paris)

<sup>46</sup> Secretaria de Movilidad del Distrito; Plan Maestro de Movilidad 2005.

<sup>47</sup> Obtained at the “Secretaria de Movilidad del Distrito” (Department of mobility of the city) and University of Los Andes (Bogota).

<sup>48</sup> Olarte, C. (2012) “Heterogeneity of social classes and job accessibility: implications of transport policies in Bogota” Working paper, Centre d’ Economie de la Sorbonne (CES).

Table 2.1: Descriptive statistics for the entire sample and for each variable

Variable	Label	Obs	Mean	Std.	Min	Max
Accessible jobs on 40 minutes	ESLM_40	112	414541,30	226526,60	32151	875709
Accessible jobs on 50 minutes	ESLM_50	112	645827,90	281513,60	84793	1140640
Accessible jobs on 60 minutes	ESLM_60	112	889232,30	287322,00	184320	1320369
Income	Income	112	689235,80	566579,90	196821	3032604
Number of jobs	Employment	112	13997,52	16632,94	197	142052
Improvement degree	Improvment	112	1,92	2,41	0	10
Population on 2007	Population	112	65526,80	50644,21	776	284499
Area of the Zone (hectares)	Area	112	368,13	164,97	86	925
Mean distance of trips	Mean_dist	112	8,69	2,57	5	20
Have at less one car	Car owners	112	6778,81	6065,13	0	27569
Average cost of travel	Aver Cost	112	1878,35	704,86	332	6080
Parks on the zone	Parks	112	48,32	35,19	1	171
Establishments promoting Welfare	Social Welfare	112	63,25	63,83	0	288
Establishments provinding Health	Health	112	3,53	3,24	0	15
Schools	Schools	112	32,76	25,08	0	135
Cultural Establishments	Cultural	112	8,12	8,18	0	40
Establishments promoting Sport and Recreation	Recreation	112	11,42	9,38	0	47
Neighborhoods of each zone	Neighborhoods	112	181,16	105,28	1	526
Working Force	W_Force	112	28543,31	39705,63	0	257862
Micro-enterprises	MiE	112	2584,13	2487,72	12	13826
Small-Medium Enterprises	SME	112	123,19	195,25	0	1674
Large Enterprises	LE	112	26,79	48,35	0	427

Source: Encuesta de Calidad de Vida para Bogotá (ECV) 2007. Secretaria de Planeación del Distrito de Bogotá; Secretaria de Movilidad del Distrito; author calculations.

An emphasis has to be made regarding job accessibility. The index for job accessibility was calculated following the methodology of Prud'Homme and Lee (1999). As stated elsewhere in this research, I define “job accessibility” as what Prud'Homme and Lee call “The effective size of labour market”. This theory is based on the assertion that the labour market is a function of the commuting time from inhabitants’ homes to zones where people work. With that methodology we are able to estimate the number of jobs they can reach in a specific time. My calculations take into account trips made by inhabitants on private and public transport.

While the subject of this study is analysis of the endogeneity and possible causality of enhancement of the public transport system on the other variables we proposed, I suppose that private cars also benefit from those improvements. In fact, improvement to the public

transport system, and more precisely the construction of Transmilenio, is also produced by an upgrading of corridors alongside Transmilenio corridors. Since the construction of TM, congestion on roads along TM corridors has decreased and the average speed has increased. Improvement of public transport produced by the construction of TM also improves travel by private car and taxi. Nevertheless, I focus my research only on travel made on public transport.

Information on socio-economic indicators such as employment, workforce, income, population and area were taken from the census conducted by the city's department of planning in 2007<sup>49</sup>. We could not use more recent information because the city hall has not completed censuses for subsequent years.

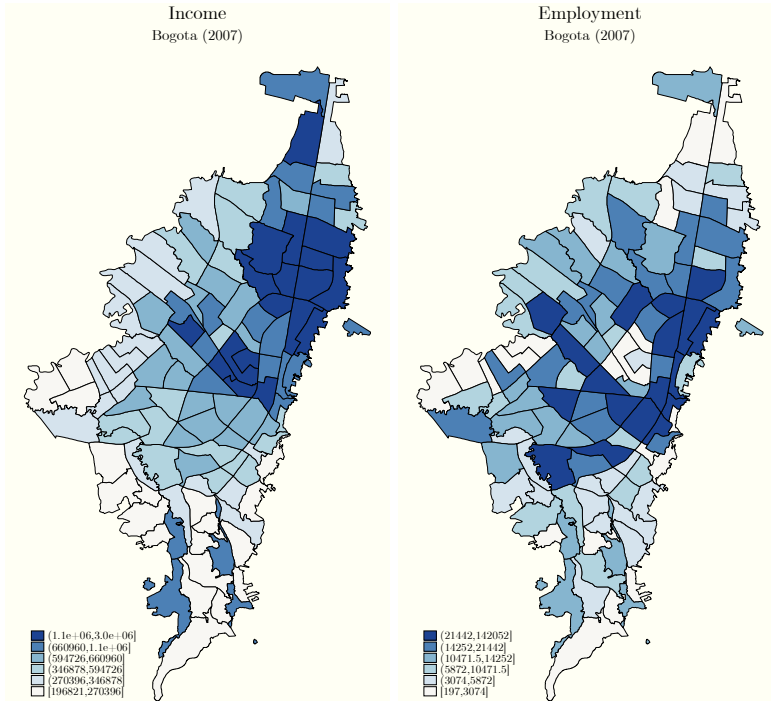
Data about the number of Transmilenio stations and lines within or bordering each zone were calculated by the author. To make those calculations, maps of the city were created, featuring the boundaries of each planning zone and the streets passed by Transmilenio. Stations within each zone were considered stations of only this zone. Stations on the border between two or more zones were considered stations belonging to both zones because both zones benefit from the station.

To complete our model I took into consideration other control variables such as the total number of men, the number of neighbourhoods in each zone and the number of cars per household. Additionally, variables describing some infrastructural characteristics and amenities of zones were taken into consideration: the number of parks, the number of schools and the number of establishments providing welfare, sport, recreation and cultural events in each zone, as well as the number of establishments providing health care, also make up part of the model.

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<sup>49</sup> Encuesta de Calidad de Vida para Bogotá (ECV) 2007. Secretaria de Planeación del Distrito de Bogotá.

Figure 2.1: Income and Employment configuration of Bogota



Author calculations based on data from Planning Department  
(Secretaria de planeacion del Distrito)

Figure 1 shows a disproportionate configuration of employment and income in the city. It is easy to identify the axes where jobs and income are concentrated<sup>50</sup>. Two different “job centres” are connected on the same two axes. The city’s highest incomes are concentrated in two zones. These can be distinguished and they are also reliable on the same axis than the two jobs centres. This axis has the particularity that it benefits from the presence of TM. A third job axis is also placed alongside another Transmilenio axis. Regarding the other zones with high levels of income, they are not very far from the TM corridor that goes from the centre to the west of the city.

Additionally, jobs are condensed far from the boundaries of the city (with the exception of the East border). Even if we see that job centres are placed at the centre-east border of the city, this border was always considered as the “centre”. Executive and almost the 100% of administrative buildings are place on that zone. Furthermore, is in that place

<sup>50</sup> Configuration of *ESLM* depending on travel time can be found on annex 4

where Bogota was founded and it could not be expanded to the East because of the presence of a big chain of mountains (Los Cerros Orientales). The expansion of the city took place essentially to the south and the north of the city and more recently to the west of the city.

Following the results of a poll made by the administration in 2005, most work travel moves from the "far" north, the south and the west to these four job centres. These are the zones with the lowest income in the city, with the exception of one zone in the north, where people with high purchasing power settled a few years ago, seeking to be far from the noise and pollution of the city.

The "centre" of the city condensed more than 50% of jobs in the city and according to the poll, most of the people commuting to this zone of the city come from the north of the city. Others travel from the north-west, the west and the south and south-west of the city.

Apparently, this configuration of Bogotanians' jobs and income of can be directly related to the enhancement of the public transport system.

The next section will focus on analysis of this possible strong relationship. Results of the models proposed in section 2 will provide some elements supporting knowledge of the existence and magnitude of this relation.

## 2.4 Results and discussion

As stated above, analysis of the correlation matrix and the variance inflation factor (VIF) of all models is recommended.

The correlation matrix<sup>51</sup> shows important relationships between some variables<sup>52</sup>, in particular the variables "Population" and "Schools". In effect, the population has correla-

<sup>51</sup> Annex 1.

<sup>52</sup> We consider as important, correlations upper 0.50.



tions above 0.50, with almost all the variables representing the characteristics or the amenities of each zone. These correlations can be interpreted as reasonable. In effect, the higher the population is, the more zones will need schools, parks, recreational facilities and sporting establishments. Likewise, if the population is bigger, it can be expected that the number of neighbourhoods will be greater as equal as the area of the zone. In despite of this, correlations just represent some control variables and not make part of the core of our analysis, it let infer that these correlations will not affect the estimations.

Nevertheless, the greater correlation is between the number of schools in zones and the number of establishments promoting sport and recreation (0.81). This is predictable if we consider that the most of the schools in Bogotá are public. They usually use the infrastructure of the zones (parks, and recreation establishments) for students' recreation and sporting activities.

Another important correlation that relates to the goal of this study is between employment and improvement of public transport (number of stations); they have a correlation index equal to 0.56. It can be also awaited but it seems not to be a problem of multicollinearity if we consider that VIF is smaller than 10. It could also represent an additional argument to suggest that transport improvements directly affect the number of jobs (model 3).

Other correlation indices above 0.50 are found. The big indices are principally between amenities variables, which is not very surprising and will not be a source of evils. None of those variables explain each other.

On the other hand, and as indicated previously for some relations between variables, regarding (VIF), no problems have been detected in the models<sup>53</sup>. On every model it is found that  $VIF < 10$ , which means that multicollinearity is low and dependent variables are uncorrelated with predictor variables.

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<sup>53</sup> Annex 2.

The following section will present the results of OLS estimations and 2SLS estimations.

### 2.4.1 OLS Results

As noted previously, for the first stage of the analysis, each model – depending on the effective size of the labour market – is regressed three times, in accordance with the three intervals of times. Table 2 shows results for the three models. There are three different results for models 1 and 2 and one result for model three.

#### Model 1: Effective Size of Labor Market

Regarding model 1, results show a not negligible  $R^2$  for each travel time, which goes from 0.583 when travel time is 40 minutes to 0.615 when travel time is 60 minutes. Taking into account the analysis of the correlation matrix and also the analysis of the VIF, it can be said that the model explains in an acceptable proportion the dependent variable.

Regarding regressors, table 2 suggests that *improvement* has a positive and big effect on the level of the effective size of labour market. In effect, for a time period of 40 minutes, the number of Transmilenio stations seems to boost the size of the labour market of inhabitants of zone  $i$  on 15,200 jobs. Furthermore, for time intervals of 50 and 60 minutes, the presence of Transmilenio improvements in the zone has a positive relationship with the size of the labour market in the order of 20,314 and 21,388 jobs respectively. These three results are significant at the 0.05 level, which is not negligible.

Regarding income on each zone, it is also shown that it has a positive impact on the size of the labour market, which was predictable. The higher the income is, the higher will be the size of the labour market, because inhabitants may choose to live in a neighbourhood that is closer to their workplace. Nonetheless, in model 1, income seems not to have a significant impact on *ESLM*.

Another variable that appears to significantly impact the *ESLM* is the mean distance between inhabitants' homes and their jobs. This variable has a negative impact on the number of jobs reachable within these intervals of time. For the three different time periods, estimators of mean distance between reachable jobs and houses are significant at the 0.01 level. Additionally, its influence on the level of *ESLM* looks to be very important. Actually, an additional kilometre of mean distance reduces the *ESLM* by 5% and 10% for any interval of time. It may seem strange but it can be considered normal. In effect, concerning the *ESLM*, results confirm the fact that, when individuals live far from their jobs, the number of reachable jobs relevant to their skills in the zone where they live may decrease. This means that the size of the labour market for people decreases if their jobs are far from their houses.

The variable *Area* is another variable that seems to be significant from a statistical point of view. In effect, table 2 shows that for any interval of time, it is significant at a 0.05 level. Nevertheless it has always, a negative sign which can be estranged. Actually, regarding the area of the zone and its negative relationship with the size of the labour market for each population living in each zone, we can suggest that it could be because jobs and income are concentrated, in a big proportion, on small zones which are placed close to the job centres, while the biggest zones are placed at the periphery of the city. People living in the biggest zones are those with smaller levels of income and are farther from job centres. In parallel, the bigger the area of each zone, the higher the number of neighbourhoods will be; that may also be the reason for the negative sign of the neighbourhoods parameter.

Table 2.2: OLS results for each interval of time

	SLM			Income			Employment
	slm 40	slm 50	slm 60	income 40	income 50	income 60	
Intercept	711,644.313*** (79,704.801)	1045928.176*** (97,313.955)	1313650.550*** (97,115.364)	-136,230.614 (312,658.436)	-134,996.960 (344,254.457)	-209,878.949 (394,996.977)	-3,632.736 (5,667.080)
Improvment	15,220.654** (7,523.774)	20,314.682** (9,185.999)	21,388.184** (9,167.252)	25,161.388 (22,197.682)	26,034.941 (22,362.994)	25,842.513 (22,434.205)	3,274.915*** (534.947)
Job_Accessibility				0.450 (0.292)	0.307 (0.241)	0.301 (0.242)	
Income	0.053 (0.034)	0.054 (0.042)	0.052 (0.042)				0.010*** (0.002)
Population	-0.362 (0.723)	-0.324 (0.883)	-0.441 (0.881)	-3.854* (2.069)	-3.949* (2.074)	-3.918* (2.077)	-0.037 (0.051)
Area	-262.545** (121.573)	-385.040** (148.432)	-388.453** (148.130)	336.586 (360.452)	338.087 (365.529)	337.181 (365.922)	21.047** (8.644)
Mean_dist	-35,218.349*** (7,161.193)	-45,881.804*** (8,743.313)	-50,838.129*** (8,725.470)	6,305.226 (23,276.488)	4,437.753 (23,691.774)	5,676.773 (24,299.335)	-408.308 (509.167)
Car owners	-3.859 (3.465)	-1.873 (4.231)	-0.770 (4.222)	8.649 (10.107)	7.539 (10.101)	7.201 (10.099)	0.229 (0.246)
Aver Cost	59.329** (26.480)	75.797** (32.331)	86.296*** (32.265)	230.366*** (75.460)	235.832*** (75.799)	233.249*** (76.579)	0.221 (1.883)
Parks	-322.012 (713.883)	-781.846 (871.601)	-151.965 (869.823)	4,351.384** (2,031.430)	4,478.577** (2,043.390)	4,287.399** (2,039.829)	-89.009* (50.758)
Social Welfare	-933.344** (385.331)	-1,140.505** (470.462)	-1,007.571** (469.502)	-2,465.939** (1,126.882)	-2,558.896** (1,129.365)	-2,607.019** (1,121.241)	-7.563 (27.397)
Health	-2,964.688 (5,759.372)	-3,710.037 (7,031.788)	-2,941.590 (7,017.438)	-18,035.172 (16,677.106)	-18,382.453 (16,739.421)	-18,646.856 (16,733.046)	234.778 (409.496)
Schools	1,053.693 (1,644.851)	1,486.035 (2,008.247)	1,243.575 (2,004.149)	-4,910.330 (4,769.123)	-4,925.664 (4,790.947)	-4,847.548 (4,789.328)	-32.605 (116.950)
Cultural	-1,027.805 (3,163.854)	85.714 (3,862.843)	-1,576.168 (3,854.960)	17,458.404* (9,036.689)	17,100.412* (9,074.786)	17,612.816* (9,075.872)	984.440*** (224.953)
Recreation	5,871.716* (3,270.352)	5,689.958 (3,992.870)	5,259.589 (3,984.722)	15,048.130 (9,549.043)	16,084.718* (9,510.627)	16,256.850* (9,496.559)	16.487 (232.525)
Neighborhoods	-649.501 (516.125)	-765.556 (630.153)	-1,110.307* (628.867)	638.618 (1,512.266)	583.495 (1,517.503)	683.448 (1,530.195)	-51.926 (36.697)
Obs	112	112,00	112	112	112	112	112
R <sup>2</sup>	0.583	0.598	0.615	0.436	0.432	0.432	0.609

Author calculations

The estimator for the variable Average cost, which represents the average cost of travel that people have to pay to reach their job, appears with a positive sign on table 2. Moreover, this estimator is significant at a 0.05 level with any travel time. It suggests that the more I pay for transport to reach my job, the higher will be the size of my labour market. It could also be expected if we consider that the price to be paid for use of the public transport we consider in this study (Transmilenio) is higher with respect to the other kind of public transport services, excepting taxis. Additionally, all Transmilenio lines were constructed on an axis passing by job centres, which makes Transmilenio the more expensive but, at the same time, the quicker transport system to reach job centres.

Regarding amenities in the zones, table 2 shows that four variables seem to have a negative effect on the *ESLM* and two variables have positive impacts. Among these six amenities, just one has a significant influence on the dependent variable. *SocialWelfare* has, for the three intervals of time, a negative influence on dependent variable with a significance level of 0.05. It may be because this variable denotes the number of establishments like nursing homes, rehabilitation centres, orphanages and establishments promoting the welfare of inhabitants with some problems interacting with society. In that vein, this kind of establishment may not have a positive effect on the labour market because it requires a lot of space in the zone and employs fewer people than companies carrying out other activities. As with *SocialWelfare*, estimators of variables *Parks* and establishments promoting cultural activities, *Cultural*, have a negative incidence on the *ESLM* but do not have significant influence on the dependent variable. Reasons may be the same as for *SocialWelfare*. *Parks* and *Cultural* take a lot of vital space in the zone and avoid the construction of roads, lines of transport systems and job centres.

Regarding establishments providing health services, *Health*, results show that they has a negative impact on *ESLM*. This seems to be counterintuitive because hospitals and health centres are supposed to create jobs. It suggests that the decision to construct hospitals in the city depends on the available area in each zone. In effect, zones where job centres are situated do not have as many areas available for construction of hospitals as the peripheral zones do. In addition, the expensiveness of domiciliary public services on jobs centres could also influence this relationship.

In summary, if a comparison of estimators of all variables is made, it can be said that the variable that most influences *ESLM* is Improvement. In addition, its influence increases with respect to the commuting time, meaning the greater individuals' commuting time, the greater will be the influence of public transports improvement on the effective size of the labour market.

In opposition, the other variable that has a significant but negative impact on the *ESLM*, with a statistical significance of 0.01, is the mean distance that people have to

commute to their jobs. As with *improvement*, *Mean\_dist* increases with commuting time, which is expected. The higher the mean distance commuted by people, the lower the *ESLM* of inhabitants living on origin zones.

### Model 2: Level of Income

Results for model 2 are also divided into three because one of the regressors is *ESLM* and it varies with respect to commuting time. On the other hand, while influences of some estimators are not different from model 1, there are also five big differences that have to be remarked upon.

First of all, the variable *Improvement* has a big influence on the level of income of inhabitants of each zone. This suggests that the higher the presence of public transport improvements, the greater will be inhabitants' income. This relationship can be interpreted from two different points of view. In effect, it is not false to suggest that the presence of Transmilenio can boost the income of inhabitants. On the other hand, it can also be said that people with greater levels of income choose to live in zones where there is more improvement of urban transport. Nevertheless, it is clear that the impact of improvement of urban transport on the level of inhabitants' income cannot be denied. However, while the improvement estimator is the one that has the largest influence on the level of income, it also has a problem in the OLS results: it is not statistically significant. It represents another additional reason to carry out the 2SLS analysis in section 4.2.

The other difference between model 1 and model 2 is that the estimators for *Area*, *Mean\_Dist*, *Parks*, *Cultural* and *Neighbourhoods* are not negative but positive. First of all, regarding the area of the zone, it indicates that the bigger the zone, the greater the average income. This relationship is expected. In effect, as suggested by Anas (1990), Glaeser, Kahn and Rappaport (2000) and other researchers, rich people sometimes prefer to live in suburbs or on zones far from the city to avoid the noise and the congestion of job centres. Additionally, in suburbs or zones far from the centre, rich people find more

space to live or to construct bigger houses than those that they find downtown or near job centres. In parallel, amenities they prioritize, aside from housing space, are safety, calm (no noise or pollution), large green spaces to do sport and for their children to play in and proximity to nature, in spite of the need to consider proximity to their jobs or to the centre of the city. This is the reason for the large and positive influences of estimators for *Parks*, *Recreation*, *Cultural* and *Neighbourhoods*, of which *Parks* and *Cultural* are those that are statistically significant, at 0.05 and 0.1 respectively.

Regarding the *Cultural* estimator and establishments promoting cultural activities, it could be interpreted that cultural manifestations like theatre, opera and concerts, among others, are not affordable for people with a limited income. Those kind of cultural expressions are revealed to be expensive, preventing accessibility by people with a limited budget; that could be the reason for the positive and statistical significance of this estimator on income.

In contrast, *SocialWelfare*, *Health* and *Schools* have a negative and not negligible influence on the level of income, but only *SocialWelfare* is statistically significant (0.05). It can be interpreted as meaning that if there are more hospitals, schools, rehabilitation centres or nursing homes, this may lead to congestion; the calm of the zone can be affected and people with bigger incomes may not be incentivized to live near those kinds of establishments. The easiest and best solution for people with high incomes is to live in distant and expensive suburbs with small density and with fewer establishments promoting health, social welfare or schools. In opposition, people with low incomes also decide to live far from the city and job centres, but in suburbs or zones with high density and important concentrations of hospitals, schools and establishments providing social welfare. Likewise those variables, the negative and statistically significant (0.01) impact of the variable *Population* is explained.

Finally, the other variable that reveals a statistically significant impact on the level of income is *Aver\_Cost*; this is also expected because if rich people decide to live far from

their jobs, they will be pushed (voluntarily) to expend more money to commute from their houses to their jobs.

As in model 1, model 2 reveals that the variable with more influence on the dependent variable is the level of improvement of public transport in each zone. Nevertheless, with respect to the level of income, this variable is not significant from a statistical point of view, and this leads us to the 2SLS analysis in section 2.2.

### **Model 3: Number of jobs**

Model 3 shows the influence of some explanatory variables on the number of jobs in each zone of the city. This model is measured with respect to the same independent variables as in model 1, but there is just one result because it does not depend on *ESLM*. Subsequently, even if the results are similar, there are also some important differences that should be clarified.

The first difference is that income is now statistically significant, at 0.01, which was not the case in model 1. This may suggest that the number of jobs will be bigger in zones where income is higher, but it also may be proposed that enterprises or companies settle in zones or near zones where income is higher (Zenou, 2000, 2008; Ross, 1998; Kain, 1968).

Secondly, table 2 shows that the area of the zone has a positive and a statistical significance (0.05) to the number of jobs in each zone. The bigger the zone, the more jobs there will be in the zone. This result is the opposite from what was found in model 1, because model 1 tries to determine the impact of the area of the zone on the inhabitants' number of reachable jobs. What was suggested in model 1 was that area has a negative impact on *ESLM*; this is very different if the dependent variable is the number of jobs in each zone. *ESLM* takes into account reachable jobs for each inhabitant with respect to their skills and employment refers to all kinds of jobs in each zone. So, this could be the reason for this differing relationship between models.



Another regressor that is significant from a statistical point of view is the number of parks in each zone. This variable has a negative influence on the number of jobs in each zone, which is logical because the more parks in each zone, the less available space there will be for the settlement of enterprises in the zone will be.

Fourthly, establishments promoting cultural activities seem to boost – and to create a significant amount of – the number of jobs in each zone. This result suggests that cultural activities are an important source of employment for the city, equal to establishments providing health care. *Schools* seems to have the opposite effect to *Health* or *Cultural*.

Aside all other results which are similar and could be read like those in model 1, the most important to note is that the variable with the bigger impact on the number of jobs on each zone is, once again, the number of Transmilenio stations. In addition to this, the estimator of this variable is significant at 0.01 level, which demonstrates the great dependence of employment on improvements to public transport. It could signify that the number of employment grows by 3.274 if an additional Transmilenio station is built in a specific zone. However, it could also denote that enterprises decide to settle in zones with high levels of improvement to public transports and great levels of accessibility (Fernandez, 2008; Kawabata, 2003).

On the three precedent models, table 2 shows that the variable *improvement* has always a big and almost the greater influence on the dependent variable, regardless of commuting time, when the variable ESLM is part of the model. Nonetheless, regarding the statistical significance, this variable is not significant in model 2.

2SLS analysis is then necessary to verify if the results of these models are not forgetting instruments that can determine or influence the number of Transmilenio stations on each zone. In other words, 2SLS analysis will let us verify if there exists an endogenous relationship between dependent variables of the three models and the variable *improvement* and, therefore, a causal relation between the number of stations in each zone and the dependent variables of each model.

### 2.4.2 2SLS Results

As defined in section 2.2, the third stage of this analysis is focused on the identification of endogeneity between the level of public transport and dependent variables. As for OLS results, it is essential to clarify that models 1 and 2 have three results depending on the commuting time.

Additionally, the three models will also be regressed three times according to the definition of the Instrument Variable (*IV*). In effect, it is suggested that the decision to construct a Transmilenio station in a zone depends directly on the density, the workforce and the number of enterprises on each zone<sup>54</sup>. In that vein, the size or the number of employees of enterprises based in each zone should be taken into account and should be differentiated. For that reason, this study proposed three different regressions of each model regarding the definition of the *IV* and in accordance with the size of companies established in each zone.

#### **Enhancements of PT defined by the number of microenterprises on zone i.**

Results presented in this subsection correspond to models 1, 2 and 3 when the VI is defined by the density, the workforce in each zone and the number of microenterprises in each zone.

First of all, table 3 shows that every estimator has the same relationship (sign) and the same statistical significance for model 1 than on OLS results. Improvement is the variable that has the higher positive and statistical influence on the size of the labour market in each zone. In parallel, the mean distance between houses and jobs is the variable that has the higher negative and statistical impact on the dependent variable. Although there is a similarity between OLS and 2SLS results for model 1, the impact of the number of stations on the size of the labour market is 50% higher with respect to OLS model results. Following

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<sup>54</sup> See section 2.2 for definition of what it was called Microenterprises, Middle size enterprises and Large enterprises

this observation, it is suggested that when improvement is treated as an  $IV$  depending on the number of microenterprises, its impact on the dependent variable increases by 50%.

Table 2.3: 2SLS results for each interval of time when:

$$impro = \pi_0 + \pi_1 W F_i + \pi_2 M i E_{si}$$

	SLM			Income			Employment
	40 minutes	50 minutes	60 minutes	40 minutes	50 minutes	60 minutes	
Intercept	703,963.433*** (76,209.254)	1031718.345*** (93,583.480)	1302852.910*** (93,355.711)	-121,333.320 (314,339.274)	-108,458.695 (323,163.063)	-159,857.237 (372,672.907)	-10,059.739 (6,948.676)
Improvment	22,117.543* (12,173.235)	32,521.548** (14,948.495)	31,071.155** (14,912.112)	40,792.818 (38,949.393)	41,285.053 (36,786.388)	43,053.538 (36,908.604)	7,588.386*** (1,109.942)
SLM				0.394 (0.306)	0.258 (0.236)	0.243 (0.238)	
Income	0.047 (0.033)	0.043 (0.041)	0.044 (0.040)				0.007** (0.003)
Population	-0.441 (0.671)	-0.423 (0.824)	-0.578 (0.822)	-3.634* (2.060)	-3.729* (1.922)	-3.694* (1.925)	-0.012 (0.061)
Area	-0.020** (0.010)	-0.029** (0.012)	-0.028** (0.012)	0.025 (0.031)	0.024 (0.029)	0.024 (0.029)	0.002** (0.001)
Mean_dist	-36,208.470*** (6,614.546)	-47,168.293*** (8,122.534)	-52,548.061*** (8,102.765)	6,706.096 (23,290.065)	4,535.453 (22,132.616)	5,150.545 (22,823.788)	-177.267 (603.107)
Car owners	-3.272 (3.307)	-0.892 (4.061)	0.086 (4.052)	9.093 (10.239)	8.080 (9.555)	7.885 (9.574)	0.484 (0.302)
Aver Cost	59.490** (24.888)	76.436** (30.562)	86.289*** (30.487)	236.064*** (75.742)	241.762*** (70.807)	240.669*** (71.623)	0.977 (2.269)
Parks	-324.728 (671.884)	-774.181 (825.060)	-159.629 (823.052)	4,440.929** (2,038.148)	4,544.679** (1,907.578)	4,388.467** (1,905.703)	-62.548 (61.262)
Social Welfare	-905.372** (362.732)	-1,094.140** (445.428)	-966.178** (444.344)	-2,472.263** (1,130.620)	-2,569.331** (1,053.969)	-2,614.283** (1,047.196)	4.153 (33.074)
Health	-3,834.870 (5,490.552)	-5,175.738 (6,742.291)	-4,215.141 (6,725.881)	-19,269.376 (17,005.259)	-19,584.524 (15,888.868)	-19,986.315 (15,885.761)	-174.459 (500.622)
Schools	763.630 (1,588.269)	979.882 (1,950.364)	839.208 (1,945.617)	-5,357.926 (4,889.940)	-5,340.447 (4,567.202)	-5,325.691 (4,571.254)	-191.838 (144.817)
Cultural	-353.538 (3,065.944)	1,227.071 (3,764.920)	-595.260 (3,755.757)	18,263.733* (9,293.874)	17,930.487** (8,707.936)	18,462.362** (8,684.017)	1,309.516*** (279.549)
Recreation	5,340.337* (3,202.302)	4,722.659 (3,932.365)	4,513.505 (3,922.794)	13,805.633 (9,940.897)	14,835.026 (9,245.787)	14,872.610 (9,239.208)	-385.920 (291.982)
Neighborhoods	-699.074 (482.502)	-834.504 (592.503)	-1,196.246** (591.061)	660.919 (1,516.013)	603.795 (1,415.777)	677.960 (1,432.348)	-52.580 (43.994)
Endogeneity - Wu - Hausman F Test	0.44933	0.94049	0.58849	0.22424	0.20373	0.25837	48.18274***
Sargan	3.337	4.646*	1.956	4.002	4.158	4.459	2.690
Heterocedasticity	19.211	18.153	15.928	36.676 ***	36.388 ***	34.986 ***	19.623
R <sup>2</sup>	0.576	0.586	0.605	0.432	0.428	0.427	0.346

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Author calculations

Regarding the endogeneity analysis, table 3 reveals that even if the number of stations in each zone remains significant and greater than in OLS regressions, and even if there is no problem regarding the choice of instruments that explain  $IV$ , the variable improvement is not endogenous to the size of the labour market. This result is counterintuitive to the

objective that this investigation tries to demonstrate but one fact is salvageable, which is that when improvement is considered as a *IV*, its statistical significance and its impact on *ESLM* increase by 50%.

Concerning model 2, 2SLS results are not significantly different from those found in OLS estimations. Similarly, relationships between variables are respected and every estimator preserves the same sign, the same statistical significance and almost the same level. It means that the number of stations in each zone is not yet statistically significant but their effect on *ESLM* is almost 70% higher than in the OLS models.

As in the previous model, selected instruments do not have problems of over-identification but the analysis of endogeneity displays that “improvement” is not endogenous to the income of each zone’s inhabitants. It was not what the study had expected and it will be explained at the end of all 2SLS results’ discussion.

Results for model 3 are slightly different. Variables such as *income*, *Population*, *Aver\_Cost* and *Car\_owners* preserve the same impact and the same statistical inference on the dependent variable as in OLS results. Likewise, the mean distance between homes and jobs has the same relationship as in the OLS model but its influence on independent variable increases by 100%. In addition, even if the variable *Area* has the same statistical influence (0.05) on the number of jobs as in the OLS model, its “real” impact is marginally (0.002) contrary to the number of parks on each zone that is no longer statistical significant but its real influence on employment is also negligible. The other group of variables does not have a significant influence on the number of jobs in each zone, with the exception of two variables that are very significant and that have a notable influence on the number of jobs.

The two regressors that have a significant effect on employment in each zone are the number of establishments promoting cultural activities and the number of stations in each zone. Regarding *Cultural*, its statistical significance is high (0.01). This result could signify that the implantation of one additional establishment promoting cultural activities

could raise by 1.309 the number of jobs in each zone. On the other hand, this result could be interpreted differently; the target population of that kind of establishment could be employees, but this study does not have more enough information to make this statement.

With respect to the number of stations, as in the OLS results, it can be observed that this is the regressor with the greater effect on the explained variable. When *improvement* is considered as endogenous and when it depends on the number of microenterprises, its influence on the number of jobs in each zone is double that of the OLS model. In addition, its statistical significance is still very high (0.01). In effect, an additional station in each zone is supposed to boost the number of jobs by 7,560. Besides, it can also be supposed that Transmilenio stations were built with the aim to be close to employment centres. Neither hypothesis moves away from the goal of this analysis, which is to demonstrate the causal relation between the number of jobs in each zone and the level of improvement to public transports.

Regarding this statement, endogeneity test reveals that *improvement* is endogenous to the number of jobs on each zone. In other words, the number of Transmilenio stations is endogenous with respect to the number of jobs. This result implies that the hypothesis is verified, which enables us to prove the following hypothesis:

$$\begin{aligned} H_0 : \rho(improvement) &= 0(exogeneity) \\ H_1 : \rho(improvement) &= 0(endogeneity) \end{aligned}$$

The p-value of Wu-Hausman F test is statistically significant (0.01), which leads to rejecting the null hypothesis of exogeneity,  $H_0$ . The endogeneity in the relation between *improvement* and the number of jobs in each zone is demonstrated.

This result is even truer if, the test of over-identifying restrictions, “Sargan N\*R-sq test”<sup>55</sup>, and heteroscedasticity test (Pagan-Hall <sup>56</sup>) are taken into consideration. In fact,

<sup>55</sup> The joint null hypothesis is that the instruments are valid instruments, i.e., uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of (L-K) overidentifying restrictions. A rejection casts doubt on the validity of the instruments.

<sup>56</sup>  $H_0$  : Disturbance is homoscedastic

those tests demonstrate that instruments have no problems of over-identification and heteroscedasticity (no rejection of null hypothesis). This means that instruments are exogenous and the residuals of the main model are uncorrelated with the set of instrumental variables. Instruments were well chosen.

Considering results for models 1 and 2, OLS results appear to be consistent. In effect, *improvement* is not endogenous when it is regressed depending on density, working force and microenterprises. By contrast, OLS results are not consistent for model 3. In fact, suspicions of endogeneity of *improvement* are corroborated, which represents an undeniable causality relation from enhancement of urban transport to the number of jobs when the number of stations are defined by microenterprises.

#### **Improvement regressed with respect to “small and middle size” enterprises**

Results presented in this subsection correspond to models 1, 2 and 3 where the variable suspected to be endogenous is defined by the density, the work force in each zone and the number of middle-size enterprises in each zone.

Results for model 1 express exactly the same relationships as in the previous subsection. This means that there is no evidence to reject the use of instrumental variables on the model. In effect, Sargan test shows that there is no over-identification of instrumental variables likewise with the heteroscedasticity test that confirm that the variables are homoscedastic. Nevertheless, as in the previous model, Endogeneity – Wu-Hausman F test allows to accept null hypothesis of exogeneity; the number of stations on each zone of the city are not endogenous on the effective size of labour market. Taking into account those previous observations, it can be confirmed that OLS results are consistent for model 1.

In contrast, the results for model 2 suppose different interpretations. The variable *Population* continues to have the same impact on the dependent variable but it ceases to have statistical significance; also, *Social\_Welfare* preserves its influence on Income but

is no longer significant at 0.05; rather it is at 0.1. On the other hand, establishments providing health services increase their negative influence on the level of income by 70% more than when *improvement* is defined by *SME*. Additionally, this variable has a statistical significance of 0.1, which is not very representative but suggests that if the number of middle-size enterprises is taken into account at the moment to define the variable improvement, an additional establishment providing health in the zone will lower the income of inhabitants by 34.500 COP<sup>57</sup>. It represents a decrease of 8%<sup>58</sup> of the minimum wage established by the government on 2007. These results could suggest that inhabitants with higher incomes prefer to live in zones with few promoters entities of health. The income of inhabitants living in zones with several promoter entities of health is 34.500 COP lower than that of inhabitants of zones with few of those kinds of establishments, which represents 8% of minimum wage for that year.

Regarding the number of Transmilenio stations in a zone and their effect on the level of income, table 4 reveals that this influence is notable. In effect, results suggest that one additional Transmilenio station will boost the income of inhabitants by 197.000 COP<sup>59</sup>, which represents 28% of the average wage of a citizen and 45% of the minimum wage decreed by the Colombian government in 2007<sup>60</sup>. But this result could also be interpreted as meaning that people that live in a zone with one more station than another zone will have an income 197.000 COP higher. This has a statistical significance of 0.01. In addition, results show that the variable *improvement* is endogenous and that there is no evidence against the veracity of instruments used on the model. On the same way, instruments do not present problems of heteroscedasticity.

Previous results affirm the hypothesis that when *improvement* depends on the density of the zone, the workforce of the zone and the number of “middle-size” enterprises,

<sup>57</sup> COP: Colombian Pesos. The exchange rate on 2007 was: 1 USD = 2078 COP; 34.500 COP = 16.6 USD

<sup>58</sup> The minimum wage represents the minimum wage that a worker have to be paid monthly; on 2007, the minimum wage in Colombia was 433.700 COP = 208 USD.

<sup>59</sup> 197.000 COP = 95 USD on 2007.

<sup>60</sup> See table 1: Average wage per month for 2007 at the city Bogota was 687.235 COP which on dollars of 2007 is 331 USD.

there is a causal relationship between the enhancement of public transport and the level of income of inhabitants.

Table 2.4: 2SLS results for each interval of time when:

$$impro = \pi_0 + \pi_1 WF_i + \pi_2 SME_{si} + u$$

	SLM			Income			Employment
	40 minutes	50 minutes	60 minutes	40 minutes	50 minutes	60 minutes	
Intercept	708,406.951*** (76,485.215)	1032649.269*** (94,123.698)	1295251.120*** (94,719.511)	-39,144.142 (367,614.009)	64,556.348 (407,977.334)	139,053.591 (472,640.016)	-15,271.339 (9,751.496)
Improvment	19,046.838	31,878.230*	36,324.391**	193,049.558*** (51,658.167)	196,398.682*** (52,688.143)	197,621.601*** (53,398.809)	11,189.875***
SLM	(13,579.695)	(16,711.348)	(16,817.133)	-0.042	-0.129	-0.159	(1,731.346)
Income	0.049 (0.033)	0.044 (0.041)	0.040 (0.041)	(0.364)	(0.304)	(0.307)	0.005 (0.004)
Population	-0.453 (0.670)	-0.425 (0.824)	-0.558 (0.829)	-2.948 (2.410)	-2.999 (2.423)	-3.039 (2.430)	0.002 (0.085)
Area	-0.020** (0.010)	-0.030** (0.012)	-0.028** (0.012)	0.028 (0.036)	0.025 (0.037)	0.025 (0.037)	0.002* (0.001)
Mean_dist	-36,304.776*** (6,597.005)	-47,188.469*** (8,118.360)	-52,383.304*** (8,169.750)	-3,876.159 (27,272.652)	-8,445.628 (27,954.481)	-10,747.558 (28,905.269)	-64.314 (841.086)
Car owners	-3.463 (3.319)	-0.932 (4.084)	0.413 (4.110)	16.128 (12.020)	16.175 (12.106)	16.338 (12.157)	0.707* (0.423)
Aver Cost	59.005** (24.830)	76.334** (30.556)	87.119*** (30.750)	263.892*** (88.634)	272.159*** (89.315)	276.431*** (90.516)	1.546 (3.166)
Parks	-341.290 (670.627)	-777.651 (825.282)	-131.297 (830.506)	4,736.085** (2,382.514)	4,665.679* (2,402.630)	4,746.860** (2,403.754)	-43.124 (85.502)
Social Welfare	-914.176** (362.040)	-1,095.984** (445.532)	-951.116** (448.352)	-2,214.583* (1,322.035)	-2,327.799* (1,328.025)	-2,343.030* (1,321.256)	14.479 (46.158)
Health	-3,532.719 (5,506.433)	-5,112.437 (6,776.288)	-4,732.048 (6,819.183)	-33,668.621* (20,008.288)	-34,241.089* (20,151.585)	-34,309.575* (20,177.473)	-528.838 (702.044)
Schools	878.794 (1,599.799)	1,004.009 (1,968.733)	642.191 (1,981.195)	-10,110.038* (5,765.620)	-10,031.781* (5,802.116)	-10,044.785* (5,819.265)	-326.908 (203.967)
Cultural	-592.708 (3,093.157)	1,176.964 (3,806.479)	-186.098 (3,830.575)	28,044.848** (10,974.733)	28,278.183** (11,094.413)	28,076.871** (11,070.517)	1,590.028*** (394.363)
Recreation	5,621.119* (3,240.725)	4,781.483 (3,988.079)	4,033.156 (4,013.324)	1,418.761 (11,786.867)	1,867.156 (11,832.242)	1,960.132 (11,853.673)	-715.235* (413.177)
Neighborhoods	-696.189 (481.055)	-833.899 (591.992)	-1,201.182** (595.740)	186.329 (1,773.443)	110.003 (1,784.926)	26.772 (1,809.478)	-55.965 (61.332)
Endogeneity - Wu - Hausman F Test	0.10503	0.61123	0.99825	23.88448***	23.52866 ***	23.15102***	432.31390 ***
Sargan	4.229	5.052*	1.694	0.898	0.907	0.973	0.496
Heterocedasticity	19.863	18.270	15.567	17.900	17.902	17.916	9.486
R <sup>2</sup>	0.579	0.5869	0.598	0.104	0.093	0.089	-0.270

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Author calculations

Regarding the variable *Mean\_Distance* and comparing its estimator with the one used when the instrumental variable was the number of microenterprises on each zone, table 4 reveals a change of sign. In effect, there is a negative influence of the mean distance on the level of income and, even if it is not significant from a statistical point of view, its influence is bigger than in precedent models. It suggests that if the distance between homes and jobs increases, it has a negative impact on the income of inhabitants. In other words, what this



result suggests is that *SME* are not placed close to zones where inhabitants have a small income or that *SME* are situated close to people that have higher incomes. On the other hand it could also reveal that people with greater incomes can decide to live closer to *SME* than people with modest incomes, and thus the negative influence of *Mean\_Distance* on *Income*.

Concerning the variable *Schools*, it is also seen that its influence on the dependent variable is doubled with respect to the previous model and their relationship remains negative. In addition, this variable is statistically significant at 0.1 which convert it on a not negligible variable on the model.

Finally, the two variables that have the biggest positive influence on the level of income are the number of establishments promoting cultural events and the number of Transmilenio stations. Regarding *Cultural*, its influence on the level of income increases by 60%. It means that, if an additional establishment promoting cultural activities is built in a zone, this could boost the income of inhabitants by 28.000 COP. This has a statistical significance of 0.05.

Results for model 3 do not differ from the model with “microenterprises” as an instrumental variable. Actually, all the variables have the same influence on inhabitants’ income. Statistical significance remains the same as in the previous model. The variables that most significantly affect the level of income are *Cultural* and *improvement*. Regarding *Cultural*, it is shown that its estimator increased by 20% over the precedent model where the instrumental variable was Micro. In the same way, the effect of the number of Transmilenio stations on the level of income of inhabitants increased by 50%.

Finally, the endogeneity test gives as a result the rejection of null hypothesis, which implies that *improvement* is not exogenous and that 2SLS results are more consistent than those found on OLS model. In parallel, the Sargan test and heteroscedasticity tests validate the use of an instrumental variable in the model.

Causality of improvement on the level of income is demonstrated.

### **Improvement regressed with respect to “Large” enterprises**

This final subsection corresponds to results of the three models when the variable *improvement* depends on density, the workforce in each zone and the number of enterprises with more than 50 employees.

As in previous subsections, results for model 1 do not change considerably. The signs, the level of the impact on dependent variable and the statistical significance of estimators remain unchanged. On the side of instrumental variables, the Sargan test and the heteroscedasticity test show that there is no evidence to reject the use of them and that there are no problems of heteroscedasticity. Nonetheless, the endogeneity test determines that there is no causality relationship between the number of Transmilenio stations and the effective size of the labour market. It implies that OLS results are consistent. 2SLS analysis is not verified and the use of instrumental variables is not justified. Endogeneity was not proven..

Concerning the results for model 2, table 5 reveals the same conclusions as when a variable suspected to be endogenous is regressed with respect to the number of middle-size enterprises. This denotes that the variable *Health* has the bigger negative impact on inhabitants' level of income. As explained above, it could imply that inhabitants with higher incomes chose to live in zones with few establishments that provide health care. The average income of people living in areas with one fewer entity that provides health services with respect to the average income of people living in areas with an additional facility of this kind is 34,500 COP higher (8% of the minimum wage).

Concerning the impact of the number of Transmilenio stations on the income of inhabitants, results reveal that first of all, this variable is by far that which considerably impacts the income of inhabitants. As in a previous subsection, it signifies that the income of inhabitants with an additional station in a zone will be on average 197.000 COP (95 USD) higher.

Table 2.5: 2SLS results for each interval of time when:

$$impro = \pi_0 + \pi_1 WF_i + \pi_2 LE_{si} + u$$

	SLM			Income			Employment
	slm 40	slm 50	slm 60	income 40	income 50	income 60	
Intercept	696,094.362*** (78,433.247)	1012411.954*** (98,263.896)	1273635.499*** (99,657.567)	-38,665.391 (368,709.311)	66,763.779 (411,342.154)	142,725.122 (478,936.966)	-17,930.795 (11,508.759)
Improvment	27,555.484* (16,193.431)	45,863.278** (20,287.693)	51,261.920** (20,575.433)	193,936.451*** (60,240.124)	198,377.717*** (62,034.597)	199,520.165*** (63,074.685)	13,027.699*** (2,376.114)
SLM				-0.045 (0.376)	-0.134 (0.316)	-0.164 (0.320)	
Income	0.043 (0.034)	0.034 (0.043)	0.030 (0.043)				0.003 (0.005)
Population	-0.420 (0.679)	-0.371 (0.850)	-0.501 (0.863)	-2.944 (2.419)	-2.989 (2.439)	-3.031 (2.445)	0.009 (0.100)
Area	-0.019* (0.010)	-0.028** (0.013)	-0.027** (0.013)	0.028 (0.036)	0.025 (0.037)	0.025 (0.037)	0.003* (0.001)
Mean_dist	-36,037.920*** (6,685.674)	-46,749.858*** (8,376.045)	-51,914.820*** (8,494.842)	-3,937.800 (27,409.879)	-8,611.248 (28,206.642)	-10,942.835 (29,226.119)	-6.675 (981.010)
Car owners	-2.935 (3.402)	-0.064 (4.263)	1.340 (4.323)	16.169 (12.127)	16.279 (12.275)	16.441 (12.342)	0.821* (0.499)
Aver Cost	60.349** (25.180)	78.544** (31.546)	89.479*** (31.994)	264.054*** (88.986)	272.547*** (89.928)	276.870*** (91.218)	1.836 (3.695)
Parks	-295.399 (680.658)	-702.224 (852.752)	-50.733 (864.846)	4,737.804** (2,387.926)	4,667.223* (2,413.226)	4,751.262** (2,415.003)	-33.212 (99.875)
Social Welfare	-889.780** (367.430)	-1,055.887** (460.329)	-908.288* (466.858)	-2,213.082* (1,325.650)	-2,324.718* (1,334.761)	-2,339.698* (1,328.044)	19.748 (53.914)
Health	-4,369.952 (5,639.089)	-6,488.536 (7,064.847)	-6,201.869 (7,165.047)	-33,752.496* (20,258.235)	-34,428.086* (20,469.202)	-34,485.508* (20,494.024)	-709.676 (827.441)
Schools	559.686 (1,651.439)	479.516 (2,068.981)	81.976 (2,098.325)	-10,137.719* (5,856.446)	-10,091.636* (5,909.067)	-10,102.750* (5,930.858)	-395.833 (242.321)
Cultural	70.010 (3,202.248)	2,266.227 (4,011.887)	977.351 (4,068.788)	28,101.822** (11,173.038)	28,410.205** (11,350.086)	28,194.966** (11,307.016)	1,733.172*** (469.876)
Recreation	4,843.099 (3,373.519)	3,502.709 (4,226.461)	2,667.288 (4,286.405)	1,346.608 (12,073.174)	1,701.704 (12,188.071)	1,801.528 (12,222.204)	-883.283* (495.007)
Neighborhoods	-704.184 (487.194)	-847.041 (610.374)	-1,215.219** (619.031)	183.564 (1,779.510)	103.703 (1,795.660)	18.774 (1,822.401)	-57.692 (71.488)
Endogeneity - Wu - Hausman F Test	0.66310	1.91267	2.60483	15.17193 ***	14.91195***	14.56189 ***	417.58137***
Sargan	3.166	3.391	1.342	0.985	1.001	1.104	1.553
Heterocedasticity	19.129	16.858	13.779	16.528	16.328	16.424	7.043
R <sup>2</sup>	0.568	0.561	0.566	0.101	0.085	0.081	-0.725

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Author calculations

In effect, concerning the endogeneity test, table 5 reveals that the number of TM stations is endogenous. It suggests that a causal relationship of the variable *improvement* and the level of income is verified when the endogenous variable depends on the number of large enterprises in each zone.

In the same way, results for model 3 suggest the same interpretations. In fact, the variable *employment* also depends considerably on the variable *improvement*. An additional TM in a zone will boost the number of jobs in this zone by 13.027. As in model 2, the level of enhancement of public transport is endogenous, which means there is a causal

relationship between the number of stations of TM on the number of jobs on each zone. For both models, there is no evidence against the use of the instruments and there are no problems of heteroscedasticity.

Causal relations are confirmed in models 2 and 3 when the number of “large” enterprises plays the role of instrumental variable.

Table 2.6: Summary of causality test results

		Test	SLM	Income	Employment
Micro	Endogeneity	No	No	Yes	
	Sargan	No	No	No	
	Heteroscedasticity	No	Yes	No	
PME	Endogeneity	No	Yes	Yes	
	Sargan	No	No	No	
	Heteroscedasticity	No	No	No	
Large	Endogeneity	No	Yes	Yes	
	Sargan	No	No	No	
	Heteroscedasticity	No	No	No	

Author calculations

## 2.5 Conclusion

From the beginning the study has focused on the fact that public transport improvements affect job accessibility, inhabitants’ income and the number of jobs in each zone of the city. In the same way, it was suggested that enhancements of public transports could have a causal relation with income, employment and job accessibility, and that was the reason to analyse the possible endogeneity of this variable. The proxy for improvement of public transport was defined by the number of stations of TM in each zone. This variable, which is suspected to be the endogenous one, is defined by some instruments on each model that their use appear to be accepted by different test (Sargan test Heteroscedasticity test).

Despite the lack of data for several periods, this “cross section” analysis displays interesting results that suggest some particular conclusions that have to be enounced.

Compilation of results reveals that on OLS regressions for the effective size of labour market, improvement to public transport always has a direct and important effect on depen-

dent variables with a statistically significant level. This corroborates findings of previous studies (Ihlanfeldt and Sjoquist, 1991).

In fact, this variable was always the one that had the biggest positive impact on the three different models, regardless of the commuting time, but its amplitude appears to be lower than expected and in some cases its statistical significance may not reveal its real importance (model 2).

Those results motivate the use of the 2SLS method, which explains the suggestion of instrumental variables in order to capture the real and thus suspected impact of the number of stations of Transmilenio on dependent variables.

Regarding the size of the labour market, variables that had a bigger but a negative effect on the *ESLM* were the mean distance travelled and the area of each zone, consistent with Prud'Homme and Lee (1999) with respect to the “three S” (Speed, Sprawl and Spread). Endogeneity of improvement of public transport on the *ESLM* was not proven at all. In effect, regardless of the size of companies in each zone and the workforce in each zone (instrumental variables), the number of TM stations in each zone has no causal effect on the number of jobs reachable within 40, 50 and 60 minutes. This may imply that, for the case of Bogotá, the decision to enhance public transport in some zones of the city – or, to be more precise, the decision to construct a TM station in a zone – could not be motivated by the jobs potentially reachable from these zones. The *ESLM* depends “significantly” on the number of Transmilenio stations but there is no evidence to assert that the degree of enhancement of public transport has a causality effect on the size of the labour market for inhabitants.

In the other hand, as OLS results for model 2 reveal, the number of stations of Transmilenio in each zone of the city has no statistical influence on income. Nevertheless, this study supposes that this variable should have a greater statistical influence on income. In effect, after applying 2SLS method and excepting when the endogenous variable is defined by the number of micro enterprises (instrumental variable), results show that improvement to public transport is significant and has an important impact on the income of inhabitants.

In addition, when instrumental variables are the workforce in each zone and the number of small and middle-size enterprises or the number of large enterprises, enhancements of public transport are endogenous to the income; thus a causality relation of improvements of public transport to income is demonstrated. Furthermore, the use of an instrumental variable reveals an underestimation of the effect of the number of Transmilenio stations on the income of inhabitants.

These results allow some suggestions. First of all it might be said that people with the highest incomes are those that can settle in zones with a high number of Transmilenio stations. Second, in order to understand the results, microenterprises appear to be established in low income zones, contrary to small, medium and large enterprises that seem to settle in zones with high levels of income. Those conclusions suggest that small, medium and large enterprises seem to be in a bigger capacity, like people with high incomes, to settle on zones benefiting more from enhancements of public transports. Until 2007, zones that have more Transmilenio stations appeared to attract people and enterprises with the highest incomes in the city.

In relation to employment, this study showed that improvement to public transport is always statistically significant. Moreover, its influence increases radically when the number of jobs in each zone depends on instrumental variables. Likewise, this is even more evident if the size of enterprises increases. As with income, the number of Transmilenio stations is endogenous to the number of jobs; hence its causality relationship is verified no matter the size of the companies. In a first time, results suggest that public transports improvements incentive the creation of jobs in a zone. Nevertheless, it could also suggest that jobs (and not workers) decide to settle on zones with better level of public transport improvements. As denoted previously, the biggest enterprises, which are those that create almost 70% of employment in the city, prefer to be close to Transmilenio stations. Microenterprises seem not to be capable of benefiting from public transport enhancements.

The results shed light on the causal effect of improvement to the public transport system on the income and number of jobs in each zone of the city of Bogotá. In particular,

they indicate that the greater the presence of Transmilenio stations, the bigger will be the income and the number of jobs. Moreover, this causal relationship is even greater if the size of companies that settle in those zones is bigger. For now, zones where the largest enterprises are located benefit from urban transportation enhancements. After testing this causality, this analysis might suggest to build and expand the Transmilenio system to zones where microenterprises, which assure 30% of formal jobs in the city, are established.

## 2.A Annexes

Table 2.7: Average commuting time according to type of transport

Conveyance	Commuting time (min)
By walk	27
Bicycle	31
Other	31
Taxi	34
Moto	35
Private cars	40
Transmilenio	41
Truck	46
Intermunicipal bus	46
Scolar bus	48
Private bus	49
Public transport diferent of TM	56
Average	40

Author calculations

Table 2.8: VIF calculations

SLM			Income			Employment		
Variable	VIF	1/VIF	Variable	VIF	1/VIF	Variable	VIF	1/VIF
education	7.72	0.129463	education	7.71	0.129664	education	7.72	0.129667
pop_2007	6.11	0.163688	pop_2007	6.98	0.167186	pop_2007	6.08	0.164413
rec_sport	4.27	0.234187	rec_sport	4.23	0.236816	rec_sport	4.27	0.234169
culture	3.64	0.274602	culture	3.69	0.270689	culture	3.04	0.328818
parla	2.98	0.335479	parla	2.76	0.361931	parla	2.86	0.349210
soc_welf	2.78	0.364112	soc_welf	2.74	0.368410	soc_welf	2.74	0.364398
employment	2.86	0.350699	slm_60_pt	2.70	0.370087	number_weig	2.11	0.474836
number_weigh	2.18	0.468232	employment	2.31	0.432448	have_a_car	2.00	0.499964
Improvement	2.07	0.487408	number_weigh	2.18	0.457708	superficie	1.82	0.547994
income	2.02	0.494262	superficie	2.12	0.470744	income	1.78	0.577608
have_a_car	2.02	0.494876	mean_dnt	2.08	0.481033	aver_cost	1.58	0.632708
superficie	1.94	0.516430	Improvement	2.08	0.481396	health	1.58	0.633736
health	1.98	0.505196	have_a_car	2.02	0.494343	mean_dnt	1.84	0.543947
aver_cost ~1	1.88	0.531610	health	1.86	0.540362	Improvement	1.80	0.568798
mean_dnt	1.88	0.531666	aver_cost ~1	1.86	0.540288			
Mean VIF	3.00		Mean VIF	3.08		Mean VIF	2.90	

Author calculations



Table 2.9: Correlation Matrix

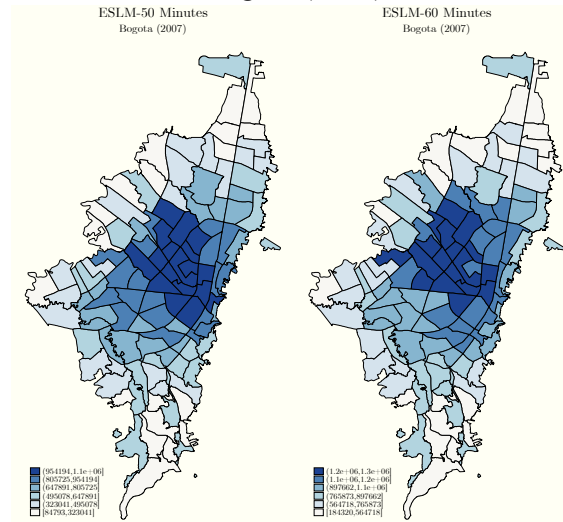
	1	2	3	4	5	6	7
	ESLM_60	Income	Employment	Improvement	Population	Area	Mean_dist
1 ESLM_60	1,00						
2 Income	0,31	1,00					
3 Employment	0,36	0,44	1,00				
4 Improvement	0,38	0,20	0,56	1,00			
5 Population	-0,24	-0,28	-0,03	0,09	1,00		
6 Area	-0,43	-0,01	0,05	-0,01	0,48	1,00	
7 Mean_dist	-0,41	0,13	-0,07	-0,16	-0,34	0,19	1,00
8 Car owners	0,04	0,00	0,06	0,14	0,57	0,24	-0,27
9 Aver Cost	0,21	0,47	0,17	0,05	-0,31	0,04	0,35
10 Parks	-0,21	-0,05	-0,03	0,06	0,74	0,43	-0,25
11 Social Welfare	-0,30	-0,38	-0,03	-0,01	0,65	0,21	-0,26
12 Health	0,00	-0,17	0,20	0,27	0,45	0,17	-0,29
13 Schools	0,08	-0,03	0,33	0,36	0,70	0,27	-0,32
14 Cultural	-0,11	-0,07	0,34	0,05	0,45	0,12	-0,21
15 Recreation	0,20	0,08	0,32	0,46	0,56	0,21	-0,32
16 Neighborhoods	-0,32	-0,02	-0,03	0,02	0,60	0,53	-0,06

	8	9	10	11	12	13	14	15	16
	Car owners	Aver Cost	Parks	Social Welfare	Health	Schools	Cultural	Recreation	Neighborhoods
1									
2									
3									
4									
5									
6									
7									
8	1,00								
9	-0,02	1,00							
10	0,45	-0,23	1,00						
11	0,24	-0,36	0,49	1,00					
12	0,22	-0,22	0,33	0,40	1,00				
13	0,55	-0,11	0,53	0,46	0,53	1,00			
14	0,13	-0,20	0,39	0,54	0,38	0,64	1,00		
15	0,51	-0,06	0,47	0,43	0,49	0,81	0,38	1,00	
16	0,37	-0,06	0,63	0,30	0,22	0,42	0,32	0,30	1,00

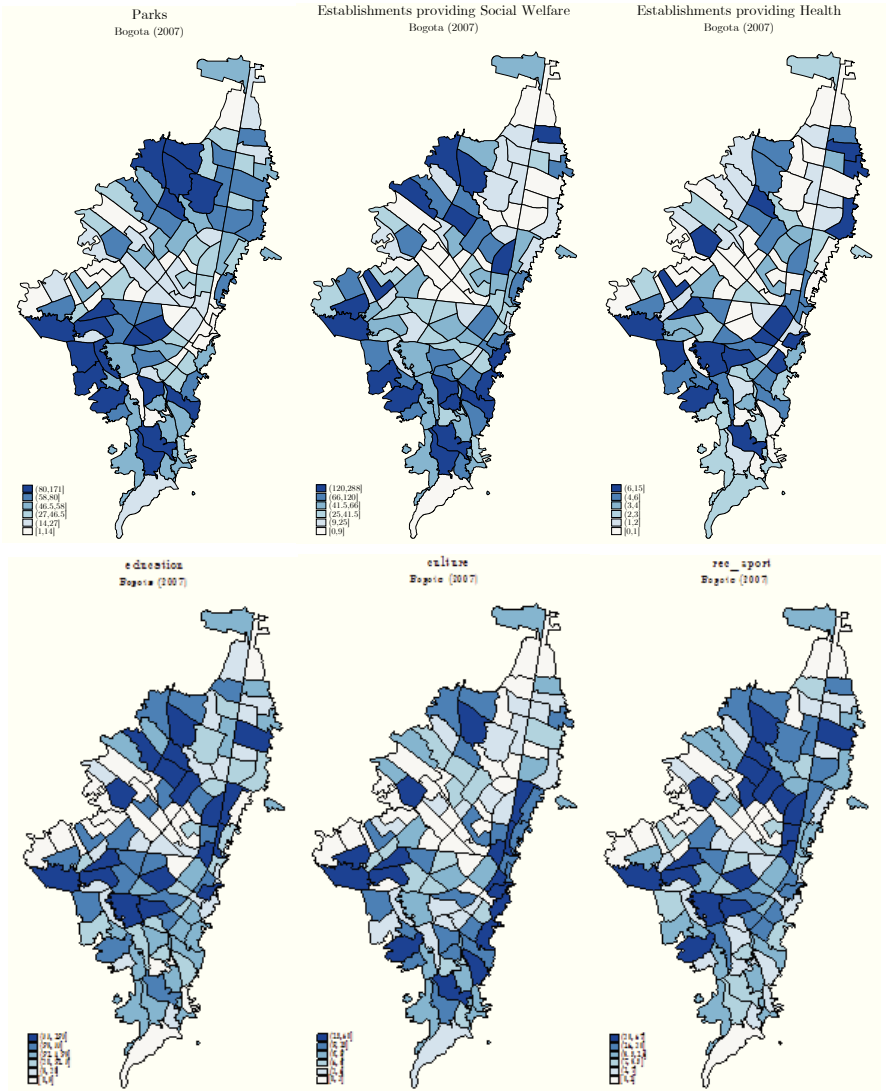
Author calculations

Figure 2.2: Size of Labor Market respecting the zone where people live (UPZ)  
Bogota (2007)



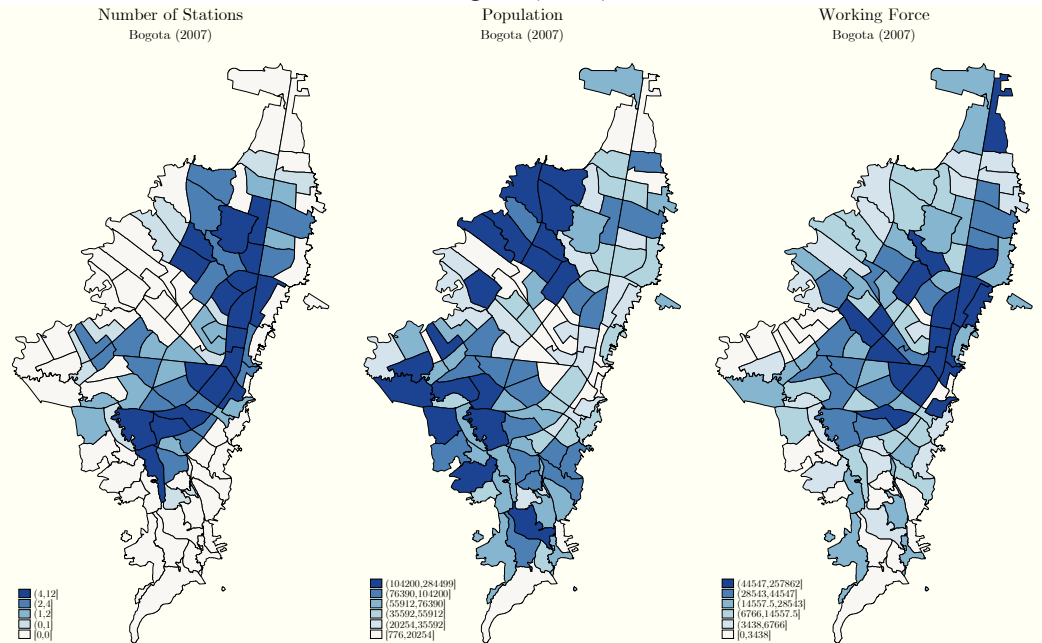
Author calculations

Figure 2.3: Amenities by Zones (UPZ) Bogota (2007)



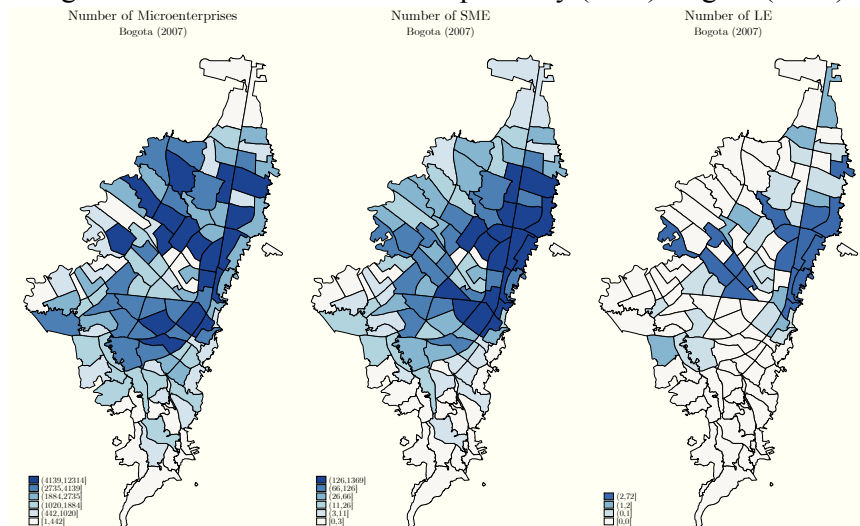
Author calculations

Figure 2.4: Concentration of Stations of TM, Population, Workforce configuration by (UPZ) Bogotá (2007)



Author calculations

Figure 2.5: Concentration of enterprises by (UPZ) Bogotá (2007)



Author calculations

# **Chapter 3**

## **Impact of urban public transport enhancements on crime rate: a diff-diff analysis for the case of Transmilenio**

### **3.1 Introduction**

#### **3.1.1 Literature review and research question**

From the early seventies, crime began to be studied from the point of view of Economics<sup>61</sup>. This new theory, called “the theory of crime”, was supported by the fact that criminals are rational and hence are able to compute their expected utilities with respect to the probability of being caught by the forces of law and order. In addition, this theory rests on the fact that criminals have the capacity to make a cost/benefit analysis between their expected utility when they commit a crime and their expected utility if they undertake another kind of “lucrative” activity at the same time.

Since this first study that gave birth to the theory of crime, several researchers have confirmed that the empowerment of police in the city has a negative effect on the spread of criminality (Ehrlich 1975, Bryett Freeman 1996, Glaeser 1996) between others. However, as Moreno (2005) remarked in his research, Cameron (1988) demonstrated that this effect is not very easy to underline because of the lack of data<sup>62</sup> on cities and also because

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<sup>61</sup> Gary S. Becker. (1968). “Crime and Punishment: An Economic Approach” *Journal of Political Economy*, Vol. 76, No. 2, pp. 169-217

<sup>62</sup> Data are generally available for the entire city as a whole and not for each of the zones that compose the city” Moreno 2005.

the decision to increase police presence is also due to the fact that, generally, previous to empowerment of the police in zones, crime was rising<sup>63</sup>.

Nonetheless, the issue of urban crime has not been only considered from the theory of crime. Research by Glaeser, Sacerote (1999), Brueckner, Thisse, Zenou (1999) and Morselli, Royer (2008) has studied this topic from the point of view of the urban form and the urban transport in the city.

Those researchers, and several others, have well demonstrated that development and enhancement of public transport has a positive impact on the insertion into the employment market of inhabitants of a city and its surroundings (Donzelot 2004, Zenou 2000). The effect of this insertion of inhabitants into the job market has a direct effect on the criminality in cities<sup>64</sup>. In effect, this fact has as its consequence a decrease in crime rates in the city because of the lower motivation of inhabitants to commit crimes; thus, an increase in social interactions takes place (Glaeser, Sacerdote, Scheinkman 2004, Brueckner 2001, Zenou 2003). This reduction of crimes and increased social interaction is, in general, more evident in poor neighbourhoods than in rich ones (Donzelot 2004, Bearse 1996).

Additionally, studies about crime have incorporated a spatial approach that has taken on greater importance in the past two decades – see Freeman et al (1996), Anselin (1998), Cohen, Tita (1999), Formisano (2002), Di Tella, Zenou (2003), Schargrotsky (2004) and Moreno (2008), among others.

However, even if there are several studies that have already looked at the spatial dependence, spatial dissemination and/or spatial configuration of crime, no studies treating links between and the possible effect of public urban transport on crime evolution were found, except the study by Moreno (2005).

The originality of this research consists in proving that the evolution of urban crime could be boosted or decreased by the presence or lack of such of enhancements of public

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<sup>63</sup> It perfectly follows the theory of “Broken windows”; Wilson J.Q. and Kelling G.L. 1982.

<sup>64</sup> Note that in this research, criminality and crime will enclose five types of criminal activities and do not take in consideration “large-scale crime”.

transport or by the development of new public urban transport. More precisely, this study intends to prove that, even if the total criminality in a city may decrease after the implementation of a new urban transport system, there could also be adaptation of criminals in some zones of the city. In other words, criminals may also enjoy the benefits of the new system in order to commit their crimes in zones which they could not access before. A spread of some types of crimes in some areas affected by the new transport system may take place. This research tries to prove that hypothesis.

### **3.1.2 Contextualization of the case of study**

This study focuses on the city of Bogotá, which is one of the most densely populated cities in Latin America and the world but, paradoxically, does not have a subway system or a system of trams. The city has more than seven million inhabitants and was part of the group of cities considered the most dangerous in the world in the early 2000s.

Bogota is divided into 117<sup>65</sup> zones composed of around 2350 neighbourhoods. Each neighbourhood has a socio-economic status which is calculated with respect to the amenities of each neighbourhood, the materials with which the house is built, the degree of accessibility for inhabitants of each neighbourhood and many other characteristics of the houses and the quarters correlated to the level of income of people. There are six socio-economic strata: stratum 6 denotes the population with the highest level of income and strata 1 denotes the poorest population of the city.

From 1960 until the end of the 1990s, the city had a chaotic urban transport system served by old buses and taxis of different kinds and different sizes. The service of public transportation was assured by private entrepreneurs (more than 60!) and public administration did not play a part in the utilities of the system. Its role was just that of “regulator”; it

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<sup>65</sup> UPZ in spanish “Unidades de Planeamiento zonal” or “zonal planning units”

assigned and defined the buses' lines as well as the companies that had to assure the service<sup>66</sup>. This method created inefficiencies regarding the quality and coverage of the service in all zones that compose the urban area, in parallel with several problems of corruption. Actually, some deputies that made part of the council of the city and that had as task to define the companies to assure the service on the city have been involved in affairs of corruption and clientelism.

At the end of the 1990s, the elected mayor<sup>67</sup> decided to reform the public transport system managed by private entrepreneurs into a system managed by a public-private partnership. With the new system, public administration has a core role in the regulation of the system, allocation of lines, administration and the exploitation of the new system.

Since its opening in December 2000, this new public transport system, called Transmilenio (henceforth TM), based on an integrated Bus Rapid Transit (BRT) system, has had a reputation as one of the most popular and successful BRT systems in the world. Mobility in the city changed radically, with a notable reduction in travel times and continued expansion of the system to various zones of the city. Today the system reaches more than 50% of zones of the city, and although the old system with old buses is not closed, TM system moves about 1.8 million passengers per day, representing almost 15% of total daily trips in the city, at an average speed of 27 km/h.

As stated above, the objective of this research is to determine if the TM system induced positive or negative changes on levels of different types of crime. In order to face of this hypothesis, this research compares crime rates taking into account the period (after or before the opening of TM system) and also identifying the zones that benefit from the system or do not.

To treat the subject of this research, the paper proceeds as follows. After a brief literature review and a brief contextualization of the case under study in this first section,

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<sup>66</sup> Administration used to define the lines and to assign the "winner" entrepreneurship after doing a call of tender

<sup>67</sup> Enrique Peñalosa was elected for a period of three years : 1998-2000



section 2 describes available data. Section 3 describes the econometric methodology used in the paper. Empirical findings are presented in section 4 and conclusions are offered in section 5.

### 3.2 Available data and descriptive analysis of data

This paper uses a big and very rich database of each crime in the city between 2003 and 2008<sup>68</sup>. The collection of crimes was possible through collaboration with the “Conflict Analysis Resource Center”<sup>69</sup> and with the permission of the Metropolitan Police Department of Bogotá (MEBOG). It supposes that every crime was spatially referenced with the exact addresses and the exact day and time when each incident took place. In order to organize the information for each UPZ, this study clusters all the events to their respective UPZ.

This research is focused on five types of crime:

- Number of homicides
- Number of robberies carried out against people with violent aggression
- Number of thefts against people
- Number of burglaries of commercial establishments
- Number of house breakings

This research focuses on comparison of the number of crimes and on an econometric analysis of crimes committed in each UPZ before and after the opening of TM. Table 1

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<sup>68</sup> More than 150.000 incidents were recorded during the period between 2003-2008

<sup>69</sup> In spanish: Centro de Recursos para el Analisis de Conflictos - CERAC

describes the statistics for each type of crime on zones that are benefiting and those that are not benefiting from the TM system.

In addition, this study captures data of crimes committed after the inauguration of the two first corridors, “Calle 80” and “Caracas”, on December 2000, but before and after the opening of the three other sections of TM<sup>70</sup>.

In effect, TM is a transport system planned to have more than 13 corridors. Three other corridors were opened after 2000. The first one is called “Americas” and was opened on December 2003. As this paper uses data from January 2003 to December 2008, the analysis takes into consideration crimes committed 12 months before the opening of the corridor called "Americas" (from January 2003 to 31 December 2003) and 12 months after its initiation (from 1 January 2004 to 31 December 2004).

Regarding the two other corridors that were opened later (NQS and Suba<sup>71</sup>), this study takes into consideration data of crimes committed 18 months before and 18 months after their opening.

The last five lines of table 1 indicate some characteristics of each zone, such as amenities, area and density, among others. Nonetheless, these data were not available for every year and every UPZ of the city; thus, the study considers that they are constant over time. This study uses these data as control variables.

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<sup>70</sup> Transmilenio has today seven different main corridors: Troncal 80, Caracas, Autopista Norte, Americas, NQS and Suba. From 2012, two new corridors were opened (Carrera, 10 and Avenida 26)

<sup>71</sup> “NQS” corridor opened on July 2005 and « Suba » corridor opened on May 2006.

Table 3.1: Descriptive statistics before and after the opening of each corridor of TM

TM Section	Variable per UPZ	Label	Obs	Before TM				After TM			
				Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Americas	Thefts to people	crimeteft	112	72,5	43,68	16	138	50,7	30,8	14	123
	Burglaries to commercial Establishments	crimecom	112	43,5	23,61	12	77	41,9	25,65	15	99
	House Breakings	crimehouse	112	32,6	29,76	1	91	27,1	18,75	3	55
	Homicides	homicides	112	23,6	23,87	2	76	19,6	23,31	0	74
	Robbery to people with violent agresions	agresions	112	87,22	67,79	3	226	87,36	79,35	2	285
NQS	Thefts to people	crimeteft	112	112,95	70,08	6	230	178,9	113,82	0	394
	Burglaries to commercial Establishments	crimecom	112	85,04	76,17	1	300	81,45	74,41	0	317
	House Breakings	crimehouse	112	56,81	39,58	0	131	51,27	39,26	0	155
	Homicides	homicides	112	23,4	20,05	0	76	19,27	17,83	0	74
	Robbery to people with violent agresions	agresions	112	87,22	67,79	3	226	87,39	79,35	2	285
Suba	Thefts to people	crimeteft	112	231,30	122,19	14	387	230,13	112,09	18	399
	Burglaries to commercial Establishments	crimecom	112	126,30	75,35	6	239	125,87	84,76	18	308
	House Breakings	crimehouse	112	125,87	95,92	3	310	94,75	60,65	5	198
	Homicides	homicides	112	22,25	19,72	0	63	22,25	20,82	2	62
	Robbery to people with violent agresions	agresions	112	181,25	175,12	25	539	223,62	242,42	18	728
Americas	Area of the zone in hectares	hectares	112	375,47	180,08	79,83	992,33	375,47	180,08	79,83	992,33
	Number of inhabitants per hectare	density_hect	112	181,16	105,27	1,00	526,00	181,16	105,27	1,00	526,00
	Establishments providing Cultural activities	culture	112	8,12	8,18	0,00	40,00	8,12	8,18	0,00	40,00
	Establishments promoting Welfare	soc_welf	112	63,25	63,83	0,00	288,00	63,25	63,83	0,00	288,00
	Establishments provinding Health	health	112	3,53	3,24	0,00	15,00	3,53	3,24	0,00	15,00

Author's calculations

Regarding data from table 1, it can be observed that with respect to the “Americas” corridor the average number of every type of aggression decreased, except the average number of robberies against people involving violent aggression, which did not change. In the case of the “NQS” corridor, the average number of burglaries of commercial establishments, the average number of house breakings and the average number of homicides decreased. Nevertheless, the average number of robberies against people with violent aggression did not change and the average number of thefts from people increased. Finally, regarding the “Suba” corridor, just the average number of house breakings decreased after the opening of TM; the average number of robberies against people involving violent ag-

gression increased significantly and the average number of the three other kinds of crime did not change.

Those remarks could suggest that the impact of TM on each type of crime depends on the moment, the zone and other characteristics of each zone. On the other hand, it may also suggest that the opening of TM did not have an effect on crime rates.

In effect, another fact, that there is non-negligible, is the difference in the number of amenities in UPZ with TM system and UPZ without TM system. Table 2 shows that UPZ which benefit from TM have a higher number of amenities than those which do not benefit from the system<sup>72</sup>. These differences vary between 20% and 37%. Nonetheless, there are two kinds of amenities among the seven taken into consideration that are more numerous in UPZ without the TM system: the number of establishments providing cultural activities and the number of establishments providing social welfare, at 13% and 17% respectively.

Table 3.2: Amenities UPZ with vs without TM system

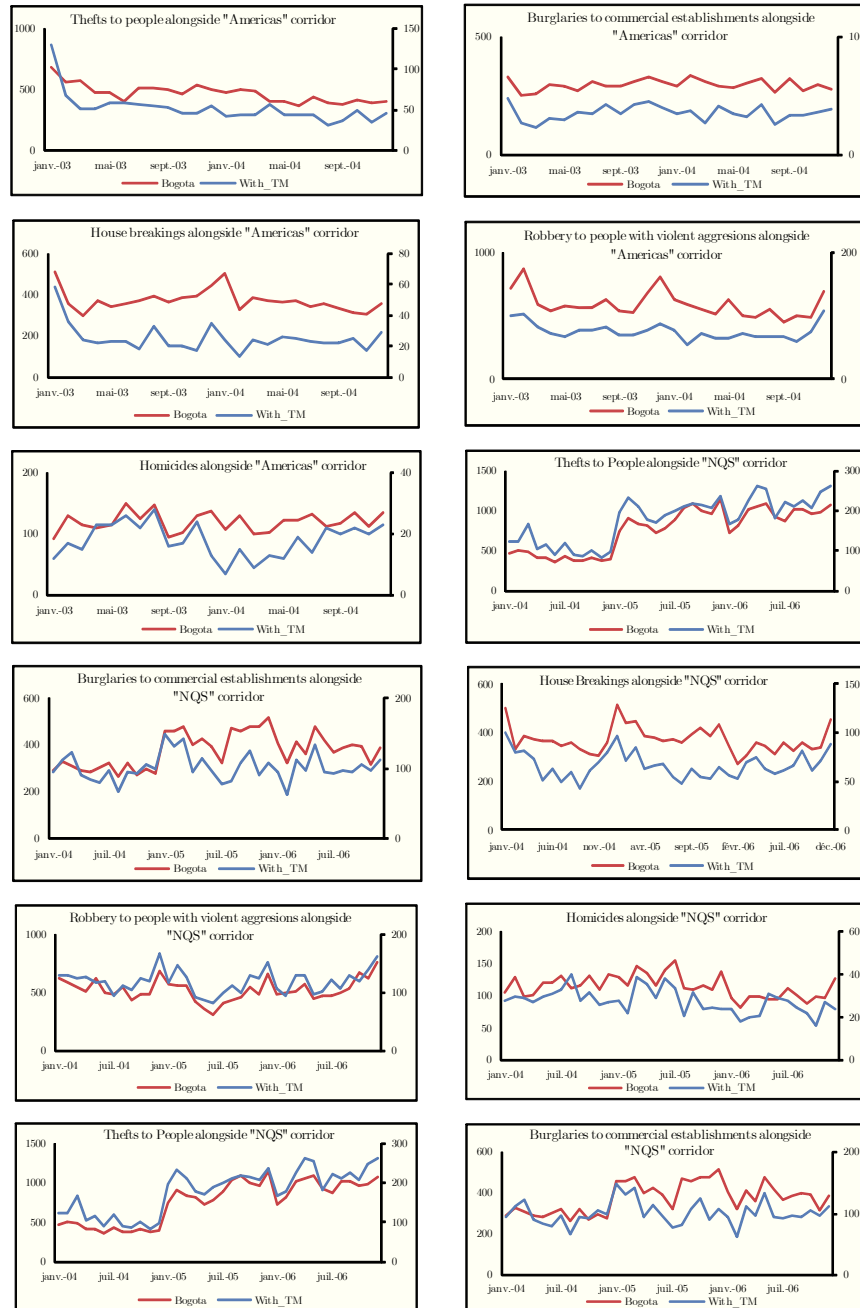
		sec	justice	rec	sport	culture	education	health	soc	welf	parks	Total
Americas	No TM	0,98		11,66		8,28	33,08	3,45	65,38		49,66	172,49
	TM	0,55		9,18		6,64	29,82	4,27	43,73		36,00	130,18
	Diff	-44 %		-21 %		-20 %	-10 %	24 %	-33 %		-28 %	-25 %
NQS	No TM	0,87		10,44		8,55	31,33	3,10	65,37		47,94	167,60
	TM	1,22		15,22		6,43	38,30	5,17	55,04		49,78	171,17
	Diff	41 %		46 %		-25 %	22 %	67 %	-16 %		4 %	2 %
Suba	No TM	0,92		10,91		8,04	31,70	3,60	61,07		45,60	161,84
	TM	1,13		18,00		9,13	46,50	2,63	91,63		83,75	252,75
	Diff	22 %		65 %		14 %	47 %	-27 %	50 %		84 %	56 %
All zones	No TM	0,88		10,15		8,49	29,76	3,14	67,04		44,50	163,95
	TM	1,05		13,89		7,39	38,61	4,29	55,87		55,76	176,87
	Diff	20 %		37 %		-13 %	30 %	37 %	-17 %		25 %	8 %

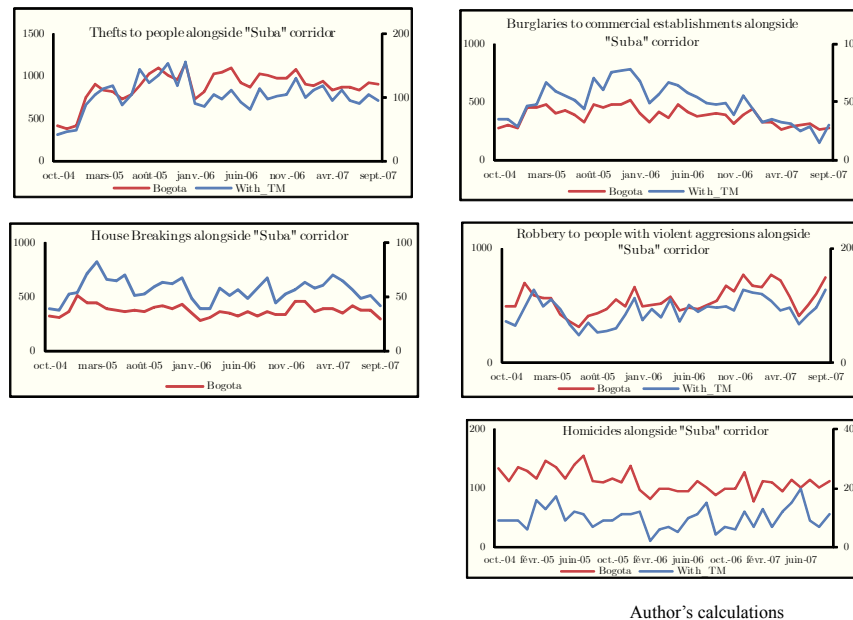
Authors' calculations

Regarding the differences of amenities between each TM corridor, table 2 shows that for the “Americas” corridor, zones that are beneficiaries of this transportation system have fewer amenities than zones not passed by the “Americas” corridor. On the contrary, with respect to two other corridors, the number of amenities is higher in zones benefiting from the “NQS” and “Suba” TM corridors.

<sup>72</sup> Last line of the table 2

Figure 3.1: Criminality on each zone vs criminality on citywide





Graph 1 presents the dynamism of each type of crime in each of the three zones studied on that paper. This dynamism is shown by the evolution of each type of crime before and after the opening of the three TM corridors. As stated above, the analysis takes into account crime rates over 36 months (18 months before and 18 months after the opening of TM). However, because of the impossibility of gaining information on crimes in 2002, only 24 months were taken into account (12 months before and 12 months after) in the analysis of crime along the “Americas” corridor.

Regarding the evolution of crime with respect to the “Americas” corridor, graph 1 shows that every type of crime decreased after the opening of TM, with the exception of the number of homicides. In effect, contrary to table 1, graph 1 shows that after the inauguration of TM, the totality of homicides did not change in zones reachable by TM but increased citywide.

On the other hand, crimes in the “NQS” corridor had a different evolution. The number of thefts from people increased in zones reachable by TM and also in the other zones of the city after TM opened its service. Regarding the number of burglaries of commercial establishments and the number of robberies against people with violent aggression, crimes

did not experience major changes after the implementation of TM. Similarly, these crimes increased when citywide data was taken. House breakings also increased in zones benefiting from TM after the implementation of the system; the opposite was the case with respect to the total number of crimes in the city. Finally, the number of homicides decreased after the opening of TM, both in zones reachable by TM and citywide.

Regarding crimes in zones connected to the “Suba” corridor, except for a decrease in the total of burglaries of commercial establishments, crime rates did not change after the opening of the TM system. The same is the case for the rest of the city. It may be inferred that the TM system had a positive effect just on burglaries of commercial establishments; other types of crime were not influenced by this system of transport.

To complete the description of the available data by each type of crime, this article intended to establish a comparison of crime rates before and after the implementation of the TM system by UPZ just on the three zones that are the object of analysis. Graph 2 presents the levels of the five types of crime in each UPZ that benefited from TM before and after its opening.

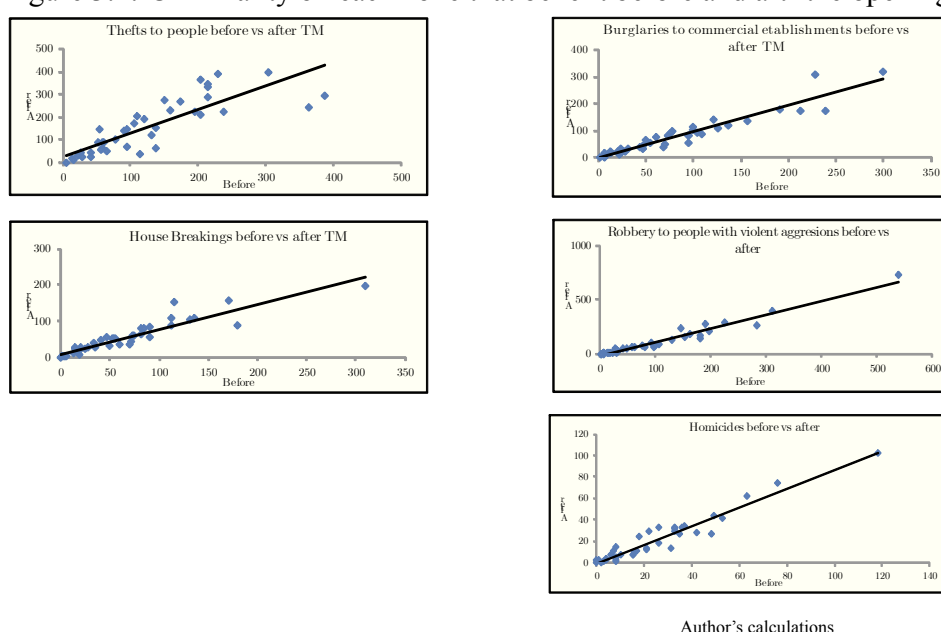
Each point of the graphs represents one of 38 UPZ connected to at least one of the three corridors analysed. The horizontal axis denotes the number of crimes before the introduction of TM and the vertical one denotes the number of crimes after the opening of the TM system.

The dots placed above the diagonal are the areas where crimes increased after the inauguration of the transportation system. It means that if the level of crimes decreased in a zone, the point that represents this zone will be below the diagonal line.

In graph 2 it can be observed that on 17 of 38 UPZ concerned, present an increasing of the number of thefts to people after the introduction of TM. In other words, almost the 45% of the zones connected to at less, one of these three corridors of TM, had an augmentation of this type of crime. Concerning the number of burglaries of commercial establishments, 16 of 38 UPZ (42%) experienced an increase in that type of crime, similar to the number

of house breakings, which increased in 14 of the 38 UPZ (37%) connected to the three corridors concerned. The number of UPZ where crimes on that the integrity of the people is threatened (robberies to people with violent aggressions and homicides) increased on less UPZ (6/38 and 10/38, 16% and 26% respectively).

Figure 3.2: Criminality on each zone that benefit before and after the opening of TM



### 3.3 Methodology

This research is focused on establishing the possible effect (negative or positive) of three main corridors of the Transmilenio system with respect to the number of crimes in different zones that compose the landscape of Bogotá. In order to identify a possible causal relationship between the TM system and its effect on criminality, this article decided to implement the “Difference in Difference” method<sup>73</sup>.

<sup>73</sup> Diff-diff from now



This methodology, which has become widespread since the initial work by Ashenfelter and Card (1985), deepened by other researchers like Millainathan (2004), Hansen (2007a, b) among others, has as its principal objective to determine the causal relationship between the implementation of a policy and its possible outputs on different groups. The goal of this technique is to evaluate the impact of a policy on output over different groups in two time periods. Those groups are indexed by treatment status. One part of the sample is supposed to be a beneficiary of the treatment in the second period but not in the first period; this represents the treatment group. The other part of the sample is not supposed to benefit from the policy in either period but, even if they are not influenced by the policy, their characteristics are very similar; they represent the control group.

Mathematically, the outcome of interest for this study (total crime of each UPZ  $i$ ),  $Y_i$  is denoted by:

$$Y_i = \alpha + \beta T_i + \gamma t_i + \delta(T_i \cdot t_i) + \theta X_i + \varepsilon_i \quad (3.5)$$

With:

$\alpha$  = constant term

$\beta$  = treatment group specific effect

$T_i$  = binary variable:  $T = 0, 1$  where 0 indicates zones  $i$  that do not benefit from TM system and 1 indicates zones  $i$  beneficiary from TM system

$\gamma$  = time trend common to control and treatment groups

$t_i$  = the two time periods: 0 represents the time period before the implementation of the policy and 1 represents the time period after the implementation of the policy

$\delta$  = diff-diff estimator which represents the true effect of the implementation of TM system

$\theta$  = effect of some explicative variables or covariates (in the model treated on this paper, they are constant<sup>74</sup>)

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<sup>74</sup> Covariates are constant due to the impossibility to have this information for each zone and each year.

$X_{ni}$   $n$  explicative variable of each UPZ  $i$ .

$\varepsilon_i$  random unobserved “error”. It supposes that the error term is on average zero:  $E[\varepsilon_i] = 0$  and that it is not correlated to other variable of the equation.

As shown in Equation 1, the number of crimes committed in each UPZ  $i$  is denoted by the output  $Y_i$  over a sample of 112 different UPZ that compose the city. The diff-diff estimator  $\delta$  is defined as the difference in average output in the treatment group before and after the opening of the TM system (those that benefit from the TM system) minus the difference in average output in the control group before and after the opening of TM in each UPZ (those that do not benefit from TM system).

Regarding the diff-diff estimator, it takes the following form:

$$\delta = Y_1^T - Y_0^T - (Y_1^C - Y_0^C) \quad (3.6)$$

Where:

$Y_0^T$  and  $Y_1^T$  denote the sample averages of the outcome for the treatment group before and after the TM opening.  $Y_0^C$  and  $Y_1^C$  denote the sample averages of the outcome for the control group before and after the TM opening.

To verify if the criminality in the UPZ served by the three relevant different corridors of TM is determined by the opening of the system, Equation 1 is regressed. After regression of Equation 1, the significance of  $\delta$  is tested in order to find the significance of the estimator. It will indicate if there are also differences in crime rates between treatment and control groups after and before the opening of the system and if there is a positive or negative impact of the TM system on crime rates on each UPZ.

Regarding the regressions, this study makes one regression for each kind of crime with respect to each of three corridors of TM that are the subject of this research. It supposes one result for each type of crime for each corridor. There are five types of crime and three corridors, which means that there are 15 results (five for each corridor).

Equation 1 takes the following form:

$$Y_{ij}^k = \alpha + \beta T_i + \gamma t_i + \delta(T_i \cdot t_i) + \theta X_i + \varepsilon_i \quad (3.7)$$

Where  $k$  = one of the five type of crime and  $j$  = one of the three corridors, “Americas”, “Suba”, “NQS”

Thus,  $Y_{ij}^k$  represents the number of crimes of type  $k$  committed on UPZ  $i$  and with respect to the corridor  $j$ .

### 3.4 Results

After applying the diff-diff method, table 3 displays results for each corridor and for each type of crime.

Regarding the “oldest” corridor, “Americas”, which takes into account crimes 12 months before and 12 months after the opening of TM, it can be observed that there are two types of crime that increase because of the implementation of the system: the number of thefts from people and the number of robberies against people with violent aggression increase in the 12 months that follow the opening of TM. Nonetheless, this increase is not statistically significant.

On the other side, the amount of the other three types of crime decreased due to the implementation of the system. However, the only statistically significant estimator is the one regarding the number of homicides on that corridor. The others two do not have statistical significance.

Regardless of the type of crime, the total number of crimes increases due to the TM. Nevertheless, it is not statistically significant. It can be explained because of the big difference in the estimators between those which increase (thefts from people and robberies

against people with violent aggression) which are not statistically significant, and those which do not increase (the rest).

Table 3.3: Diff-Diff results

Type of Crime	Americas (2003-2004)	NQS (2004-2006)	Suba (2005-2007)	All period (2003-2007)
Thefts to people	2,344	-1,516	-2,993	-1,810
Burglaries To Commercial Establishments	-0,255	-2,883***	-1,318	-1,363*
House Breakings	-0,587	-0,756	1,513	-0,010
Robbery to people with violent aggresions	0,516	0,007	1,746	2,654
Homicides	-0,772**	-0,429*	0,617**	0,288
Total type of crimes	0,650	-4,300*	-2,709	1,528

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Authors' calculations

Concerning criminality with respect to the “NQS” TM corridor, table 2 shows that, contrary to what is observed for the “Americas” corridor, robberies against people with violent aggression represents the only type of crime that increases after TM. Nevertheless, this estimator is not statistically significant. It means that the number of thefts from people decreases, as does the number of burglaries of commercial establishments, the number of house breakings and the number of homicides.

However, just two estimators of these types of crime are statistically significant: those of the number of burglaries of commercial establishments and the number of homicides (statistically significant at 1% and 10% respectively).

This may infer that the implementation of the TM system on the “NQS” corridor led to a decrease, with statistical significance, of the number of those types of crime. In effect, these coefficients indicate that there is a difference on 2.883 and 0.429 crimes between the UPZ that benefit from TM and those that do not benefit from the system.

Results of the regression of the totality of criminality show that the number of crimes decreases statistically significantly (10%). It may be explained by the fact that just one kind of crime increases while the other four types of crimes fall.

Regarding the “Suba” TM corridor, results are also different. In effect, just two kinds of crime decrease due to the TM system: the number of thefts from people and the number of burglaries of commercial establishments. Nevertheless, these estimators do not have statistical significance.

Among the other types of crime that increase due to the TM corridor “Suba”, just the number of homicides has statistical significance (at 5%). The amount of the other two types of crime grows but in a lower proportion with respect to the decrease in the other types of crime, which may explain the results for the total of crimes.

In effect, results from the regression of the total number of crimes with respect to this corridor indicate that the diff-diff estimator is negative. This means that the total number of crimes decreases due to the opening of the “Suba” corridor.

The last column of table 2 shows that, regardless of the TM corridor, between January 2003 and November 2007<sup>75</sup> two types of crime increase because of the TM system. In effect, the diff-diff estimator shows that the number of robberies against people with violent aggression and the number of homicides are higher due to the implementation of the TM system in the city. Nonetheless, these estimators are not statistically significant.

The other three diff-diff estimators indicate that, due to the TM system, the amount of that type of crime was reduced. However, just one estimator among these three types of crime is statistically significant at 10%: the number of burglaries of commercial establishments.

Regardless of the type of crime and the corridor, the total number of crimes increased between January 2003 and November 2007, but the estimator is still not statistically significant.

A summary of table 3 may be provided. It shows that:

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<sup>75</sup> Twelve months before the opening of « Americas » corridor and 18 months after « Suba » corridor

- TM causes an increase in the number of thefts from people just for the “Americas” corridor, but the diff-diff estimator for this variable is never statistically significant.
- The number of burglaries from commercial establishments decreases on every corridor and also for the period between 2003 and 2007 because of TM system; the diff-diff estimator is only statistically significant for the “NQS” corridor.
- House increase just with respect to the “Suba” corridor. The estimator has no statistical significance.
- The number of robberies against people with violent aggression increases on every corridor, and also regardless of the corridors (fourth column), due to the opening of the TM system. Nevertheless, this estimator has no statistical significance.
- The number of homicides with respect to the opening of TM corridors decreases on “Americas” and “NQS” corridors but increases on the “Suba” corridor. These estimators are always statistically significant.
- Regardless of the type of crime, criminality decreases on the “NQS” and “Suba” corridors but increases on the “Americas” corridor due to the opening of the TM system. Regardless of corridor and types of crime, criminality increases between 2003 and 2007 due to the implementation of the TM system.

Finally, as stated above, it can be noticed that the only corridor that presents an increase in criminality is “Americas”. In parallel, it is also the only corridor that presents fewer amenities in zones that benefit from TM with respect to the number of amenities in

zones that do not benefit from the TM system. However, amenities are invariant for every period, which limits the analysis of this article regarding the importance of the impact of amenities on crime rates with respect to transport system enhancements.

### 3.5 Conclusion

Several researchers have studied the link between public transport and its impacts on urban density, urban employment and hedonic prices. This paper has tackled the impact of enhancement of public transport on five different types of urban crime in 112 different zones of Bogotá.

Results suggest that the enhancement of the public transport system represented by the introduction of a new public transport system has a causal effect on crime rates.

However, results are not homogeneous on all corridors regarding all types of crime. Even if a causality relation is demonstrated for some corridors of Transmilenio, it suggests that the impact of public transport improvements on crime rates for each zone of the city is not unidirectional.

Notwithstanding this, two types of crime have constantly evolved with respect to the opening of three different corridors of Transmilenio: the number of burglaries of commercial establishments and the number of robberies against people with violent aggression. The first one saw a reduction in the number of crimes while the second experienced an increase in the number of crimes.

Among the five types of crime that were the object of this paper, just one type has statistically significant results which imply that the TM system has a direct impact on that type of crime: homicides. However, the impact is not the same on the three corridors that are object of this study, reinforcing the fact that, even if TM has a direct effect on crime rates, this effect does not only depend of the presence of TM. Other variables may influence this evolution.

Regardless of the type of crime but taking into account total criminality on each corridor of the TM, this paper found that crimes increased in just one of those corridors due to the construction of TM: it is the case of zones that benefit from the “Americas” section. The Transmilenio system seems to be the principal cause of this increase. Nonetheless, an important question about this result emerges with respect to the amenities of each area that make up the city.

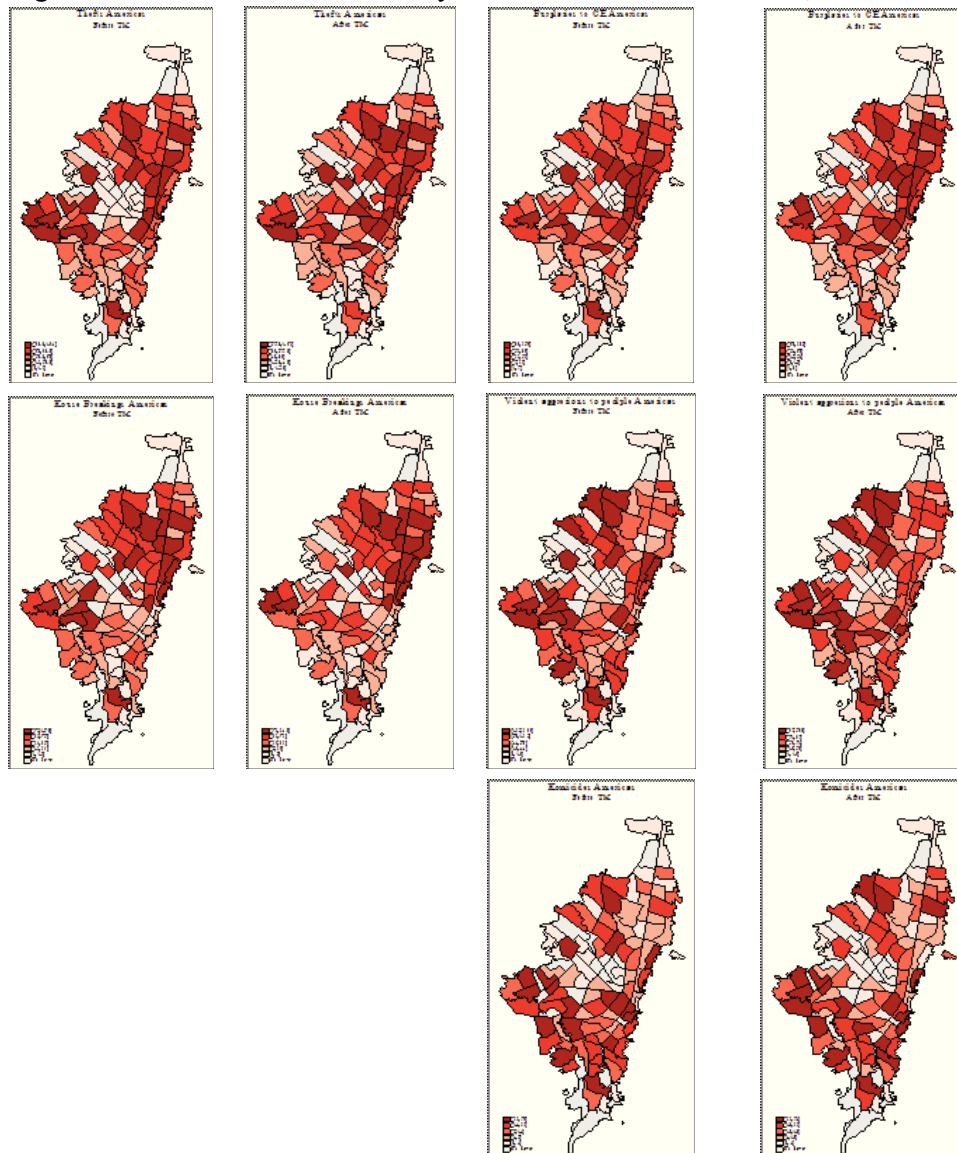
Along this Transmilenio section, the zones benefiting from the system have fewer amenities than the ones that do not. This may suggest that the number of amenities in each zone of the city has also an important effect on crime rates. Nevertheless, data regarding amenities are invariant because they are not available for each zone and for each period. A study with data for each zone and for each period should be done to confirm this hypothesis.

Finally, it is well known that behaviours like criminality may have a spatial dependence or a spatial correlation that may clarify in a better way the evolution of crime rates in different zones of a city. A study focusing on this last subject should be done.



### 3.A Annexes

Figure 3.3: Evolution of criminality on TM corridor “Americas”; before vs after



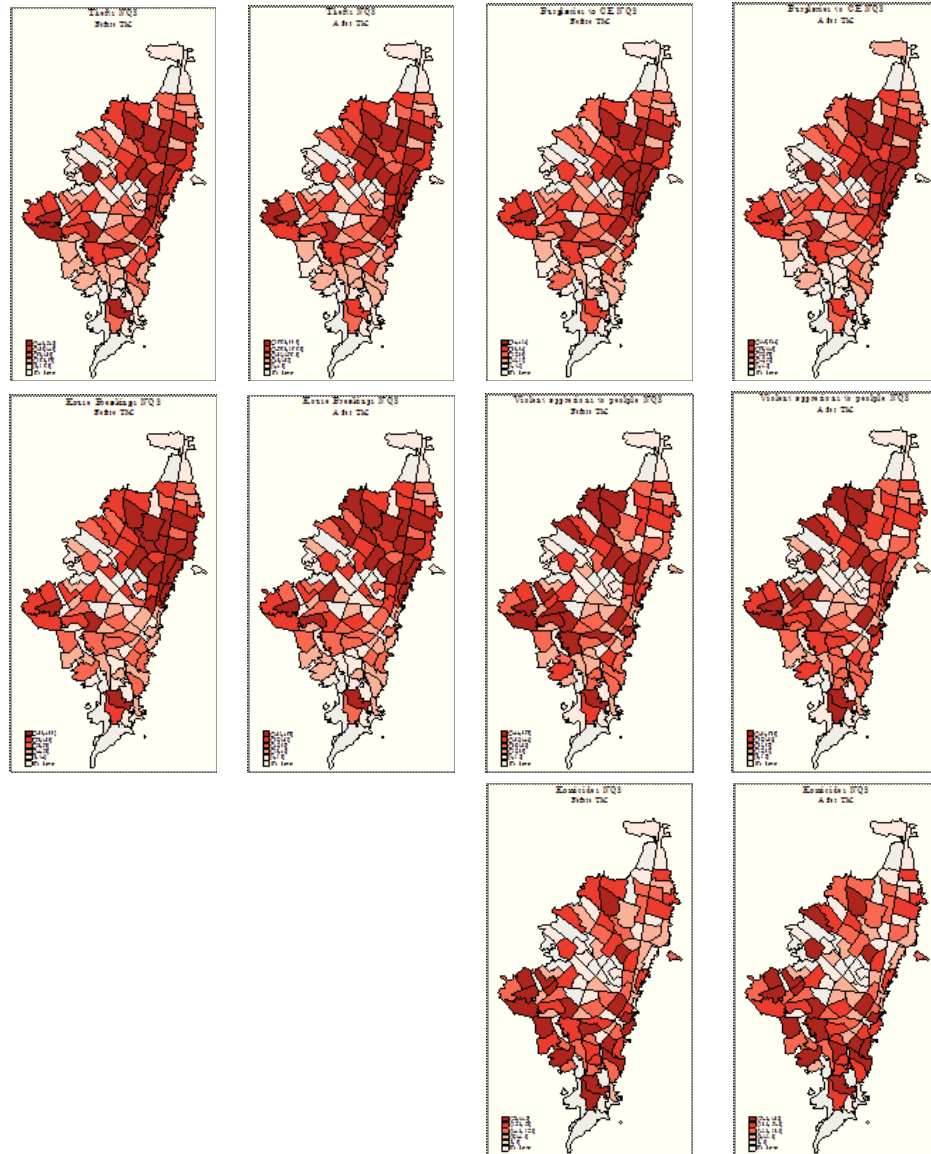
Author's calculations

Evolution of criminality on TM corridor “Suba”; before vs after



Author's calculations

Figure 3.4: Evolution of criminality on TM corridor “NQS”; before vs after



Author's calculations

## **Chapter 4**

# **Criminality spread: a “Boomerang effect” of public transport improvements?**

### **4.1 Introduction**

A long line of theory in public economics has suggested that urban transport plays an important role in social configuration and therefore, in urban structure (Glaeser 2003; Bruekner and Largey 2006). The landscape of the urban and social structure can change significantly because of these reactions. Urban transport and accessibility play a central role, because social interactions are at the centre of this scheme. In effect, as Glaeser and Scheinkman (1999) establish, 70% of the spatial variation of crime can be explained by social interactions and 30% can be justified by local attributes.

Another line of thought, in sociology, suggests that inequality and social interactions play important roles in districts' crime rates (Hipp 2007). Furthermore, crime and inequality have a strong relationship with social interactions and, hence, with urban and social structure (Glaeser 2008; Bruekner, Thisse and Zenou 1999). In effect, as various authors have argued, inequality and crime depend on the degree of social interactions. By transitivity, this research emphasizes the fact that criminality and social interactions are directly related to urban transport. However, it seems rather contradictory that the relationship between urban transport and criminality has not been the subject of profound development in economics, given that transport is considered as a vital instrument to delineate and to control the growth of cities and to fight inequality and poverty (Cervero 2003, 2004). Actually, the greater the level of transport accessibility, the higher the level of social interactions, and the higher the probability of individuals interacting with their neighbours (Putman 2000).

In other words, when accessibility of transport increases in a district or in a neighbourhood, inhabitants have more opportunity to interact with other people in the city. The probability of greater levels of social interaction may be higher with public policies looking to stimulate the development of urban transport (Holtz-Eakin and Schwartz 1995). Thus, in a local context, urban transport has to be considered as a local attribute which influences local social interactions.

Consequently, the significance of social interactions in crime behaviour could be considered essential. Jens Ludwig and Jeffrey R. Kling (2006) confirmed that crime is contagious in areas where there are already criminals<sup>76</sup>. Regarding this, we can suggest that this conduct can take a worse dye when we consider social interaction behaviour as a social multiplier (Glaeser, Sacerdote and Scheinkman 1999, 2003). In consequence, social interactions may lead to more crime and could be a factor that encouraged people to go to low-density tracts.

As Brueckner and Largey (2006) stipulated, in opposition to Putman (2000), social interaction could not to be automatically in zones with high density maybe, because it is in those zones that criminality rates are generally higher. People are briefly distant from their neighbours in high-densities tracts maybe because of a higher supply of entertainment activities attracting criminals or maybe because of their fears. In effect, when a person lives in a high-density neighbourhood, he will promptly perceive a higher level of criminality.

This perception may encourage people to live in areas with a high presence of security controls (guards, cameras, etc.), which will lead to a rise in households' or enterprises' expenditures. Another possible consequence of this perception is that people will decide to move to areas with low density as a mechanism to flee offenders. These areas are generally located far from the city centre, in the suburbs; this will motivate the growth of "edges cities", which will be adapted as new sub-centres of the city (Alonso 1964, Anas 1990). Generally, people who want to avoid criminality decide to shift to zones considered more

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<sup>76</sup> See also the broken windows theory: Wilson, J. Q. and Kelling, G. L. (1982)

secure, which will translate to higher land prices. People who have “high” economic resources can choose to move, but these are a minority; a large part of people cannot move to an area with these characteristics because of their limited budget.

If urban transport has to be considered as a local attribute and social interactions are strongly linked with urban transport, it seems reasonable to say that crime can be effectively robustly associated to urban transport. However it cannot be forgotten that other variables such as population, income, employment rate and workforce, among several other factors, delimit social interactions and, therefore, crime rates.

This research focuses on analysis of different kinds of crimes in a city of a developing country: Bogotá. This city has been known for its high criminality rates in the past, as well as for the implementation of an ingenious and innovative Bus Rapid Transport (BRT) system called Transmilenio (TM) in 2000. The purpose of the present paper is to take advantage of these features and to identify the magnitude of the nexus between crimes and improvement to urban transport in each zone of the city.

In this respect, studies have demonstrated that transport infrastructure in the roads and highways of a city has a positive impact on employment and economic growth (Holtz-Eakin and Schwartz 1995; Barr 2000). Similarly, Moreno (2005) makes a spatial econometric analysis of the impact of TM on criminality alongside a TM corridor. He demonstrated that global criminality is smaller closer to the corridor, but also that there are some types of crime which are more frequent if the distance to the BRT corridor is less. However, there is no research that has tried to differentiate criminality configuration between zones that benefit from improvements of public transport such as a BRT system and zones that do not benefit from it, which represents the principal added value of this study.

This research also differs from others because it attempts to make a cross-section analysis of the impact of public transport improvements on criminality levels using the propensity score matching (PSM) methodology. In addition, in order to reinforce results from the PSM methodology, a spatial autocorrelation analysis of each type of crime between the 112 zones composing the “bogotanian” landscape will also be done.

The paper proceeds as follows. Section 2 reviews the literature about the link between social interaction, transport and criminality, as well as some studies about Bogotá. Section 3 put lectors in context about Bogotá and its urban transport system emphasizing on Transmilenio. The fourth section describes data and the econometric methodologies approaches used in the paper. Empirical findings are presented in section 5 and conclusions are offered in section 6.

## **4.2 Social interaction, criminality and mobility**

### **4.2.1 Criminality and social interaction**

As many authors have revealed, social interactions are crucial in the behaviour of an individual (Glaeser 1996, Freedman 1996). An individual is more stimulated to become a criminal if their peers are criminals. In opposition, the same motivation is not present if his peers are not criminals. This behaviour depends directly upon social interactions and distance from jobs and residential zones.

Concerning the difference in types of crime, violent crime and property crime are more common in big cities than in small ones (Glaeser and Sacerdote 1999). In addition, crime rates are higher in central cities than in suburbs (Bears 1996) because of larger unemployment and density rates. In fact, as Putman (2000) suggests, density is a factor which determines the level of social interaction; low density reduces social capital and therefore social interaction.

Individuals' behaviours are not only a function of their desires but also a function of their entourage. Considered as a behaviour, criminality and its progress depends on spatial structures in neighbourhoods and zones, thus it also depends on social interactions. Glaeser, Sacerdote and Scheinkman (1996) argue that 30% of criminality depends on local attributes and Zenou suggest that 70% is associated with social interactions. However,

social interactions depend also upon local attributes such as amenities like transport accessibility, parks and entertainment places, among others.

If we consider urban transport as a local attribute we can say that it can also determine social interactions. If accessibility of transport increases in a neighbourhood, inhabitants will have more opportunity to interact with other people in the city. The probability of growth of social interactions is higher in the presence of public policies which stimulate the development of urban transport. Density will be higher and with more people to interact with, individuals find more opportunities to relate.

Nevertheless, if we take into consideration Brueckner's suggestion (2003), this type of behaviour can also lead people to think that anybody can be a criminal. In high-density zones, every neighbour is suspicious which, in turn, encourages a decline in social interaction and induces people to search out zones of low density which are, generally, far from the centre of the city.

Additionally, with enlarged accessibility, heterogeneity of neighbours or districts during the day will be higher and socio-economic differences will be more perceptible. According to Hipp (2007), this will lead to a higher feeling of exclusion or injustice within the society, which can have negative consequences such as criminality as an instrument with which to pronounce one's feelings.

Hipp (2007) shows the different effects of the distribution of classes in crime levels. He proposes six different "theories of crime" to illustrate the link between crime rates and social sharing of the district. He concluded that in Seattle, income inequality increases the scale of several types of crime in a neighbourhood. It supposes that people compare themselves with respect to other people living or not in the same neighbourhood. If they consider that they are in an unfair or an unequal economic and social condition, they will react aggressively against those who live in better economic and social conditions: they will have a tendency to "equalize the gap" within the district. This is called by Hipp the "Relative Deprivation Theory".



Another “theory of crime”, verified by Hipp, is “Routine Activity Theory”. In fact, he proved a positive relationship between general inequality in a district and crime. Growth of inequality leads to an increase in the number of “potential targets” (those who have high incomes) and “motivated offenders” (those who don’t have a high socio-economic level). If these two types of agents live more closely, criminality index will tend to go up. Criminals will be obligated to choose between stealing from a neighbour (and being recognized by him) or from an individual who doesn’t live in his quarters or in his district. According to that, we can say that commuting cost, as well as reputation effect, can play an important role in criminal behaviour. Offenders will face a cost-benefit analysis which will depend on their commuting cost but also the probability of being recognized by someone who lives in the same neighbourhood and, so, the probability of being arrested or rejected by the society.

As stated above, if districts are composed by different social groups and if social heterogeneity is significant, social interaction can decrease. Hipp (2007) and Putman (2000) found in their studies a positive relationship between a small level of social interaction and criminality. In fact, they saw a low level of social interaction in neighbourhoods with low homogeneity. Hipp named this behaviour “The social distance and social disorganization theory”. In fact, this social distance will be a consequence of an income inequality and heterogeneity of races in a same district. A higher inequality level in a district can lead to higher crime rates because of a reduced level of social interaction. What Hipp means is that income inequality is more significant than inequality per se. His model reveals a positive relationship between inequality and crime, but this link is reduced when he takes into consideration the income inequality. Nevertheless, he does not reject inequality as a significant factor.

In addition, the high social multiplier implies that crime and its effects will be significant (Becker and Murphy 2000; Glaeser, Sacerdote and Sheinkman 2002; Ludwig and King 2006). From the point of view of criminals, this social multiplier can create positive externalities. In fact, the spread of crime in a district or in a specific zone of the city decreases the probability of being arrested. So, criminals profit from this multiplier, but it

also has a negative externality: their earnings decrease because of the entry of more competitors in the market (more criminals). The crime market is reduced as well as commuting costs lowering.

#### **4.2.2 Criminals' mobility and jobs' centers**

The impact on offenders' earnings of the distance travelled to commit their crimes has been studied by some authors. As is shown in Morselli and Royer's (2008) research, distance can be perceived as a factor of criminal achievement. Mobile offenders seem to report higher financial earnings from crime than immobile offenders. Many authors have established that property crimes require greater distance than violent crimes. Indeed, violent crimes like homicide or crime with predatory violence require short distances to be achieved, in opposition to shoplifting or commercial crimes which need higher distances. Between these we found motor vehicle thefts, which do not need to be accomplished so far from home but need a greater distance for resale of the auto parts.

From this perspective, we can see that compensation between the probability of arrest and perception of higher earnings can stimulate offenders to travel long distances. In effect, there is a positive correlation between distance from house and earnings. But distance is also related to commuting costs. In fact, distance represents a cost because it also signifies time and time has a value. When time of transportation within a city decreases, costs also decrease. So, if a criminal sees their commuting costs decrease, he will be more stimulated to travel and to commit crimes in zones connected to the transport network.

In addition, as Morselli shows, criminal earnings and individual crime commission rates have a positive relationship (Tremblay and Morselli 2000; Morselli and Royer 2008). But the relationship between criminal earnings and distance travelled can be positive. In effect, the highest gains from a highest distances travelled by offenders, rouse to a more efficient criminal involvement and, as a consequence, the rate of crime commission decreases.

Considering the age of delinquents, Morselli and Royer (2008) found mobile offenders and immobile offenders have different ages. Those who travel to commit their crimes are younger and have more contact with other criminals. When a criminal travels to commit their crimes, generally he will have contact with other criminals, which can be a source of learning and can grow into a criminal network with higher earnings. The difference in gains between mobile and immobile offenders is clearly demonstrated.

Actually, mobile criminals report much higher earnings, according to Morselli and Royer (2008). Their conclusions were: (i) there is a positive and strong relationship between criminal earnings and offending perimeter, (ii) lifestyle and age have significant impacts on criminal earnings, (iii) criminals' gains are not significantly influenced by costs of crime (Morselli and Tremblay 2004), (iv) crime type is very important to typify the magnitude of the relationship between gains and offending perimeter, (v) immobile offenders have lower earnings.

Criminals are confronted with a trade-off between going to an area with high density and less probability of arrest but where they will probably obtain low earnings or going to low-density areas with higher earnings but also higher probability of going to prison.

Indeed, earnings will change in function of the situation of the place in the city. Generally, those earnings will be superior in places with a high density of jobs; therefore the productivity of a zone may also determine the levels of crime rates. Criminals are supposed to follow jobs-quarters where density is upper the mean of the city and where probability to be caught is lower.

Zenou (2003) shows that individuals have a tendency to commit more crimes in Central Business Districts (CBD) than in suburbs. This is almost true when we take in consideration some North American CBD's but it is not the same on some European CBD like in Paris or in London<sup>77</sup>. Actually, when commuting costs of accessing the CBD are low, criminals will be encouraged to go there as a result of high density and low probability of being

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<sup>77</sup> See criminal reports of both cities

arrested (monocentric city). Crime is elevated in the CBD because criminals, generally, live in poor neighbourhoods placed in suburbs.

Nevertheless, when poor people live in the CBD and the accessibility to other areas of the city from CBD increase, which is in some respects the case in Bogotá and other cities in developing countries, the probability of observing the same behaviour that Zenou shows can also increase.

### **4.2.3 Some studies about BRT system and its effects in Bogota**

Since 2000, some effects of the new BRT system in Bogota have been studied. The most common studies are related to the impact of Transmilenio on the property and land values (Perdomo, Mendoza, Mendieta and Baquero 2007; Mendieta and Perdomo 2007; Rodriguez and Targa 2010). Other studies have focused their interest on the impact of the Transmilenio system on inhabitants' accessibility and on inequalities (Rodriguez and Targa 2004; Bocarejo and Oviedo 2012).

Nonetheless, few studies have examined the relation between criminality and transport in Bogota and in other cities over the world using spatial data. Moreno (2005) made the only spatial econometric analysis of criminality in Bogota related to urban transport. It involved surrounding TM zones one year before and one year after the opening of this new public transportation system in the city. His findings represent a good indication of what can be expected from this research. He found that global criminality decreases alongside the TM corridor but a "sub-regional" spatial analysis of data showed that some surrounding TM zones experience an intensification of some type of crimes such as thefts from people, robberies of commercial establishments and robberies of houses. In addition, according to socio-economic characteristics, the zones with worsts socio-economic conditions present higher levels of criminality, which was expected.

On the other hand, Estupiñan and Rodríguez (2008) demonstrated that the support to build an adaptable environment for the use and the boardings to the BRT system stations

represents an important barrier to private car use and has a positive effect on urban transport use. Nevertheless, while it was not the core of their research, they also found “unexpected” characteristics in their results. In effect, “lack of safety and insecurity (factor 3,  $p < 0.01$ ) unexpectedly is related to transit use, with high insecurity and low safety was associated with higher transit use”. These observations, coupled with the different studies quoted above, reinforce the main subject of this research<sup>78</sup>.

### 4.3 Bogotá: Public transports development

Bogota is the most populous city in Colombia, with more than 7 million inhabitants. From the 1970s to the end of the 1990s, density grew by 50%, from 100 inhab/ha in 1973 to 150 inhab/ha inhabitants in 1993 and 170inhab/ha in 2005.

The social structure in the city changed in turn. The gap between rich people and poor people is also bigger than in the 1970s. Rich people and poor people live in different zones and different neighbourhoods divided into six different socio-economic strata. Those who live in strata 5 and 6 (the richest strata) are placed in the north and north-east of the city and they represent 6% of the population. The south, centre and west of the city are composed of strata 1, 2 and 3 (the “poorest” population) which represent 81% of the population; strata 4 represents 13% and characterizes the population of the middle class who live in the west and north-west of the city.

Since the 1960s, inhabitants have revealed the desire to live close to the “rich” people who, in their turn, decided to settle in the north of the city. Because of this evolution and transformation of social and urban structure, population spread took place. In addition, a degradation of urban transport conditions was inevitable. Before the 1960s Bogotá had a tramway system service ensured by the public administration. However, because of the spread of different social classes, with “rich people” finding the north and east of the city

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<sup>78</sup> “Low income pricing and crime” “Delincuencia en Bolivia”,

a “desirable” place to live, we saw a sprawl of the urban structure and hence a decline of the efficiency of urban transport system in the city, notably in the case of the tramway. The tramway disappeared because of this loss of efficiency and also because of lobbying from private entrepreneurs who revealed their intentions to participate in the public transport system in the city as suppliers of the service.

After the tramway declined, the public administration gave the right to assure the service with buses to private entrepreneurs: this was the nature of the expansion of Bogotá’s public transport system and hence the expansion of public buses until the end of the 1990s.

In the 1990s, the city’s public transport system was composed of private entrepreneurs assembled into about 60 private enterprises assuring the provision of the service in the city. The public administration played no part in the utilities other than its regulatory role.

At the beginning of the 1990s, as a consequence of the growth of the urban territory, the government decided to differentiate and decentralize the city into 20 different districts (localidades), adopting in this way a sort of “Parisian mould of decentralization”. One of those districts comprises part of the rural zone of the city (Sumapaz) and the others compose the urban area.

Since this reorganization, several planning policies have been suggested by the government, with the development of an urban transport system the more relevant of those: Transmilenio<sup>79</sup>.

Today, Transmilenio is an integrated Bus Rapid Transit (BRT) system, using busways (84 km), stations (114) and terminals (7) connected by an inter-urban transport system. It is adapted for articulated buses (1262 buses) with the capacity to carry 60–120 passengers, but they move almost 150 passengers in peak hours. The system moves about 1.7 million passengers per day at a mean speed of 27 km/h.

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<sup>79</sup> [www.transmilenio.com](http://www.transmilenio.com)

The Transmilenio system was implemented in 2000 and today is one of the most popular and successful Bus Rapid Transit (BRT) systems in the world. After its implementation, mobility in Bogotá changed radically. Travel time decreased by 66% (from 1h30 to 30 min) and hence, accessibility also increased considerably, connecting the north and the south of the city in about 50min per trip<sup>80</sup>.

The implementation of this BRT system led reorganization of the public transport network in Bogotá. With the Transmilenio system, the transportation system of the city is shifting to a public–private partnership mechanism. The public administration ensures the construction and maintenance of corridors and stations and the private sector assures the operation of the system under concession contracts.

This new transport system encouraged a change of the social and urban structure in the city. Rich and poor neighbourhoods are now easily connected directly by Transmilenio, which can have a direct effect on the social and urban configuration, as in the 1960s.

## **4.4 Data and methodology**

### **4.4.1 Descriptive statistics and available data**

The data collected for this study consider all 112 zones of the city as of December 2007. Several characteristics of each zone were taken into consideration in order to explain the criminality rates. This research was able to access a very rich database of all crimes committed in the city<sup>81</sup> in 2007. These crimes were spatial-referenced with the exact addresses where the incident took place. In order to make a cluster analysis with respect to the zones

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<sup>80</sup> Before Transmilenio or today in a private car, this same trip take around 2,5 hours at less. The route is of at least, 20 kilometers

<sup>81</sup> A big thank to the Conflict Analysis Resource Center (CERCAC) that furnished this database and enriched this research with the permission of the Metropolitan Police of Bogota (MEBOG).

of the city, each crime was assigned to one of those zones depending on the address at which it happened. In addition, crimes were differentiated into six different types: homicides, thefts from people, robbery against people with violent aggression, burglaries of commercial establishments, house breakings and bank robberies. Because of the low number of bank robberies in each zone, this type of crime could be confused with a dummy variable, so this study decided not to take into consideration this kind of crime. There remain five types of crimes which will be the subject of the analysis: they represent the variables to explain.

As stated above, the core of this paper is to analyse Transmilenio's impact on crime rates in each zone of the city. The presence of these improvements to public transport was defined as the presence of at least one station of the TM system in a zone. Nevertheless, most TM stations are placed on the intersection of two or more zones and in corridors of the TM system that separate two adjacent zones. In these cases, this research considers that a TM station acts as part of both zones. Following this method, data reveal that there are 61 zones that benefit from the presence of TM and 51 without a TM station.

In order to evaluate the impact of other variables on crime rates, secondary data were also included in this analysis: the number of jobs in each zone of the city, the average income of inhabitants of each zone as equal as the average cost of travel for an inhabitant from each zone and the extension on hectares of each UPZ, conform the socio-demographic and socio-economic group of variables. This data was taken from the census conducted in the city in 2007 by the city's Department of Planning<sup>82</sup>. It was not possible to find more recent information because the city hall has not made other censuses for subsequent years.

Other kinds of information, such as the number of establishments providing health services (hospitals, clinics, radiological centres, etc) and the number of establishments promoting welfare (nursing homes, rehabilitation centres, orphanages, etc) and cultural events (cinemas, theatre, malls) represent amenities of each zone.

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<sup>82</sup> Encuesta de Calidad de Vida para Bogotá (ECV) 2007. Secretaria de Planeación del Distrito de Bogotá.



Table 4.1 : Descriptive Statistics

Variable	Label	Obs	Mean	Std. Dev	Min	Max
Thefts to people	crimeteft	112	110,05	92,34	3,00	569,00
Burglaries to commercial Establishments	crimecom	112	37,71	38,44	2,00	302,00
House Breakings	crimehouse	112	44,34	38,67	1,00	244,00
Homicides	homicides	112	11,46	11,25	0,00	53,00
Robbery to people with violent aggresions	lesiones	112	73,17	74,87	0,00	515,00
Presence of Transmilenio Station	presencetm	112	0,54	0,50	0,00	1,00
Area of the zone in hectares	hectares	112	375,47	180,08	79,83	992,33
Number of small enterprises	smallenter	112	65.77679	128.7845	0,00	1110,00
Number of inhabitants per hectare	density_hec	112	181.1607	105.2794	1,00	526,00
Number of jobs on each zone	employment	112	13997,52	16632,94	197,00	142052,00
Mean Income of people of each zone	income	112	689235,80	566579,90	196821,00	3032604,00
Average cost of travels for people of each UPZ	aver_cost_travel	112	1878,35	704,86	332,00	6080,00
Establishments providing Cultural activities	culture	112	8,12	8,18	0,00	40,00
Establishments promoting Welfare	soc_welf	112	63,25	63,83	0,00	288,00
Establishments provinding Health	health	112	3,53	3,24	0,00	15,00
Number of households on each zone	households	112	16448,11	13249,69	2,00	73794,00
Working Force	w_force	112	28543.31	39705.63	0,00	257862
Have at less one car	have_a_car	112	6778.813	6065.128	0,00	27569
Wealth	wealth	112	.6339286	.4838944	0,00	1

Author's calculations

#### 4.4.2 Models and methodology

Several researchers have studied the impact of transportation infrastructure on land values and on the accessibility on a city. These studies generally used a multiplicity of mathemati-

cal and statistical methods (Salon and Shewmake 2011) that involve hedonic regressions, 2 SLS regressions, propensity score matching and spatial regressions among several others. Regarding criminology, it is also common to find several studies focusing on the identification of causal effects of socio-demographic and socio-economic characteristics on different kind of crimes (Apel and Sweeten 2010). Those studies also use the same econometric techniques and several of them take a “treatment effects” approach to projects or policies in order to make causal effect estimations.

The methodology used in this paper encloses two different techniques: Propensity Score Matching (PSM) and spatial regression analysis. The use of these two methodologies aims to find:

- How criminality rates depend on some characteristics of each zone and how they are comparable to other zones.
- How this criminality is spatially auto-correlated between zones (not time that conduct to make a cross-section regression and not a panel data analysis).

Each type of crime will be regressed with respect to some variables that represent some socio-economic, demographic and infrastructure indices of each zone of the city.

The model applied and followed in both PSM and spatial econometric analysis is:

$$\begin{aligned}
 Crime_i^t = & \beta_0 + \beta_1 presence_i + \beta_2 hectares_i + \beta_3 density\_hec_i + \\
 & + \beta_4 employment_i + \beta_5 income_i + \beta_6 culture_i + \beta_7 soc\_welf_i + \quad (4.8) \\
 & + \beta_8 health_i + \beta_9 aver\_cost\_travel_i + \varepsilon_i \quad (4.9)
 \end{aligned}$$

where:

- $Crime_i^t$  is the number of crimes of type  $t$  committed in zone  $i$ .
- $presence_i$  is a dummy variable that takes a value of 1 if there is at least one TM station on zone  $i$  and 0 if not.
- $hectares_i$  is the area of each zone measured in hectares.
- $density\_hec_i$  is the density of zone  $i$ .
- $employment_i$  is the number of jobs in zone  $i$ .
- $income_i$  is the average income of inhabitants of each zone.
- $culture_i$  is the number of establishments promoting cultural activities,  $soc\_welf_i$  is the number of establishments providing social welfare,  $health_i$  is the number of establishments providing health and  $aver\_cost\_travel_i$  is the average cost of travel to reach zone  $i$ .

### Propensity Score Matching modeling

This article adopts the methodology used in Heckman et al. (1997). It tries to compare criminality rates in zones with TM stations with criminality in zones that do not have TM stations. Generally, this comparison could be possible if each zone has the same set of covariates but, because of spatial dimensions, it is not possible to do so unless using a statistical matching technique such as PSM. The fact that each zone has some similar characteristics makes the comparison plausible. In effect, the matches are selected on the basis that those characteristics have a great degree of resemblance. It assumes that there is no

selection bias based on unobserved characteristics. Thus, when each zone of the city has those characteristics, it will have a greater or lesser probability to benefit from the TM system.

A logistic model has to be estimated previously in order to use the results from those estimations as the basis of propensity score matching.

The dependent variable of the logistic regression reflects the probability that a zone has at least one station of TM with respect to some socio-economic characteristics of each zone (match on the basis of the propensity score). The binary variable takes two different values:  $Y = 0$  if the zone does not benefit of the presence of TM and  $Y = 1$  if there is at least one TM station. It can be expressed as follows:

$$\text{Pr } ob(Y = 1) = F(X, d), \text{Pr } ob(Y = 0) = 1 - F(X, d) \quad (4.10)$$

where  $d$  is a vector that reflects the impact of independent variables ( $X$ ) on the probability that a zone has a TM station.

This logistic regression is defined as follows:

$$\begin{aligned} \text{Pr } esence_i = & \beta_0 + \beta_1 \text{households}_i + \beta_2 \text{hectares}_i + \\ & + \beta_3 w\_force_i + \beta_4 \text{wealth}_i + e_i \end{aligned} \quad (4.11)$$

Where  $\text{households}_i$  is the number of households in zone  $i$ ,  $w\_force_i$  is the workforce in each zone and  $\text{wealth}_i$  is a dummy variable revealing if the population of zone  $i$  is on average “rich” or “not rich”<sup>83</sup>.

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<sup>83</sup> Bogota is segmented on 6 socio economic stratus. If a neighbor is considered as stratum 1, it means that the population is poor. In contrast, if the neighbor is stratum 6 it means that there are more rich people than poor people. In this study, the variable  $\text{wealth}_i = 1$  if the average stratum of the zone is 5 or 6. If  $\text{wealth}_i = 0$  it means that people is not rich.

Once this probability is estimated, the criminality rates in zones with presence of TM is contrasted with the crime rates in zones without TM presence. The criteria of comparison is done by the similar probability (nearest neighbour search) of having a TM station that the sample has estimated through socio-economic and geographic characteristics.

Theoretically, it supposes that there is a difference between criminality rates in treated group  $Y_i^1$  and criminality rates in the untreated group,  $Y_i^0$  (with  $(1 < i < 112)$ ).

Mathematically, the PSM technique pairs observations (treated and untreated) on the estimated probability to being treated (propensity score). Then, the effects related to the fact that there is at least one station of TM will reflect an increase or a decrease in crime rates. The difference ( $\Delta$ ) of the contrast variable regarding criminality rate is denoted as:  $\Delta = Y_i^1 - Y_i^0$ , where  $\Delta$  is unknown because of the impossibility to observe (simultaneously) crime for each zone, with the assumption that every zone may benefit or not from the TM system<sup>84</sup>.

The criminality rate for each zone  $i$  is estimated as a function of observable characteristics ( $X_i$ ) of each zone and unobservable characteristics ( $e_i^1$   $e_i^0$ ):

$$Y_i^1 = X_{i1}B^1 + e_i^1 \quad (4.12)$$

$$Y_i^0 = X_{i0}B^0 + e_i^0 \quad (4.13)$$

As stated above,  $Y_i^1$  and  $Y_i^0$  represent the criminality rate in zones with and without TM presence. Vectors  $B^1$  and  $B^0$  are the coefficients associated with  $X_i$  observable characteristics and  $e_i^1$  and  $e_i^0$  represent the error terms.

To evaluate the impact of public transport improvement on zones' crime rate, PSM uses statistical averages called "Average Treatment Effect on the Treated" ( $ATT$ ). In order

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<sup>84</sup> It is not possible to know what could be the crime rate on a zone  $z_i$  that benefits from TM system if it do not benefit from it.

to determine the *ATT*, the average treatment effect (*ATE*) must first be defined, which is the average response to treatment for a random sample from zones defined by:

$$ATE = E[\Delta] = E[Y_1 - Y_0] \quad (4.14)$$

where

$$\begin{aligned} E[Y_1 - Y_0] &= E[Y_1 | D = 1] \Pr(D = 1) + E[Y_1 | D = 0] \Pr(D = 0) - \\ &\quad \{E[Y_0 | D = 1] \Pr(D = 1) + E[Y_0 | D = 0] \Pr(D = 0)\} \end{aligned} \quad (4.15)$$

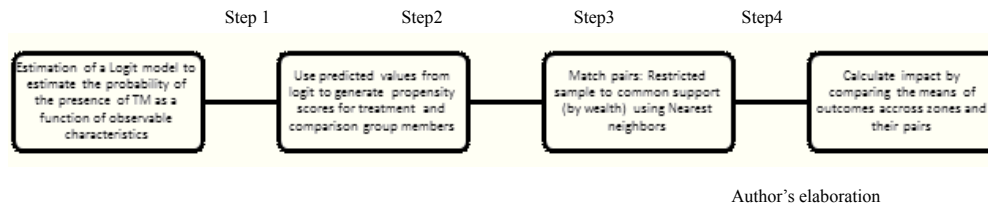
Thus, the *ATT* is note as:

$$ATT = E[\Delta | X_i, D = 1] = E[Y_1 - Y_0 | X_i, D = 1] \quad (4.16)$$

$$ATT = E[Y_i^1 - Y_i^0 | X_i, D = 1] = E(Y_i^1 | X_i, D = 1) - E(Y_i^0 | X_i, D = 0) \quad (4.17)$$

*ATT* is presented as the expected value of the difference of crime rates given the characteristics  $X_i$  of each zone that benefits from the TM system. This is equal to the difference between the expected value of the crime rate in zones with the TM system and the expected value of the crime rate in zones without the TM system. Then the information for the untreated group (the zone without the TM system) is used as a tool to compare this information with treated groups (zones with the TM system). *ATT* is the average response to treatment for a sample of zones treated.

Figure 4.1: PSM different steps



If there are statistically significant differences between the crime rates in zones with and without presence of the TM system, it is possible to conclude that the system has an effect on UPZ with TM station and the crime rates. The impact is positive or negative if the match differences of means on crime rates of each treated and untreated group are positive or negative modeling.

### Spatial Econometric modeling

After estimation of the impact of improvement to the TM system on crime rates, this paper considers also that it could be a spatial correlation of different types of crimes. In order to evaluate this, the paper has contemplated the use of econometric techniques from a spatial econometric approach. Results from this econometric procedure will show if there may be a contagion or diffusion effect of crime between different zones.

Some studies (Anselin 1999; Moreno and Vaya 2008) emphasize the fact that cross-section and panel data analysis may have some spatial effects. Those effects have to be taken in consideration in order to improve econometric analysis.

Spatial dependence or spatial autocorrelation takes place if a variable of a zone, in this case the crime rate of zone  $i$ , is related to the same variable in other zones. This autocorrelation may be positive if the presence of a specific phenomenon in a zone (crime) leads to a spread of it in other zones. Conversely, if it leads to a reduction in other zones, it is a negative autocorrelation. If the variable (crime) is randomly distributed, there is no spatial autocorrelation.

Even if OLS estimation can be done with cross-section data, there must be independence within observations. However, if data are geographically differentiated, the probability of multidirectionality problems is high (Moreno and Vaya 2008) and so OLS estimations may lose their meaning.

If the spatial dependence is taken into consideration, and in order to solve the multidirectionality problem, spatial associations among variables (crime) have to be quantified. To identify and validate the presence of global autocorrelation the Global Moran's I and Global Geary's G tests were used. Those tests allow the study to contrast the presence or absence of spatial dependence of each dependent variable (type of crime). Results of those tests will show if the variable (type of crime) is randomly distributed across space or if, in contrast, if there is a significant association of similar or dissimilar values within regions.

After defining the presence of spatial autocorrelation, the study proceeds to definition of the most adaptable model type. The Lagrange multiplier test and the robust Lagrange multiplier test for spatial lags and for spatial errors are the diagnostic tests for identification of the model.

To develop this kind of analysis, a spatial weights matrix  $W_{ij}$  has to be defined. With this matrix, the examination will be able to reflect the degree of interdependence that may exist between each pair of zones  $i$  and  $j$ <sup>85</sup>.

In effect, it is possible that, in the context of a regression model, spatial dependence is observed as a consequence of spatial correlation of some variables (spatial lag dependence) or as a consequence of the existence of spatial dependence on the error term (spatial error dependence) of each model. These two scenarios introduce two kinds of spatial models:

- The spatial lag model that fits covariates or spatial lag to describe mean.

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<sup>85</sup> Anselin 1988.



- The spatial error model that assesses the residuals and specifies error dependence structure inference.

The spatial lag model supposes that each location is correlated with every other one, while spatial error supposes that each error is correlated with every other one.

## 4.5 Results

### 4.5.1 Results from PSM methodology

PSM methodology suggests that a Probit or Logit model should be used in order to generate propensity scores for treatment from predicted values. These models allow researchers to determine the probability that a zone benefits, at least, from the presence of one Transmilenio station even if this station is placed in the zone or along the border of the zone. This study used a logistic function; the dependent variable is  $\text{Presencetm}=1$  if there is at least one TM station and 0 if not. The presence of Transmilenio in a zone, even if as an independent variable in the main model (equation 1), depends on other variables (see subsection 4.2.1). It denotes that  $\text{Presencetm}$  is like an endogenous variable that depends on some other variables<sup>86</sup>.

Results of the estimation of the Logit model, the marginal effects and the elasticity of each regressor are shown in table 2. The probability that a zone benefits from the presence of at least one TM station increases with the number of households in each zone.

In the same way, this positive relation is observed with respect to the workforce and “social belonging”: if the population of a zone is on average “not poor”, the probability

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<sup>86</sup> To demonstrate endogeneity of  $\text{Presencetm}$  a 2SLS analysis was made before for each kind of crime; results do not appear on this paper because it does not make part of the aim of the article.

that Transmilenio will pass within or along this zone is higher. In contrast, the probability that a zone benefits from improvement of public transport decreases with respect to its size.

Elasticity of each independent variable has to be interpreted partially and held constant with all other things. It signifies that an increase of 1% of the number of households in each zone increase by 0.22% the probability of having a TM station in a zone. In parallel, if the workforce or the average of “not poor” people increases by 1% in a zone, the probability that this zone benefits from public transport improvements may increase by 0.08% and 0.16% respectively. Instead, if the area of the zone rises on 1%, the probability to have a TM station on that zone may drop on 0.40%.

Table 4.2: Logit model, marginal effects and elasticity

VARIABLES	Presencetm	Marginal effects	Elasticity dy/dx
Constant	-0.08092 (0.574)		
households	0.00005*** (0.000)	.0000134*** .00001	.2208132*** .08429
hectares	-0.00433*** (0.002)	-.0010762*** .0004	-.404088*** .14846
w_force	0.00001* (0.000)	2.83e-06* .00000	.0808714* .04297
wealth	1.02476** (0.460)	.2507054** .10781	.1614141** .07249
Log likelihood	-66,932795		
Prob>chi <sup>2</sup>	0,0004	LR chi <sup>2</sup> (4)	20,51
Observations	112	Pseudo R <sup>2</sup>	0,1328
Standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			

Authors' calculations

Precedent results were used in the propensity score matching analysis. Five-Nearest-Neighbour option was used to create the sample for analysis<sup>87</sup>.

Table 3 displays PSM results. It can be denoted that the number of “Thefts from people” committed in zones that benefit from TM is on average 133 while the average

<sup>87</sup> Results of PSM were found using the nearest neighbor method which is based on the comparison of the criminality of each zone with TM with the criminality of each zone that do not has a TM station and that has the closest value of the propensity score. The result of estimation is then the average of comparisons of criminality rates over all zones with TM station (ATT).

number of thefts from people in zones without TM is 78. The biggest difference in thefts committed between these two kinds of zones in 2007 is approximately 54. Those results are statistically significant at 1% level.

Regarding the number of thefts from commercial establishments, it can also be seen that the number of events is bigger in zones that benefit from TM than in zones which do not benefit from this transport system (45.86 vs 25.76).

Table 4.3: PSM - differences between matched and unmatched variables

Variable	Sample	Treated	Controls	Difference
crimeteft	Unmatched	133.065574	82.5294118	50.536162
	ATT	133.065574	78.4786885	54.5868852***
crimecom	Unmatched	45.8688525	27.9607843	17.9080681
	ATT	45.8688525	25.7672131	20.1016393***
crimehouse	Unmatched	49.7704918	37.8431373	11.9273545
	ATT	49.7704918	36.4098361	13.3606557*
lesiones	Unmatched	72.3934426	74.0980392	-1.70459659
	ATT	72.3934426	67.9803279	4.41311475
homicides	Unmatched	11.4754098	11.4509804	.024429444
	ATT	11.4754098	10.7868852	.68852459

Authors' calculations

Results for this type of crime are also statistically significant at 1% level.

On the other hand, there are more house breakings in zones benefiting from the TM system: on average 49.7 house breakings in zones with TM presence and 36.4 in zones without the TM system. These results are also statistically significant but at 10% level.

Finally, regarding the number of robberies against people with violent aggression and homicides, it is also found that they are most frequently perpetrated on UPZ with at least one Transmilenio station. Nonetheless, these results are not statistically significant. However, differences in the number of occurrences of the event are very shallow, which may imply that such types of crime do not depend in large proportion or do not take a big influence from the improvement of public transport.

On the other hand, in order to confirm the impact of the presence of improvement of public transport on the level of crime in each zone of the city, equation 1 was also regressed as an OLS model. Table 4 denotes that the presence of TM always has a positive impact on crime rates. Actually, among all the independent variables, “Presencetm” has the biggest impact on the variable to be explained.

Table 4.4: OLS results

Scope of analysis	Variables	Crimeteft	Crimecom	Crimehouse	Lesiones	Homicides
	Constant	-7.938 (31.029)	0.771 (11.017)	-21.459 (15.315)	-85.320*** (23.488)	-7.104* (3.937)
Improvements	presence TM	27.992** (13.780)	3.012 (4.893)	12.849* (6.801)	20.468* (10.431)	1.258 (1.748)
Socioeconomic and demographic	hectares	0.105*** (0.036)	0.021 (0.013)	0.084*** (0.018)	0.138*** (0.027)	0.011** (0.005)
	smallenter	0.346** (0.138)	0.103** (0.049)	0.162** (0.068)	-0.041 (0.105)	0.003 (0.018)
	density_hec	0.055 (0.079)	0.003 (0.028)	0.089** (0.039)	0.213*** (0.060)	0.042*** (0.010)
	employment	0.001 (0.001)	0.001*** (0.000)	-0.001** (0.000)	0.000 (0.001)	0.000 (0.000)
	income	0.000 (0.000)	0.000 (0.000)	0.000** (0.000)	-0.000 (0.000)	-0.000 (0.000)
	aver_cost_travel	0.010 (0.010)	0.001 (0.004)	0.003 (0.005)	0.008 (0.008)	0.001 (0.001)
	culture	2.849*** (0.993)	0.560 (0.353)	0.530 (0.490)	2.706*** (0.752)	0.137 (0.126)
Amenities	soc_welf	-0.243 (0.147)	-0.031 (0.052)	-0.035 (0.073)	0.360*** (0.112)	0.037* (0.019)
	health	-1.084 (2.290)	-0.259 (0.813)	-1.343 (1.130)	-0.390 (1.734)	0.463 (0.291)
Observations		112	112	112	112	112
R-squared		0.568	0.686	0.400	0.624	0.532
Standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

Authors' calculations

OLS results confirm previous findings. In effect, TM presence has the biggest impact on the number of thefts from people, the number of robberies against people with violent aggression and the number of house breakings. In contrast, crimes in which TM presence has lower incidence in absolute terms are homicides and burglaries of commercial establishments.

Like the PSM methodology, OLS results reveal that the presence of TM in a zone has statistical significance to thefts from people and house breakings. In contrast, table 4 displays that the presence of TM in a zone has also a statistical significance in the level of robberies with violent aggression and does not have statistical significance to burglaries of commercial establishments.

#### **4.5.2 Results from Spatial econometric methodology**

Given that this paper uses geographical data and tries to study differences and similarities between zones of the city, a spatial analysis from an econometric point of view may be useful to complete this approach.

According to spatial econometrics analysis, this research proceeds first to establish if there exists a spatial autocorrelation of the different types of crime. To carry out this first step, the most traditional approximation to study the effect of spatial dependence is the calculation of global statistics (Moran and Getis tests). These statistics allow the contrast of the hypothesis (null hypothesis,  $H_0$ ) that says a variable is randomly distributed on space or if in contrast there exists a significant spatial likelihood of variables.

Moran's I statistics have as the null hypothesis ( $H_0$ ), that variables (crimes) are randomly distributed in the space. The null hypothesis for Getis's G statistics tries to contrast if there is no a spatial concentration of a variable. A rejection of the null hypothesis in both cases suggests that crime there is a spatial dependence and a concentration of crime and so, that crimes on a specific zone may affect or are related with crime rates of neighbouring or closest zones.

Table 4.5: Moran's I and Getis' G

Variables	I - Moran	G - Getis
crimeteft	0.065***	0.930***
crimecom	0.050***	0.959
crimehouse	0.103***	0.871***
homicides	0.024***	0.974*
lesiones	0.019***	0.944**
*** p<0.01, ** p<0.05, * p<0.1		

Authors' calculations

Table 5 exposes that, for the case of Bogotá, for every kind of crime, Moran's I statistics are significant at 1% level, indicating that all types of crime have a spatial dependence. Getis's G statistics suggest that every type of crime presents a geographical concentration except for burglaries of commercial establishments.

Given previous results of global spatial autocorrelation tests, it can be asserted that crimes are directly spatially auto-correlated. Each type of crime in a zone of the city of Bogotá has an impact on the number of crimes in contiguous zones.

Once spatial autocorrelation is corroborated, spatial regression has to be done in order to determine the spatial dependency between the dependent variable and regressors.

To define the spatial regression model, it is advisable to do some diagnostic tests. The Lagrange multiplier test and the robust Lagrange multiplier test for spatial lags and spatial errors were used as diagnostic tests in order to identify the better model for each type of crime.

Table 4.6: Diagnostic identification tests

Test	Crimeteft	Crimecom	Crimehouse	Lesiones	Homicides
Spatial error					
Moran's	3.474***	0.760	4.846***	6.030***	0.120
Lagrange multiplier	0.988	0.188	2.944*	5.469**	0.593
Robust Lagrange multiplier	1.051	0.134	0.692	8.951***	0.497
Spatial lag					
Lagrange multiplier	3.905**	0.064	7.731***	0.597	0.201
Robust Lagrange multiplier	3.969**	0.010	5.478**	4.079**	0.106

Authors' calculations

Table 6 reveals that LM error statistic is significant for “robbery against people with violent aggression”. It implies that there is a spatial dependency on the error term and hence, the most adaptable model should be a spatial error model. On the other hand, LM lag statistics are significant for “thefts from people” and “house breakings”, which suggests that the spatial dependence is observed as a consequence of a spatial correlation of some variable (spatial lag dependence; thus, a spatial lag model may be most adaptable to these types of crime.

Conversely, the identification test has no statistical significance regarding burglaries of commercial establishments and homicides. It does not give information about the model that should be used for these types of crime. Nevertheless, a spatial lag model will be made in view of the fact that LM lag and robust LM lag statistics are lower than LM error and robust LM errors.

Results for spatial regressions are described in table 7. It can be seen that, as for OLS results, for spatial lag models the presence of Transmilenio improvement in a zone is the variable that has the biggest impact on every type of crime. In parallel, the Presencetm coefficient is statistically significant at 10% level for types of crimes for which LM lag and/or LM error statistics are statistically significant (Thefts from people, house breakings and robbery against people with violent aggression). Besides, even if the impact is positive, improvement of public transport seems not to have a statistically significant impact on the level of homicides and on the number of burglaries from commercial establishments.

Table 4.7: Spatial regress results

Scope of analysis	Variables	Crimeteft	Crimecom	Crimehouse	Lesiones	Homicides
	Constant	-63.343 (40.866)	4.466 (17.794)	-44.369*** (16.370)	-70.578** (29.710)	-7.118** (3.594)
Improvements	presence TM	25.074* (12.965)	3.160 (4.680)	11.221* (6.308)	16.738* (9.839)	1.244 (1.597)
Socioeconomic and demographic	hectares	0.108*** (0.033)	0.020* (0.012)	0.077*** (0.016)	0.128*** (0.027)	0.011*** (0.004)
	small-Enter	0.348*** (0.129)	0.102** (0.047)	0.156** (0.063)	-0.039 (0.096)	0.005 (0.017)
	density_hect	0.066 (0.074)	0.001 (0.027)	0.090** (0.036)	0.214*** (0.056)	0.045*** (0.009)
	employment	0.001 (0.001)	0.001*** (0.000)	-0.001** (0.000)	0.000 (0.001)	0.000 (0.000)
	income	-0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	-0.000 (0.000)	-0.000 (0.000)
	aver_cost_travel	0.008 (0.010)	0.001 (0.003)	0.002 (0.005)	0.005 (0.007)	0.001 (0.001)
	culture	2.923*** (0.929)	0.554* (0.335)	0.624 (0.454)	2.786*** (0.696)	0.153 (0.118)
	soc_welf	-0.259* (0.138)	-0.029 (0.050)	-0.040 (0.067)	0.354*** (0.104)	0.032* (0.018)
	health	-1.103 (2.140)	-0.262 (0.772)	-1.302 (1.044)	-0.178 (1.593)	0.455* (0.273)
Observations		112	112	112	112	112
Sigma		59.440***	21.440***	28.993***	44.319***	7.572***
Statistics Spatial Lag or Spatial Error						
Rho / Lambda		0.571*	-0.106	0.680***	0.789***	-1.057
Log likelihood		-616.83691	-502.23973	-536.66689	-584.57169	-386.34701

Authors' calculations

For the case of socio-economic and demographic variables, spatial regressions results suggest that the area of the zone (hectares) is, from a statistical point of view, determinant on the level of every kind of crime studied in this paper.

Regarding the number of small enterprises in each UPZ, results indicate that it has a positive and statistically significant impact on crimes without violent aggression against people (thefts from people, burglaries of commercial establishments and house breakings). It suggests that the more small enterprises there are in a zone, the more the number of these types of crime will increase, and vice versa with crimes with violent aggression.



Conversely, density of each zone has the opposite effect. In effect, the bigger is the density in a zone, the bigger is the impact of this characteristic on the number of crimes with aggression and the biggest is the number of house breakings. Regarding the other socio-economic and demographic variables, even if they have a positive impact on the number of crimes, their impact is weak.

Finally, table 7 indicates that two of the three variables denoting amenities in each zone have a negative impact on the number of crime. Sometimes they are statistically significant; sometimes not. It suggests that the greater the number of establishments that promote and provide welfare and health in a zone, the lower will be the number of crimes. The impact of establishments providing cultural activities such as cinemas and theatres, which are generally placed near big malls, on the number of crimes is positive and statistically significant. It means that crime will be greater in zones with a big number of that kind of establishment and it can be explained because of the large number of people who frequent these places.

As expected, inasmuch as diagnostic tests reveal, there is no preferable model for burglaries from commercial establishments and homicides; their spatial autoregressive parameter ( $\rho$ ) for spatial regressions is not statistically significant. It suggests that the model proposed do not capture the spatial dependence which is transmitted to the error terms. Nevertheless, it does not imply that there is no spatial correlation (the Moran and Getis tests showed this before); rather it suggests that the model is not the better one for these kinds of crime.

Conversely, the spatial autoregressive parameter ( $\rho$ ) for “thefts from people” and “house breakings” and the coefficient on the spatially correlated errors ( $\lambda$ ) for “robberies against people with violent aggression” are positive and statistically significant. This signifies that there is a spatial dependence in the data and that spatial regression models are a better alternative than OLS models. Models are well designed and capture the effect of spatial dependence.

## 4.6 Conclusion

This research demonstrated throughout that there exists a positive and significant relation between public transport improvement and the level of crime in each zone of the city of Bogotá.

Firstly, a PSM approach revealed significant differences in the average numbers of any type of crime between the treated zones that benefit from Transmilenio and those which do not. The zones of the city benefiting from improvement of public transport always have bigger crime rates than those where TM is not provided.

Based on observed predictor obtained from the precedent logistic regression, PSM results confirmed that the presence of Transmilenio in a zone has a positive impact on the level of crime rates in each treated zone. It suggests that improvement to public transport raises the level of any type of crime, with statistical significance for crimes without violent aggression. A causality relationship is almost demonstrated.

Important differences are shown regarding crime without violent aggression against people. Burglaries of commercial establishments are 78.02% more frequent in zones with at least one Transmilenio station. Regarding the number of thefts from people, the difference is close to 69%, and it is 36.7% for house breakings.

Regarding crimes with “violent aggression”, results showed that there are also more crimes in zones where Transmilenio passes. Nonetheless, differences are smaller (6.4% for both). It suggests that even if crimes with violence are most recurrent in zones served by Transmilenio, these types of crime seem not to depend in an important proportion on public transport provision in a zone. Murderers will not go to a zone to perpetrate their crimes in Transmilenio but they may benefit from the. This seems to not be the case for crimes without violence.

Offenders who do not use Transmilenio may also benefit from those improvements to public transport. Actually, with the construction of Transmilenio there was an upgrading

of corridors alongside Transmilenio corridors, which led to an enhancement of travel by private cars along TM corridors.

These results have to be interpreted with a lot of care. The fact that this study does not include a dynamic analysis over time does not reveal concrete conclusions. Indeed, these results may also signify that transport policies in the city were focused on the development of improvement of public transport in zones with high crime levels. However, PSM results demonstrate that if the time characteristic is not taken into consideration, predictors based on a logistic regression that defines the presence of TM stations in a zone have a positive and causal relation with crimes not featuring violence in any zone of the city.

As for the results of logistic regression, the importance of wealth appears to be significant in the probability that a zone is served by the TM system. It may explain why crimes without violence, the principal causes of which are economic, are situated in zones benefiting from the Transmilenio system.

Once the importance of public transport improvement to crime had been demonstrated, it was also very important to know if there is a diffusion or contagion effect of delinquency among the zones composing the city.

Global spatial statistics reveal that, regardless of their type, crimes are always spatially correlated. Zones with higher crime rates spread these rates systematically to adjacent zones.

Regarding spatial regressions, diagnostic tests suggest that when thefts from people, house breakings and robberies against people with violent aggression are regressed with respect to some characteristics of zones, there is a clear spatial dependence with high levels of concentration of those crimes.

Other types of crime, such as homicides and burglaries of commercial establishments, do not reveal a concrete spatial concentration when they are regressed with respect to the same variables. It is important to insist that it does not reflect the “absence” of spatial

dependence of these types of crime, but it may suggest that for these crimes, explanatory variables could be other than those proposed in the models suggested.

Explanatory variables that represent “socio-economic and demographic characteristics” always have a positive effect and, in some cases, statistical significance to the level of crime. Variables from this group that have a higher impact on crime rates with statistical significance were “the area in hectares” of zones (for any type of crime), the number of small enterprises (regarding crimes without violent aggression) and the density of each zone (regarding crime with violent aggression and house breakings). It suggests that the more small enterprises there are in a zone, the higher will be the rates of crime without violent aggression. It could be explained because, generally, small enterprises in Bogotá are part of the commerce and services sectors. If there are more small enterprises in a zone, density will be higher during the day and so the potential victims for that type of crime will be higher. Streets and commercial establishments will be most frequented and hence, it will make it easier for offenders to commit their crimes. The number of establishments promoting cultural events has the same effect on crimes, perhaps for the same reason as the number of small enterprises.

Conversely, the other two variables grouped into “amenities” do not have the same impact on crime levels. In effect, the number of establishments providing welfare and health appear to be good instruments to decrease the number of crimes without violent aggression in zones. It suggests that if more of those sort of establishments are present, offenders will be less motivated to commit crimes, in line with the thesis of Hipp (2007) regarding the six theories of crime.

Finally, regarding improvements to public transport, like in OLS models, spatial regressions suggest that, among the variables considered, it represents the principal characteristic of the zone that make raise crime rates regardless the type of crime. As explained above, this variable is statistically significant only for the three types of crime for which diagnostic tests are statistically significant (spatial lag model and/or spatial error model).

However, this research demonstrates the large and direct effect of public transport enhancement on crime rates.

Unfortunately, socio-economic data for periods before and after the operation of the system could not be compiled and represents the next step to deepen research on the subject. After the compilation of those data it may be possible to determine the exact impact of public transport improvements in crime rates of any zone of the city. However, despite the fact that this research could not make an analysis over time, it represents an important study with strong evidence of what can be called a “boomerang effect” of improvement of public transport.

## General Conclusion

This dissertation reveals a significant influence of urban transports enhancements on urban crime. Said enhancements may have direct or indirect impacts on different kinds of crime in a city.

As suggested in the introduction and then corroborated on the development of this dissertation, urban transport system has a direct impact on the social and the economic configuration of the city. The placement of job centers as well as the settlement of houses and the concentration of highest incomes are directly related to urban transports. Nonetheless, this dissertation does not neglect that the construction of urban transport systems try to respond about the needs of the city. In fact, public transportation axes may also be planned with respect to the places where jobs and houses are already located.

The eventual multiplicity of sub-centers in a city may be also a consequence of the development of public transports. Sub-centers which can be defined as places with a high concentration of jobs or houses are, at their turn, places with high levels of social interactions and social disparities. Nevertheless, even if it is already demonstrated that high levels of social interactions lead to a better productivity, social fragmentation on zones with high density and high presence of urban transports is also accompanied with a rise of social tensions crystalized on high levels of criminality.

The first two chapters of this dissertation allow to show that, from the social fragmentation point of view, Transmilenio does not benefit bogotanians at the same level. The probability to find a job on a specific interval of time between people with highest income and people with lowest income is not the same. Nevertheless, the proximity to an axe or to a Transmilenio station increases the size of labor market of inhabitants and it may induce people to move near this transportation system.

Once these results are obtained, the second chapter searched to prove the endogeneity of the enhancements of public transports on the concentration of jobs and on the level of

income. Adopting the presence and thus, the number of Transmilenio stations on each zone of the city as the suspected endogenous variable, results of chapter two show that the presence of Transmilenio is endogenous to the number of jobs and the level of income. Those results validate the suspicions made on the first chapter regarding the effective size of labor market and its relation with the socio-economic characteristics (level of income and “social class”) of people that can enjoy from this transportation system.

The thesis that there may be a causal relationship between these variables takes more relevance. Those two chapters attest the first part of the reasoning of the dissertation. In effect, the characteristics of transport systems influence encourage and consolidate the formation of sub-centers in a city. The concentration of jobs, the concentration of houses and thus, the urban structure is, in some aspect, affected by public transports. Density, the social fragmentation and social interactions are also influenced by urban transports.

Having proved this big relationship, the two subsequent chapters focused on the causal relation between the presence of Transmilenio in a zone and five different kinds of crime. Nonetheless, the difference in difference estimation was inconclusive. For some corridors, Transmilenio seems to have a causal relation on crimes but in other corridors it seems to have no significant impacts. In order to have conclusive results, a cross section analysis for one period (2007) was done on the last chapter. In effect the availability of control variables was the biggest limit for the precedent chapter.

Another econometric methodology which may be more adequate to the purpose of the dissertation was adopted. Results conclude that the quantity for every kind of crime is higher on zones benefiting from Transmilenio.

It is important to consider that the construction of Transmilenio do not benefit just the people who use Transmilenio but also people who use corridors alongside Transmilenio. In effect, the construction of this system improve the congestion of ways beside BRT’ corridors.

Results are conclusive. The probability that the transportation system pass by a zone of the city depends on the income, the working force and the population of each zone (the variables taken in consideration on the two first chapters). Then, the SEM estimations proved a causal relationship of Transmilenio on criminality. In addition, it was also demonstrated that there exists a spatial dependence on the concentration of crimes and that the principal characteristic of the zones that makes raise some kinds of crimes is the presence of Transmilenio.

Nevertheless, this dissertation is confronted with several limits that should be solved on further researches in order to obtain better results.

The four chapters of this dissertation suffer from the most common limit of all empirical studies: a solid data base. In effect, one of the weaknesses of the first chapter is linked to the fact that the information of employment for each zone of the city does not take in consideration the informal labor market. It could represent a bias from the moment that almost 50% of the employed population has an informal job in Bogota. Because of the none existence of this information, this research assumes that the two labor markets, formal and informal, have the same characteristics and are similarly spread in the city.

Another important weakness of the date set is the availability of control variables for different periods. In effect, control variables are available only for one year (2007). Because of this lack of information, even if the aim of the second chapter is attained and even if results are consistent, it is most suitable that this analysis is performed for two different periods.

In order to deal with this problem, chapter three tried to provide a dynamic analysis. In effect, it assumes that covariates are constant over the time. This assumption lets infer that better and most consistent results could be found with finer data. In fact, results may be most conclusive with covariates for each period.

Taking into account those empirical problems, chapter four developed a static analysis for the year on which all the information is available. As it was already said, results are



conclusive and convincing but it is undeniable that these may be more reliable if a dynamic analysis is done.

Furthermore, despite the fact that the limits of the availability of control variables, the data set about criminality is, in contrary, very rich and detailed. This feature and the fact that no researches had studied, on a small spatial scale (by zone on a same city), the possible effects of urban transport improvements on crime represent the main added values of this dissertation. In spite of the limits of this work, we consider that the problematic, as well as the responses that this dissertation provides are pertinent and reliable and that it will stir the interest for future researches that will help to advance the study of the Economic Science.

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## List of tables

- Table 1: Summary of the dissertation.....	P.46
- Table 1.1: Descriptive statistics according to the type of job of those people whose reason for the trip is to work .....	P.59
- Table 1.2: Descriptive statistics according to the socio-economic class of people whose reason for the trip is to work.....	P.60
- Table 1.3: Number of trips with "work" as their reason, by subcenter.....	P.61
- Table 1.4: Distribution of number of trips generated and attracted by transportation by subcenter.....	P.62
- Table 1.5: Effective size of labor market for people travelling in public vehicles when neither UPZ has a direct connection to TM.....	P.65
- Table 1.6: Effective size of labor market for people travelling in public vehicles when neither UPZ has a direct connection to TM.....	P.67
- Table 1.7: Effective size of labor market for people travelling in public vehicles when neither UPZ has a direct connection to TM.....	P.68
- Table 1.8: Differences of times between socio-economic classes.....	P.72
- Table 1.9: Mean distance of trips by subcenter.....	P.72

- Table 1.10: Workforce and number of jobs by subcenter.....	P.72
- Table 1.11: Jobs and direct access to TM by subcenter.....	P.73
- Table 1.12: Workforce and direct access to TM by subcenter.....	P.73
- Table 2.1: Descriptive statistics for the entire sample and for each variable.....	P.88
- Table 2.2: OLS results for each interval of time.....	P.95
- Table 2.3: 2SLS results for each interval of time when:	
$impro = \pi_0 + \pi_1 WF_i + \pi_2 ME_{si} \dots\dots\dots$	P.102
- Table 2.4: 2SLS results for each interval of time when:	
$impro = \pi_0 + \pi_1 WF_i + \pi_2 SME_{si} + u \dots\dots\dots$	P.107
- Table 2.5: 2SLS results for each interval of time when:	
$impro = \pi_0 + \pi_1 WF_i + \pi_2 LE_{si} + u \dots\dots\dots$	P.110
- Table 2.6: Summary of causality test results .....	P.111
- Table 2.7: Average commuting time .....	P.115
- Table 2.8: VIF calculations .....	P.115
- Table 2.9: Correlation Matrix .....	P.116
- Table 3.1: Descriptive statistics before and after the opening of each corridor of	
TM .....	P.126



- Table 3.2: Amenities UPZ with vs without TM system .....	P.127
- Table 3.3: Diff-Diff results .....	P.135
- Table 4.1 : Descriptive Statistics .....	P.156
- Table 4.2: Logit model, marginal effects and elasticity .....	P.165
- Table 4.3: PSM - differences between matched and unmatched variables .....	P.164
- Table 4.4: OLS results .....	P.167
- Table 4.5: Moran's I and Getis' G .....	P.168
- Table 4.6: Diagnostic identification tests .....	P.169
- Table 4.7: Spatial regress results .....	P.170

## List of figures

- Figure 1: Logical enchainment of theoretical analisys of this research.....P.39
- Figure 2.1: Income and Employment configuration of Bogota.....P.90
- Figure 2.2: Size of Labor Market respecting the zone where people live (UPZ) Bogota  
(2007) .....P.117
- Figure 2.3: Amenities by Zones (UPZ) Bogota (2007).....P.118
- Figure 2.4: Concentration of Stations of TM, Population, Workforce configuration by  
(UPZ) Bogotá (2007).....P.119
- Figure 2.5: Concentration of enterprises by (UPZ) Bogota (2007).....P.119
- Figure 3.1: Criminality on each zone vs criminality on citywide.....P.128
- Figure 3.2: Criminality on each zone that benefit before and aftr the opening  
of TM .....P.130
- Figure 3.3: Evolution of criminality on TM corridor "Americas";  
before vs after.....P.140
- Figure 3.4: Evolution of criminality on TM corridor "NQS";  
before vs after.....P.142
- Figure 4.1: PSM different steps.....P.161