JUAN CARLOS ECHEVERRY
ANA MARÍA IBÁÑEZ
ANDRÉS MOYA
LUIS CARLOS HILLÓN

The Economics of TransMilenio, a Mass Transit System for Bogotá

The provision of urban public mass transportation in Latin America has exhibited marked swings during the last century. Various cities have experimented with public and private provision, as well as different types of market regulation ranging from almost total liberalization to intervention in fares, route allocations, bus size, service quality, and exclusive road lanes. Despite the importance of this sector for the quality of social life and urban economic development, the literature contains little theoretical research on the market failures characteristic of this industry. There are also few studies on the consequences of alternative provision and regulation arrangements. This paper contributes to this second area of research. We describe the experience of Bogotá, Colombia, where a new hybrid system of urban public transport was put in place at the beginning of this century—hence its name, TransMilenio. The new system was designed after decades of learning about the failures of both publicly and privately owned systems. It currently supplies more than 20 percent of daily trips. By 2015, the complete TransMilenio system is expected to transport 80 percent of the city's population at an average speed of 25 kilometers per hour with a service quality similar to an underground metro system.

Several market failures affect the provision of urban mass transit: unclear definition of property rights on the curbside and on the road; collusion,

Echeverry, Ibáñez, and Moya are with the Universidad de los Andes, Department of Economics, in Bogotá, Colombia. Hillón is with the Colombian Ministry of the Environment.

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which results in fares set above competitive equilibrium levels; misalignment of the incentives of bus drivers and owners (a typical principal-agent problem); and congestion and pollution.[1] In many developing countries, these market failures are exacerbated by weak regulation and enforcement. In Bogotá over the last three decades, city transportation was in the hands of private entrepreneurs, and local authorities were in charge of regulating the system and maintaining the road infrastructure. This arrangement suffered to some degree from all of these market failures. At the end of the 1990s, the system had an excess supply of usually empty and slow buses, low-quality service, and widespread inefficiency. Average travel time to work was one hour and ten minutes; obsolete vehicles were used; average speed was only ten kilometers per hour during peak hours; 70 percent of air pollution in the central corridors was generated by traffic; and accidents were frequent.

TransMilenio, a hybrid public-private scheme, was designed to overcome these market failures and improve urban transport quality. The first market failure, the unclear definition of property rights on the curbside and on the road, was solved via exclusive lanes and the construction of restricted-access elevated stations. Passengers pay for access to a system of buses and stations, as in an underground metro system, and not for access to the vehicles, as was previously the case. TransMilenio uses the left lane of the streets, and there is no staircase for accessing the buses, which facilitates transfers in different directions and improves the speed of passengers' movements.

The second failure TransMilenio addressed involved fares. These were traditionally set above competitive equilibrium levels, largely as a result of capture of the regulator. The theoretical literature identifies reasons for market power by the bus owners that can also support overpricing. Overinvestment in busses was profitable, leading to excess supply, low use, overcrowding of streets, low speeds, and pollution. In contrast, TransMilenio fares are set at the level at which they finance the long-term cost of provision, defined through a route-tendering process in which potential providers compete for the exclusive use of the roads based on the lowest cost bidding. Fares evolve based on the change in input prices and the number of passengers transported.

TransMilenio also faced a third market failure, which resulted from the private solution to the agency problem between affiliating firms and bus

1. Estache and Gómez-Lobo (2005).

driver-owners. Under the traditional scheme, firms extracted their revenues from affiliated buses, while the driver-owners' revenues depended on the number of passengers. This arrangement caused an excess supply of buses and infighting among them for each extra passenger, with undesirable effects on safety, pollution, and congestion. TransMilenio introduced a new arrangement in which bus owners are private firms that charge per kilometer traveled, not per passenger, and drivers are employees whose salary is determined by a labor contract that is unaffected by the number of passengers traveling. The public sector participates in the network configuration and system regulation and supervision, and the private sector operates the buses. In addition, a different private company is in charge of fare collection.

After its launch in January 2001, TransMilenio significantly improved traveling conditions for its users and reduced traffic on its corridors. The system reduced travel times for TransMilenio users by 32 percent, particulate matter pollution fell by 9 percent in some areas of the city, and accident rates dropped by 90 percent in the TransMilenio corridors.

But there have been problems, as well. Perhaps the most significant shortcoming of TransMilenio is related to the transition between the traditional transportation system and the new one on currently unserved corridors. To secure support for TransMilenio, the local government provided politically powerful traditional transportation firms with more routes in the remaining corridors, where they relocated most of the vehicles displaced by TransMilenio. Congestion, pollution, and travel times have worsened for riders of the traditional system.

We carry out a cost-benefit analysis to assess the impact of the first phase of TransMilenio on travel times, the environment, and traffic accidents in the whole city. Despite the sizable benefit that TransMilenio has bestowed on its users, the net benefits for the whole city of implementing the first phase appear negative. This is the result of the spillovers caused by the slow scrapping rates and the maintenance of weak regulation of the traditional system.[2]

This paper provides policy lessons for cities in developing countries planning to undertake similar reforms in this industry. The cost-benefit analysis identifies policy mistakes during the implementation of TransMilenio that

2. Contracts for TransMilenio private operators required them to buy traditional system buses and scrap them, to prevent those buses from being relocated to unserved TransMilenio corridors. The authorities did not effectively enforce this process, however, so traditional system buses that were displaced by TransMilenio's operation were, in fact, relocated to other corridors.

led to negative spillovers and reduced the benefits of TransMilenio. Recognizing these risks up front is useful for avoiding similar mistakes in cities that are planning to reform their mass transit system. The paper is organized as follows. The next section reviews the market failures prevailing in the provision of public transport, describes Bogotá's mass transit system before TransMilenio, illustrates the main characteristics of the new system, and discusses some political economy issues of its implementation. Both positive and negative changes in the quality of life resulting from the new mass transit system, as well as its particular adoption and a cost-benefit analysis, are included in the subsequent section. A final section presents our concluding remarks.

Mass Transit Market Failures in Bogotá and the TransMilenio Reform

Many cities in developing countries have experienced a pendulum in the operation of their public transit system. Bogotá, for instance, evolved from privately owned trolley buses at the end of the nineteenth century to a fully public bus system in the first half of the twentieth. In the second half of the last century, developing countries witnessed a slow transition back to private ownership owing to the lack of flexibility and productive inefficiency that characterized state ownership and operation. The mixed success of the last decades regarding private provision, liberalization, and market competition, especially in cities in developing countries, led to a reconsideration of this model and the adoption of so-called hybrid models that combine public and private features. The main reason for this paradigm shift is the evidence of market failures that hinder a fully private provision from reaching socially optimal outcomes.

Market failures in the provision of urban mass transit include unclear definition of property rights on the curbside and on the road; the fact that fares are set above competitive equilibrium levels; a principal-agent problem stemming from a possible misalignment of the incentives of bus drivers and owners; and externalities of street congestion and air and noise pollution. In addition to these market failures, developing countries frequently suffer policy failures in the form of weak regulation and enforcement.

Property rights usually are not clearly defined on the road or on the curbside.[3] The absence of properly defined "rights to waiting passengers"

3. Klein, Moore, and Reja (1997).

implies that the fare received from a pedestrian at the curb does not belong exclusively to the firm authorized to operate on that route. In the absence of regulation and control, other means of transportation can interlope and offer pedestrians a ride, which they may accept because waiting time is costly.[4] The implication of this lack of property rights differs in developed and developing countries. Demand for mass transit in developed countries can be low (that is, markets are *thin*), in which case it needs to be induced by a regular, high-quality service. Once this demand is created, incentives arise for illegal interlopers to start operating. Hence investments by legal operators may not be recuperated. This induces underinvestment. In contrast, demand in developing countries tends to be high (that is, markets are *thick*).[5] Excessive bus entry is the norm, resulting in strong competition for passengers on the curb. This strong competition spurs distortions in investment, such as deficient service quality and the use of small vehicles, which are more maneuverable but produce more pollution, congestion, larger investment per seat, and safety problems.[6]

In developing countries, fares are often set above competitive equilibrium levels. This promotes excessive entry of buses. Because buses are not perfect substitutes, price competition is not an effective mechanism for regulating the optimal quantity of buses in the market. To minimize waiting time, riders prefer to use the first bus that arrives even though a cheaper bus may come along in a few minutes. Time, not fares, might be the most important decision variable for the rider, so the bus can exercise its market power by raising fares. As a result, prices are set above efficient levels and returns on investment are high, creating incentives for entry and an excessive number of buses on the road.[7] This feature can also result from, or be exacerbated by, the capture of the regulator. The excess supply of buses, paired with deficient service, leads to congestion, pollution, and traffic accidents.

Another source of market failures results from the private solution to the principal-agent problem. This solution, which tries to cope with the misalignment between the interests of the bus driver and the bus owner, introduces further inefficiencies in the provision of mass transit. The profits of bus owners depend on the number of passengers carried per bus. To align the interests of bus owners and drivers, the owners typically pay the drivers

4. Evidence shows that passengers consider waiting time more costly than travel time.
5. Most of the population in these countries lacks transportation alternatives.
6. Estache and Gómez-Lobo (2005).
7. Evans (1987).

based on the number of passengers carried. This contract between the owner and the driver, however, introduces further complications for the provision of mass transit. On the one hand, bus drivers compete for passengers to maximize their payments, causing negative externalities in terms of safety problems and congestion. On the other, this compensation scheme promotes the use of smaller buses, despite the congestion and pollution problems, because they are better equipped to compete for passengers.

The problems described above are deepened and new inefficiencies arise when drivers are responsible for fare collection. High monitoring costs promote the sale of vehicles to the drivers and cause the atomization of the bus industry in terms of bus ownership. Although this atomization is effective for aligning the interests of the owner and drivers, it leads to additional costs. The large number of owners makes it difficult to exploit economies of scale on coordination and economies of density. Deficient regulation, weak enforcement, and capture of institutions also worsen market failures.

The Mass Transit System in Bogotá before TransMilenio

Essentially all of the market failures mentioned above characterized the public transportation system of Bogotá in the second half of the twentieth century. This industry went through three periods in terms of ownership and regulation: (i) simultaneous provision and ownership by the state and the private sector (through the mid-1980s); (ii) private firms specialized in intermediating routes between the regulator and the bus owners and drivers (mid-1980s to the early 1990s); and (iii) private provision and the emergence of different types of buses, with fares dependent on the quality of service, such as carrying seated passengers only, providing clear bus stops, and opening new routes (early 1990s to the present).

In an initial phase, mass transit was exclusively provided by a public company, resulting in economic inefficiencies, an excess of drivers per vehicle, and inflexibility in supplying sufficient transport services and new routes for a growing city.[8] Increasingly, the regulatory agencies found that private firms could supply new routes and either complement or replace the existing ones at cost-efficient levels. The resulting private scheme had three types of actors: the local government, bus owners, and firms acting as intermediaries between them. Each bus owner operated a specific route after purchasing one of the slots approved by the authority and then paying

8. Urrutia (1981).

a monthly affiliation fee to the intermediary.[9] Originally, the intermediary firms owned the buses, and the drivers were in charge of fare collection. The drivers' income depended on the number of passengers carried, which served to align the interests of drivers and bus owners. However, this solution led to strong competition among drivers of different companies. Moreover, most routes sought to cover the central part of the city, where the highest number of passengers is concentrated. Overlapping routes exacerbated traffic congestion, street competition, and traffic accidents.

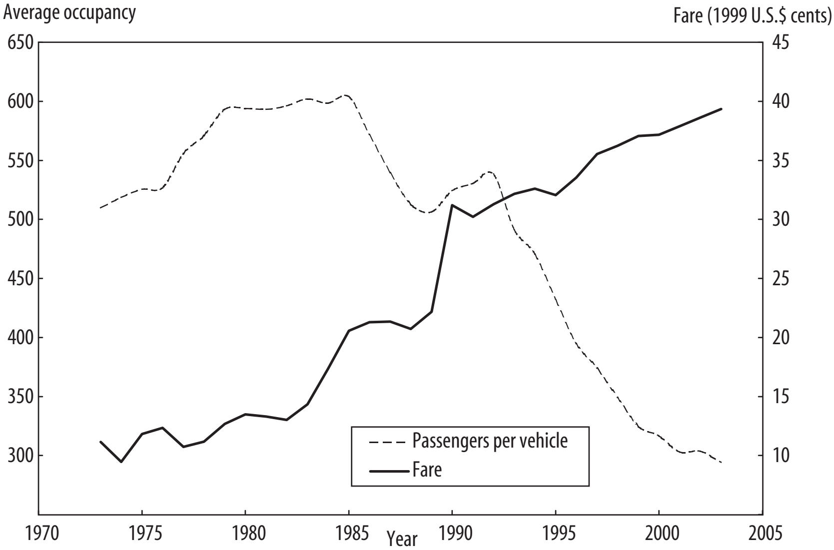
In the early 1980s, fare setting depended on recurrent negotiations with the regulator and local authorities and on a subsidy system implemented to avoid transferring high fuel costs to passenger fares. The high return on the bus investment promoted oversupply, as fares and subsidies surpassed marginal costs. The gradual elimination of subsidies in the 1980s led to two developments. First, higher fares were granted to unsubsidized vehicles, which were obliged to comply with higher quality standards than their subsidized counterparts. The average fare increased from U.S.$0.10 in 1975 to U.S.$0.40 in 2004, in constant 1999 dollars (see figure 1). Since Bogotá did not experiment with fare liberalization, these fare increments were mostly the result of the strong bargaining power that private transport firms attained in the 1980s.[10] Second, the absence of price competition made the market a poor regulating mechanism for the optimal quantity of buses. Returns to investment were high, which created incentives for the entry of an excessive number of buses. Figure 2 illustrates the evolution of the public bus fleet in Bogotá. The increasing trend accelerated in the first half of the 1990s, peaking at approximately 22,000 vehicles. This was accompanied by a sharp decline in average occupancy after 1985. The daily number of passengers per vehicle stabilized briefly in the early 1990s and then fell dramatically from 538 in 1992 to 294 in 2003. Frequent fare hikes offset the subsequent income losses and served as an incentive for the entry of more vehicles, resulting in further reductions in the number of passengers per vehicle.

The industry further separated the affiliating firms from the bus owners and drivers. The atomization of the ownership structure was caused by the high costs of monitoring the drivers' revenue collection. The solution of

9. In 1995 the cost per slot was between U.S.$2,300 and U.S.$4,600, the affiliation fee ranged from U.S.$100 to U.S.$600, and the monthly fee varied between U.S.$5 and U.S.$35 (Lleras, 2003).

10. Private transporters started to participate in politics either directly via their own candidates in the city council or indirectly via funding the campaigns of traditional politicians.

FIGURE 1. Bus Fare and Average Occupancy, 1973–2003



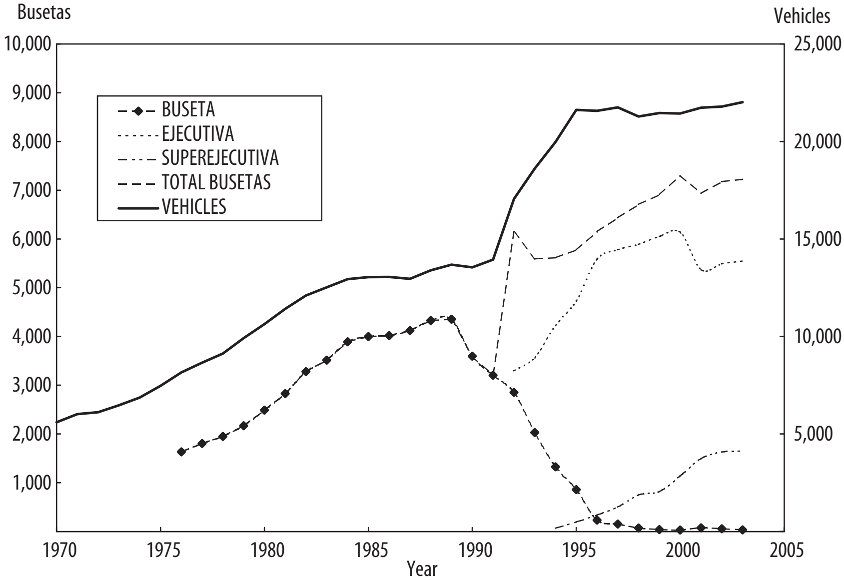
Source: Authors' calculations, based on data from the National Administrative Department of Statistics (DANE).

this agency problem led the affiliating firms to specialize in obtaining routes from the authorities and affiliating as many buses as possible. Since the aging of the existing fleet increased operating costs, the firms sold old vehicles, usually to the drivers themselves, and owned only new buses.[11] At this point, the number of vehicles on the streets was completely determined by the affiliating firms, because the public company had been liquidated. The firms obtained as many routes as possible and earned their income basically from affiliation rather than from the number of passengers transported. The firms also established a cartel to consistently push for bus fare hikes and the authorization to extend the service life of buses.[12] This struc-

11. The increase of driver-owners as a solution to the limited monitoring capacity of the affiliating firms is also documented for the case of Santiago de Chile (Estache and Gómez-Lobo, 2005).

12. Bus fares were historically set through negotiation processes with the local authorities. Only in 1997 was an effort put forth to tie them to a transport costs basket (Decree 3109 of 1997). Estache and Gómez-Lobo (2005) propose a model for explaining the overprovision of services in a private equilibrium when fares are too high. Their key argument is the fact that buses are not perfect substitutes, but differentiated products. Hence the bus stopping in front of a passenger enjoys a "market power" over its competitors due to the cost

FIGURE 2. Public Transit Vehicle Fleet in Bogotá, 1970–2003[a]



Source: Authors' calculations, based on data from DANE.

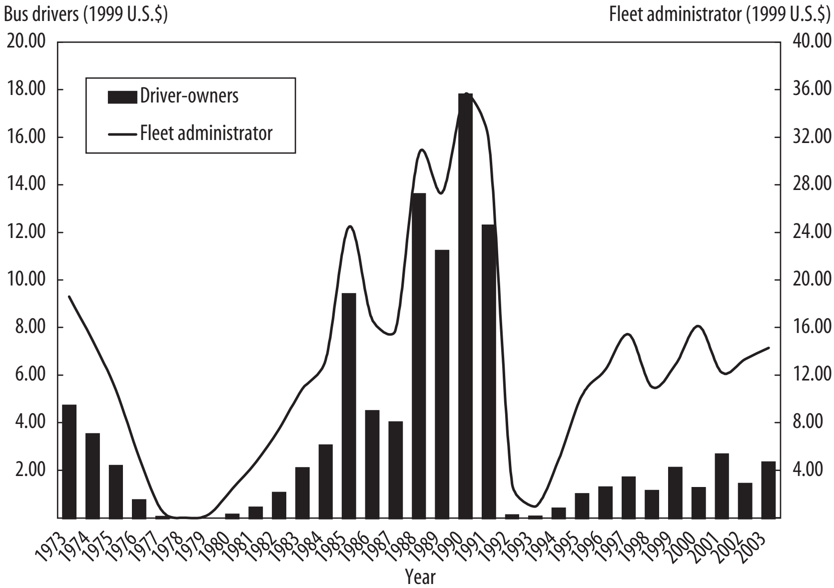
a. While busetas carry an average of 25 passengers and operate with low-quality standards, busetas ejecutivas and superejecutivas, introduced in the early 1990s, offer an average capacity of 50 seated passengers and better service and, consequently, require higher fares than traditional busetas.

ture intensified the struggle for economic rents, increased the number of buses on the streets, and contributed to the aging of the vehicle fleet. Market and policy failures thus accentuated the problem of oversupply.

We estimated the economic rents for Bogotá's traditional mass transit system by simulating the contracts between affiliating firms and owner-drivers (see appendix A for a description of the methodology). This industry operated at efficiency levels (nearly zero profits) in only two periods: the end of the 1970s and the beginning of the 1990s (see figure 3). Outside of these two periods, economic rents were positive, substantial, and highly

of waiting, which is highly valued by eventual passengers; this permits the charging of a higher fare. Consequently, rising tariffs create excessive returns to investment and promote the entry of new buses beyond the socially efficient level (see pp. 12–15). The capture of (or political influence on) the regulator is yet another reason for high fares. As a result of excessive entry, buses in Bogotá and Santiago, Chile, have witnessed a sharp decline in occupancy, as illustrated below.

FIGURE 3. Daily Simulated Economic Rent per Vehicle, 1973–2003



Source: Authors' calculations, based on DANE (2003).

variable. These rents rose in the 1980s, when fares grew from U.S.$.10 to U.S.$.30, which was associated with the introduction of smaller capacity vehicles. Rents accrued to both the fleet administrating firms and the bus owner-drivers.

As figure 3 illustrates, however, the composition of rents changed in the 1990s, favoring the affiliating firms vis-à-vis bus owner-drivers, and total daily rents never returned to the peak observed at the end of the 1980s. A new development was observed at the beginning of the 1990s, when the affiliating firms lobbied for further fare increases based on different levels of service quality. The so-called executive buses carried only seated passengers, used relatively new vehicles, and offered faster service at higher fares than traditional buses. This behavior reveals either the capture of the regulator or the authorities' ignorance regarding the true costs of bus transportation, or both.

In sum, the market failure stemming from the absence of price competition in urban bus transport was exacerbated by a policy failure that granted free affiliating privileges and periodic fare negotiation with a cartel, leading to systematic economic rents. In addition, this incentive scheme forced bus drivers to compete for passengers along the central corridors. Drivers therefore did not respect assigned bus stops or delineated areas for bus transit in the pursuit of passengers.[13]

At the end of the 1990s, the excess bus supply, coupled with a substantial increase of private vehicles, exceeded the traffic capacity of Bogotá. From 1991 to 1995, the total number of cars registered in Bogotá increased by 75 percent, and 40 percent of the country's vehicles were circulating in the city.[14] By 1998, private cars occupied 64 percent of the road space and mobilized only 19 percent of the population.[15] As a result, gridlock was commonplace, accidents abounded, and travel times were unbelievably high. Estimates show that in 1995 the average number of daily trips per household was 11.9, the average number of daily trips per person was 1.7, and the total number of daily trips was about 10 million.[16] The average speed for public transportation during peak hours was ten kilometers per hour, which could drop to five kilometers per hour in the center of the city.[17] Inequality of travel times between public transport users and car owners was sizeable. Mean travel time was 66.8 minutes for public transport users, whereas car owners faced a mean travel time of 42.6 minutes.[18] These problems finally led to a rethinking of the entire bus transport system in Bogotá, which culminated in the design and implementation of the first phase of the TransMilenio system in 2001.

The Features of TransMilenio

The authorities designed and adopted TransMilenio to tackle the consequences of the market and policy failures described above. The key elements of the new system are concession contracts for service providers (namely, TransMilenio transporters and feeder buses); vertical separation of the transportation service and fare collection; bus remuneration based on kilometers traveled rather than passengers transported; fare setting based

13. The road infighting among drivers for every extra passenger is locally known as the penny war (*la guerra del centavo*).

14. Lozano (2003).

15. Chaparro (2002).

16. In 2000, Hong Kong, which has a population similar to Bogotá (7,394,170 inhabitants), reported 12 million total daily trips.

17. Chaparro (2002).

18. Lleras (2003).

on long-term investment recovery following a tendering process (that is, competition for the road); exclusive road lanes (the left lane of each road, to facilitate turning at intersections by private automobiles); and exclusive curbside service in metro-like stations, which constitute an organized system of express and slow routes and facilitate transfers.

As Lleras states, TransMilenio is "a flexible, rubber-tired rapid transit mode that combines stations, vehicles, services, and driving lanes . . . into an integrated system."[19] The first phase of TransMilenio was designed for 35,000 passengers per hour per direction; it covers 42.4 kilometers of exclusive bus lanes along three of the main transit corridors. In these corridors, central lanes are dedicated exclusively to TransMilenio operations, and passengers at the stations are their exclusive customers. The stations are in the middle of the road like a metro system, which facilitates bus transfers. The bus fleet consists of 470 buses for the first phase of the system, with better mechanical conditions and environmental performance than those of the traditional system. The bus stops include fifty-seven stations, located every 700 meters, equipped with pay booths, registering machines, surveillance cameras, and infrastructure such as bridges, pedestrian crossings, and traffic lights designed to ease the entrance of passengers into the system. At the end of the corridors, three principal access stations serve as a meeting point for feeder buses and buses from the traditional system that work in neighboring municipalities. Feeder bus passengers have an integrated tariff, so riders do not have to pay twice for using the feeder system and TransMilenio. Feeder buses, which share corridors with the traditional system, have bus stops every 300 meters in the lower socioeconomic areas of the city and are synchronized by the operators with a satellite system to minimize travel and wait times for passengers.[20]

TransMilenio solved the agency problem present between owners and drivers by establishing a prepayment scheme, in which users buy tickets in booths located in the stations, as in underground systems around the world. Therefore, bus drivers do not have to deal with collecting payment fares like they do in the traditional system. Previously, drivers' incomes depended on the number of passengers traveling, whereas TransMilenio drivers are salaried employees with no direct relation to fare collection.

The market failure deriving from an opaque property right definition for roads and curbsides, which is present in different degrees in thick and thin

19. Lleras (2003).

20. Each TransMilenio bus has a capacity of transporting 160 passengers, while feeder buses can transport seventy passengers.

mass transit markets, was solved via exclusive bus transit lanes and exclusive stations.

Finally, the recurrent problem of setting fares above market equilibrium levels was solved with concession contracts awarded through public competition. The concessionaires' income is no longer associated with the number of passenger-trips serviced. Transport providers, both local and foreign, are called to associate and participate under a new set of rules. The new transport firms own a number of buses that meet certain specifications and whose operation is subject to the leadership of a central authority, TransMilenio S.A. These buses have a specified service life stipulated at the outset of the contracts. The concessions expire when the vehicle fleet reaches an average mileage of 850,000 kilometers, with no individual bus reaching more than 1,000,000 kilometers. If the average mileage threshold is reached in less than ten years, then the concession extends to the tenth year. If the average mileage threshold is not reached by the tenth year, the concession lasts until this happens or until the fifteenth year, whichever comes first.[21] The new contracts also establish a payment per kilometer traveled. The number of kilometers traveled depends on the manner in which the central authority dispatches service and, ultimately, on demand. The reward per kilometer traveled is the central variable by which the firms compete for these contracts.

TransMilenio S.A. carries out thorough calculations of the costs involved in the provision of the transportation service, as well as demand forecasts, which enables the authority to set the range of acceptable fees per kilometer traveled. This range guarantees a fair return to the participating investors and is used as a parameter in the selection process of the concessionaires.[22] TransMilenio thus represents a hybrid private-public model that replaces competition on the road by competition for the road.[23]

These measures turned the entire incentive scheme of the previous system upside down. They eliminated the affiliating firm and the license business. They also removed any gains from cutting maintenance costs, since the service is to be provided over a specified period under safety and efficiency standards: cutting down on costs today implies incurring greater costs tomorrow to comply with the norms. These measures gave rise to a

21. There is a restriction by which the concessionaire is forbidden to add new vehicles to the fleet to deliberately bring its average mileage down when a certain portion of the concession period has expired. This contract resembles those analyzed by Engel, Fischer, and Galetovic (2001).

22. The range is given by a real return on investment between 14 percent and 16 percent.

23. Estache and Gómez-Lobo (2005).

true transportation firm able to earn a return on its capital comparable to what it would receive in any other business of comparable risk.

Feeder buses are also organized through concession contracts awarded through competition. These contracts are slightly different from the main service contracts: they are awarded for a ten-year period subject to the condition that no individual vehicle should exceed 950,000 kilometers during the time of the concession, and income to the feeder buses is defined as a combination of revenues paid per kilometer traveled and per passenger served. The reward system is designed to prevent opportunistic behavior from the transport firms. Feeder buses bring passengers from outskirt locations into the TransMilenio system, but most of the time they do not transit on exclusive public transport lanes, making it difficult to control the kilometers they travel. The regulating authority, TransMilenio S.A., has calculated the maximum fixed operation costs that a firm will incur per bus, and it agrees to remunerate the firms based on the number of passengers carried and kilometers traveled. Under this rule, traveling without passengers becomes unprofitable for the feeder bus.

Taking the responsibility of collecting fares away from the bus drivers and centralizing the management of fare revenues under an independent fiduciary entity further contribute to the improved operation of the new system.[24] Booths at the TransMilenio stations collect the system's revenues and are managed through a fiduciary contract. This not only relieves the system of information asymmetries and aids in the collection of taxes, but also has a considerable impact on road safety.[25]

The last important element of the new scheme is the fare-setting procedure. Under TransMilenio, travel fares cease to be negotiable. The written contracts subject the concessionaires to operate under the fares set by the public regulating authority, TransMilenio S.A. The fare-setting procedure and fare adjustment over time are part of the contracts.[26] TransMilenio travel fares are set to cover the long-run average costs of operation, includ-

24. In the previous system, passengers paid the drivers on entering the buses, which was a distraction to the drivers and contributed to congestion and accidents.

25. At the moment, the regulator lacks a direct monitoring instrument for the fare collection contract.

26. The procedure for calculating the technical fare for TransMilenio comprises four steps. First, the basis of the calculation is the pesos per kilometer offered by the main transport and feeder transport concessionaires, and the pesos per ticket offered by the revenue collection concessionaire. The calculation also contemplates the cost of the fiduciary revenue management and TransMilenio's management (both of which enter the formula as percentage shares). Second, the weight of each input in total operation costs is calculated using

ing the administration costs of the regulating authority and costs of the fiduciary contract through which fare revenues are managed.

Authorities decided during the design stage that fares would not be set to recover the infrastructure investments, since that would render the system unfeasible. TransMilenio fares set to recover the system's operating costs were already significantly higher than the current bus fares. Imposing on TransMilenio the obligation of recovering the infrastructure investments or its maintenance costs would have resulted in negative profitability, thereby eliminating the participation of the private sector. In addition, the intervention on TransMilenio corridors includes a full renovation of two lanes for private cars and the curbside; benefits from this investment accrue not only to TransMilenio providers and users, but also to other population groups. Thus investment in the infrastructure required to operate the system was said to be social investment.

After the opening of the first TransMilenio lines, traditional buses continue to mobilize nearly 80 percent of the population. The TransMilenio concession contracts obligated the operators to purchase and scrap buses that previously operated in TransMilenio corridors. Only 1,410 of these buses were effectively scrapped, however, and the remaining 4,670 buses were relocated into unserved TransMilenio corridors. Although the demand for the old system dropped, causing revenues per vehicle to fall, a loose regulation of the system permitted the excessive entry and overprovision of services in these corridors. Moreover, the fares for the traditional system were still allowed to rise after TransMilenio came into operation, as illustrated in figure 4. The introduction of TransMilenio thus did not spur a substantial reduction in the transport fleet of buses from the traditional system.

Some Political Economy Considerations of TransMilenio's Adoption

Before the adoption of TransMilenio, the local authorities' biggest concern was the opposition the system could face from traditional transporters. These companies had derived substantial rents over the decades, and they

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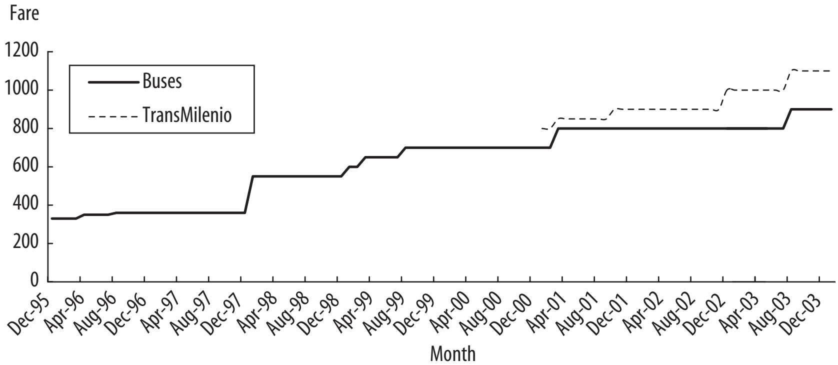
the numbers contained in the contracts, and costs are adjusted assuming a monthly average of 6,400 km per vehicle. Third, to conform to available coin values, the passengers' fare is rounded to the nearest multiple of fifty. Finally, the difference per ticket goes into a fund that compensates for cost increases not reflected in the fare. Costs are revised monthly, and the fare is revised (up or down) to the next closest multiple of fifty when the technical fare changes by more than twenty-five pesos.

FIGURE 4. Nominal Fares: Buses versus TransMilenio, 1995–2003



Source: TransMilenio S. A.

might feel threatened by the TransMilenio intervention. However, the firms were also aware that problems related to public transportation, such as congestion, pollution, and accidents, had reached worrying levels. A growing consensus thus emerged in the late 1990s in favor of a regime change, in the form of either a subway or a transformation of the bus system.

Bogotá witnessed several episodes of protest against the new system.[27] The strikes and protests lost momentum quite rapidly, however, and demonstrations on other issues consistently outnumbered TransMilenio-related incidents. Between 1999 and 2000, five events were organized against TransMilenio, and TransMilenio-related protests represented only one-fifth of total political demonstrations in the sector even at their peak. Activity against this initiative had already ceased by 2001.

An important factor facilitating the transition was the national government's decision to support a new transportation system for Bogotá. The central government's willingness to partly finance the associated infrastructure investments became a critical argument to convince transporters that this was the right time for reform.[28]

27. Estache and Gómez-Lobo (2005) document similar reactions in the case of Santiago, Chile.

28. In the 1990s, Colombian presidents supported either a subway or a bus solution. Elected Bogotá mayors followed suit because any solution would require substantial financial resources. Consequently, local authorities' choices regarding the new public transport system were partly determined from the outside. The city authorities revealed the TransMilenio blue print in 1999 after a new national government rejected the subway alternative for Bogotá.

Finally, the municipal government decided that any solution would be pursued in association with the traditional transportation firms of Bogotá, and they used the allocation of new routes in the non-TransMilenio corridors to reward affiliating firms for their willingness to participate in TransMilenio. The traditional transporters relocated their buses to new routes granted by TransMilenio authorities themselves, and not by the traditional regulator. The municipal representatives thus chose not to abandon the old businesses in the proportion in which TransMilenio replaced them, but simply to relocate them. Unfortunately, this produced damaging effects on the other corridors in terms of speed, congestion, pollution, and riding time, as illustrated below.

Cost-Benefit Analysis of the First Phase of TransMilenio

The ultimate goal of TransMilenio is to improve the quality of life in Bogotá. Although only 25 percent of the system has been put in place so far, its impact is indicative of what can be achieved. Travel times for TransMilenio passengers have dropped, and traffic congestion, air pollution, noise levels, and frequency of traffic accidents have decreased significantly in TransMilenio corridors. However, some unexpected negative spillovers have emerged. Traffic congestion and pollution have heightened along corridors not served by TransMilenio owing to the slow scrapping rate of buses in the traditional public transit system. This section presents a cost-benefit analysis of the first wave of TransMilenio contracts.

The Impact of TransMilenio on the Quality of Life in Bogotá

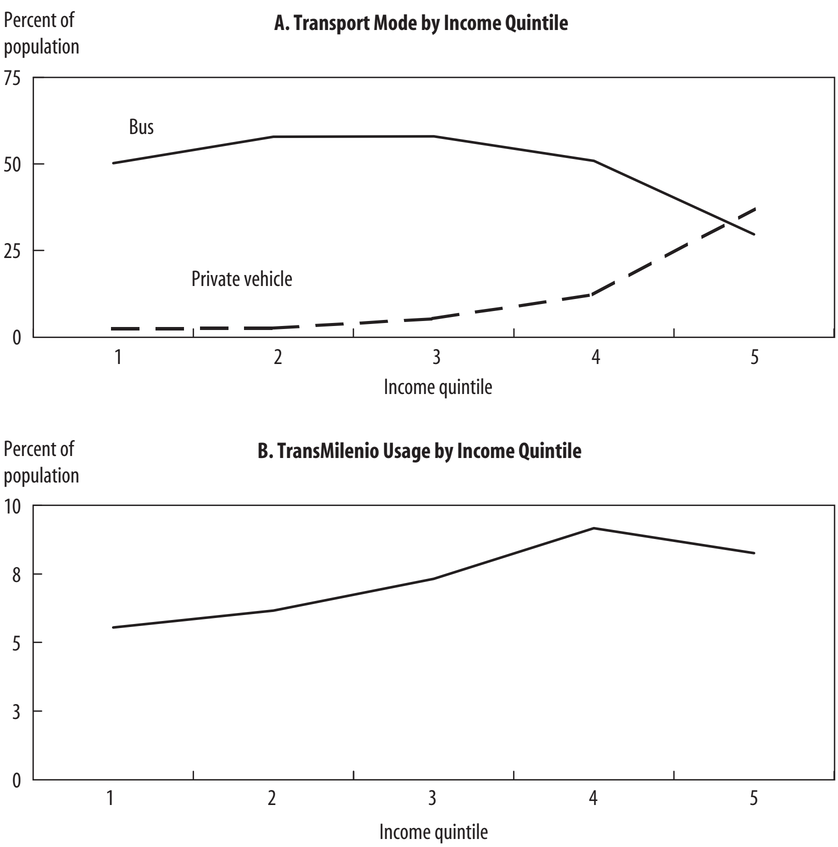
Soon after TransMilenio came into operation, many public transportation users switched to this new public transit mode. The year before the introduction of TransMilenio, 69 percent of individuals relied on public transportation. After TransMilenio became available in 2001, 6 percent of individuals switched from traditional public services to the new alternative. This share of the population using TransMilenio has expanded continuously, and the new system served 13 percent of the population in 2003.[29] TransMilenio has not increased the overall attractiveness of public transit, however, since the share of the population using cars has remained

29. The first phase of TransMilenio, which represents 25 percent of the total expected network, covers 13 percent of the public transportation demand in Bogotá.

constant since its adoption. Thus the demand for public transport as whole did not expand, but rather the appearance of a new transportation mode led to a distribution of this demand between TransMilenio and the traditional system.

Demand for public transportation stems mainly from the lower-income households, yet TransMilenio users are concentrated in the fourth and fifth income quintiles, as seen in figure 5. In contrast, demand for traditional buses is primarily from the first, second, and third quintiles. The highest income quintiles thus use TransMilenio more than the lower in-

FIGURE 5. Use of Public Transportation, by Income Quintile



Source: Authors' calculations, based on DANE (2003).

TABLE 1. Time Spent Traveling from Home to Work
Percent of individuals

Time spent	*2001*	*2002*	*2003*
Less than one hour	74	68	74
Between one and two hours	23	29	17
More than two hours	4	2	5

Source: Authors' calculations, based on Napoleon Franco (www.napoleon.com.co)

come quintiles.[30] The top two quintiles are also the main users of private vehicles.

TransMilenio's impact on travel times and average speed varies widely across users of TransMilenio, private vehicles, and the traditional public transport system. Two years after TransMilenio began operating, the average trip time in Bogotá decreased to 35 minutes, from 44 minutes in 2001. The average speed of cars increased to 20 miles per hour, from 16.8 miles per hour in 2000.[31] Table 1 shows that the percentage of individuals who spent more than an hour traveling from home to work fell from 23 percent to 17 percent, while the frequency of trips under one hour rose during 2003.

The benefits of travel time reductions accrued mainly to TransMilenio users. The average speed of other forms of public transportation actually dropped, which caused travel times to increase by 10 percent.[32] Slow scrapping of buses from the traditional system may be causing the uneven distribution of benefits. An important share of these buses were relocated to corridors not served by TransMilenio, worsening congestion. Attributing worsening congestion solely to the relocation of buses is not accurate, however; slow adoption of other measures to control traffic congestion and the increase in the number of taxis, as a result of simultaneous interventions, are partially responsible, as well.

Lleras studies TransMilenio's impact on public transportation users, mainly through travel times.[33] In 2002 a revealed preference survey was

30. Of all TransMilenio users, 62 percent (325,925 users) correspond to the fourth and fifth income quintile, while 38 percent (203,830 users) correspond to the first three income quintiles (DANE, 2003).

31. See www.transitobogota.gov.co.

32. To date, the impact on travel times for riders using unserved corridors has not been officially measured. The union of small providers of public transportation argues that travel times in unserved corridors increased by 10 percent as a consequence of bus relocation ("Pico y Placa seguirá en discussion," *El Tiempo,* 11 March 2001).

33. Lleras (2003).

applied to 2,095 public transport riders who could choose between TransMilenio and the traditional system for their transportation. Respondents were interviewed in the street near areas where routes from the two systems run. The survey elicited information about the transportation mode selected, the expected attributes of the trip, and various socioeconomic characteristics. The data were used to estimate random utility models, which provide the coefficients to calculate the value of time for users of both systems in the different stages of the process (for example, walk-in and walk-out times). The study shows that declines in travel times were not uniform across TransMilenio users. TransMilenio passengers starting the trip in the vicinity of the main corridors travel 12 minutes less per trip than passengers of the traditional system. In contrast, passengers requiring one or more transfers did not experience drops in travel times. In fact, total travel time is two minutes shorter in the traditional system because of the waiting time required for the TransMilenio feeder routes.[34]

Waiting-in and waiting-out time increased for all TransMilenio users, however, because these times are extremely low for the traditional bus system.[35] TransMilenio users have to buy tickets, wait in line, exit the station, and walk to the final destination, whereas users of the traditional system enter the bus at any location, pay the bus driver directly, and stop the bus at the point nearest to their destination, since there are no official bus stops in Bogotá. Improvements in TransMilenio travel times arise, therefore, from in-vehicle travel time.

Estimations of the value of time for TransMilenio passengers, vis-à-vis users of the traditional system, show unambiguous improvements in traveling conditions for the former. Overall, people are willing to pay less for savings in travel time than people using the traditional system, indicating that TransMilenio is a less "painful" experience. For example, the value of waiting time for the traditional system is U.S.$3.08 per hour, while in TransMilenio it is U.S.$1.14 per hour.[36]

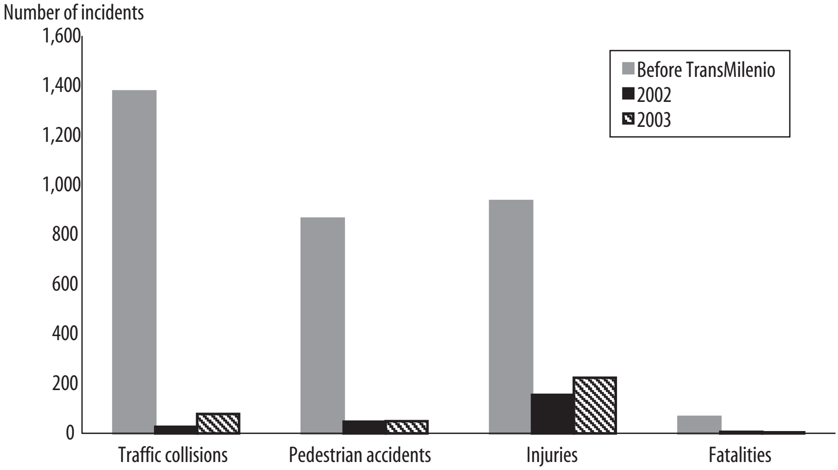
These figures indicate that the first phase of TransMilenio enhanced travel conditions for a certain population group, although improvements

34. Lleras (2003).

35. Waiting-in time refers to the time spent waiting for the bus; waiting-out time is calculated from the time the passengers step off the bus until they arrive at their destination. Lleras (2003) estimates that waiting-in and waiting-out times increased 2.95 and 5.16 minutes, respectively, for TransMilenio users vis-à-vis users of the traditional public transport system.

36. Lleras (2003).

FIGURE 6. Traffic Accidents in TransMilenio Corridors before and after the Intervention



Source: TransMilenio S. A.

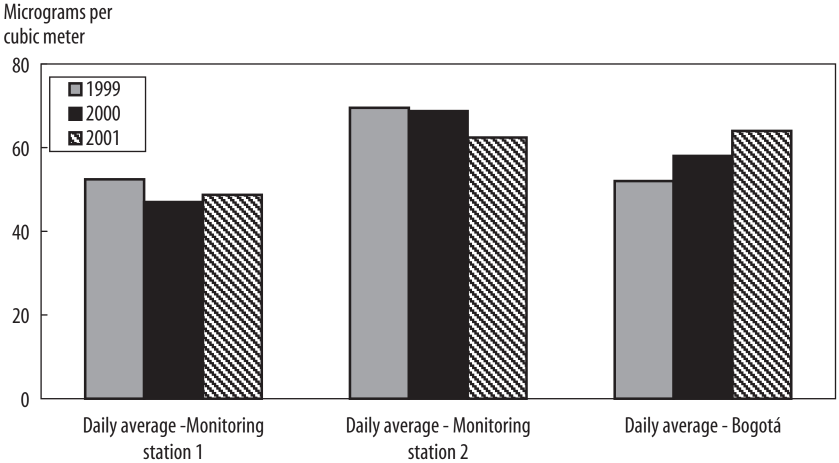
should not be entirely attributed to the new mass transit system.[37] Nevertheless, benefits from the new system are not distributed widely across the entire population; gains were perceived largely by TransMilenio users, in particular downtown dwellers.

The quality of services also improved, and TransMilenio corridors experienced a decline in the external costs caused by public transport—namely, accidents and pollution. Traffic accidents decreased dramatically in TransMilenio corridors. Figure 6 depicts the incidence of traffic collisions, pedestrian accidents, injuries, and fatalities in TransMilenio corridors before and after the system came into operation. After two years, traffic collisions and pedestrian accidents decreased by 94 percent, injuries to passengers by 76 percent, and fatalities by 94 percent. This is, by all accounts, an impressive performance.

Finally, air pollution, which is a major concern in Bogotá, exhibited a declining trend in TransMilenio corridors. Half of the districts in the city currently exceed the particulate matter (PM-10) and ozone pollution limits. Studies indicate that automobiles are the most significant emission

37. Bogotá's authorities implemented several programs to transform traffic conditions, including mobilization restrictions during traffic peaks, investment in road infrastructure, and increased traffic fines.

FIGURE 7. Average Daily Readings of Particulate Matter, Citywide and in Monitoring Stations near TransMilenio[a]



Source: Authors' calculations based on data from the Bogotá Air Quality Monitoring Network (*Red de Monitoreo de la Calidad del Aire de Bogotá,* or RMCAB).

a. The RMCAB maintains thirteen monitoring stations, located throughout Bogotá, that measure hourly emissions for a group of pollutants.

source in Bogotá, contributing 70 percent of air pollution.[38] Reductions in traffic congestion increased the speed of other vehicles and thus curbed emissions in TransMilenio corridors. TransMilenio also appears to have improved air quality by transporting more passengers in less time with better vehicles.[39] In 2000–02 the citywide average of PM-10 emissions grew by 23 percent, but it fell by 8 and 11 percent in the two TransMilenio corridors shown in figure 7. Although the environmental authorities of Bogotá adopted a group of measures to control air pollution over the last decade, evidence indicates TransMilenio contributed substantially in this respect.[40]

38. Cavallazi (1996).

39. This superior performance of TransMilenio vehicles contributes to the control of mobile source emissions. TransMilenio buses transport 1,596 passengers daily, which is five times the number of passengers for traditional public buses, and the average speed is 17 to 44 percent faster. The average age of public buses is fifteen years. TransMilenio buses have catalytic converters, emissions are below the limits required by the Euro II norm, some vehicles use natural gas, and noise levels are less than ninety decibels (Ibáñez and Uribe, 2003).

40. Measures include the use of catalytic converters for new cars, mandatory inspection and maintenance, and mobilization restrictions.

Méndez analyzes the impact of several pollution programs implemented in Bogotá.[41] Her study evaluates the evolution of particulate matter and ozone in monitoring stations located near TransMilenio corridors and far from industrial areas from 1997 to 2002. Méndez defines categorical variables to denote the implementation of three policy interventions (namely, the introduction of TransMilenio, mobilization restrictions, and mandatory inspection and maintenance) and then estimates time series regressions to predict the trend of particulate matter and ozone levels, controlling for these policy interventions. Her results reveal that TransMilenio is the most effective program for curbing pollution, with a much stronger impact than programs specifically designed to control emissions. Mandatory inspection and maintenance reduced ozone levels by 13.6 percent, while restrictions on car mobilization lowered ozone levels by 21 percent. The first phase of TransMilenio, however, produced a 28.8 percent decline in ozone levels. Similar estimations for particulate matter indicate that TransMilenio abated PM-10 pollution levels by 9.2 percent.

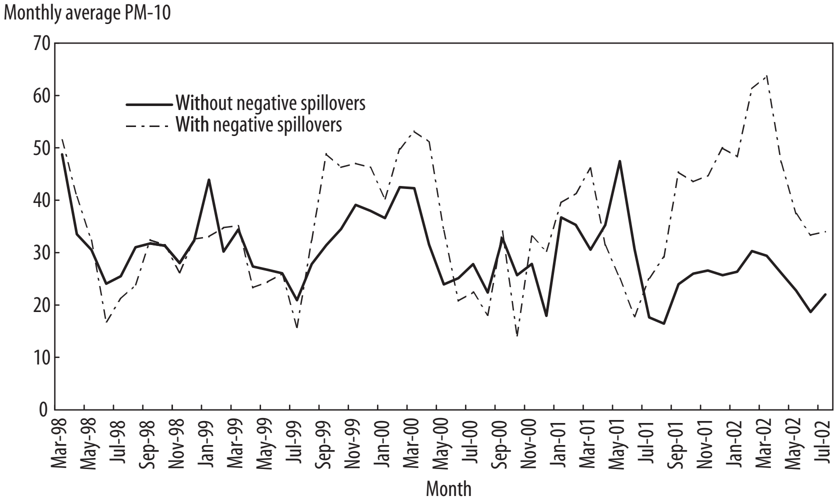
Air pollution levels rose in other areas of the city, because the slow scrapping rate of buses from the traditional system triggered the relocation of buses to non-TransMilenio corridors. To evaluate the negative pollution spillovers of TransMilenio, we used a difference-in-differences approach to compare readings from a monitoring station located near a TransMilenio corridor to readings at a baseline monitoring station. The baseline monitoring station should have two characteristics: it should have similar particulate matter readings to the TransMilenio monitoring station before entry into operation of the system; and it should be located near a non-TransMilenio corridor without negative spillovers from bus relocation. Other interventions in the city can also affect the results, namely, the entrance of new taxis and the construction of new TransMilenio corridors. The evolution of particulate matter in both monitoring stations is illustrated in figure 8.

Readings of PM-10 soared in the monitoring stations with negative spillovers after TransMilenio fully entered into operation in June 2001.[42] It remained constant in the monitoring station without the negative spillovers. The difference-in-differences calculations indicate that bus reloca-

41. Méndez (2004).

42. TransMilenio started partial operations in January 2001, and the full system with the three trunk corridors was in place in June 2001.

FIGURE 8. Particulate Matter Readings from Monitoring Stations with and without Negative TransMilenio Spillovers, 1998–2002



Source: Authors' calculations, based on data from RMCAB.

tion caused particulate matter emissions to increase by 10.5 percent, more than offsetting the reductions in PM-10 readings in TransMilenio corridors. Although the change cannot be attributed solely to TransMilenio, this was the main intervention in Bogotá's traffic system in the period.

Air pollution can cause serious damages to health, and particulate matter and ozone levels appear to increase the incidence of acute respiratory illnesses in Bogotá. Lozano estimates a concentration response function that links daily respiratory hospital admissions in 1998; the study finds a strong link between incidence of respiratory health admissions and particulate matter levels.[43] In fact, a 25 percent increase in particulate matter causes a 21.8 percent rise in respiratory health admissions, while decreasing particulate matter emissions by 25 percent results in a 17 percent reduction in respiratory health admissions.

The impact of the first phase of TransMilenio reveals positive results for the people attended by the system, but ambiguous results for the rest of the city. Travel times for TransMilenio users fell, safety improved, congestion dropped, and air quality increased, yet these benefits are restricted

43. Lozano (2003).

to TransMilenio corridors. Meanwhile, the relocation of buses increased congestion in non-TransMilenio corridors, causing a deterioration in traveling conditions for passengers of at least some corridors of the traditional system and a rise in pollution levels. Once the full system comes into operation, the negative spillovers should decrease significantly or disappear.

Cost-Benefit Analysis

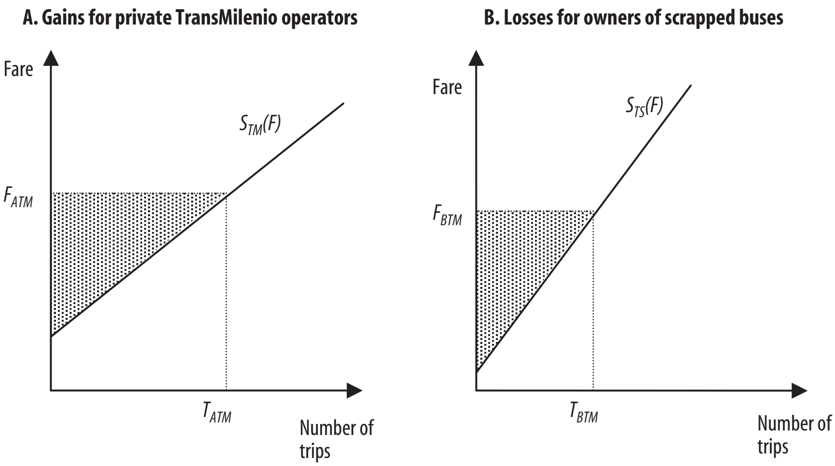
Understanding the welfare gains and losses from the introduction of TransMilenio is crucial for evaluating whether investments in this new scheme produced net benefits for the population and identifying future adjustments to the system. Welfare changes can be approximated by measuring variations in the consumer and producer surplus caused by the adoption of TransMilenio. We used the above information and data on investments, costs, and revenues of the system's operation to conduct a cost-benefit analysis. Only the first phase of TransMilenio (25 percent of the system) was evaluated. Ideally, we should estimate the consumer and producer surplus before and after TransMilenio and then calculate the changes in both surpluses; however, data restrictions limited our analysis to calculating changes in both surpluses as a result of the adoption of the system. A detailed description of the assumptions and methodology used to perform the analysis is included in appendix B. Table 2 presents a summary of results.[44]

Who wins and who loses with TransMilenio? The previous section suggests how benefits and costs are distributed among different groups of the population. We now undertake a detailed cost-benefit analysis to clarify those findings. On the production side, benefits arise for the private TransMilenio operators but are lost for the owners of the scrapped buses. The producer surplus of private TransMilenio operators represents welfare gains. In contrast, the former producer surplus that the owners of the scrapped buses no longer collect represents welfare losses. The shaded areas depicted in figure 9 denote those welfare gains and losses.

On the demand side, the evaluation of TransMilenio must account for changes in travel times faced by TransMilenio users and users of the traditional system. An appropriate welfare indicator for these changes is the willingness to pay for improvements in travel time. The value of time is defined as the marginal rate of substitution between travel time and a mon-

44. Detailed calculations of the costs and benefits are available on request.

FIGURE 9. Welfare Gains for Private TransMilenio Operators and Welfare Losses for Scrapped Buses[a]



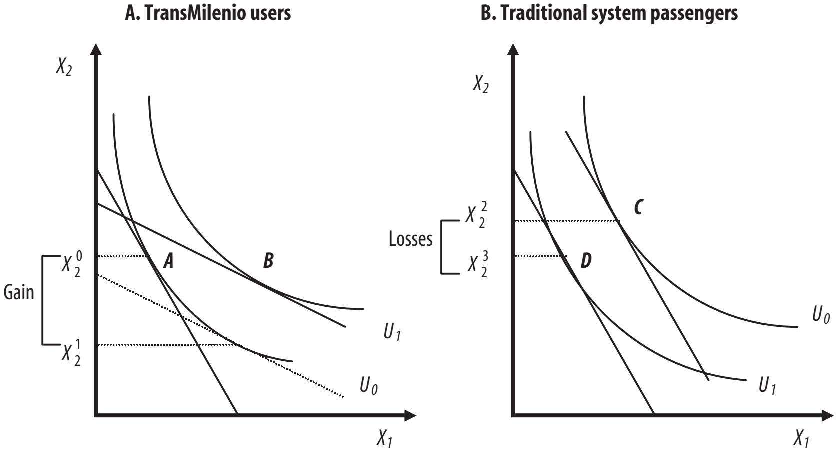
a. The shaded area denotes welfare gains (panel A) and losses (panel B). The subscript BTM indicates the fare and number of passengers in TransMilenio corridors before TransMilenio, and the subscript ATM indicates the fare and number of passengers after TransMilenio. Supply curves for private TransMilenio operators and for owners of scrapped buses (STM and STS, respectively) are assumed to depend on fares (F).

etary cost. Figure 10 presents welfare changes resulting from the adoption of TransMilenio. When TransMilenio started operations, TransMilenio users experienced two welfare enhancing effects: travel time decreased, and the ride was more pleasant than on the traditional system.[45] The movement from point A to point B in the indifference curve map for TransMilenio users shows the combined effect on utility; $X_2^0 - X_2^1$ measures willingness to pay for these improvements in traveling conditions. Riders of the traditional system faced costs from increases in travel time, while their traveling conditions were practically unchanged. As a result, travel times rose, but the marginal rate of substitution between savings in travel time and the numeraire good remained constant. By moving from the status quo (point C) to the new condition (point D), riders of the traditional system experienced welfare losses, represented by $X_2^2 - X_2^3$.

The adoption of TransMilenio also produced both positive and negative impacts on pollution readings, leading to gains and losses for the popula-

45. The improved quality of the ride reduces willingness to pay for improvements in travel time.

FIGURE 10. Welfare Effects from Impacts on Traveling Conditions and Travel Times[a]



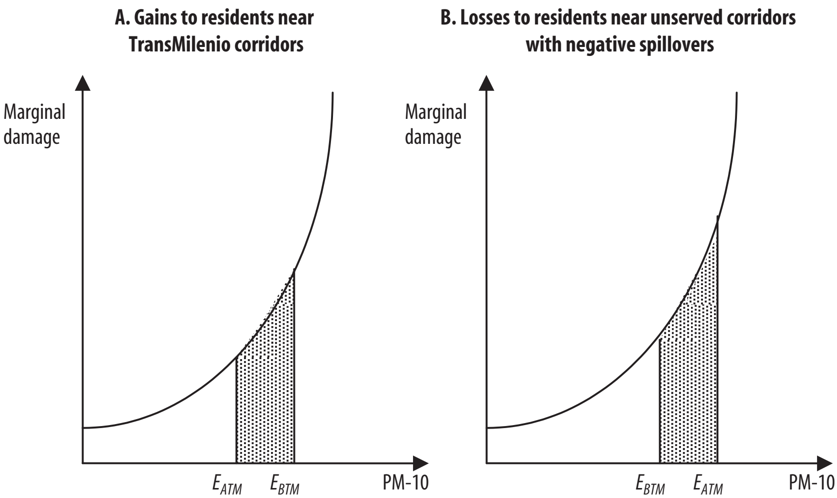
a. The horizontal axis represents savings in travel time (X1), and the vertical axis represents a numeraire good measured in monetary units (X2).

tion. Residents located near TransMilenio corridors experienced welfare gains from drops in pollution, while bus relocation heightened congestion and deteriorated air quality in some of the unserved TransMilenio corridors. To establish the welfare impact of these opposite effects, we use the marginal damage function (which corresponds to drops in utility as a result of pollution, measured in monetary terms) to calculate welfare changes from the adoption of TransMilenio. Figure 11 shows how to value these welfare impacts for both groups of the population.

Finally, society as a whole benefits from the decrease in fatalities in TransMilenio corridors stemming from enhanced traffic and security conditions. We use the value of a statistical life, which shows aggregated individuals' willingness to pay for risk reductions, to measure reductions in the risk of death in TransMilenio corridors.

This series of figures offers an insight into who wins and who loses after the adoption of TransMilenio. We now perform a cost-benefit analysis to establish whether the benefits offset the costs or whether the costs from negative spillovers offset the benefits provided to TransMilenio users. The cost-benefit analysis incorporates the revenues and costs from TransMilenio operations, as well as initial investment. Operational information comprises revenues from fare collections, operational costs for concession-

FIGURE 11. Welfare Gains for Residents near TransMilenio Corridors and Welfare Losses for Residents near Unserved Corridors



aires, fare collection expenses, administrative expenditures of TransMilenio S.A., and management costs for the fiduciary. Infrastructure investments and maintenance costs of corridors are also incorporated.

We also calculated the forgone revenues of firms operating previously in TransMilenio corridors. Before TransMilenio came into operation, nearly 6,080 buses operated in those corridors; of those, approximately 1,410 were scrapped, and the remaining 4,670 were relocated to unserved TransMilenio corridors. Forgone revenues were estimated for the scrapped buses.

Our estimation of welfare losses and gains from variations in travel times for users of both TransMilenio and the traditional system considers all stages of traveling from one destination to another: waiting time, in-vehicle travel time, and walking-in and walking-out time. Lleras calculates the value of time for each stage.[46] Public transportation demand encompasses two groups: users that require one or more transfers and users that travel directly to their destination. The estimation includes the values calculated for both segments.

We also consider the benefits and costs associated with changes in particulate matter levels. Méndez provides figures from emissions reductions

46. Lleras (2003).

in TransMilenio corridors.[47] Emissions increases from negative spillovers were calculated using a difference-in-differences approach. We calculated the impact of particulate matter pollution on the incidence of acute respiratory illnesses based on a concentration-response function estimated by Lozano for Bogotá.[48] We then valued the changes in the incidence of acute respiratory illness as a consequence of TransMilenio using willingness to pay for reductions in respiratory health admissions, also reported by Lozano.[49]

Finally, we calculated the gains from reductions in traffic fatalities in TransMilenio corridors. We estimated the risk of death before and after TransMilenio based on the number of passengers and the number of deaths. Bowland and Beghin report the value of a statistical life (VSL) for Chile; we adjusted these values for Colombia using the GNP per capita for both countries.[50]

The analysis does not incorporate two main welfare benefits accruing from TransMilenio as a result of data restrictions, namely, gains from reduced traffic collisions and injuries (reported in figure 6) and gains from the reduction in petty thefts and general insecurity in TransMilenio corridors. Data simply are not available for calculating the welfare benefits from these variables.

Table 2 presents the net present value of the cost-benefit analysis for different discount rates.[51] The calculation of the net present value occurs in two stages: we first calculate the net benefits for TransMilenio corridors, without accounting for negative spillovers on unserved corridors and then incorporate the effects on unserved TransMilenio corridors. Results reveal that the benefits in TransMilenio corridors significantly offset costs; net benefits are U.S.$3.7 million for a 9 percent discount rate. Once negative spillovers are incorporated in the analysis, net benefits are negative, at

47. Méndez (2004).
48. Lozano (2003).
49. Lozano (2003).
50. Bowland and Beghin (1998).
51. We also calculated net benefits, considering infrastructure investments (a net loss of U.S.$64 million for a discount rate of 9 percent). However, there are several arguments against including infrastructure investments in the cost-benefit analysis. First, the bulk of infrastructure investment is street pavement, most of which would have been done anyway and is the responsibility of city authorities. Second, a full renovation of two lanes for private cars and the curbside was required for TransMilenio's operation, such that benefits from this investment not only accrue to TransMilenio providers and users, but also to other population groups. Third, this infrastructure lasts for decades, allowing city dwellers to reap the benefits over a very long period.

TABLE 2. Cost-Benefit Analysis of TransMilenio's First Phase
Millions of 2002 dollars

Item	Discount rate 7 percent	Discount rate 9 percent	Discount rate 12 percent
Forgone revenues, traditional system	−3.628	−2.720	−2.114
Forgone operational costs, traditional system	2.702	2.025	1.574
Revenues, TransMilenio	6.858	5.046	3.870
Operational costs, TransMilenio	−6.005	−4.410	−3.378
Costs from increased waiting time for TransMilenio, no transfer	−0.608	−0.447	−0.343
Costs from increased waiting time, transfer	−1.686	−1.240	−0.950
Costs from increased walking in and out time, no transfer	−2.766	−2.034	−1.559
Costs from increased walking in and out time, transfer	−3.026	−2.225	−1.705
Benefits from reductions in travel time, no transfer	6.217	4.572	3.504
Benefits from reductions in travel time, transfer	5.852	4.303	3.298
Benefits from a 9.1 percent reduction in PM-10 in TransMilenio corridors	0.283	0.212	0.165
Benefits from reductions in mortality	0.832	0.625	0.486
Net present value, TransMilenio	5.03	3.71	2.85
Travel time costs for traditional system users, no transfer	−5.014	−3.762	−2.925
Travel time costs for traditional system users, transfer	−10.239	−7.682	−5.973
Costs from a 10.5 percent increase in PM-10 in traditional corridors	−0.357	−0.268	−0.208
Net present value, traditional system	−15.61	−11.71	−9.11
Total net present value	−10.59	−8.00	−6.26

Source: Authors' calculations.

U.S.$8 million. The increased travel times for users of the traditional system, resulting from bus relocation, drive these results. Pollution in non-TransMilenio corridors also reduces benefits, but the contributions are not significant and are partially offset by drops in pollution in TransMilenio corridors. Benefits stemming from less in-vehicle travel time for TransMilenio users, operational revenues, and reductions in mortality, although significant, are not sufficient to cover these costs.

Because congestion costs are highly nonlinear, the congestion relief brought about by TransMilenio has been more than offset by increases in congestion in others areas. Currently, TransMilenio covers 13 percent of the public transportation demand, whereas the public transportation system covers the remaining 87 percent. TransMilenio has indeed improved the traveling conditions of its users, but it has worsened the conditions of a high proportion of the population—namely, users of the traditional public system.

Negative spillovers have resulted from three features of the current mass transit system of Bogotá. First, only 25 percent of the TransMilenio network has been constructed so far. Because the TransMilenio network is only partially operating, the benefits arising from the economics of coordination and density are not being fully exploited. Second, the scrapping rates required in the first phase of TransMilenio contracts are insufficient. Buses that were previously operating in TransMilenio corridors and that should have been scrapped were relocated to unserved corridors, which heightened congestion. Finally, high fares and imperfect controls on the entry of new buses into the traditional public system promoted the entry of new buses and slowed the exit of old ones. In fact, the second wave of contracts defines more stringent scrapping rates than did the first phase. Fares are still excessively high, creating an incentive for the entry of new buses.[52] In addition, controls on the entry of new buses are difficult to enforce, allowing so-called pirate buses to operate citywide.

There are two important caveats to these results. First, our analysis does not incorporate some important benefits, like fewer traffic accidents and better security in TransMilenio corridors, because of data restrictions. These benefits would certainly change the results. Second, given that TransMilenio will eventually serve the vast majority of the road network, negative spillovers from bus relocation should disappear once the network is complete. Nevertheless, the analysis sheds some light on drawbacks of the TransMilenio system that should be adjusted for the next phases. The design of the system should take into account negative spillovers to the traditional public transportation system in order to minimize them. Moreover, TransMilenio and the traditional system should not operate separately, but should be integrated into a single mass transit system. Finally, the prevailing incentives (such as high fares) that spur the entry of new buses, despite the fact that many of them travel empty, should be eliminated.[53]

Concluding Remarks: The Road Ahead

TransMilenio has become a cornerstone in the history of urban public transportation in Colombia. Today at least five Colombian cities with over half a million people each are applying for central government resources to replicate the Bogotá system. Other cities in Latin America are planning to follow suit. The design of TransMilenio mimicked the interventions in

52. Castro and others (2001).
53. Castro and others (2001).

mass transit systems of Curitiba, Brazil, and Quito, Ecuador, but it introduced some novelties that have become its trademark. The new transit system is a hybrid model that combines public planning of the network structure, route tendering conditions, regulation, and supervision, with private operation of the separate functions of revenue collection and transport service. Among the most salient features are the financial fiduciary management; the division of services among separate private providers that simultaneously administer the firm TransMilenio S.A.; the flexible contracts for bus operation; the separation of concessions for feeder buses and regular buses; the payment per kilometer instead of per passenger; the definition of property rights for the road and the curbside; and the use of the faster left lanes.

This paper is the first to provide a full economic account of the origins, design, political economy, and costs and benefits of TransMilenio. The system had a sizeable impact on users by improving travel conditions significantly. Congestion, pollution, and traffic accidents fell sharply in TransMilenio corridors. But the type of transition adopted for corridors not covered by TransMilenio caused unforeseen negative spillovers, as a consequence of slow scrapping rates and bus and route relocation. Although the cost-benefit analysis for the first phase of the corridors covered by TransMilenio is positive, the citywide net effect is negative mainly as a result of increases in travel time for passengers using the traditional transport system. To minimize the negative spillovers during the full implementation of TransMilenio, integration of the traditional and new systems should continue, and strict regulation of the traditional public transportation system should be crafted.

There remain potential vulnerabilities. As Estache and Gómez-Lobo indicate, the institutional capacity of the national and municipal planning authorities for defining the network configuration, quality requirements, and service levels are crucial.[54] One of the advantages of the private system is its flexibility to modify routes, cover new developing areas of the city, and bring bus routes closer to consumers. These challenges now need to be answered satisfactorily by good planning and regulation. The tendering system requires special care to ensure competition and avoid collusion among potential bidding concessionaires, as has been argued in the case of Pereira, the second Colombian city to implement a TransMilenio-type system. The application of contracts also needs to be monitored. This is par-

54. Estache and Gómez-Lobo (2005).

ticularly true for the revenue collection contract, whose performance is central to the system's profitability.

Recent events demonstrate other deficiencies in Bogotá. The number of daily passengers has increased from 800,000 to 900,000, and the number of vehicles on the road remains the same. Passenger jamming has become the rule, and the problem is an especially severe problem during peak hours. Long lines to purchase access cards are coupled with crowds waiting at the curb to enter the buses. People find it difficult to board the buses. Waiting time, a critical variable in any public transportation system and one of TransMilenio's big achievements early on, has started to rise. Security has deteriorated, and theft is common. As a result, people have begun to complain about the TransMilenio monopoly.[55]

Additional vulnerabilities are related to financing and political support. TransMilenio depends on fiscal resources from the city and the nation. Both political will and financial difficulties could prove obstacles in the future. The last two municipal administrations strengthened the system's institutional framework. The new national and municipal administrations that entered office in August 2002 and 2004 had earlier criticized aspects of TransMilenio, but since taking office these new leaders have embraced it and promised to improve it.

Finally, the fact that a democratically elected mayor appoints the head of the public company, TransMilenio S.A., poses a potential problem. One or two individuals can decide the future of the entire system. The system needs to strengthen an impersonal and institutionalized regulatory arrangement. One such decision might involve the scrapping process of the first lines of TransMilenio.

The implementation of TransMilenio holds several policy lessons for cities in developing countries planning to reform their public transportation system. The design of TransMilenio successfully reduced many market failures plaguing the provision of public transportation in developing countries. This hybrid system, in which the public sector participates in the regulation of the system and network configuration while the private sector operates the buses, avoids the problems inherent in both public monopoly or unregulated private provision. Breaking the link between passenger-trips serviced and profits eliminates the incentives to atomize the bus industry, removes the perverse signals to use smaller buses, and enhances

55. *Transmi-Lleno* (or Transmi-full) became slang for TransMilenio. On 10 March 2004, passengers protested by sitting on the road after an accident delayed a long queue of TransMilenio buses for hours.

traffic conditions. The allocation of exclusive property rights over a route abolishes the excess supply of buses, and the competitive tendering of the right to operate on a route pushes fares towards efficient levels.

But the gradual implementation of the new system along with the parallel operation of a poorly regulated traditional system brought unexpected negative results. Since congestion costs are highly nonlinear, the welfare losses from heightened congestion in unserved TransMilenio corridors more than offset the benefits from TransMilenio, even though those benefits are sizable. This suggests the adoption of a new public transportation system must run parallel to an appropriate regulation of all other public transit providers.

Appendix A: Econometric Estimates for Rents

To calculate the economic rents for affiliating firms and bus drivers, we estimated the demand per vehicle and the income per passenger using time series regressions, using two approaches. The first approach estimates an ordinary least squares (OLS) regression that corrects for autocorrelation; the second approach estimates an autoregressive moving average exogenous variables (ARMAX) model.

The observed demand per vehicle is estimated with a distributed lag model in which a lagged variable for the number of passengers is included as an explanatory variable:

$$q_t = \beta_0 + \beta_1 q_{t-1} + \beta_2 v_t^2 + \varepsilon_t + \delta\varepsilon_{t-1}$$

where q_t is the daily number of passengers per vehicle, q_{t-1} is the lagged daily number of passengers, and v_t represents the number of buses. We estimated several models. The model that best approximates the functional form is presented table A1.

The ARMAX model provides the best estimation, and autocorrelation is eliminated. The signs of the coefficients are as expected. β_0 is equivalent to autonomous demand, β_1 incorporates the influence of prior periods, and β_2 includes the influence of size of the total fleet, which is negative in all the estimates.

To estimate income per passenger, the production function curve for a congestion good is estimated using a polynomial regression model.

$$Y_t = \alpha_0 + \alpha_1 V + \alpha_2 v^2 + \alpha_3 v^3 + \varepsilon_t + \delta\varepsilon_{t-1},$$

TABLE A1. Econometric Estimates of Demand[a]

Coefficient	*OLS model*	*ARMAX model*
β_0	605.2	123.34
β_1		0.8064
β_2	-0.15×10^{-6}	$-0.167 \times 10^{-}$
6		
δ		0.3363**
Sum of the square of the errors	40648.9	6003.83
$E(\epsilon_t)$[b]	0.24*	$= 0$

*Durbin Watson; ** statistically significant at the 2 percent level.
Source: Authors' calculations.
a. All figures are statistically significant at the 1 percent level unless otherwise specified.
b. $E(\epsilon_t) = 0$ implies that autocorrelation does not persist.

TABLE A2. Econometric Estimates of Income per Passenger

Coefficient	*OLS model*	*AR(1) model*	*ARMAX model*
α_0	52.8123	21.4539	33.5797
α_1	-0.1212×10^{-1}	-0.5918×10^{-3}	-0.7134×10^{-2}
α_2	0.1062×10^{-5}	0.1053×10^{-6}	-0.6694×10^{-6}
α_3	-0.2484×10^{-10}	-0.2776×10^{-11}	$-0.1538 \times 10^{-}$
10			
δ		0.9674	0.8316
Sum of the square of the errors	284.49	139.77	137.78
$E(\epsilon_t)$[a]	0.7466*	$\neq 0$	$= 0$

*Durbin Watson.
Source: Authors' calculations.
a. $E(\epsilon_t) = 0$ implies that autocorrelation does not persist.

where Y represents the income per passenger, which is a variable that approximates the fare. To correct for autocorrelation, ARMAX and first-order autoregressive, or AR(1), models were estimated. The results are presented in table A2.

Calculating rents involves calculating the gains and costs to each vehicle. Gains are determined by the number of vehicles in circulation, for which a production function of the public transportation sector is defined. Costs per vehicle include fuel expenses, parts replacement, maintenance, depreciation, insurance costs, taxes, and purchase value of the vehicle.[1] We calculated the average cost per vehicle for each year. Rents for the affiliating firms were estimated by adding up the benefits for the buses they own, revenues from routes allocations, and operational costs.

Contracts between the affiliating firm and bus owners are simulated by maximizing benefits from affiliating firms subject to positive benefits for the

1. The prevailing interest rate for each year was used.

bus owners. We thus obtained the optimal number of vehicles per affiliating firm, the affiliation fee, and rents for the affiliating firm and bus owners.

Appendix B: Methodology of the Cost-Benefit Analysis

We performed the cost-benefit analysis for the length of the first wave of the contract: 2000–15. All values are in millions of 2002 U.S. dollars. Population growth rates for 2004 and 2005 are projections from the National Administrative Department of Statistics (DANE); for 2006 onwards, we used the average population growth for 2001–05.

We calculated TransMilenio revenues by multiplying the number of TransMilenio users by the technical fare. For 2001, 2002, and 2003, we used observed values for the number of passengers, as reported by TransMilenio S.A. For 2004 onwards, the revenues were calculated assuming that the number of passengers increased with the population growth rate.

We estimated the revenues for the traditional bus system as follows. First, the number of passengers on the Caracas and Avenida 80 corridors before the implementation of TransMilenio was obtained from DANE for 1996 and adjusted for 2001 using population growth rates for Bogotá. Castro and others provide the revenues and costs per passenger for the different types of buses that operated in these trunk corridors before TransMilenio.[2] We estimated the number of buses that operated in these trunk corridors (approximately 6,080 buses) based on the number of routes in these corridors and the average number of buses per route; this information was provided by Express del Futuro, one of the TransMilenio concessionaires. With regard to scrapping, TransMilenio S.A. reports that for every TransMilenio bus that entered the system, three traditional system buses were scrapped. Nearly 470 TransMilenio buses came into operation, so 1,410 traditional buses (23.2 percent of the total) were effectively scrapped; we assume that the remaining 4,670 buses (76.8 percent) were relocated to other corridors. We calculated the forgone revenues of the traditional buses as the number of passengers multiplied by the revenue per passenger for buses in the Caracas and Avenida 80 corridors. We estimated the gains from forgone operational costs of traditional buses previously operating in TransMilenio corridors as the number of passengers multiplied by the operational cost per passenger for buses in the Caracas and

2. Castro and others (2001).

Avenida 80 corridors. Operational revenues (costs) for traditional buses that relocated to unserved TransMilenio corridors were calculated as the revenues (costs) of traditional buses multiplied by the percentage of buses that relocated to other corridors (76.8 percent).

We calculated five types of operational costs: (a) feeder line costs: the number of passengers in the feeder lines multiplied by the feeder rate per passenger; (b) trunk corridor cost: the number of kilometers multiplied by the bus fare per kilometer; (c) fare collection costs: a rate per passenger multiplied by the number of passengers; (d) operational costs for TransMilenio S. A: 3 percent over the technical fare multiplied by the number of passengers; and (e) fiduciary contract cost: 0.0387 percent of total revenues. For the first four operational costs, we used observed values reported by TransMilenio S.A. for 2001, 2002, and 2003. For 2004 onwards, the number of passengers increases by the population growth rate.

Infrastructure costs for the first phase of TransMilenio are based on values reported by Lleras.[3] Costs include trunk corridors, bus stations, bus terminals, access to stations, bus depots, operations control center, and buses.

Maintenance costs are the total maintenance costs reported by the *Instituto de Desarrollo Urbano* (IDU) and TransMilenio.

Time costs break down into several components. The value of time is from Lleras.[4] All times were assumed to remain constant over the period of analysis. (a) Waiting time: we calculated increases in waiting time as the difference in waiting time of TransMilenio and traditional system users and then multiplied this figure by the value of waiting time for TransMilenio users and the number of TransMilenio users. (b) Walking-in and walking-out time: we calculated increases in walking-in and walking-out times as the difference between TransMilenio and traditional system users and then multiplied this figure by the value of walking time for TransMilenio users times the number of TransMilenio users. (c) In-vehicle travel time: we calculated reductions in in-vehicle travel time as the difference between TransMilenio and traditional system users and then multiplied this figure by the value of travel time for traditional system users and the number of traditional system users. (d) Travel time for users of the traditional system: increases in travel time for users of the traditional system amount to ten percent according to Lleras.[5] We then multiplied this increase

3. Lleras (2003).
4. Lleras (2003).
5. Lleras (2003).

by the value of travel time for traditional system users and the number of traditional system users that transit throughout corridors to which traditional buses were relocated. (e) Negative congestion spillovers in traditional system corridors: five city corridors received the bulk of relocated buses when TransMilenio began its operation (namely, Avenida Calle 68, Carrera 7a, Carrera 13, Carrera 15, and Avenida 19). Information regarding the number of daily passengers that transit these selected corridors was provided by the District's Transit Secretariat. (f) TransMilenio times: we calculated all TransMilenio times for two segments of the population. Segment one includes users who do not use feeder lines, as their trips originate in the vicinity of the Trunk Corridors (55 percent of the population, according to Lleras).[6] Segment two encompasses the remaining 45 percent, who start their trips in areas served by feeder lines and thus have to engage in one or more transfers. (g) Traditional system times: we calculated all traditional system times for two segments of the population. Segment one includes those who only take one bus to their destination (55 percent of the population), while segment two (the remaining 45 percent) includes those who take two or more buses to their destinations.

We estimated the effects on air pollution as follows. Reductions in PM-10 emissions associated with TransMilenio operations in trunk corridors were based on Méndez.[7] Emission reductions or increases in TransMilenio corridors are assumed to affect 20 percent of the population. Finally, we conducted a difference-in-differences analysis to determine the increases in PM-10 emissions associated with traffic spillovers to non-TransMilenio corridors.

To determine reductions in mortality, VSL estimates for Chile were adjusted for Colombia using the per capita GNP of both countries.[8] We then calculated the risk of death for public transportation users before and after TransMilenio as the number of deaths divided by the number of public transit users.

To calculate TransMilenio's net present value, we used social discount rates of 7.00 percent, 9.33 percent, and 12.00 percent.

6. Lleras (2003).
7. Méndez (2004).
8. VSL estimates for Chile are from Bowland and Beghin (1998).