FROM BOGOTÁ TO BERNAL: HOW LESSONS FROM COLOMBIA’S TRANSMILENIO CAN IMPROVE SAN FRANCISCO’S MUNI

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“The first article in every constitution states that all citizens are equal before the law. That is not just poetry. It's a very powerful principle. For example, if that is true, a bus with 80 passengers has a right to 80 times more road space than a car with one.”

-Enrique Peñalosa

Enrique Peñalosa took office as mayor of Bogotá in October of 1997 with a strong vision for mobility, where every citizen had an equal set transportation options. Just four years later, in December of 2001, Bogotá launched what would become the world standard in bus rapid transit technology: the TransMilenio.

A bus rapid transit (BRT) system combines technology, psychology and urban planning to radically increase the effectiveness of a bus transportation system. This effectiveness comes in the form of faster travel times, lower costs, decreased congestion, higher transit usage rates and more mobility for a city’s citizens. While there is no formal standard for what a system must do in order to constitute a BRT, groups have created guidebooks and scoring standards to share knowledge on the various options that transportation planners have at their disposal.

As population growth in urban centers continue to outpace suburban and rural landscapes, mobility and urban livability are becoming the focus of urban planners across the United States. In the last century, public transit often took a backseat to the privately owned automobile. The economic and environmental demands of the twenty-first century as well as the rise of millennial generation require a revaluation of this paradigm. Bus rapid transit’s rapid rise to prominence in the past decade demonstrates its instrumental role in building livable urban centers as Bogotá’s effective development demonstrates.

This research report will use Bogotá’s TransMilenio as a model to recommend changes to the San Francisco Muni. It will initially discuss what distinct features make Bogotá’s TransMilenio the world’s premier bus rapid transit system. It will then examine what specific benefits those features have delivered to Bogotá and its citizens. It will close with an evaluation of features that may be best suited for implementation on the San Francisco Muni system in the near future.

TransMilenio: The BRT Concept’s Successful Modern Implementation

The TransMilenio stands out as the standard for a modern bus rapid transit system. Since Curitiba launched the first iteration of a BRT system in the 1970s, little advancement had been made until Enrique Peñalosa and Bogotá set their sights on re-envisioning transit for Bogotá. When Peñalosa became mayor, Bogotá had been notorious for its traffic and urban congestion, including buses and private automobiles. Around 30,000 buses (21,000 licensed and 9,000 unlicensed (i.e. illegal)) roamed the streets in a “Guerra del Centavo” (“war of the penny”). Citizens hailed buses like they were taxi cabs, making every curb a de facto bus station. Plans for an 18-mile stretch of rail entered a fifth decade of planning at an estimated cost of 168 million
dollars per mile. Yet only three years passed since the initial planning for the TransMilenio began before Phase I of the TransMilenio launched at a cost of 9.4 million dollars per mile.

The Transit Cooperative Research Program (TCRP), part of the United States’ National Research Council, credits the TransMilenio with having all six “key” features of a full-fledged BRT system: dedicated running ways, attractive and functional bus stops, easy-to-board vehicles, off-vehicle fare collection, use of ITS, and frequent all-day service. Almost all of the TransMilenio’s corridors meet the ITDP’s gold standard for BRT systems. That said, each of these features remain attainable with different on the ground strategies (e.g. painted lanes instead of curb-separated lanes), and most modern BRTs include a mix of those features without necessarily all of them.

Dedicated running ways in Bogotá take the form of dual lane paths separated with concrete dividers from automobile, bicycle, motorcycle and pedestrian traffic. This feature is critical to keeping buses out of the congestion that results from other traffic on the road. Keeping buses protected from automobile congestion contributes to a higher average speed. This rapidly reduces travel time for riders. In some cities (e.g. Japan), painted lanes may be sufficient; but in Bogotá, it was necessary to have full curbs as road rules are often disregarded by private drivers. This dual lane system stands out as one of TransMilenio’s main innovations for two reasons. First, when a bus has finished loading, it can pull out of the stop without waiting for the bus positioned in front of it to depart, reducing travel times since buses spend less time at stations. Second, this allows for express bus lines to bypass stations without being held up by other local buses.

TransMilenio’s modern platforms usher riders in through toll-gates and provide a pleasant environment until their bus arrives. This closed system allows for off-bus fare validation in that riders may only enter the bus through specific entry points accessible only through a turnstile at the entry to the station. Sliding doors contribute to both a safer rider environment and quick boarding on a level plane to the buses (which have high floor heights like conventional buses). This height equivalence eliminates the time needed for riders to ascend a set of stairs to enter the bus. Long stops with up to five different stopping bays keep boarding for multiple routes (local, limited, or express) separate, increasing the speed at which buses enter and depart the station.

Buses that serve the TransMilenio corridors continue to be among the world’s most advanced. For example, bi-articulated buses capable of holding up to 270 riders came online in 2009. Each bus is owned and operated by private companies that are paid per mile by the TransMilenio governmental agency. At least two firms operate on every corridor. TransMilenio furthers competition by creating a fund to reward good behavior. TransMilenio collects payment from operators if they fail to operate as expected (e.g. if they stop at the wrong station) then disburse 90 percent of the fund’s revenue to the best performing operator. Buses cost the operators around $200,000, a fraction of what a $2,000,000 light rail train car costs, and articulated buses hold up to 160 riders over the course of their 10-year service life. Their appearance is modern and sleek — in stark comparison to the existing buses of Bogotá (of which
7 to 9 are typically scrapped for each new bus brought online.\textsuperscript{25} The modern buses provide riders with an experience closer to a metro train, increasing the physical comfort of the ride and therefore customer satisfaction.

Off-bus fare collections play a crucial role in bringing the speed of the TransMilenio on par with metros. Typically, off-board fare collection becomes effective once 2,500 pphpd (people per hour per direction) is reached, which is surpassed by the TransMilenio.\textsuperscript{26} Off-bus payment reduces the boarding and alighting times from 2-3 seconds to 0.3 seconds — a significant time savings when buses regularly hold 100 or more riders.\textsuperscript{27} The TransMilenio utilizes a smart card system to collect and validate fares instead of a coin, paper, or magnetic strip system. By making the riders pay upon entering the station, the rider flow rate entering and exiting the bus can be maximized.\textsuperscript{28} However, this can cause significant congestion at large stations with only limited turnstiles for fee collection. TransMilenio uses a flat rate fare, payable upon entry and collected by a card payment system. These fares bring in $270,000 per day via the card systems, which are bid for and operated by private parties in a similar fashion to the buses.\textsuperscript{29} While a distance-based fare structure would maximize revenue and provide more nuanced rider usage data, it would unduly impact the lowest income riders. These riders tend to travel the farthest distance on the TransMilenio and saw the greatest reduction in travel time out of any income group (18 minute reduction on average for those making less than $4.2 per day compared to 10 minutes in the wealthiest group).\textsuperscript{30}

The TransMilenio’s intelligent transportation system leverages three distinct pieces of technology to improve the system’s operation: traffic control priority, intelligent routing, and GPS timing for riders. At any given time, a handful of traffic controllers watch and direct signal lights for the up to 1,000 buses operating in the TransMilenio system.\textsuperscript{31} For example, if they see an opportunity to catch a lagging bus up to schedule, they can extend a green light.\textsuperscript{32} The operators each can communicate with specific drivers to instruct them to skip a stop if their bus is already overcrowded, or vice versa.\textsuperscript{33} These operators rotate between spending time in the central control center and as coordinators within the station in order to always understand the what is happening at a micro and macro level within the system.\textsuperscript{34} With the GPS data, TransMilenio shows the estimate for the next buses via electronic signage within a station.\textsuperscript{35} This can reduce stress and balance loads between buses — for example, if a bus looks overcrowded and a rider sees that the next bus is only two minutes away, they may wait for the next bus, reducing the potential for overcrowding on the initial bus.\textsuperscript{36}

TransMilenio’s operating corridors leverage a “feeder” system of local buses to bring riders to the main “trunks” of the TransMilenio. These feeder buses are free for riders and increase the load factor on each TransMilenio trunk bus line.\textsuperscript{37} With these feeders, TransMilenio achieves 80 percent load factors at peak times and 70 percent load factors during non-peak times.\textsuperscript{38} During the highest peak period, Bogotá can sustain up to 35,000 pphpd\textsuperscript{39} with peaks up to 45,000 with overcrowding — a staggering amount when compared to Curitiba’s maximum of 10,000 pphpd, and close to the highest-capacity metros. To optimize bus flow, TransMilenio uses a wide variety of local, limited and express options. During standard operating hours, buses
arrive every 3 minutes, increasing up to every 1 minute during peak times. Dwell times (alighting and boarding) hover between 20 and 30 seconds — a fraction of the time a conventional bus requires.

Bogotá’s Revitalization: Benefits from the TransMilenio

TransMilenio’s impact can be broadly distributed between social, economic, and environmental categories. Social impacts include time saved by riders, increased access to the city for all citizens, reduced accidents and injuries, and increased civic pride. Economic impacts consist of time saved by riders, increased property values, and the application of the savings by the government compared to other alternatives. Bogotá’s environment benefited from reduced levels of noise pollution and emissions.

Bogotá experienced a wide array of social benefits from the TransMilenio’s implementation. Riders’ transit times were cut substantially: by 32 percent on average. One TransMilenio employee experienced a reduction from 2 to 3 hours down to 45 minutes per direction on his daily commute. This time savings allows riders to spend more time at their destinations (whether their work, their home, or elsewhere) and less time in transit. Access to the city for many of Bogotá’s low-income citizens was increased through the TransMilenio system.

For example, Colombia’s two poorest (of six total) income groups represent 37 percent of the ridership, and another 47 percent are from the third poorest income group (i.e. those earning between $5.9 and $11.4 per day). As mentioned above, these groups saw the greatest reduction in travel time. Safety benefits came both in the form of 93 percent fewer traffic fatalities and 83 percent fewer injuries. Overall, accidents dropped by over 300 percent in the two years after TransMilenio launched.

Customer satisfaction increased and citizens embraced the TransMilenio as a source of civic pride. In fact, ten percent of private vehicle drivers switched to the TransMilenio system during Phase I. That being said, as growth of the system has slowed after its initial upswing in support, satisfaction has begun to taper off and decline slowly.

Economic impacts were substantial. As mentioned in the previous paragraph, citizens saved time each day. This allows them to be more productive by working greater hours or participating in leisurely activities such as spending time with family or shopping. In Bogotá, the value of waiting time is pegged at around $1.14 per hour, meaning that during one rush hour period, a single TransMilenio corridor could result in a savings of around $29,000 (assuming two peak hours with 40,000 passengers each traveling 40 minutes instead of 60, due to the average reduction of travel time by 32 percent). Apartment rental values increased by 6.8 percent to 9.3 percent for every five minutes closer they were to a TransMilenio station (similar to how a home in the Bay Area of the United States increases in value by $1,578 for each 0.03km closer it is to a BART station). The government thus saved substantial amounts of money by building a BRT system in lieu of a metro system. These revenues could be put towards other civic efforts, like building bike paths and public parks. The cost per mile of the TransMilenio Phase I was 9.4 million dollars per mile while the cost per mile of the TransMilenio Phase II was around double that. Phase II cost more because it included more public plazas, had more
sophisticated building techniques, and required more purchase of private land. Nevertheless, both were cheaper than the light rail, which was estimated at a cost of 168 million dollars per mile.

Both emissions and noise reductions contributed to environmental gains. Over the decade since TransMilenio’s launch, there has been a 40 percent drop in air pollutants (SO2 dropped 43%, NO2 18% and particulates by 18%). With the new buses meeting Euro II and Euro III emission standards, carbon emissions should be reduced from 2001 to 2016 by 5.86 million metric tons. Noise was reduced to a maximum of 90 decibels, which compares favorably to the BART system, which regularly exceeds 100 decibels.

**Recommendations: What the San Francisco Muni Can Learn**

Since Bogotá and San Francisco remain very distinct cities with different challenges and potential for benefits, implementing a few lightweight features to the Muni system would be advisable as compared to building out a handful of full-fledged BRT corridors. The passenger loads for most Muni lines are not on a scale for which full-fledged BRT system would make sense. San Francisco does also offer limited light rail, metro, and heavily rail systems in coordination with the bus system via the Muni Metro, BART metro, and Caltrain. Typically, conventional bus corridors are optimal if peak demand is low (less than 15,000 pphpd). BRT systems are optimal if peak demand is between 15,000 and 40,000 pphpd (with rail working well for over 40,000 pphpd). For most parts of San Francisco, this precludes full-fledged BRT from being the optimal transit solution. That said, there remain benefits ripe for capturing by implementing a few of the BRT features to the Muni bus system.

These hybrid systems by no means qualify as BRT systems based on the ITDP BRT Standards, and thus should not be branded as such in order to prevent dilution of the BRT concept. Nevertheless, this hybrid model has been successful in the past. For example, London successfully implemented a few BRT features (painted bus lanes, etc.) to on its conventional bus systems in order to meet its transit objectives. At the moment, San Francisco is preparing to launch its first BRT system: the Geary Corridor Bus Rapid Transit project. This 6.5 mile corridor currently serves more than 50,000 trips per day and is scheduled to be completed in 2019 with dedicated lanes, signal optimization, all-door boarding, low-floor buses, and enhanced bus stations at a total cost of 225 to 260 million dollars. While the Geary corridor will be welcomed, three changes could be made to the conventional Muni system to maximize its effectiveness.

First, the San Francisco Muni could create dedicated lanes for the buses via paint. This creates a permanence for the bus lanes that are currently protected only in bus stops by red curbs and white traffic lines, reducing the motorist invasion of bus space. One challenge that these dedicated lanes would create are problems for private automobiles making turns. This can be overcome by shifting mindsets of what drivers feel they are entitled to. San Francisco is well positioned to do this as drivers are already accustomed to being restricted to where and when...
they can make turns (e.g. Market Street, 19th Street, San Jose Ave during rush hour, etc.). Transit times would then be reduced as Muni buses, as in Bogotá, would not be subject to the same traffic congestion that private vehicles (and current Muni buses) face.

Second, the San Francisco Muni could transition to purchasing low-floor buses. These buses cost anywhere from 50,000 to 100,000 dollars more than traditional, high-floor buses, and suffer from accelerated wear and a less supple ride. However, these buses would reduce station dwell times in that passengers do not have to climb a set of stairs to board the bus, and descend a set of stairs to leave the bus. This would also increase the accessibility for elderly passengers for whom a regular set of bus stairs is difficult and time consuming. By reducing these dwell times, total transit times would be reduced, making the bus system a more attractive option. San Francisco is planning on using low floor buses on the Geary Street Corridor, but a widespread implementation would see even more benefit.

Third, electronic fare payment could be shifted off the Muni buses to the bus stops. Off-bus fare collection remains critical in Bogotá to reducing dwell times, and moving the Clipper card readers from the buses to the stations would create a similar effect. The cost is relatively low in that the Clipper card system is already built and capable of tracking Muni use. When first implementing the Clipper card system, Muni estimated that it would save 17 million dollars between 2010 and 2019. That estimate took into account the placement of clipper cards on each bus, so the cost of transferring the Clipper card readers from the buses to the stations would likely not be significant. Fare evasion would not be significantly changed in that the Muni system already uses a proof of payment system (versus a closed station system of the TransMilenio).

Together, these three changes could be made to reduce the transit times for the conventional Muni system. By reducing transit times, Muni’s conventional bus system would save current riders time, benefitting them both socially, economically, and environmentally in ways that parallel to the BRT in Bogotá. It would also make Muni a more attractive alternative to other forms of transportation, like privately-owned cars, or other automobile-equipped transportation systems like Taxis or Uber.

**Moving Forward**

Bogotá’s successful TransMilenio by no means provides a drag and drop solution to transit challenges faced by the city of San Francisco. The TransMilenio’s success was facilitated by the other urban strategies that accompanied it (e.g. bike path paving, removal of private car parking along sidewalks, etc.) for the 7.5 million city citizens, serving 1.7 million rides per day during the workweek. For the government of Bogotá, the TransMilenio was an urban planning decision, not merely a transpiration decision. This comprehensive change should be seen in context with bike plans and walking plans, since the TransMilenio facilitated these increases in those modes in Bogotá. For example, moving forward, Bogotá plans to double the amount of green space per citizen. As San Francisco moves forward with its Muni system, it must keep in
mind that none of these features in and of themselves creates a BRT system, and that a broader perspective is needed to affect real transportation change. A BRT system is not a one-size fits all solution that can simply be dropped into a city.\textsuperscript{79}

Since the TransMilenio’s successful launch, many new challenges have arisen. Not all of them have been addressed, often because of the large amount of political willpower that each solution would take.\textsuperscript{80} Overcrowding remains the biggest problem facing the TransMilenio today, which partially is a measure of its success in its popularity, but partially due to a lack of follow-through on the intended initial expansion, where in some corridors loads reach 48,000 pphpd.\textsuperscript{81} In fact, for some corridors in Bogotá, a metro would provide the closest match of demand to supply.\textsuperscript{82} What can be learned from this is that a BRT system needs to be part of a more holistic approach that has buy-in from all parties.
References


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