Metrobús Line 4, a Medium Level BRT concept for historic districts with advanced features

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Abstract

Bus Rapid Transit (BRT) is rapidly growing as an effective public transport choice for medium and high capacity corridors, and has been applied extensively in developing countries due to its low cost, rapid implementation and high impact.

In April 2012 México City expanded its BRT system Metrobús to 95 km with the introduction of Line 4. The line runs through the historic downtown district and has an extension to the International Airport. It is 28 km long, has 32 intermediate stops, 2 terminals and 2 stations for the airport. Service is provided with 54 EURO V 12m low floor buses. Eight of them are hybrid diesel/electric; the first fleet of hybrid buses in México. The line carries 50 thousand passengers per day, meeting its expected ridership.

Line 4 has a different configuration than the previous BRT corridors, with characteristics adapted to the downtown historic district. México City´s downtown is a complex site for designing, implementing and operating public transport systems. It combines narrow streets; buildings and monuments of significant historic, cultural, touristic and commercial value; and high volumes of pedestrian traffic, often using the streets due to narrow and insufficient sidewalks.

The final design and operations of Line 4 are respectful of these conditions. This paper summarizes the most important observations of an operational assessment of the corridor during the first months of operation, with a special focus on road safety issues. It also includes recommendations for improvement. This case study provides valuable information to practitioners seeking transit applications in historic districts, and a reference to researchers in urban public transport.

Key Words: Bus Rapid Transit, Sustainable Transport, México, Historic Districts, Road Safety

Introduction

Bus Rapid Transit –BRT- has become an attractive public transport choice for medium to high capacity corridors (Hidalgo and Gutierrez, 2012). There are about 154 cities worldwide with BRT and bus priority corridors, with a special concentration on Latin America (33% of the BRT and bus corridors length and 63% of the total passengers per day) and a growing presence in emerging Asian countries (BRTDATA, 2013). Most of the BRT systems worldwide have been implemented in the last 15 years; with several design and operational elements under permanent evolution. In this context it is very useful to have case studies of particular systems that involve special characteristics.

This is the case of the new Line 4, of the Metrobús System of México City. In the continuum of BRT applications (Diaz and Hinebaugh, 2009), Metrobús Line 4 can be considered a Medium Level BRT (Muñoz and Hidalgo, 2012). It has distinctive design and operational characteristics adapted to the particular conditions of the historic downtown district, and it constitutes an interesting experience for practitioners and researchers in the field of public transport.

This paper includes background information on México City and its historic district; the system general characteristics; operational indicators; and detailed information on the infrastructure, fleet, and user information and road safety features. It is based on a detailed review during the first months of operation (Priego et al, 2012), complemented with a road safety inspection (Wass et al, 2011). The paper finalizes with conclusions and recommendations, including lessons for other systems facing similar conditions.

Background Information

México metropolitan area is one of the world's largest urban conglomerations in the world. The Metropolitan Zone of México Valley (ZMVM) includes 60 municipalities of the State of México and 16 Delegations of the México Federal District, with a total population of 20.1 million and covering 7,854 sq km (Wikipedia, 2012). The ZMVM generates more than 49 million trips per day. Of those, 5.6 million trips (11%) are made by car (INEGI OD 2007).

To face its growing sustainable development concerns, México D.F. has advanced the "Green Plan", which includes interventions in several sectors (SMA, 2012). In mobility, the plan includes public transport interventions such as BRT and metro expansions.

BRT is a recent addition to México City mass transit options, with a rapid expansion. The first Metrobús BRT line started operation In June 2005 on *Insurgentes* avenue (16 km). Between 2005 and 2012, the city implemented 4 lines for a total of 95km serving 800,000 passengers per workday.

Metrobús Lines 1, 2 and 3 are "High Level BRT" corridors, incorporating exclusive median lanes, enclosed stations with prepayment and level boarding, large articulated and bi-articulated buses, advanced information technology systems and a distinctive image (Wright and Hook, 2007;

Levinson et. al, 2003; Diaz and Hinebaugh, 2009; Muñoz and Hidalgo, 2012). Line 1 started operations on June 19, 2005 along *Avenida Insurgentes* with 20 km. It was extended to 30 km in 2007, has 45 median stations and serves 400 thousand passengers per day (Gómez-Flores, 2012). Line 2 was implemented in December of 2008, is 20 km long, has 36 stations and serves 165 thousand passengers per day; Line 3 initiated on February 2011 and has length of 17 km on *Eje 1 Poniente*, has32 stations and serves 140 thousand of passengers per day (Gómez-Flores, 2012).

Line 4 has different characteristics than the previous Metrobús lines and can be considered a "Medium Level BRT" (Muñoz and Hidalgo, 2012). It was designed in accordance with the special characteristics of the historic downtown district: narrow streets, buildings with significant historic, cultural, touristic and commercial value; and high volume of pedestrians walking in the streets, given very narrow and insufficient sidewalks. Moreover, many of the roads and sidewalks were encroached with street vendors.

Line 4 enhances transit access for more of one million persons with trip destinations in the historic downtown district (INEGI OD 2007). It complements five Subway Lines -1, 2, 3, 8, and B-, one suburban rail line -*Suburbano* 1-, two trolleybus lanes, and the bike sharing system *Ecobici.*

Metrobús Line 4 provides an important addition to sustainable mobility in the main activity center of the city. It is aimed at proving a high quality connection among the different mass transit options to the key destinations in downtown and the airport. It was also implemented with the purpose of attracting trips from less efficient mobility options (microbuses and private cars), and thus reduce air pollutant and greenhouse emissions.

Implementing Line 4 faced several problems, requiring a very extensive recovery of public spaces encroached by street vendors, while preserving historical buildings and monuments. Initially, the project was intended only for downtown, but the city administration decided to provide a link to the international airport for tourists and the airport terminals' workers.

Metrobús Line 4

The 28 km Line 4 started operations on April 1, 2012. It connects *Buenavista* terminal (a transit hub, with direct access to Metro, Suburban Rail and two Metrobús Lines) with *San Lázaro*, through two parallel alignments (Figure 1a) using bus only lanes. From *San Lázaro* there is an extension running on priority lanes to the International Airport of México City AICM, Terminals 1 and 2. The line features 32 intermediate stops, two terminals and two stops at the AICM.

Service is provided with a fleet of 54 EURO V vehicles – 46 Ultra Low Sulfur Diesel ULSD buses and eight Hybrid Diesel-Electric buses. These buses are low floor, 12m long, and have doors on the right hand side (curbside). There are two services routes running in loops from *Buenavista* to *San Lazaro* (north and south loops), and one service connecting to the AICM.

Line 4 has specific characteristics that differ from the "High Level BRT" corridors implemented in Lines 1, 2 and 3:

- Very narrow right of way (Figures 1b to 1e), with bus and pedestrian only streets in many sectors (Figures 1c and 1d)
- Recovery of public spaces previously encroached by streets vendors (Figures 1b to 1f)
- Low platform stations and terminals (Figures 1g and 1h)
- Smaller, low floor buses with more advanced propulsion technologies (Figures 1i and 1j)
- Curbside boarding and aligning (Figures 1d and 1i)
- On-board fare validation (single door entry, Figure 1i)
- Security cameras on board and user information screens (Figure 1i).
- Card sales and recharge only at terminals and external points, like mini markets.
- Totems to indicate bus stop location according to guidance by the downtown historic district authority (Figures 1d and 1f)
- Accessibility for people with different mobility needs (Figures 1d and 1i)

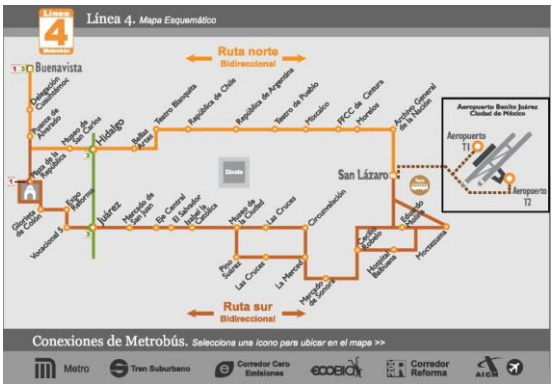

Figure 1a. Schematic Plan of Line 4

Figure 1b. Excusive Bus Lanes and Urbanism

Figure 1c. Bus and Pedestrian Only Street

Figure 1d. Curbside Bus Station

Figure 1e. Curbside Exclusive Bus Lane

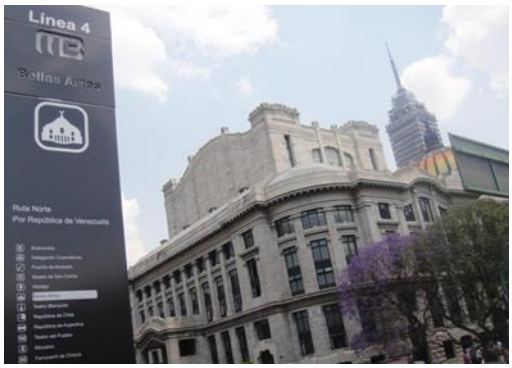

Figure 1f. Totem Marker at Bellas Artes Stop

Figure 1g. Buenavista Terminal Exterior

Figure 1h. Buenavista Terminal Interior

Figure 1i. Low Floor Entry and Bus Interior

Figure 1j. Low Floor 12 Hyabrid Bus

Operational indicators

Ridership

The line 4 carries 50,000 passengers per day (maximum reached 56,000 passengers per day in October 2012). Maximum ridership is observed on Saturdays, with a decrease in 3% during weekdays and 50% on Sundays (Priego et al, 2012, Figure 2). The route "E2" is the most demanded

concentrating 55 percent of the total ridership. Passenger maximum load was observed at 668 passengers per hour per direction (Priego et al, 2012, Figures 3a and 3b).

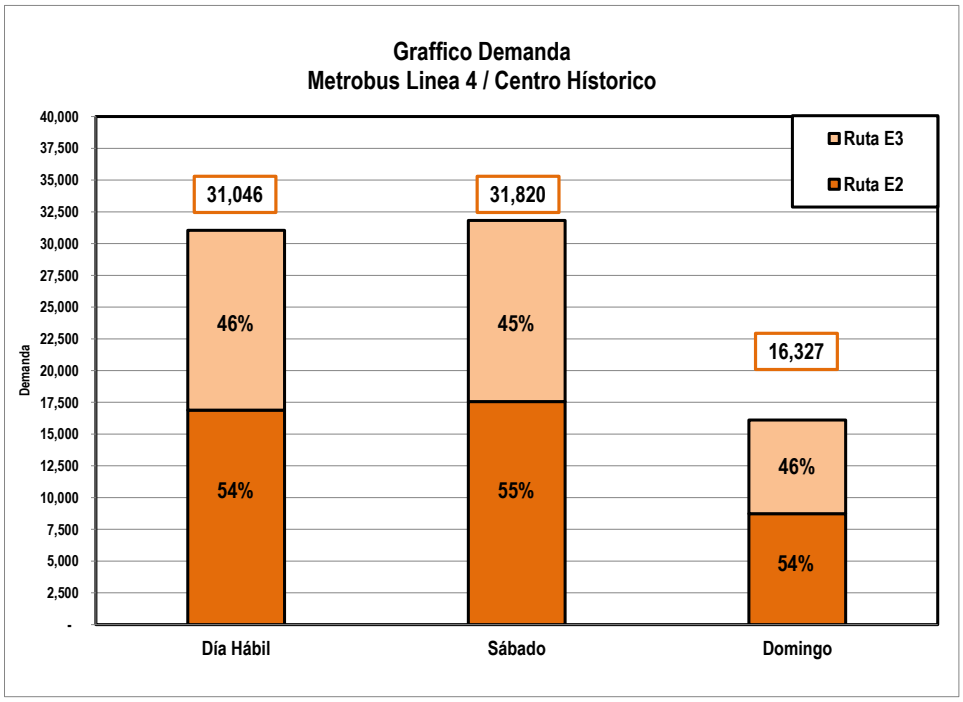

Figure 2. Passenger Ridership by Day of the Week (May 2012)

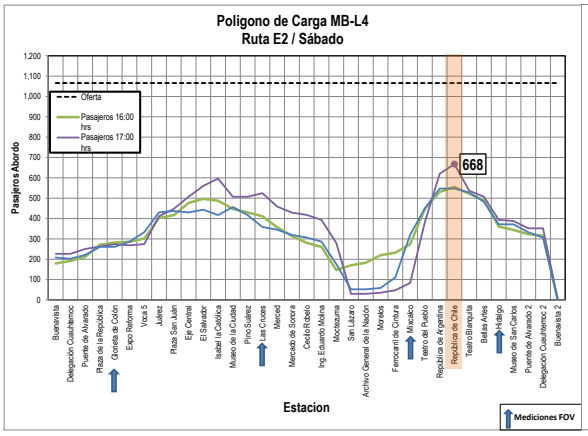

Figure 3a Boardings- Route E2-Saturday

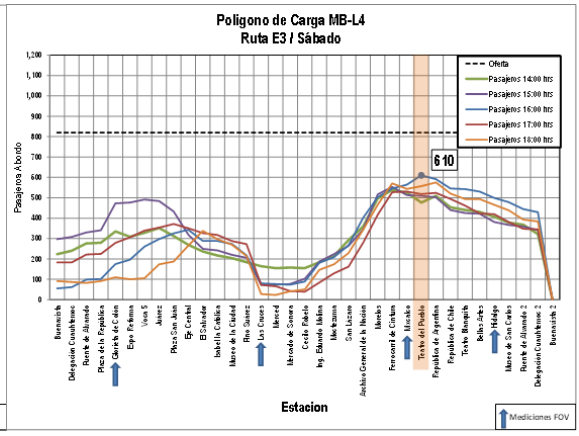

Figure 3b Boardings Route E3-Saturday

Regularity

Field observations indicate lack of regular service frequency. Less than 50 percent of the arrivals occurred within the programed headway. Irregular service causes long waiting times for a large proportion of users. The longest measured waiting time was of 24 minutes, for a programed 3 minute interval.

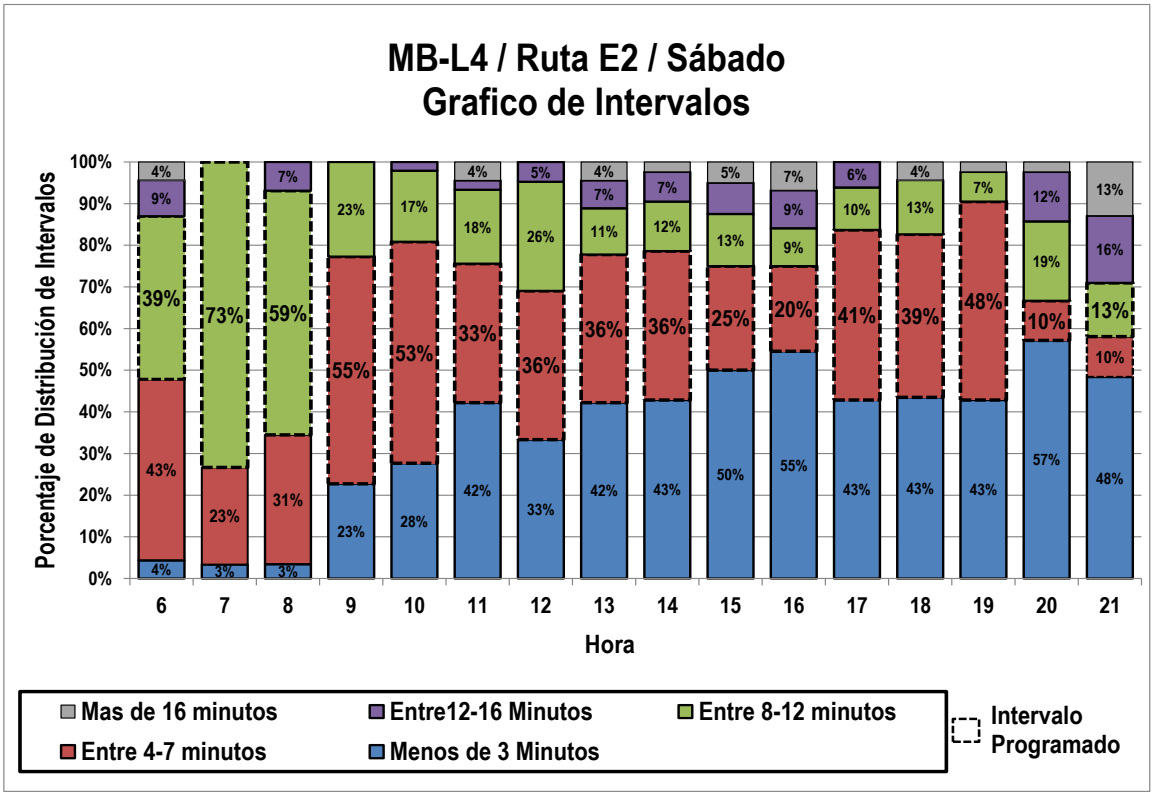

Figure Intervals route E2-Saturday

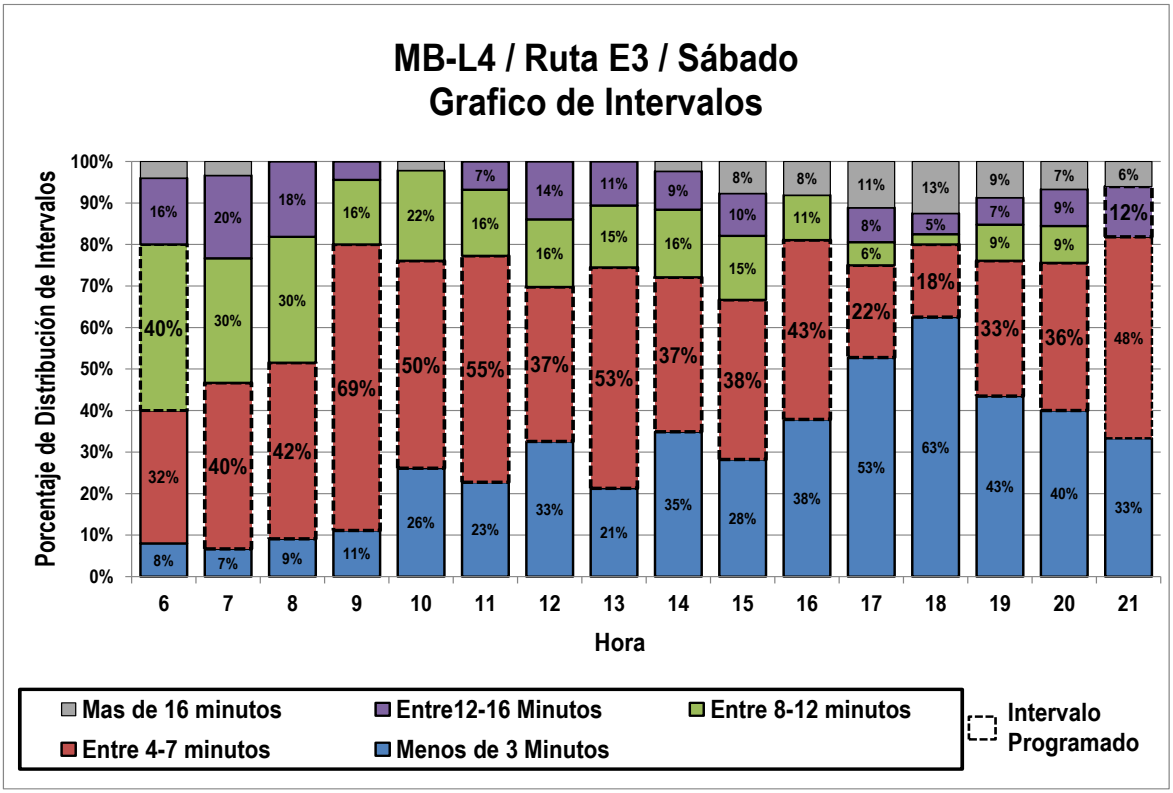

Figure 4. Headways route E3-Saturday

Cycle time analysis and delays

Peak cycle time is between 1:22 and 1:36 hours depending on the loop and the day of the week. The south loop E3 takes less time than the northern loop E2 (Figure 5a). Travel speeds are 9.9 km and 9.0 km/hr respectively (Figure 5b). There are large speed variations along the routes, with a minimum of 4.1 km/h and a maximum of 19.1 km/h (Figure 5b).

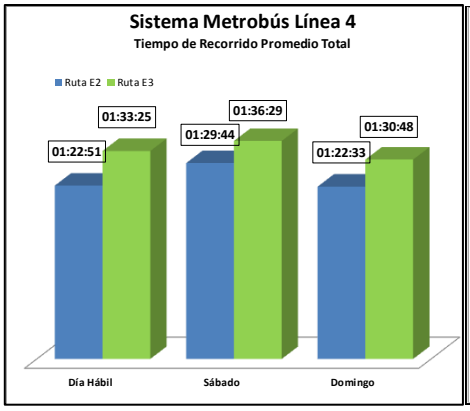

Figure 5a. Cycle Times

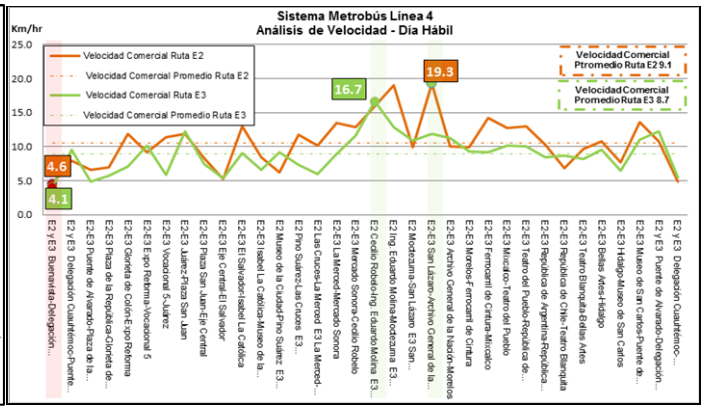

Figure 5b. Travel Speeds

For both routes –E2 and E3- the main factor of delays is the stop time at traffic lights. Stop time at intersections was 28% of the cycle time in Route E2 and 34% in Route E3 (Fiugres 6a and 6b).

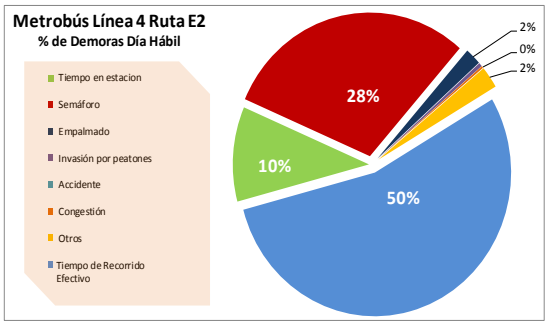

Figure 6a. Cycle Time Analysis Route E2

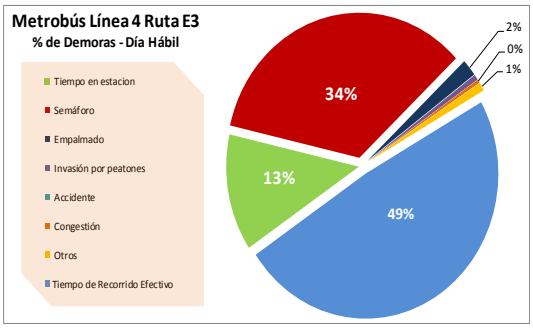

Figure 6b. Cycle Time Analysis Route E3

Infrastructure

Metrobús Line 4 infrastructure differs from that on Lines 1 to 3. The design was intended to have a "cleaner", accessible and safe corridor, with the following features:

- new concrete pavement
- realignment and separation of lanes
- wider sidewalks with higher levels for accessibility
- separated signals for buses and for mixed traffic
- pedestrian traffic lights

Due to the characteristics of historic center, it was necessary to keep the original layout and to preserve the urban landscape around the historic buildings and monuments. The area is under the jurisdiction of the Historic Center Authority of México City, which has established several regulations to preserve the area's character and attractiveness.

It was then necessary to create particular designs and significantly change the characteristics used in other BRT corridors. For instance, the stations are open platforms on the sidewalk, only raised to flush with the low floor buses. Similar considerations were required for the terminals.

Stations

Line 4 has 32 stations and 2 terminals –*Buenavista* and *San Lazaro*-. Regular bus stops were installed out of Historic Center main zone –*Perimetro A*-; only totems were installed inside of Historic Center main zone, as normal bus shelters or more complete stations were not possible. All the stations are 34 cm high to ensure accessibility; they feature ramps and tactile guides for people with disabilities.

Figure 7a. Schematic of Bus Stations

Figure 7b. Terminal Station San Lázaro

Figure 7c. Ramp, Platform and Bus Shelter

Figure 7d. Platform with Totem

The authors´ analysis of the bus stops indicates:

- The area required for passengers waiting at the stations seems to be sufficient for the demand in a regular operation. However long lines were observed due to service irregularity (when the interval between two consecutive buses was above 5 minutes).
- The manual docking on the far side of the driver is difficult; some buses have scratches in the right hand side.
- The totems are good solution for the architectonic restrictions set forth in the Historic Center. Nevertheless these stops do not provide any protection for sunlight and rain to the passengers.
- In general, the information provided at the stations was insufficient, with some information in very small font (like the location of external re-charge stations), it seems necessary to provide more information to the users, especially considering that this is a very different kind of service, mainly intended to provide connectivity with other mass transit lines and with the airport.

Lanes

Due to the characteristics of the downtown area, Line 4 has three different types of bus lanes:

- Bus priority streets, semi-exclusive operation (Figure 1c). The lanes can be used for access to parking lots, but vehicles are not able to continue traveling for more than two blocks along the bus priority lane.
- Median exclusive lanes (Figure 1b).
- Curbside lanes shared with other public transport services (short sections where bus only lanes were not possible).

In the connection to the airport (outside the historic district) there are median and curbside bus priority lanes.

Signals and pavements markings

Most intersections are signalized and have central area control systems. All crossings are demarcated with zebra crossing paint. Some important observations regarding intersections:

- The traffic light cycle time and phases are quite sufficient for vehicles and pedestrians, however the cycle phases are not calibrated to give the preference to the Metrobús corridor. As a result there are long stop times for Metrobús buses.
- New vertical signs have been installed, providing fairly adequate information of streets directions, pedestrian crossings, prohibited left turns, and bus priority.
- There is insufficient information on Metrobús line 4. It is a new concept and it is necessary to provide more information and make a strong differentiation between the exclusive and shared lanes, available parking lots, flow directions, and so on.

Technological Components

Fare collection system and fare integration

The entire Metrobús system operates with a flat fare of MXP 5.00 per trip (USD 0.37). The fare collection system allows for full integration among the different Metrobús lines within a 2 hour time window. The shuttle for the airport has a differentiated fare of MXP 30 pesos –USD 2.22, for a single trip, and allows the integration with the other lines.

Fare validation in Line 4 is on board –except at the terminals, where validation occurs at the entrance (off-board). There are two validation devices in the front door of the buses, at the right hand side (close to the driver) and the left hand side (Figure 8). The fare media is a smart contactless card usable in the entire Metrobús system. The city is working in the integration of the fare collection in Metrobús with the Metro, Light Rail and Trolleybuses.

Buses

Line 4 includes a fleet of 54 EURO V low floor buses, with right hand side doors, 12 m length, and capacity for 90 passengers. Eight vehicles are hybrid Diesel-Electric buses; the first fleet of hybrid buses in México.

Buses include some additional features to increase passenger comfort and security as compared with other Metrobus vehicles, such as air conditioning, baggage racks, closed circuit TV cameras on board and automatic passenger counting devices.

The operator of the route reports 25%-30% fuel savings in the hybrid buses as compared with the diesel buses.

a. On board fare collection device next to the driver

b. Access to the bus (front door)

c. On board fare collector on the left side

Figure 8. On board fare collection

User Information

Due to the differences of this line with the previous ones, the communication campaign was an important element during the first weeks of operation. The campaign included (Figure 9):

- Distribution of flyers with system information
- Specially designed web page
- Information in major newspapers
- Guides at each station to provide direct information to the users

Despite the introduction of this campaign, there was disinformation regarding the new service at the beginning among potential users. Most common concerns included lack of information on the routes, the payment system, points of card recharge and service hours.

Figure 9. Information Campaign Materials and Guides

Road safety

Due to the combinations of narrow streets, high volume of pedestrians walking in the streets, insufficient width of sidewalks, bicycles, and vehicles, it was important to give special consideration to road safety in the corridor and its area of influence.

Prior to final implementation, in July 2011, a Road Safety Audit was undertaken (Wass et al, 2011). Special considerations for road safety in bus corridors were applied (Duduta, et. al, 2012a), which follow special research using crash models, audits and inspections (Duduta, et. al, 2012b). The audit was complemented with an inspection In June 2012, to document changes in final implementation and to identify outstanding issues. The main recommendations included in the audit report (2011) were considered in final implementation (2012), enhancing the traffic safety for all road users. There still are some issues that require attention.

Protected pedestrian islands

The number of intersections along the corridor featuring protected pedestrian space increased from 21 (27%) before the audit to 73 (93%) after the implementation of audit recommendations. Figure 10 shows the condition before and after at a particular intersection (*Jesus Garcia and Luis Donaldo Colosio*).

Pedestrian signals

The number of signalized intersections along the corridor featuring pedestrian signals increased from 37 before the audit to 49 after the implementation of audit recommendations (a 32% increase). Figure 11 shows the traffic signals in a particular intersection before and after the implementation of the corridor.

Figure 10. Pedestrian Crossing at *Jesus Garcia* and *Luis Donaldo Colosio* Before (2011) and After (2012)

Figure 11. Pedestrian Crossing at *Jesus Garcia* and *Luis Donaldo Colosio* Before -without Pedestrian Traffic Signal (2011) and After- With Pedestrian Traffic Signal (2012)

Recovered sidewalks

Extensive pedestrian areas were recovered, previously encroached by street vendors, particularly in the area of *La Merced* market. Figure 12 indicates the conditions before and after the intervention in *Miguel Alemán* Street.

Terminals and pedestrian safety

The original design of the terminal at *Buenavista* (*Puente de Alvarado* Street) involved the potential of several conflicts between pedestrians and general traffic. The audit recommended pedestrianizing the street to provide safe access. This recommendation was implemented (Figure 13).

Figure 12. Sidewalks in *Miguel Aléman* Street before (2011) and after the corridor implementation (2012).

Figure 13. Render of the design of pedestrian access to *Buenavista* Terminal before the Road Safety Audit (2011), and Actual Pedestrian Street to Access the Terminal (2012)

Traffic signs

Overhead signs did not provide clear indication of the exclusive bus lanes. The road safety audit recommended special colored signs to increase visibility to general traffic. Figure 14 shows how the overhead signs were modified.

Figure 14. Overhead signs before and after intervientions at *Puente de Alvarado* Street.

Traffic calming

Special traffic calming features were recommended in the road safety audit and implemented in the project. Figure 15 shows *Eje 3 Eduardo Molina*, which is a very wide street with high vehicle speeds and frequent jaywalking. It was considered a mayor black spot for run-overs. The implemented project includes a signalized pedestrian crossing, with very clear zebra crossing paint, and four refuge islands to break up the crossing and provide additional safety to pedestrians.

Figure 15. *Eduardo de Molina* Av. Before (2011) and After (2012) the intervention, displaying good protection for pedestrians.

Conclusion and recommendations

Metrobús Line 4 constitutes an innovate approach to transit provision in historic districts, considering the restrictions of such an environment. It substantially differs from the previous BRT corridors in Mexico City, displaying changes in infrastructure, vehicles, information technologies and operations. It is a good reference example for practitioners and a research case study in the evolution a of bus systems. Special considerations included the operation in very narrow streets, the architectonic respect to the character of this area, and the inclusion of advanced vehicle technologies. It shows ingenuity and exemplifies the core characteristic of bus-based transit systems: being flexible.

For narrow streets in downtown areas the priority given to the majority of users of public transport over the rest of the traffic is remarkable. Also the careful urban design and the use of cleaner vehicles are important. The corridor is also part of a network and not an isolated initiative. There is physical, operational and fare integration with other Metrobús corridors, and physical integration with other mass transit modes and with the public bikes systems *Ecobici*. The city is working in expanding fare integration to the Metro system.

The corridor displays relative low speed and throughput as compared with other BRT corridors around the world (see BRTDATA, 2013; Hidalgo and Carrigan, 2010). It is more intended to connect long haul mass transit lines (Metro, Suburban Rail and full BRT) with destinations across

downtown and the airport, than providing fast, high capacity connectivity. It has reached its forecasted demand within a short time span (less than six months). Nevertheless it faces some issues that deserve consideration:

Road Safety

While several recommendations of road safety audits were included in the final implementation, there are still risks. Jaywalking pedestrians and usage of bus lanes by bicyclists and manual goods carriers (*diablitos*) is common, requiring careful driving of the operators and education and enforcement for other road users. As peak speeds are not high (19 km/h) the overall risk is not fatal, yet there is concern with the cycle time that may push bus speeds up. In that context it will be important to consider special outreach, signaling and some support from the police. One particular section, along *Eje 1 Oeste Circunvalación* is still encroached with street vendors, adding to the pedestrian risks. It is recommended to clear this space and improve the traffic safety condition for all road users. In the consideration of road safety issues in other bus corridors it is recommended to use the guidelines by Duduta et al (2012a).

User information

The communication campaign before implementation was good, but it was insufficient for the requirements during the first weeks of operation. It is considered necessary to have a continued information systems for new users and to improve the information in the bus stops and terminals. The connection to the airport is well below the demand expectation (Mora, 2012), partially due to the lack of information for arriving tourists. User information is important for the success of transit systems (see Weber et al, 2011)

Accessibility

In general accessibility is provided in all the stations and buses, however is important to note that some characteristics of the surrounded area should be improved in order to offer connections to most places such as schools, hospitals, business, and so on. Consideration of the good practices along the corridor (continued sidewalks, clearing of encroachments and obstacles), can be considered in transversal streets within the area of influence of the corridor. Recommended guidelines for accessibility have been developed by Rickert (2007).

Buses

The buses have good quality standards providing air conditioning, baggage racks, on board cameras, and passenger counting devices. A fraction of the fleet constitutes the first hybrid bus fleet in México. Inclusion of advanced technologies like those considered in this application is one interesting trend in the industry (See Hidalgo and Muñoz, 2012). It is recommended to assess the cost and benefits of such decisions.

Fare collection system

The fare collection system worked in a proper way. Mexico City retained the mapping of the contactless fare collection cards, providing flexibility to the entry of fare collection operation

(Varano, 2010). This is a recommended practice. However the information on the external recharge points is not clear for users. It is suggested to have better information on this issue.

Operation

The operation of the two routes in Metrobús Line 4 is affected by long red phases at the intersections, creating high variability in bus arrivals. It is important to maintain the service regularity as users are willing to wait for the service just for a short period of time. There are other options to access destinations in downtown, especially in short trips. It is recommended to improve the signal programing and also increase the operational control to reduce bunching. For further reference on control technologies see Delgado et al (2011).

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