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Impact Analysis of Transoeste Bus Rapid Transit System in Rio de Janeiro

ITDP Brazil
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Acknowledgments

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Sumário Executivo

O corredor de Bus Rapid Transit (BRT) Transoeste, no Rio de Janeiro, não é somente um corredor com reconhecimento internacional e certificação ouro, mas também o primeiro de quatro corredores de grande capacidade a serem implantados na cidade. Quando todos os corredores forem entregues, a cidade terá uma rede de mais de 150 km de corredores de BRT de alta qualidade, integrados aos sistemas de metrô, trens urbanos e bicicleta pública, entre outros serviços de transporte. Este grande investimento em infraestrutura é fundamental para a transformação do Rio de Janeiro em direção a uma cidade mais sustentável, com ar mais limpo, pessoas mais saudáveis, tempos de viagem mais curtos, e custo de viagem mais acessível à população.

O objetivo deste relatório é examinar os ganhos do Transoeste em seus primeiros nove meses de operação, de modo a compreender o impacto para os passageiros; informar o público sobre o resultado da implementação deste novo sistema na cidade; fazer recomendações aos operadores sobre como melhorar o desempenho e ao mesmo tempo lidar com o aumento da demanda; assim como fazer recomendações sobre como melhorar o sistema como um todo, com lições para os outros corredores a serem implementados na cidade do Rio de Janeiro.

Os resultados encontrados na análise são claros: o Transoeste melhorou drasticamente a mobilidade, as emissões e o nível do conforto de viagem, e apresenta um precedente de sucesso para o sistema de BRT que está sendo implementado na cidade. Com estas considerações feitas, no entanto, é preciso alertar para o fato de que o corredor Transoeste tem questões críticas: os tempos de espera dos passageiros ainda são significativos, devido a procedimentos de embarque ineficientes, e as frequências de ônibus estão 25% mais baixas do que as planejadas. Ambos estes aspectos devem ser resolvidas para manter os impactos positivos da Transoeste no tempo de viagem, no conforto e na sua imagem do sistema como parte de um novo paradigma de mobilidade do Rio de Janeiro.

Estas melhorias também serão necessárias para lidar com o rápido crescimento no número de passageiros, como o que temos visto desde junho de 2012, assim como com a estimativa futura de demanda quando o corredor for integrado à estação de metrô do Jardim Oceânico.

Os indicadores impactos do Transoeste, conforme descritos neste relatório, estão listados abaixo:

Média de tempo reduzido por viagem	40 minutos/viagem
Média de tempo reduzido de viagem por pessoa	14 dias/pessoa/ano
Valor de tempo reduzido para todas as viagens	R$ 70 milhões/ano
Redução dos quilômetros percorridos pelos veículos	56.8 milhões km/ano*
Redução de uso de combustível	44 milhões litros/ano*
Redução de emissões de dióxido de carbono (CO2)	107,000 toneladas/ano*
Redução de emissões de material particulado (PM)	6.9 toneladas/ano*
Redução de emissões de óxidos de nitrogênio (NO_x)	206 toneladas/ano*

*Estimativa anual considerando vinte anos

Executive Summary

The Transoeste Bus Rapid Transit (BRT) line in Rio de Janeiro's West Zone is not only an internationally recognized gold-standard BRT in and of itself, it is also the first of four major gold-standard BRT corridors to be built in the city. When all corridors are built, the city will have a network of more than 150 km of high-quality BRT lines to further complement its subway, commuter rail, bike-share and other alternative transport services. These investments are crucial for shifting Rio de Janeiro onto a more sustainable path, with cleaner air, healthier people, shorter travel times and improved access for lower travel cost.

The objective of this analytical report is to look at the achievements of Transoeste in its first nine months of operations to understand the impacts it is having on users and within the corridor; to inform the public on the impacts of this new system and inform the operators on ways of bolstering its performance as demand increases; and to further development of high-quality BRT corridors within Rio de Janeiro.

The overall results of the analysis are clear: Transoeste has drastically improved mobility, emissions and comfort within its corridor and presents a successful precedent to carry forward as BRT expands both within the corridor and across Rio.

With these successes noted, Transoeste is not in the clear completely: Significant waiting times for passengers due to inefficient boarding procedures and bus frequencies 25 percent lower than planned must be addressed in order to maintain Transoeste's beneficial impacts on travel time, comfort and its positive image as Rio de Janeiro's new form of mobility.

Such improvements will also be necessary to cope with the rapid growth of ridership experienced thus far and forecasted to continue over the next two years as the line extends to the new Jardim Oceânico subway line.

A summary of the Transoeste's impacts as found in this analysis are presented below:

Impacts on corridor:

Average Time Saved per Trip	40 minutes / trip
Average Time Saved per Person	14 days / person / year
Value of Time Saved for all trips	R$ 70 million / year
Vehicle Travel Reduction	56.8 million kilometers / year*
Fuel Use Reduction	44 million liters / year*
Carbon Dioxide (CO2) Emission Reduction	107,000 tons / year*
Particulate Matter (PM) Emission Reduction	6.9 tons/year*
Nitrogen Oxides (NO_x) Emission Reduction	206 tons / year*

*Estimate over 20 year period

I. Introduction and background

1.1 Objective

The objective of this study is to investigate the impacts that Transoeste, the first BRT implemented in Rio de Janeiro, has provided to its users over the previous bus lines servicing the corridor and potentially over driving a private car.

1.2 Methodology

Transoeste's impacts were assessed through the lenses of mobility, comfort and environmental indicators.

To identify changes in mobility and comfort on the corridor following Transoeste's implementation, the ITDP Brazil office conducted a sample survey of Transoeste users in October 2012. The survey sought to provide quantifiable data on users' travel behavior and level of satisfaction with Transoeste compared to previous bus service. A complete description of the methodology and results of the user survey, including the survey itself, can be found in Appendices I and II of this report. The report also draws on municipal data on bus frequencies, fleet size, travel times and ridership to further assess mobility and comfort. This information, along with ITDP observations of the system, was used to calculate travel time savings, as well as ridership demand and service capacity at stations along the corridor.

To assess the environmental impacts of the project, the above data was also analyzed with the Transportation Emissions Evaluation Model for Projects (TEEMP), a methodology developed by ITDP and recommended by the Global Environment Facility (GEF). This process uses project inputs to estimate the impact on vehicle distance traveled along the corridor, carbon emissions and pollution, and fuel consumption over a 20-year period. For more detailed information on the TEEMP Model, please see Appendix III.

1.3 Transport Trends in Rio

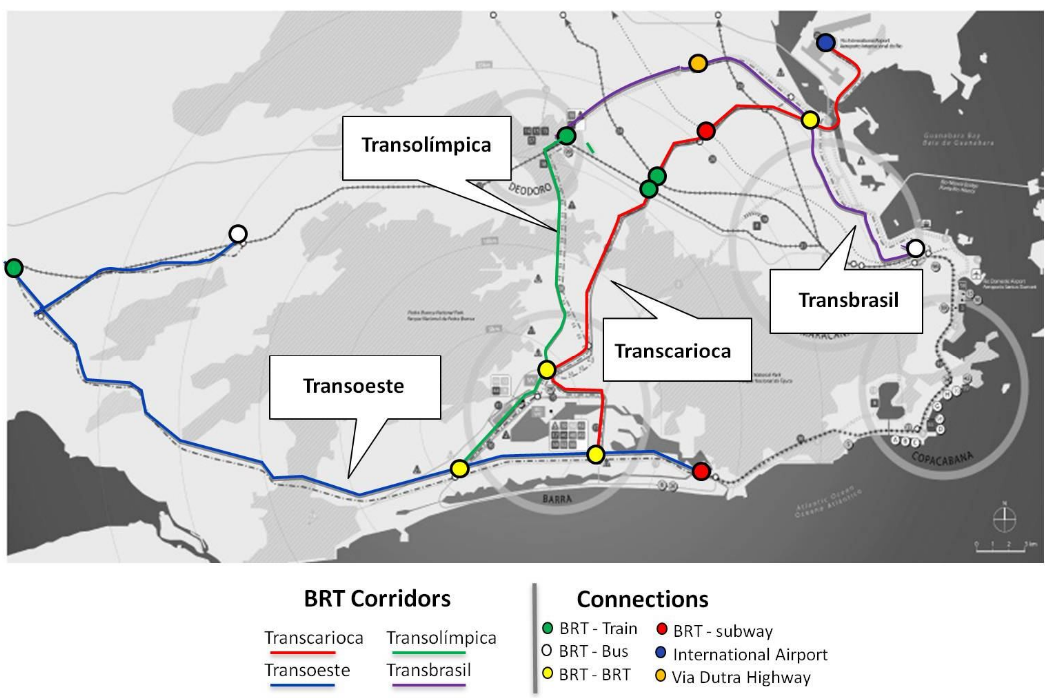
As incomes in Rio de Janeiro have risen over the last decade, motorization has increased such that the city is now facing widespread issues with traffic congestion and other adverse social, economic and environmental impacts from this growth in automobile use. Rio de Janeiro's automobile fleet has grown steadily at an average rate of 5 percent per year, from around 1.7 million light-duty vehicles (LDVs) in 2001 to about 2.8 million in 2011, which represents a total increase in motorization of 61 percent during the ten-year period. [1]

[1] Observatório das Metrópoles (2013).

In the streets of Rio, traffic congestion has also increased significantly. In 2003 the average speed for private vehicles in the most important transportation corridors in the city was 27 km/hr. By 2012 the average speed had declined by 35 percent to just 20 km/hr.[2] By 2032 the average speed in the city is expected to decrease to 16 km/hr.

Given these patterns in motorization and decrease in average speeds, the city of Rio de Janeiro adopted an aggressive plan to improve public transportation options in the city and metropolitan area. The plan includes investment in the expansion of the city's subway system as well as the construction of segregated busway systems that will help the city alleviate some of the pressing mobility problems and aid its preparation for two major sporting events: the 2014 Soccer World Cup and the 2016 Olympics. Transoeste is the first of four Bus Rapid Transit (BRT) corridors to be constructed by 2016, which will total 150 km of busways when complete (Figure 1). City officials expect that these corridors will accommodate demand for approximately 1,700,000 daily trips.

Figure 1. BRT corridors by 2016



Source: Secretary of Transportation, Rio de Janeiro, January 2013.

[2] O Globo, http://oglobo.globo.com/transito/cariocas-convivem-cada-vez-mais-com-engarrafamentos-3471657

1.4 Transoeste Project Development and Implementation

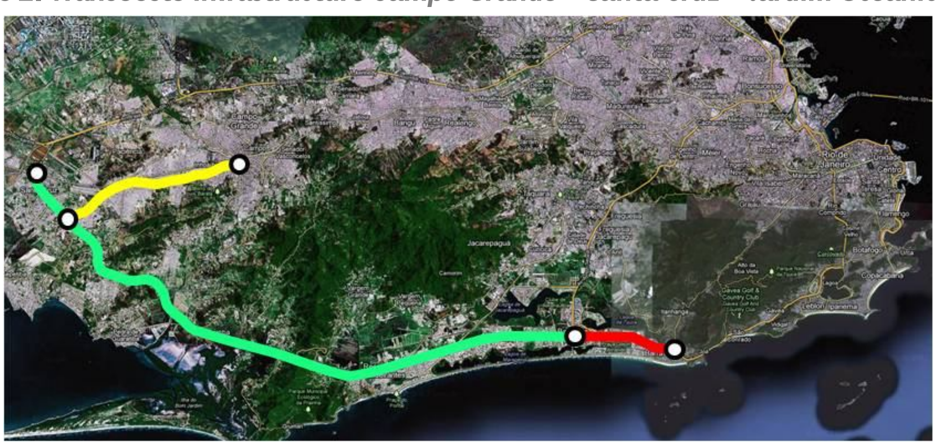
In the face of growing congestion, pollution and cost of motorized mobility, the city of Rio de Janeiro is investing in a BRT network because of BRT's ability to transport high passenger volumes at relatively high speeds with good service quality, all at a fraction of the cost of a rail project.

> ***"This is the first BRT, with others to come. It is a cultural change around how people move about in the city. It's like a subway train on wheels, at much lower costs." —Eduardo Paes, Mayor of Rio de Janeiro***

The first phase of the Transoeste corridor opened in June 2012 and runs from Santa Cruz neighborhood, in the northwestern part of the municipality, to Alvorada Terminal in the heart of Barra da Tijuca neighborhood, in the southern part of Rio's West Zone (Figure 2). For the most part, this section of the corridor runs through Avenida das Américas, the main thoroughfare in Barra da Tijuca and Recreio dos Bandeirantes neighborhoods. The extension of the corridor to Campo Grande neighborhood east of Santa Cruz has been under limited operations since early 2013, with expected service expansion during the remainder of 2013.

The final implementation phase, which will link Alvorada Terminal to Jardim Oceânico Station, located at the far eastern end of Barra da Tijuca, is set to be completed by 2016, in time for the Summer Olympic Games. The Jardim Oceânico station will be a key intermodal station, linking the Transoeste BRT to the expanded subway system. By the time Transoeste is completed in its entirety, it will feature approximately 60 km of BRT infrastructure with a total of 68 stations and an expected total demand of 220,000 passengers per day by 2016.[3]

Figure 2. Transoeste infrastructure *Campo Grande – Santa Cruz – Jardim Oceânico*



The green line shows the 38.6 km section of Transoeste in operation since June 2012. The yellow section from Santa Cruz to Campo Grande has been under construction and beginning limited operations as of early 2013. The red section will connect Alvorada Terminal to the future Jardim Oceânico subway station at the eastern edge of Barra da Tijuca neighborhood by 2016.

[3] Secretary of Transportation, Rio de Janeiro, 2013.

Table 1. Transoeste implementation phases

CORRIDOR	OPENING DATE	EXTENSION	TOTAL STATIONS
Santa Cruz–Alvorada	June 2012	38.6 km	34 (March '13) 36 (total planned)
Santa Cruz–Campo Grande	2013 (scheduled completion)	16.3 km (Santa Cruz–Campo Grande) 15.8 km (Campo Grande–Santa Cruz)	8 (Feb. '13) 24 (total planned)
Alvorada–Jardim Oceânico	2016 (scheduled completion)	5.7 km	8 (planned)

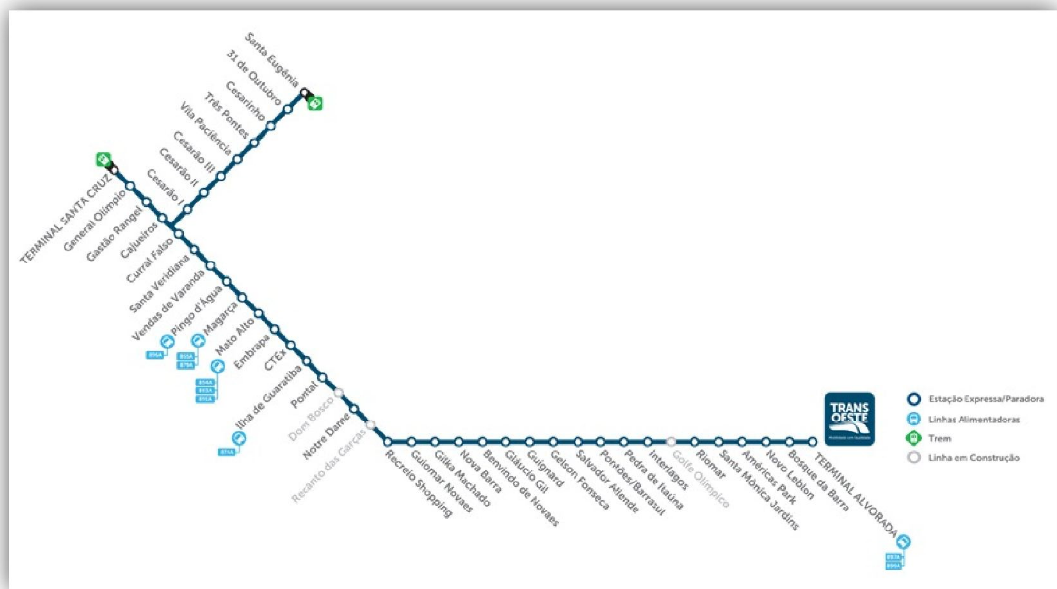
Source: Secretary of Transportation, Rio de Janeiro, February 2013.

1.5 Transoeste Service Implementation

As of March 2013, Transoeste operates 34 stations between Santa Cruz and Alvorada terminals, on 38.6 km of continuously separated busway, on which it operates 91 articulated Euro V diesel buses. Its operations have also expanded to 8 out of 24 total stations along the 16 km section of busway that arcs north and east from Santa Cruz Terminal to Campo Grande Terminal, which is still under construction (Figure 3).

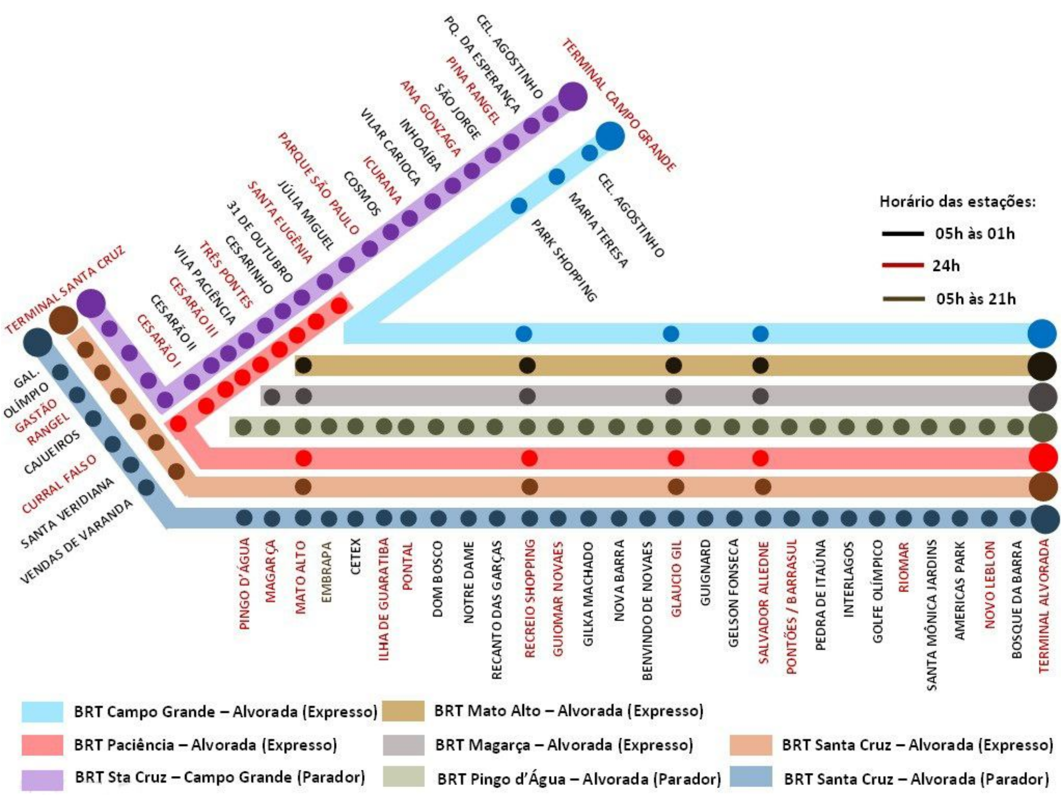
Transoeste was operating five services as of March 2013, with expected service expansions (Figure 4). These five services include local and express service between Alvorada and Santa Cruz terminals as well as local and express services between Alvorada Terminal and Pingo d'Água station in Guaratiba neighborhood, which services Mato Alto, Magarça and Pingo d'Água stations (transfer points for several BRT feeder lines with a high number of boardings and alightings). Transoeste's newest service is an express service between Salvador Allende station in the Recreio neighborhood and Santa Eugênia station in the Paciência neighborhood (note: this station was not yet open during the Transoeste user survey in October 2012). As of March 2013, there are also 11 feeder lines for the BRT, which are discussed in section 1.7.

Figure 3. Transoeste current station map, March 2013



Source: Transoeste Ligeirão website, March 2013.

Figure 4. Transoeste final services map, in progress



Source: Transoeste Ligeirão website, March 2013.

1.6 Bus Line Optimization

During the planning stage of the corridor, the Rio de Janeiro Transport Department identified 48 bus lines that had at least an indirect impact on the Transoeste corridor. About 30 to 35 of those lines have been or are planned to be reduced or eliminated for the implementation of 36 feeder bus lines to be completed once the corridor is finished in its entirety**.** The Transoeste user survey identified that approximately 65 percent of all Transoeste riders previously rode one of four main bus routes, as shown in Table 2 below. Transoeste gained riders from at least a dozen other routes, but no other single route than the four mentioned above accounted for more than 2 percent of Transoeste riders.

Table 2. Pre-Transoeste bus lines with highest mode shift to Transoeste

LINE	ORIGIN/DESTINATION	DAILY DEMAND	FLEET	FLEET WITH/ AC
853	Vila Kennedy–Barra	8,275	22	2
SV853	Vila Kennedy–Barra	4,645	12	0
854	Campo Grande–Barra	8,485	19	0
SV854	Campo Grande–Barra	809	4	1
855	Bangu–Barra	14,600	25	2
882	Santa Cruz–Barra	1,967	32	6
	TOTAL	**38,781**	**114**	**10**

According to Rio de Janeiro's Secretary of Transportation (SMTR), as of February 2013, five bus lines had been removed from the Transoeste corridor (lines 387, 877, 878, 882 and 897). Of the remaining lines, only three will be maintained (lines 853, 853SV, 876), and the rest will be consolidated. Some lines will be turned into feeder lines to the BRT to maintain service to areas adjacent to the BRT corridor (Table 3). The bus fleet is expected to be reduced by 57 percent, from approximately 350 to 150 buses.[4]

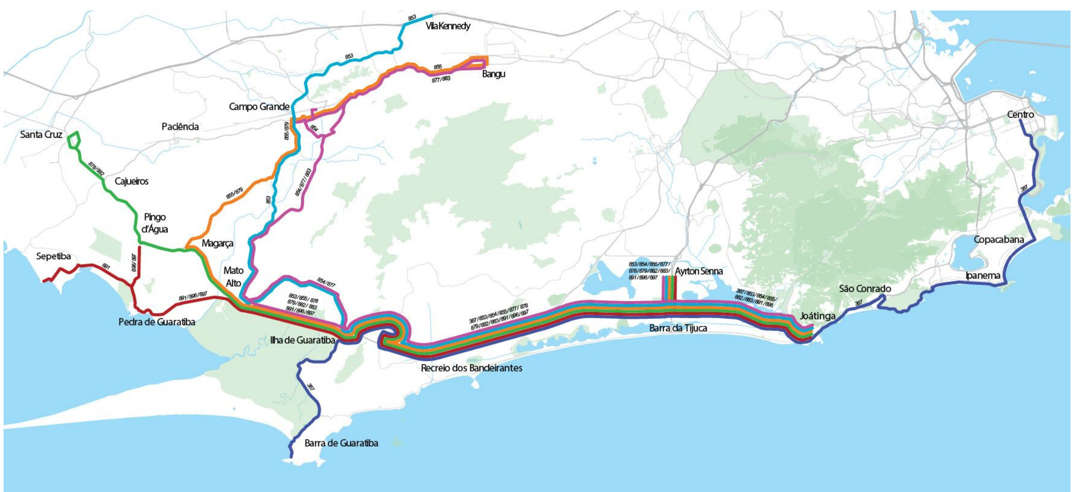
[4] Secretary of Transportation, Rio de Janeiro, 2013.

Table 3. Pre-Transoeste bus lines altered or removed (February 2013)

LINE	ORIGIN-DESTINATION	SITUATION	NEW SERVICE
878	Santa Cruz–Alvorada	Removed	Transoeste + 899 Feeder
882	Santa Cruz–Barra da Tijuca	Removed	Transoeste + 899 Feeder
897	Pingo d'Água –Alvorada	Removed	Transoeste + 899 Feeder
877	Campo Grande–Alvorada	Removed	879 Feeder + Transoeste + 899 Feeder
387	Marambaia–Centro	Removed	874 Feeder + Transoeste + Regular Bus
854	Campo Grande–Barra da Tijuca	Altered	854 Feeder + Transoeste + 899 Feeder
883	Bangu–Barra da Tijuca	Altered	883 Feeder + Transoeste + 899 Feeder
896	Pingo d'Água–Barra da Tijuca	Altered	896 A Feeder + Transoeste + 899 Feeder
855	Bangu–Barra da Tijuca	Altered	855 Feeder + Transoeste + 899 Feeder
879	Campo Grande–Alvorada	Altered	879 Feeder + Transoeste
891	Sepetiba–Barra da Tijuca	Altered	891A Feeder + Transoeste + 899 Feeder

Source: Secretary of Transportation, Rio de Janeiro, February 2013.

Figure 5. Pre-Transoeste bus lines altered or removed — route map



1.7 Feeder lines

Service previously provided by 11 regular bus routes on and adjacent to the Transoeste corridor has been replaced by 11 feeder lines as of March 2013 (Figure 6). As of March 2013, average weekday feeder bus ridership was approximately 41,000. As BRT service expands, other regular bus lines will be altered and formed into feeder bus lines.

Table 4. Transoeste feeder bus lines

LINE	ORIGIN	DESTINATION	AVERAGE WEEKDAY RIDERSHIP (MARCH 2013)[5]
853A	Vila Kennedy	Mato Alto	2,272
854A	Campo Grande	Mato Alto	3,499
855A	Bangu	Magarça	6,693
874A	Ilha	Marambaia	274
879A	Campo Grande	Magarça	3,138
883A	Mato Alto	Bangu	6,788
891A	Sepetiba	Mato Alto	1,789
896A	Pedra de Guaratiba	Pingo d'Água	2,996
897A	Alvorada	Ayrton Senna (via Barra Shopping)	1,283
899A	Alvorada	Joatinga	7,249
899D	Alvorada	Downtown	4,954
		TOTAL	**40,935**

Figure 6. Transoeste feeder bus route map

Feeder buses are all Euro V, non-articulated buses with A/C and require no transfer fare to the BRT service (Figure 7). The impact of feeder bus lines on transfers is discussed in Section 2.5.

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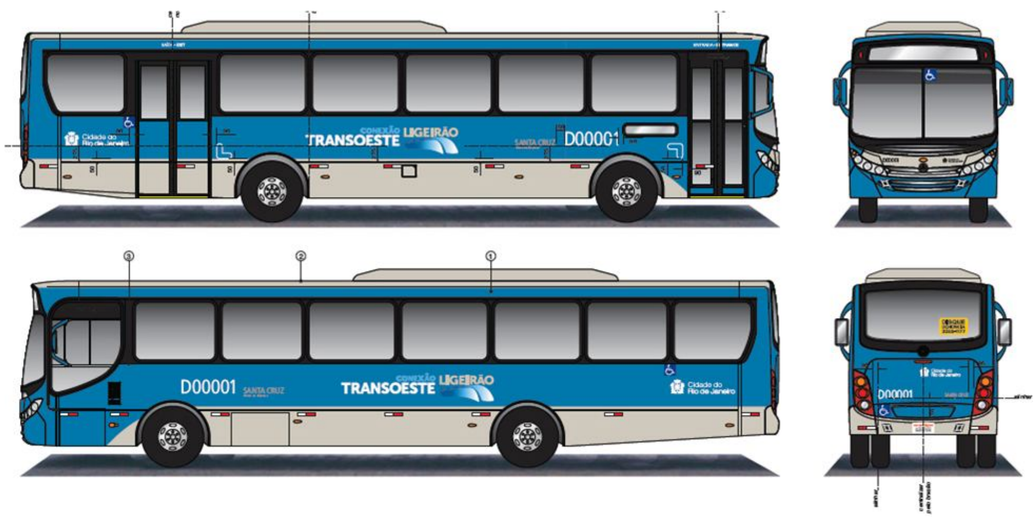
[5] BRT Report March 2013 (operational data), Secretary of Transportation, Rio de Janeiro.

Figure 7. Transoeste feeder buses



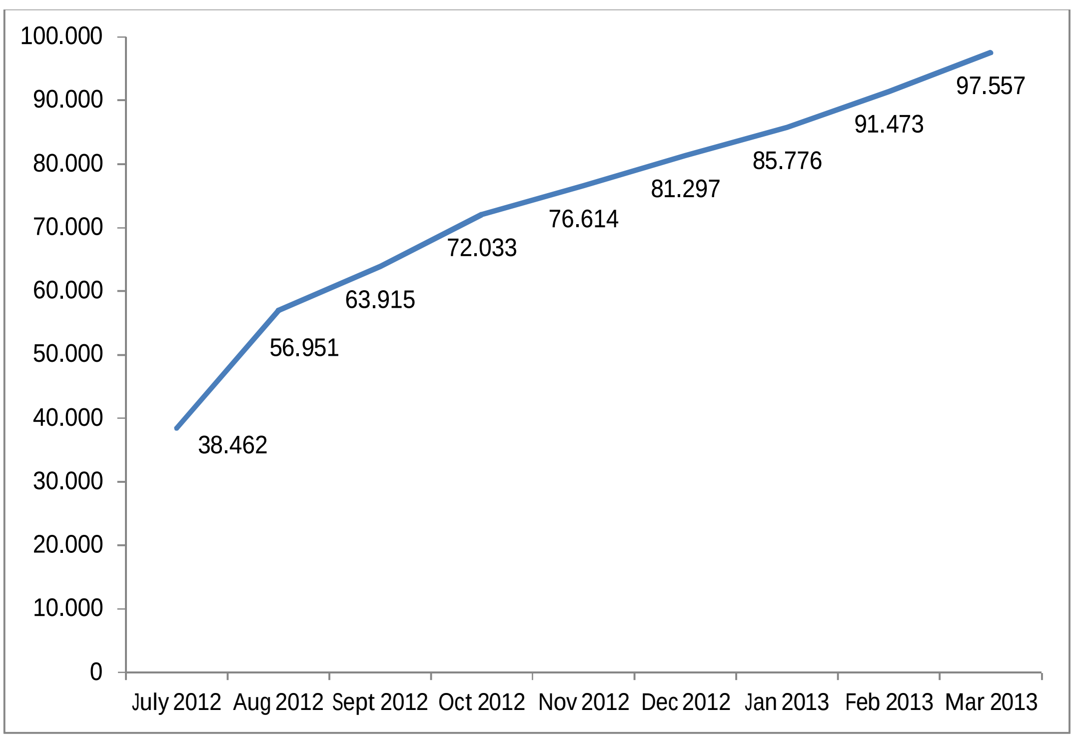
Source: Transoeste Ligeirão website, 2013.

II: Impacts of First Phase of Transoeste

2.1 Ridership

After significant and steady ridership growth in Transoeste's first nine months of operation, average weekday daily ridership on Transoeste as of March 2013 was approaching 100,000 passengers (Figure 8). In addition, ridership surpassed 104,000 daily passengers on March 15, 2013[6]. It is difficult to say exactly how much bus ridership the corridor accommodated before the implementation of Transoeste for comparison, because so many routes had partial coverage of the corridor and route ridership data was only collected in aggregate, not by station. However, ITDP's September study shows that 15 percent of Transoeste riders previously did not ride the bus (see Section 2.2.). Also, even the minority of routes that now require a transfer have high total travel-time savings (see Section 2.5), meaning it is unlikely the implementation of the BRT lost riders. These factors suggest that ridership has grown considerably on the corridor following BRT implementation. Furthermore, ridership is only more likely to grow as Transoeste improves and expands operations and when it links to the subway system.

Figure 8. Transoeste ridership growth (July 2012–March 2013)

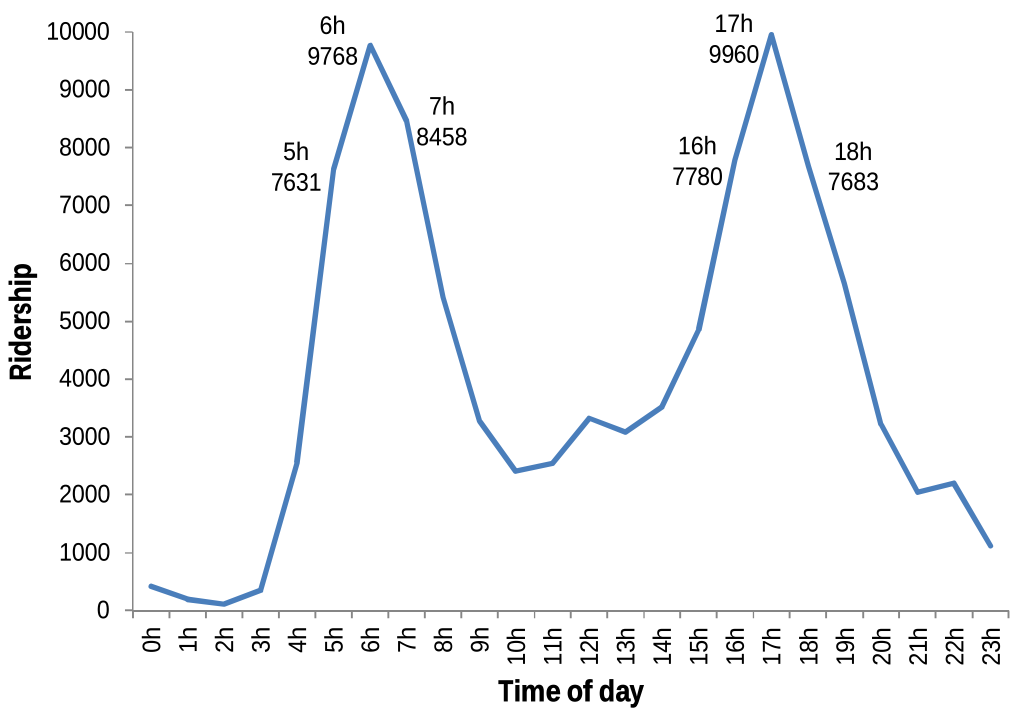


Source: BRT Reports July 2012–March 2013 (operational data), Secretary of Transportation, Rio de Janeiro.

[6] BRT Report March 2013 (operational data), Secretary of Transportation, Rio de Janeiro.

One item of concern for the system is that it exhibits extremely high peaks in travel activity for only one hour in each direction per day (Figure 9). This is a classic "peaking problem" of the corridor's existing travel demand due to regional land use and transportation demand patterns. Peak travel hours of 6 am and 5 pm were attracting over 9,000 — and at times 10,000 — boardings per hour in March 2013. This peaking issue, combined with underachievement in bus frequency at peak hour, is currently resulting in long wait lines at several stations at peak hour. The implications of this and potential solutions are discussed in Sections 2 and 3, respectively.

Figure 9. Average daily ridership by hour for Transoeste, March 2013



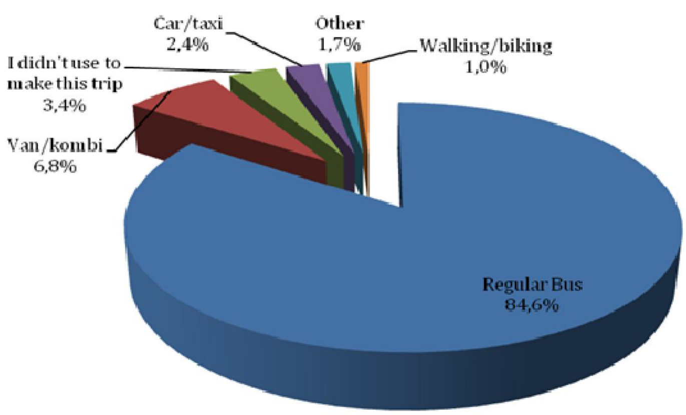
Source: BRT Report March 2013 (operational data), Secretary of Transportation, Rio de Janeiro.

Ridership is expected to increase as the Campo Grande section is completed, yielding 110,000 total passengers per day. After expansion to Jardim Oceânico station by 2016, linking Transoeste to the subway, ridership is predicted to double, reaching 220,000 passengers per day. Beyond pure ridership increases, off-peak demand is also anticipated to increase once the corridor is completed, though peak demand should also remain strong. Off-peak demand is especially expected to pick up for passengers traveling within the Barra da Tijuca neighborhood and those integrating with the subway to travel to the South Zone and city center for educational and leisure activities.

2.2 Modal Shift

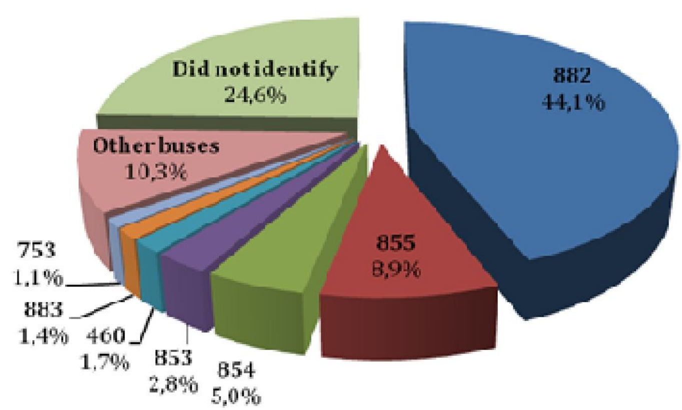
Projects that encourage mode change from cars and taxis to public transport are important both within the city of Rio to lower air pollution and greenhouse gases as well as on the Avenida das Américas in particular, to improve travel time, and to reduce vehicle congestion and cost of travel. The October survey of Transoeste passengers identified that the large majority of users (85 percent) used regular buses to make the same trip before Transoeste, 7 percent used vans or kombis — informal shared transportation — while 2 percent made the trip by car or taxi. Merely 1 percent of passengers previously made their trip by bicycle or on foot (Figure 10). Of the 85 percent of users who previously used regular bus service, 44 percent identified using bus line 882 alone and 60 percent said they used either bus line 882, 885, 854 or 853 (Figure 11).

Figure 10. Modal shift: How did you make this trip before Transoeste existed?



Source: ITDP Survey, October 2012.

Figure 11. Previously used bus services

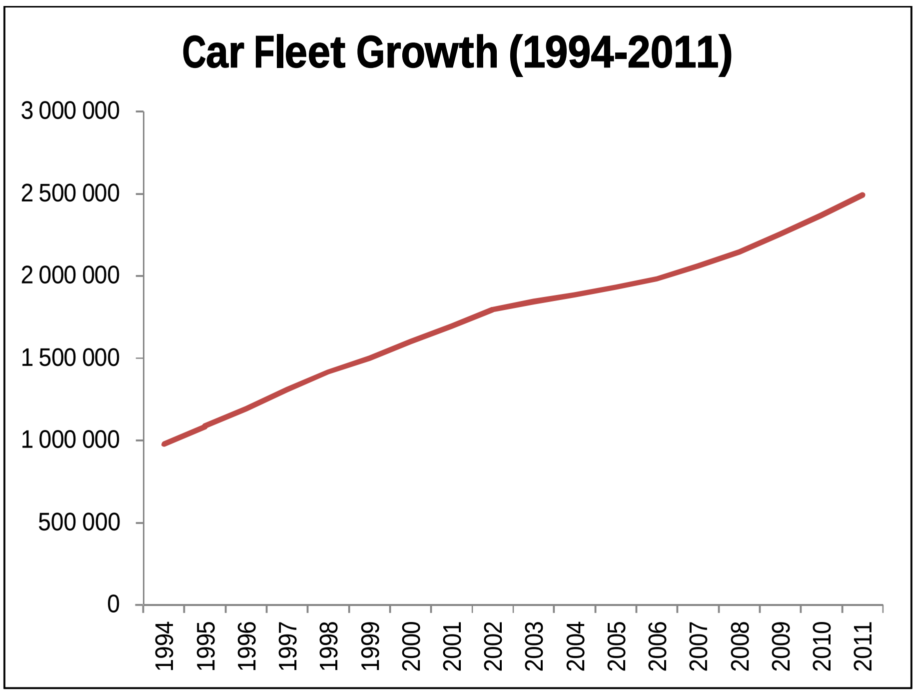


Source: ITDP Survey, October 2012.

While modal shift from cars and taxis to BRT appears initially low at 2 percent, it is expected to increase considerably over the coming months and once the bus and subway are integrated at Jardim Oceânico station.

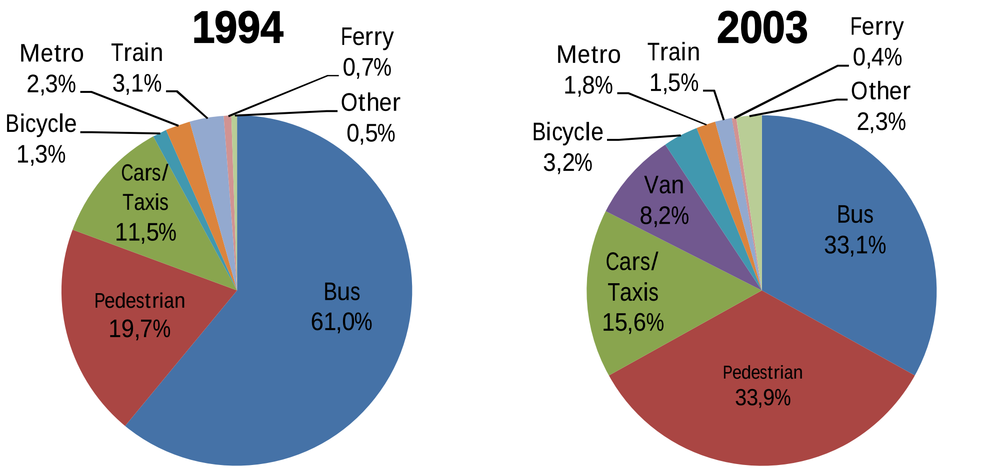
Increasing bus ridership is also a significant achievement in a city where automobile ownership has grown rapidly (Figure 12) and bus modal share has fallen (Figure 13). If Transoeste catalyzes bus ridership and mode share growth in the corridor, this would represent a significant improvement over a scenario in which the BRT was not built and bus ridership continued to decline in future years. The BRT will make public transit far more competitive with cars and taxis in this corridor in future years.

Figure 12. Motorization trends, Rio de Janeiro municipality



Source: DENATRAN (1994–2011).

Figure 13. Historical modal split, 1994 versus 2003



Source: Plano de Transporte de Massa da Região Metropolitana do Rio de Janeiro (RMRJ) (1995), Plano Diretor de Transporte Urbano (PDTU) da RMRJ (2003).

2.3 Bus Speed and Travel-Time Savings

Table 5. Observed bus speed and travel times

	REGULAR BUS SERVICE (BEFORE)	TRANSOESTE (EXPRESS)
Average travel time from end to end (minutes)		
Peak hours	2:25	0:52
Nonpeak hours	2:25	0:52
Average bus speed from end to end (km/h)		
Alvorada–Santa Cruz	16	44
Santa Cruz–Alvorada	16	46

Source: Operational data, Secretary of Transportation, October 2012.

Transoeste's Bus Rapid Transit infrastructure and operational design have cut the average travel time for a bus trip within the corridor by 62 percent over the traditional bus service. Transoeste saves each passenger 40 minutes per trip on average, which adds up to 14 days per year for the average commuter who makes two trips per day. With 104,000 daily trips, this translates to an aggregate time savings of 21 million hours per year for all passengers along the corridor. This is not only more convenient for bus passengers, it also has a real value for economic productivity in the region. The value of time saved for transportation is usually conservatively calculated by taking one third of the average hourly wage rate in the city (ten Reais) [7] and multiplying it by the number of hours saved for users. This means that the time the Transoeste is currently saving its users is valued at **70 million Reais per year**.

Table 6. Travel-time savings and value calculations

Avg. Time Savings per Trip*	Total Hours Saved Daily	Annual Time Savings for a Commuter**	Total Yearly Hours Saved	Annual Time Savings Value (USD)	Annual Time Savings Value (Reais)
40 min.	69,000 hrs.	14 days	21 million	USD 35 million	BRL 70 million

** Based on average trip distance, not including difference in wait times.*

*** Based on average commuter who makes two trips per weekday*

[7] Rio de Janeiro Municipality, Average Wage, Brazilian Census IBGE (2010).

2.4 Waiting Time, Capacity and Overcrowding

Transoeste's BRT infrastructure has greatly improved bus speeds and travel times. However, it is currently operating without a sufficient number of vehicles to meet demand, particularly at peak hours. This creates significant waiting times for users at these hours, specifically at terminal stations. At the busiest periods, surveys indicate riders must wait for up to four buses to pass before they were able to board. The average user reported waiting in line for 1.4 buses to pass before being able to board and reported an average perceived waiting time of 13 minutes.

Waiting times are a function of demand, bus capacity and bus headways. Bus headways refer to the length of time between buses and can be halved to find the average waiting time for a bus route that is not above capacity, since riders will generally arrive at an equal distribution throughout the time between buses. While it varies depending on the station, during off-peak hours, Transoeste buses for all lines at the Alvorada station were scheduled to operate at headway of six minutes for express buses (a three-minute average wait time) and 8 minutes for local buses (a four-minute average wait time) in early 2013. Peak-hour headways are much shorter and were scheduled to be three minutes for express service and six minutes for local service.

However, in an audit of the actual bus headways achieved at Alvorada station, the peak-hour headways observed are approximately 25 percent longer than the bus operator's target. This may be due to long boarding times at terminal stations and/or other operational issues with bus circulation described below, which restrict the number of loaded buses that can exit the station per hour. For ITDP's recommendations on how to improve bus frequencies, see Section 3.1.

Table 7. Planned versus observed peak hour bus frequency, January 2013

Line	Service	Bus/Hr Planned	Bus/Hr Observed
Alvorada–Santa Cruz	Express	20	15
	Local*	n/a	n/a
Alvorada–Pingo d'Água	Express	20	15
	Local	10	8
Recreio–Paciência	Express	8.6	8.6**
TOTAL		**58.6**	**46.6**

*Alvorada–Santa Cruz local service only runs during evening off-peak hours.

** Assumed frequency, not observed.

Source: Rio Ônibus, January 2013 and Observations March 28, 2013.

At terminal stations and some intermediate stations, buses fill to beyond their capacity during peak hours. This creates long boarding lines, which also increase wait times. Of the passengers surveyed, 73.2 percent of express passengers reported waiting more than 7 minutes and 42.5 percent of local passengers reported waiting more than 12 minutes. Wait times for peak-hour service have been as much as 40 minutes based on headway times, survey reports and observations.

In addition, during peak hours at terminal stations, Transoeste has two and sometimes three separate lines for passengers to board the bus at the terminal stations, which affects waiting time. In the "sitting line" riders queue up to be allowed to enter the bus first for a guaranteed seat. The "sitting line" takes longer (approximately 20 to 40 minutes at peak) as most riders are going from one terminal station to the other and seats for an hour-long bus ride are preferred. Users who are in a hurry or do not need a seat can enter a faster line for a standing position on the bus (approximately ten to 20 minutes at peak hour). After enough passengers from the "sitting line" have entered the bus and the seats are filled, riders from the "standing line" are allowed to enter and fill a portion of the standing space. Some stations have a third line for "priority" passengers, including elderly, disabled and pregnant passengers, who are allowed to board before everyone else and are allocated a fixed number of reserved seats per bus. In completing this two- to three-step loading process, the bus must advance between lines in the station, adding delay to the process.

2.5 Impact of Transfers

Transoeste's significant savings in speed and bus vehicle miles traveled were made possible through significant bus route rationalizing. Bus route rationalization reduces overlap and redundancy, and can improve bus route frequency and speed, but they also often impose transfers for users who previously did not have them. In the case of Transoeste, it appears that approximately 41,000, or 39 percent, of users now experience a transfer (based on feeder route ridership, see Section 1.7). However, as discussed below, for a third of these passengers these transfers are only temporary due to sections of Transoeste that are not yet completed. Also, for all or nearly all passengers, the increase in bus speeds from Transoeste more than makes up for any time spent transferring.

Currently 12,000, or 29 percent, out of the 41,000 daily feeder riders use the 899 feeder line, which is a temporary feeder until the BRT trunk line is extended to Jardim Oceânico in 2016. Additional riders on the 854 and 879 feeder lines with origins/destinations near the Campo Grande BRT trunk line (currently under construction) may alter their trips to travel directly on the BRT trunk line when it is extended to Campo Grande, depending on travel and transfer times for the feeder routes. The elimination of these temporary transfers alone, when the corridor is completed in its entirety, would decrease the proportion of Transoeste riders that experience a transfer to approximately 25 percent. Additionally, taking into consideration that Transoeste's ridership is expected to double as it becomes more competitive with private modes when it is linked to the subway in Jardim Oceânico, and it is expected that a lower proportion of these riders will require transfers, the proportion of Transoeste riders who face transfers would further decrease upon corridor completion.

While approximately 39 percent of current Transoeste riders and 25 percent of future riders face transfers, the time impact of transfers is still important to consider. Currently the maximum average transfer waiting time is five minutes for a local bus in the off-peak period (which runs on a ten-minute frequency). Current low bus frequencies mean that passengers at some stations have to wait up to 15 minutes to stand, or longer to sit on a bus, at peak period. However, even if it is assumed that the average peak-hour traveler has to wait 15 minutes for a transfer, this wait time is still more than offset by the average time savings per trip of 40 minutes (see Section 2.3) on the Transoeste trunk line.

Further, since 63 percent of all current transfers and 93 percent of transfers post-2016 take place west of Ilha de Guaratiba station and the vast majority of users boarding at stations west of Ilha de Guaratiba station exit at Alvorada terminal, these users are assured that even a maximum 15-minute transfer time would be made up four times over by the estimated 60-minute travel-time improvement of the BRT service over the direct normal bus just between Ilha de Guaratiba station and Alvorada terminal. Even passengers beginning their trip on the 854 or 879 feeder lines and ending in Barra da Tijuca, whose route will require two transfers up until 2016, would spend a maximum of 30 minutes transferring buses but save 60 minutes on the BRT trunk line, for a net travel-time savings of 30 minutes minimum. The only riders who may have a slower total transfer time would be the very small number or riders who use Transoeste for very short trips and whose origin/destination station is so close to their transfer station on the BRT trunk line that the speed increase on the BRT does not make up for the transfer time. Since most Transoeste users are traveling a significant distance on the system, this is likely to affect only a very small number of riders.

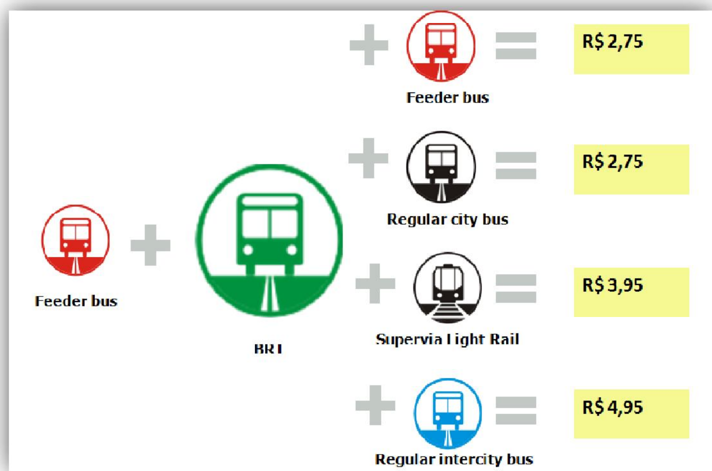
2.6 Impact on Cost to Users

For the 85 percent of transportation users who shifted from regular bus service to BRT Transoeste, trip cost has not changed significantly. Transoeste's R$2.75 fare (approx. USD 1.38) is the same as regular bus fare.

Unlike on regular bus service, all transactions on Transoeste require using an electronic fare card, which yields faster boarding and increased operational transparency and facilitates transfers. Transoeste's single fare covers up to two feeder bus trips — or a combination of one feeder bus trip and one regular bus trip — within a two-hour period (Figure 14).

Transoeste passengers using the Bilhete Único smart card, typically granted by employers, would have also been able to use one single fare to make two regular bus trips within a 2-hour period before Transoeste. However, out of the 44 percent of Transoeste users who currently do not use the Bilhete Único smart card[8], those who used to make transfers between regular buses before Transoeste without Bilhete Único are now offered more mobility at a reduced cost.

Figure 14. Transoeste fare integration



Source: Rio Ônibus, January 2013.

[8] BRT Report March 2013 (operational data), Secretary of Transportation, Rio de Janeiro.

2.7 Comfort

Comfort is one of the key service qualities that can attract "choice" riders from other modes and maintain them, reversing the trend of lower bus ridership and increased car use over time. For bus passengers with relatively long travel times, such as on the Avenida das Américas corridor, comfort on the bus (as well as in the stations) is a significant factor of the mode's competitiveness. Transoeste not only cut travel times by half, it also made it easier for passengers who need seats to find them, reduced crowding on buses, made stations more comfortable and brought air-conditioning from 9 percent of buses to 100 percent of buses — all important features for work commuters in a subtropical location. Transoeste also utilizes diesel buses with the highest emissions standards (Euro V) to reduce unpleasant and unhealthy air pollution from buses. The fleet currently uses B5 biodiesel and intends to move to B20 biodiesel in the future.

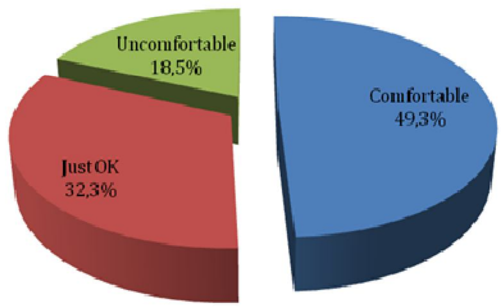
Table 8. Percent of buses with air-conditioning and low emissions technology

Rolling stock	Before Transoeste	After Transoeste
Percent of buses with air-conditioning (%)	9%	100%
Percent of buses with Proconve7/Euro V technology	0%	100%

Source: Operational data, Secretary of Transportation, 2012.

The "sitting" and "standing" line system acts as a service innovation, allowing users to make a choice based on their priorities: comfort (sitting) versus speed (standing). Ideally this system also allows bus line attendants to ensure buses leaving terminal stations will not be filled to or over capacity at peak periods so that passengers can travel comfortably and buses can pick up additional riders at intermediate stations. However, this is not always the case. With demand at the stations exceeding the supply of buses, some people enter "full" buses, causing crowding. Passenger surveys showed that about 50 percent of passengers found the capacity of the buses comfortable despite some complaints of overcrowding and an additional 32 percent of passengers rated bus capacity as only "okay" (Figure 15).

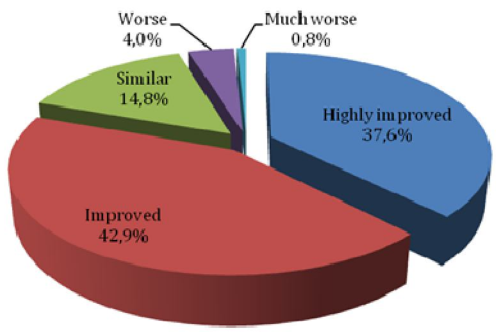
Figure 15. Passenger capacity rating



Source: ITDP Survey, October, 2012.

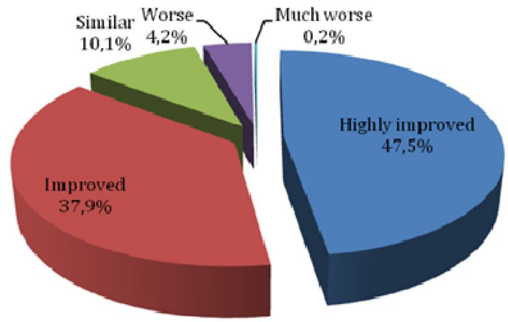
These comfort-oriented developments are not unnoticed among users. Of the bus riders surveyed, 81 percent responded that bus comfort either "improved" or "highly improved" with the introduction of Transoeste compared to previous bus service (Figure 16). Similarly, 86 percent of respondents identified station comfort as being either "improved" or "highly improved" after Transoeste (Figure 17).

Figure 16. Transoeste bus comfort rating compared to "before" scenario



Source: ITDP Survey, October 2012.

Figure 17. Transoeste station comfort rating compared to "before" scenario

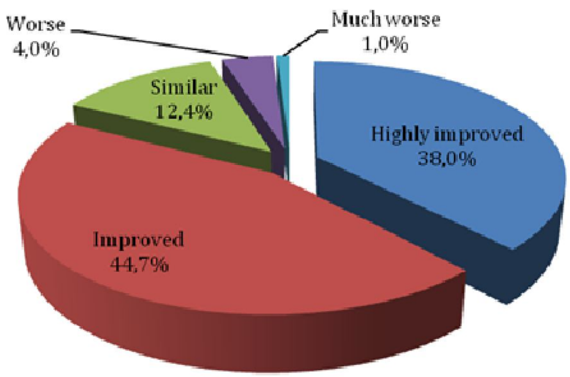


Source: ITDP Survey, October 2012.

2.8 Public Opinion

When asked to compare Transoeste's service to previous bus service, surveyed riders were positive on a whole, with 82.6 percent responding that public transportation service, in general, either "improved" or "highly improved" with the introduction of Transoeste (Figure 18).

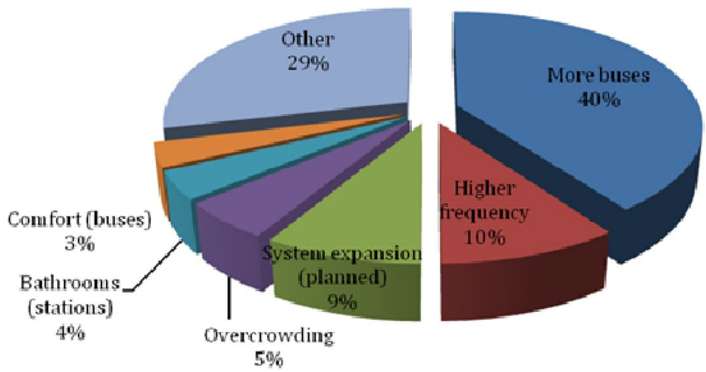
Figure 18. Transoeste service rating compared to "before" scenario



Source: ITDP Survey, October 2012.

From the user survey, the majority of recommendations related to addressing the low bus headways and subsequent overcrowding—45 percent of passengers surveyed recommended increasing the bus fleet and/or improving bus frequency (Figure 19). An additional 5 percent of surveyors complained specifically about overcrowding. Another common recommendation was to install bathrooms in stations.

Figure 19. Public recommendations



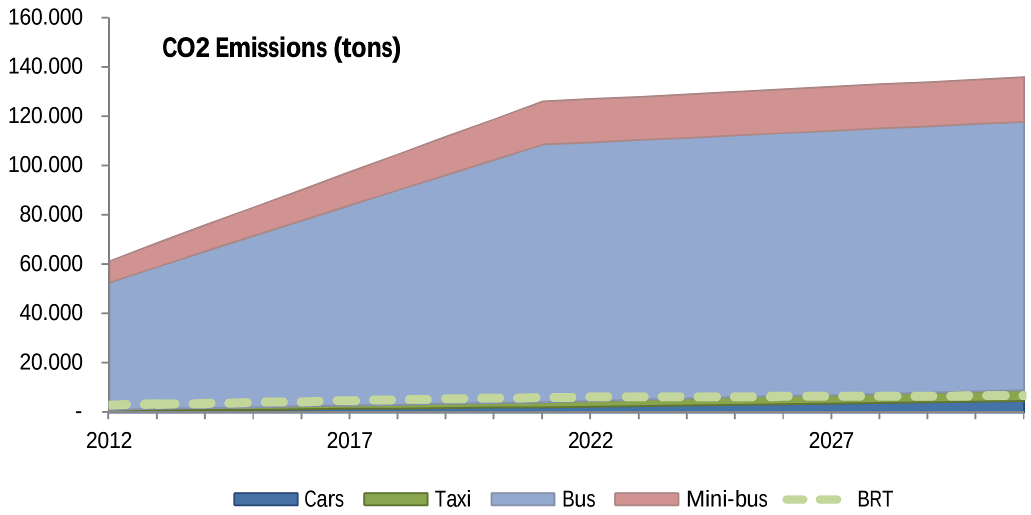
Source: ITDP Survey, October 2012.

2.9 Emissions

An analysis of the Transoeste project over its first 20 years of operation shows that it will create a dramatic reduction in emissions and fuel consumption along the corridor. This analysis was completed using the Transportation Emissions Evaluation Model for Projects (TEEMP), a methodology developed by ITDP and recommended by the Global Environment Facility (GEF). The model calculates transportation projects' emissions over a 20-year period using a variety of inputs, ranging from the length of the corridor and BRT ridership to the fuel efficiency of vehicles. The analysis compares the BRT scenario to business as usual, assuming the regular introduction of more efficient buses and other vehicles over time in both scenarios.

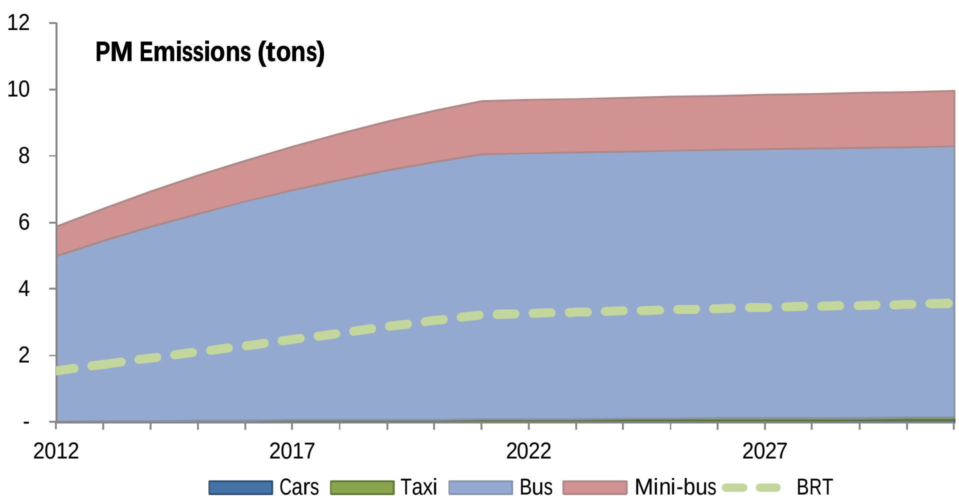
Emissions in the Transoeste corridor would decrease in the BRT scenario primarily due to more efficient transit vehicles and operations along the corridor and to a lesser extent due to a shift of riders from private motor vehicles to BRT. The modal shift calculations are based on the modal shift observed in an October 2013 survey and projections of future modal shift, which doubled the percentage of trips shifted from motor vehicle trips to BRT every ten years. Compared to business as usual, the BRT scenario shows an average reduction of 107,380 tons of carbon dioxide (CO_2) emissions per year and a 95 percent reduction in bus and paratransit (i.e., vans and kombis) emissions along the corridor over 20 years. Particulate matter (PM) and nitrogen oxides (NO_x) emissions also are shown to be reduced by 6.0 and 206 tons per year, respectively. Yearly emission for CO_2, PM and NO_x are shown in Figures 20–22.

Figure 20. Calculated CO_2 emissions



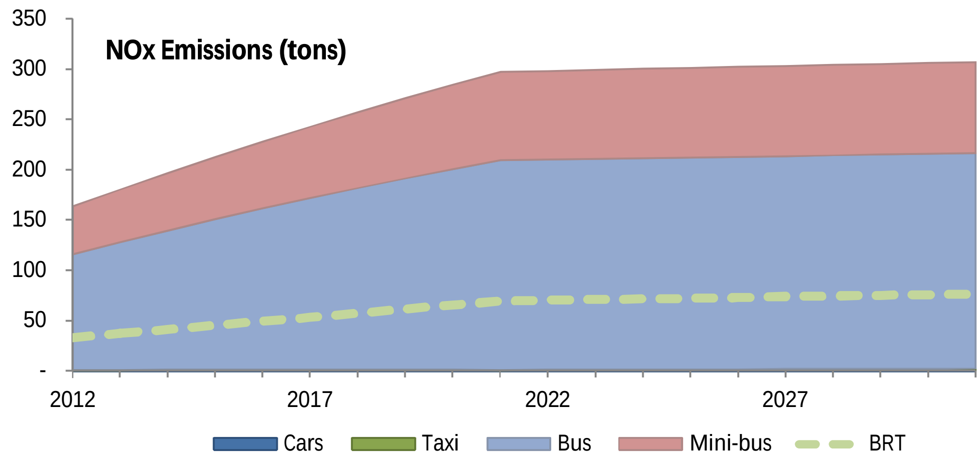
Note: Solid-area portions refer to modes in a no BRT scenario the impacts of the BRT are depicted by the line

Figure 21. Calculated PM emissions



Note: Solid-area portions refer to modes in a no BRT scenario; the impacts of the BRT are depicted by the line

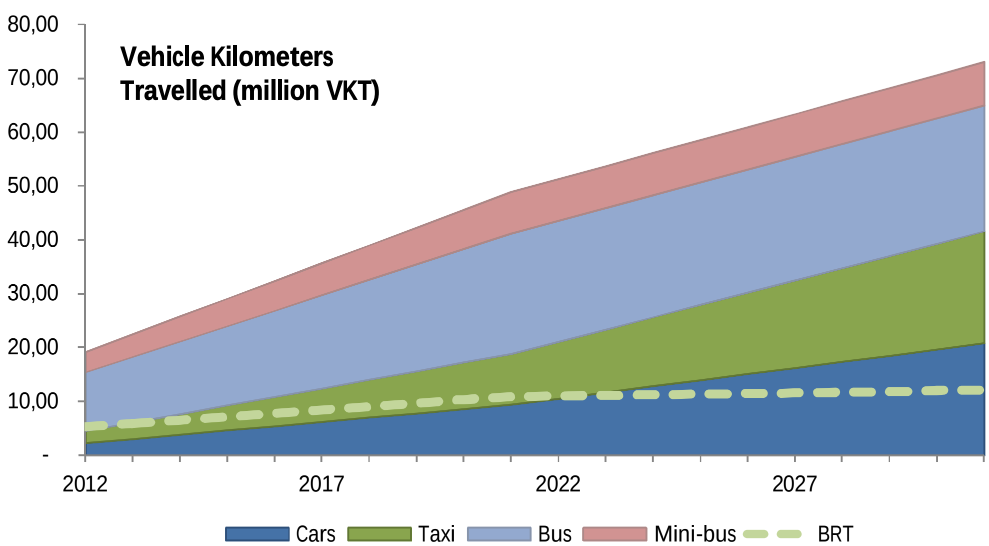
Figure 22. Calculated NO_x emissions



Note: Solid-area portions refer to modes in a no BRT scenario; the impacts of the BRT are depicted by the line

The total amount of vehicle travel was reduced by an average of 38.4 million kilometers each year, 15 million of which is due to passengers' shifting from private vehicles to BRT (Figure 21). For transit and paratransit alone, the amount of transit vehicle travel was reduced by 61 percent, while transporting 12 percent more transit passengers, a sharp increase in efficiency.

Figure 23. Annual vehicle kilometers traveled



Note: Solid-area portions refer to modes in a no BRT scenario; the impacts of the BRT are depicted by the line

Transoeste will reduce fuel consumption by an average of 44 million liters each year from 2013–2030 (Figure 24). The reduction results from reduced vehicle kilometers traveled by buses due to rationalized routes, mode shift from private motorized modes to buses and the employment of larger, more modern buses with higher fuel efficiency and passenger capacity. Fuel savings increase over time as ridership along the corridor grows and more travel shifts from private vehicles to BRT.

Figure 24. Fuel savings due to Transoeste BRT

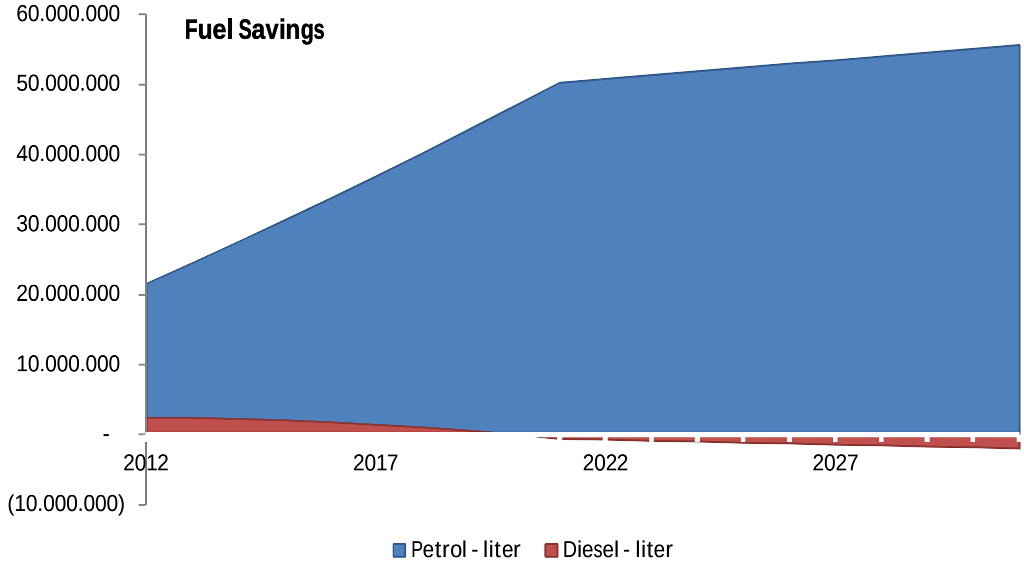


Table 9. TEEMP Model results

Vehicle Travel Reduced	56.8 million kilometers / year
Fuel Use Reduction	44 million liters / year
CO_2 Emission Reduction	107,000 tons / year
PM Emission Reduction	6.0 tons / year
NO_x Emission Reduction	206 tons / year

III: Recommendations for Improvement

3.1 Increase bus frequency to improve capacity and waiting times

With many reports of long waiting times and uncomfortably full buses and significant growth in ridership still predicted for the future, it is clear that Transoeste must increase bus frequencies, especially at peak hours. Recent independent observations reveal that Transoeste's peak-hour bus frequencies are underperforming by 24 percent. Remedying this issue is not only important for Transoeste's operational efficiency but also crucial to the public image of Transoeste and all of Rio de Janeiro's BRT projects. Public disapproval over long lines and overcrowded buses will erode political support for the system and harm its ability to attract and retain riders. Improving bus frequency will require a combination of procuring more buses and putting them into service on strategic routes to maximize their impact as well as optimizing operational procedures, especially loading, so that more buses can move more quickly through the stations.

Fortunately, the existing BRT infrastructure can easily accommodate the necessary increase in bus frequency. Current observed peak frequencies (March 2013) are close to 30 buses per hour (two-minute headways) for express service and eight buses per hour (7.5 minute headways) for local service[9], whereas ultra-high-capacity systems in Bogotá and Guangzhou have 12 times as many buses with 360 buses per hour (ten-second headways). Transoeste's current service plans call for 40 express buses per hour (1.5 minute headways) plus ten local buses per hour (six-minute headways) for a total of 50 buses per hour from Alvorada station during peak hours.[10] However, bus counts in March 2013 show that the system is only achieving 38 buses per hour, or 24 percent lower than planned.[11] If the system can achieve the target frequencies of 50 total buses per hour, this should accommodate current ridership demand along most segments of the system currently. However, between Gláucio Gil and Mato Alto, up to 62 total buses (58 express and four local) per hour are needed to meet ridership demand during the evening peak, while current service plans only call for 59 buses (49 express and ten local) (see Figure 25 and Table 10). Even fewer buses than those planned are actually observed. Between Alvorada terminal and Salvador Allende station, ten local buses are needed to meet demand, ten are planned, but only eight were observed per hour. Along the entire corridor, the peak demand at any point is for 58 express buses and ten local buses per hour, with a potential combination shown in Table 10. The degree to which the underperformance in bus frequency is due to insufficient number of vehicles in service or inefficient loading times and slow speeds is unclear. ITDP recommends the operators review this issue.

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[9] Observations, March 28, 2013.

[10] Operational headway data, Rio Ônibus, January 28, 2013.

[11] Observations, March 28, 2013.

Figure 25. PM ridership demand versus observed and planned capacities

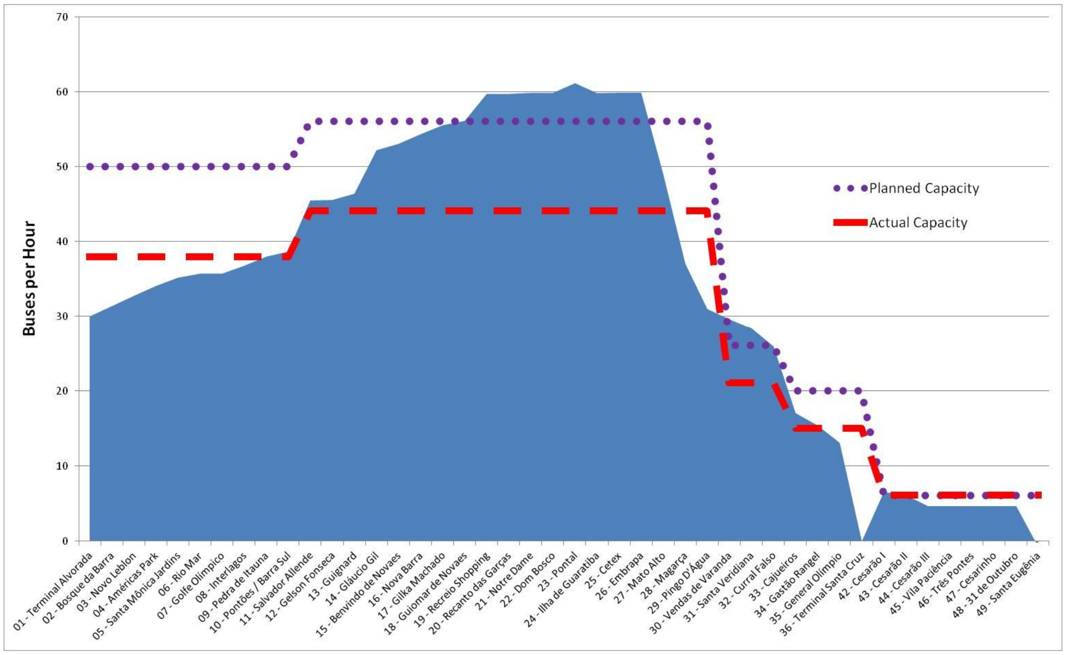

Table 10. Scheduled peak-hour bus frequency, January 2013

Line	Service	Bus/Hr Planned	Bus/Hr Observed	Bus/Hr Demanded (Est. March 2013)
Alvorada–Santa Cruz	Express	20	15	22***
	Local*	n/a	n/a	n/a
Alvorada– Pingo d'Água	Express	20	15	22***
	Local	10	8	10***
Recreio–Paciência	Express	8.6	8.6**	14***
TOTAL		**58.6**	**46.6**	**68**

Source: Rio Ônibus, 2013 and Observations March 28, 2013.

*Alvorada–Santa Cruz local service only runs during evening off-peak hours.

** Assumed frequency, not observed.

*** Demand for express and local buses may be distributed differently among service lines.

What does appear clear is that the corridor's excess demand can most efficiently be met by increasing the number and frequency of buses on the Recreio–Paciência route, which runs between Salvador Allende and Santa Eugênia stations. This route covers the section of the corridor with the highest passengers per peak-hour direction and the largest gap between passenger demand and observed supply/capacity of buses, resulting in the highest wait times. Buses added to this shorter Recreio–Paciência route will also achieve the highest cost benefit because the buses are run only on the portion of the corridor that has the densest demand. Currently this section has 58 buses per hour planned though actual performance is lower, while demand is sufficient to require 60 to 65 buses per hour. However, as the Transoeste expands and ridership continues to increase, bus frequencies will eventually need to be increased on all Transoeste routes.

To attain a higher bus frequency, observed existing operational inefficiencies must be addressed. For example, at Terminal Alvorada, based on observations, inefficient loading operations resulting in long bus loading times, reducing the number of buses that leave the station each hour by as much as 25 percent. This in turn reduces bus frequency at stations along the rest of the corridor. To improve capacity at the terminal, boarding procedures should be streamlined so that buses do not need to move positions for each line of passengers — priority, sitting, standing — to board. Bus loading could also be reorganized to happen in multiple bays at one time or such that a second bus begins loading passengers from one line (i.e., priority line) while the first bus loads from the second line (i.e., sitting line). Finally, the schedules of the buses need to be coordinated so that a sufficient number of buses reach the terminal station to meet the peak-hour demand in the opposing direction.

Operations can also designate a number of buses to run "deadhead" trips, completing the counter-peak-direction portion of their route's round-trip without making any intermediate stops. This would return more buses more quickly to the high-demand portion of the route, increasing overall frequency in peak directions where it is needed, and decreasing frequency in the counter-peak direction where it is not.

Newspapers have also reported that overcrowding on buses often prevents bus doors from closing. When buses pull away from the station, the open doors activate a speed governor that prevents the buses from traveling fast due to safety concerns.[12] If this is true, it exemplifies the compounding problems that result problems from not running a high-enough bus frequency: Low bus frequencies result in overcrowding, which results in slower operations, which in turn further lowers bus frequencies.

It is not yet clear to what degree the current underperformance of peak-hour bus frequency is due to lack of vehicles on the route and operational and loading inefficiencies. It does, however, seem clear that a more comprehensive audit of the number of buses running, their loading times and the actual frequencies should be performed immediately. It seems likely that both bus procurement and operational improvements are already critical and will only become more so in the future as the system grows. Special attention must also be given to ensure that lessons learned at the Alvorada station are incorporated into the planning for terminal station Jardim Oceânico, which will need to accommodate significantly more people and buses per hour than Terminal Alvorada currently does. Any bottlenecks at the new terminus will limit the overall capacity of the system.

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[12] O Dia, http://odia.ig.com.br/portal/rio/brt-viagem-%C3%A9-mais-r%C3%A1pida-mas-repleta-de-transtornos-1.564495

3.2 Address Peaking Problem with Variable Fares

Currently Transoeste's BRT lanes and stations have more than enough capacity to easily accommodate the needed increase in buses and frequency to satisfy demand. In the future, however, after Transoeste's ridership surges when it is linked to the subway and options for increasing bus frequency to address peak-hour demand become more limited, one option to consider is to implement a variable pricing scheme. Such schemes give users an incentive to travel in off-peak hours, therefore reducing overcrowding on specific buses at specific times. They also have the advantage of enabling bus operators to address overcrowding without requiring capital investment in buses or other infrastructure or additional operating costs. The schemes can be designed to be either revenue neutral (by raising peak fares and concurrently lowering off-peak fares), or to place no additional cost burden on riders (by only discounting off-peak fares), or to generate revenue (by raising fares only at peak hours). The schemes are generally successful at shifting a small but often critical number of peak riders to an off-peak time. Rio may also be less responsive to such a program because many employers pay for the transit fare of their workers, giving workers little incentive to change commute times. When Metrô Rio experimented with variable fare pricing in 2010, a 3-percent decrease in peak ridership was accomplished.

Based on successful examples from Bogotá's TransMilenio BRT and subway systems in Santiago, São Paulo, Fortaleza and Rio, there appear to be two main approaches to implementing variable pricing schemes to reduce peak-hour strain: (1) small, targeted fare discounts, such as have been implemented in Metrô Rio, São Paulo Metrô and Fortaleza, or (2) complete overhauls of the fare scheme, as implemented in Bogotá and Santiago.[13] Although Metrô Rio and São Paulo show how targeted fare discounts can function, Santiago and Bogotá demonstrate how an entire new fare structure can be quite effective at redistributing ridership. Furthermore, a new fare structure can provide off-peak discounts while being revenue neutral with small peak-period fare increases. Santiago, for example, uses three tiers of pricing.

It is worth noting once again that transit operators should use fare pricing policies only after a system has reached its maximum capacity and further additions of buses are not possible. Using fare policies to reduce overcrowding before reaching maximum system bus capacity can be politically contentious and risk the success of the implementation of future fare policies to reduce overcrowding when no other option or capacity is available.

[13] Eric Agar, 2013.

3.3 Address Peaking Problem with Transit-Oriented Development

Transoeste's peaking problem, discussed above, is rooted in the land use and economic development patterns that drive regional transportation demand. In the case of Rio de Janeiro, there is an acute jobs/housing imbalance that has concentrated employment in the city center, South Zone and Barra da Tijuca areas but much of the housing that is affordable to employees is located far from these locations. Such jobs/housing imbalances place particular stress on transport systems because they require high levels of capacity in only one direction at peak travel hours: into employment centers in the morning and out of employment centers in the evening. This requires large investments in system capacity that is only utilized for one or two hours per day, threatening cost-effectiveness in the system. For every full bus or train going into the city in the morning, there is generally an empty one traveling in the opposite direction.

Peaking problems are one important reason for integrating transport and land-use plans to ensure the development of mixed-use areas and a good balance of jobs and housing, which in turn mitigate harsh imbalances in travel patterns. Stockholm, Sweden, is an excellent example of a city that over the decades has developed dense, mixed-use areas with both employment and housing in even peripheral areas along rapid transit corridors to ensure more balanced, bi-directional travel demand. This development pattern of developing dense, mixed-use areas along transit corridors is known as Transit Oriented Development (TOD).

Rio de Janeiro can improve on its peaking problem by implementing zoning laws and developing incentives that encourage TOD along the corridor. TOD will bolster ridership, help diversify the travel demand patterns, reduce peak-capacity strains and improve financial viability of the transit service by adding fares in the reverse-commute direction.

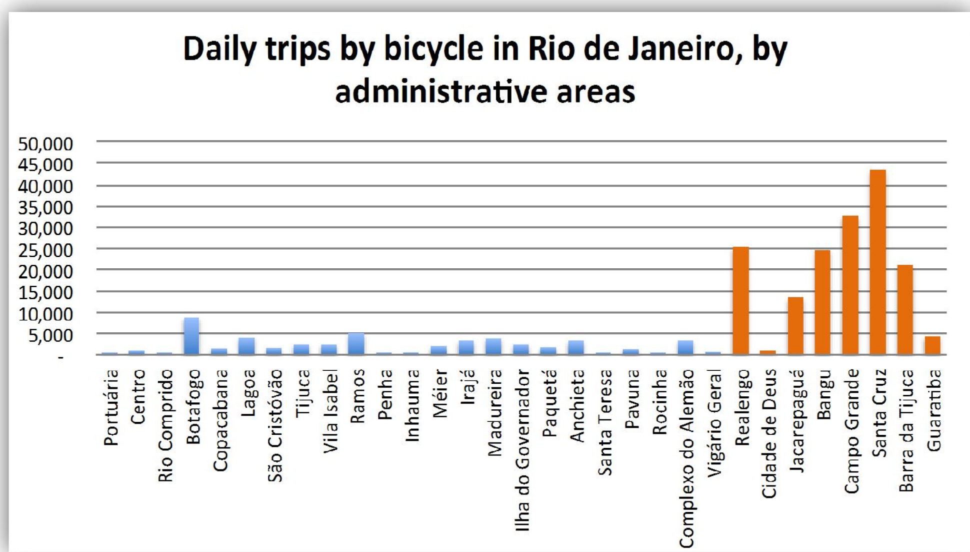
3.4 Improve Pedestrian and Bicycle Access and Safety

From ITDP's BRT Standard, integration and access are key elements of a Gold Standard, best-practice BRT system. Efficient integration between different modes is an effective way of attracting and retaining transport users. Stations that offer seamless transfers between modes and are easily accessible are key to improving public transport mobility, especially in the case of Transoeste. While Transoeste was rated Gold Standard with a total score of 86 out of 100 points, the corridor stands to gain points in the Integration and Access section. This was Transoeste lowest-rated section, earning 8 out of 14 points. The full BRT Standard scorecard for Transoeste is available in Appendix IV. In the BRT Standard, NMT integration and access is based on grading elements such as pedestrian access, secure bicycle parking, bicycle lanes and bicycle-sharing integration.

Bicycle use in West Zone

Santa Cruz and Campo Grande areas support the most daily trips by bicycle in the Rio de Janeiro municipality (Figure 26). Furthermore, the Barra da Tijuca and Guaratiba areas, where the Transoeste corridor also passes, also have high numbers of daily bicycle trips.

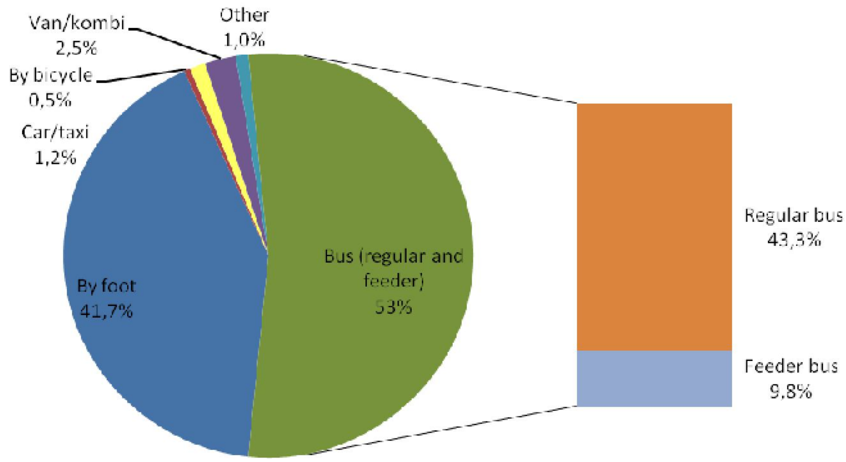
Figure 26. Daily trips by bicycle in Rio de Janeiro, 2003



In orange, the neighborhoods in the West Zone, representing 76% of all daily trips in the City of Rio. Source: PDTU (2010).

The user survey results showed that only 0.5 percent of passengers used bicycles to integrate with the system (Figure 27). Considering Transoeste serves the West Zone, an area with a proven high volume of cyclists, the system is clearly missing the opportunity to provide proper infrastructure to better integrate the modes and improve access to transport.

Figure 27. Transport mode used to access/egress Transoeste



Source: ITDP Survey, October 2012.

Bicycle Lanes

Bicycle path networks integrated around the stations can improve customer access, provide a full set of sustainable travel options and enhance road safety. A dense bicycle network that is highly permeable to cyclists will connect major residential areas, commercial centers, school and business centers to nearby mass transit stations, aiming to provide the widest access.

Using bicycles to reach transit stations gives the passengers the benefit of improving the crucial last-mile trip, shortening the total door-to-door travel time. Using bicycles as feeders to Transoeste is also one of the cheapest ways to bring people to the station, and is much less expensive than running feeder bus service. All destinations within five km of a trunk corridor should be connected by a formal cycle way. This gives the bicycle a role of feeder to the BRT system, not only improving connectivity but also improving significantly the catchment area of the station. A station has a catchment area of 300 to 500 m for pedestrians. With a bicycle network, the catchment area goes up to five km around the stations. When the bicycle is perceived as part of the feeder mechanism, it can also alleviate some of the operating costs associated with the provision of feeder bus services to the last-mile trip.

Secure bicycle parking

Bicycle parking at stations is necessary for users who opt to access the station by bicycle. Little or no bicycle parking limits the possibility of the bicycle serving as a feeder system to the BRT. A BRT corridor planned to properly integrate with NMT infrastructure should have secure and weather-protected bicycle parking at least in terminal stations and in stations with proven high demand, and standard bicycle racks elsewhere.

All Transoeste stations currently have few and poor-quality bicycle racks. (PHOTO) Stations in the West Zone, such as Santa Cruz, Guaratiba and Campo Grande, are normally packed with bicycles, fully utilizing not only the bicycle racks but also fences and any other public equipment surrounding the BRT station where a bicycle can be locked. Transoeste stations with high bicycle access or potential should have a secure and weather-protected parking facility. There are two experiences that could be replicated, one from São Paulo and another from Rio.

In 2001, a bicycle parking facility was set up at the Mauá train station in the metropolitan area of São Paulo by the Association of Bicycle Users of Mauá (ASCOBIKE), offering services to 200 users a day. This was a secured, enclosed facility equipped with metal hooks to store bicycles vertically. In addition to storage, the facility also offers various services to members, such as coffee, water, special parking for women and the elderly, shoe polishing, toilets and changing rooms, tire pumps and a repair shop in addition to legal support and a health-plan scheme for ASCOBIKE members. Users pay a USD 5 monthly membership or nonmember can buy a daily pass for USD 0.50. With such a comprehensive package, it is not surprising that by 2008, the facility was already serving 1,700 users per day, and it is the biggest bicycle parking garage in the Americas. The ASCOBIKE facility is maintained by the association's own resources, which comes from monthly membership payments. The space utilized was granted by the train operator, which subsequently sponsored facility renovations and its expansion[14].

Another model, albeit simpler, is Supervia's bicycle parking stations in Rio. In 2012, the train operator launched 3,000 parking spaces in six stations, exclusively for train passengers. The operator covered the total investment of USD 2 million. Users pay a one-time USD 2.5 registration fee but all future facility use is free of charge with a valid train ticket. The facilities offer toilets, water and repair workshops.

Either model would greatly improve the current facilities along Transoeste's corridor, and costs could be covered directly by the operators, with a small fee for the user.

[14] ITDP, 2010.

Bicycle-sharing integration

Ideally, a city that already has a public bicycle-sharing system should also position mass transit stations as a priority location for bicycle-sharing system stations. Rio's bicycle-sharing network, Bike Rio, has not yet reached the West Zone, as it has thus far been concentrated in the South Zone. However, the new bidding process will create an opportunity to address this issue, matching the new Bike Rio stations to the Transoeste ones. Costs for the implementation would be covered by the Bike Rio operator who holds the concession rights.

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Annex I: Transoeste Survey Results

General

Objective

A sample survey of BRT Transoeste users was conducted by ITDP in October 2012 to gauge public opinion on the perceived benefits of the Transoeste Bus Rapid Transit (BRT) system. The survey sought to identify changes in level of comfort and mobility among transport users before and after Transoeste was implemented. In addition, the survey aimed to provide quantifiable data on users' travel behavior and level of satisfaction with Transoeste system as compared to users' opinions of the public transport services previously available.

Survey characteristics

Six survey collectors individually asked participants the questions and administered a total of 409 surveys. The survey period took place on two workdays within the same one-week period (*cf.* Appendix A). A total of 192 surveys were collected on Tuesday, October 16, followed by 217 surveys collected on Thursday, October 18. Survey collecters randomly sampled Transoeste users between 8 am and 8 pm. The number of surveys collected at each Transoeste station was proportional to the average number of transactions per day at the station (*cf.* Appendix B). For example, since approximately 17 percent of Transoeste transactions were calculated as occurring at Santa Cruz station, approximately 17 percent of surveys were administered at that station.

User characteristics

Among the randomly selected surveyors, the distribution between men and women was relatively balanced, with 52.4 percent women and 47.6 percent men. Surveys were also evenly adminstered to both express and local service users: 54.8 percent of passengers surveyed were using the local service and 45.2 percent were using the express. On average, users of both services traveled 19.5 stations, out of 36 total stations (*cf.* Appendix C). The average trip length among passengers, based on perceived travel time, was 36.5 minutes.

The large marjority (80.4 percent) of passengers used Transoeste to get to and from work. Besides work, 12 percent of passengers were running errands, 4.6 percent were traveling to and from school, and 2.9 percent were traveling for social reasons (Figure 1).

Among Transoeste passengers surveyed, 22.1 percent reported that they owned a private vehicle. Of those passengers who own cars, 71.4 percent had left their car parked at home during their trip. In 22.6 percent of cases the car was not currently working, and 4.8 percent of respondents said another person was using the car (Figure 2).

Mobility

The survey helped identify modal shift among public transport users after the introduction of Transoeste. The large majority of users, 84.6 percent, used regular buses to make the same trip before Transoeste, and 6.8 percent used vans or kombis — informal shared transportation. Another 2.4 percent made the trip by car or taxi. Merely 1 percent of passengers previously made their trip by bicycle or on foot, and 3.4 percent of passengers surveyed did not make the same trip before Transoeste opened. The remaining 1.7 percent of passengers made the trip using other modes of transportation, such as train, motorcycle or a combination of modes mentioned above (Figure 3). Of the 84.6 percent of users who previously used regular bus service, 44.1 percent identified using bus line 882 alone and 60.9 percent identified using either bus line 882, 885, 854 or 853 (Figure 4).

In terms of complementary transportation, 94.8 percent of users accessed Transoeste or their destination either by bus or on foot; 41.7 percent accessed Transoeste or their destination on foot; and 53.1 percent accessed Transoeste or their destination by bus. Of those passengers using buses as complementary transportation, 18.5 percent specifically identified using Transoeste feeder buses (Figure 5).

When asked to compare Transoeste's service to previous bus service, responses were positive on the whole, with 82.6 percent of those surveyedresponding that public transportation service, in general, either "improved" or "highly improved" with the introduction of Transoeste (Figure 6).

Comfort

In terms of comfort improvements, between previous bus service and Transoeste, responses were also positive, with 80.5 percent responding that bus comfort either 'improved' or 'highly improved' with the introduction of Transoeste (Figure 7). Similarly 85.5 percent of respondants identified station comfort as being either "improved" or "highly improved" after Transoeste (Figure 8). Another indicator of passenger comfort that the survey addressed was perceived wait time. For both express and local services, average perceived wait time among Transoeste users was approximately 13 minutes (13.5 minutes for express service and 12.8 minutes for local).

Improvements

As a final, open-ended question, respondents were asked to offer any recommendations or complaints about Transoeste system. The overwhelmingly apparent recommendations or complaints related to low bus headways and subsequent overcrowding. A total of 45.2 percent of passengers surveyed recommended increasing the bus fleet and/or improving bus frequency (Figure 9). (Of the passengers who commented on improvements that could be made on Transoeste, 60 percent recommended increased bus fleets and bus frequency.) An additional 4,9 percent of respondentss complained specifically about overcrowding. See Figure 9 for further recommendations made by passengers surveyed.

Due to these concerns, portended by various reports of overcrowding and buses running over capacity in the Brazilian news, the survey also investigated a few indicators related to overcrowding and low bus headways. Despite complaints, 49.3 percent of passengers surveyed rated Transoeste's capacity as comfortable. On the other hand, 32.3 percent considered the BRT's capacity just okay, and 18.5 percent found it unbearable (Figure 10). Additionally, 64 percent of respondents said that they let buses pass because they are too full. Passengers who let buses pass tended to let between two and three buses pass, or 2.37 buses on average (Figure 11 and 12).

In addition, for both express and local services, average perceived wait time among Transoeste users was approximately 13 minutes, with 73.2 percent of express passengers reportingwaiting more than seven minutes and 42.5 percent of local passengers reportingwaiting more than 12 minutes.

Figures:

Figure 1. Trip purpose

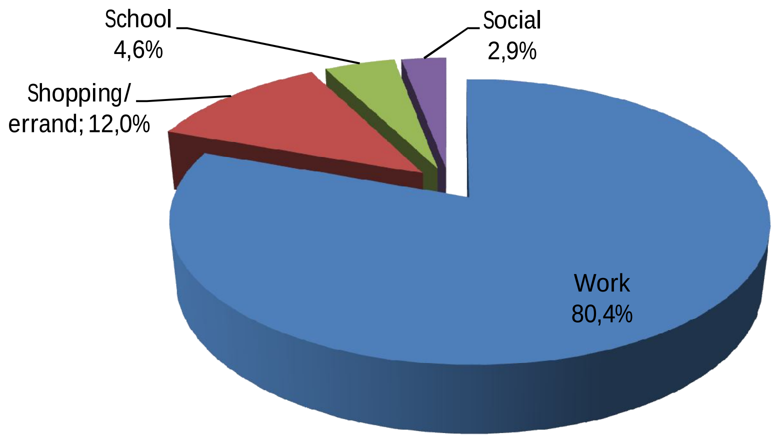


Figure 2. Car ownership and location

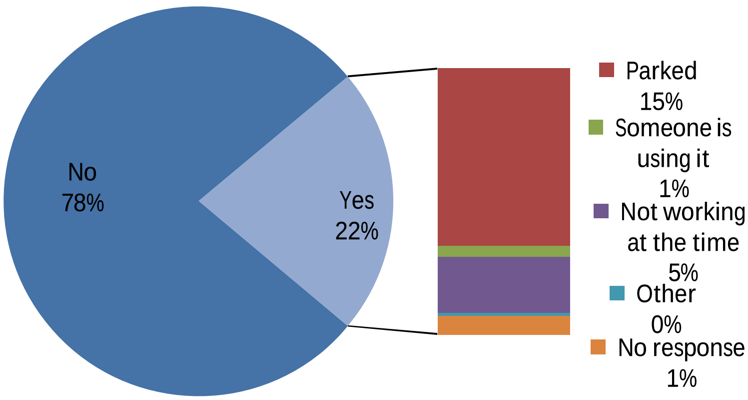


Figure 3. What did you use to take before Transoeste? (Modal shift)

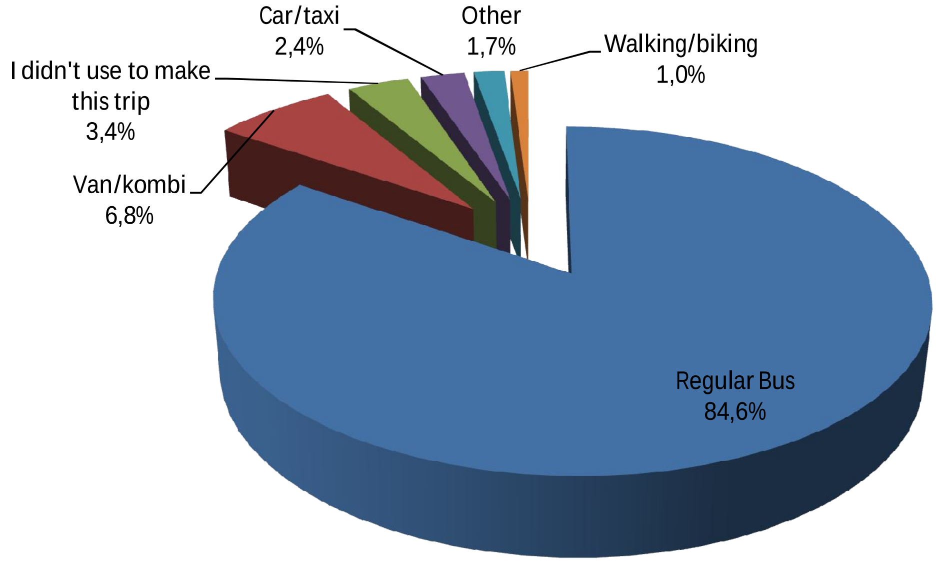


Figure 4. Previously used bus services

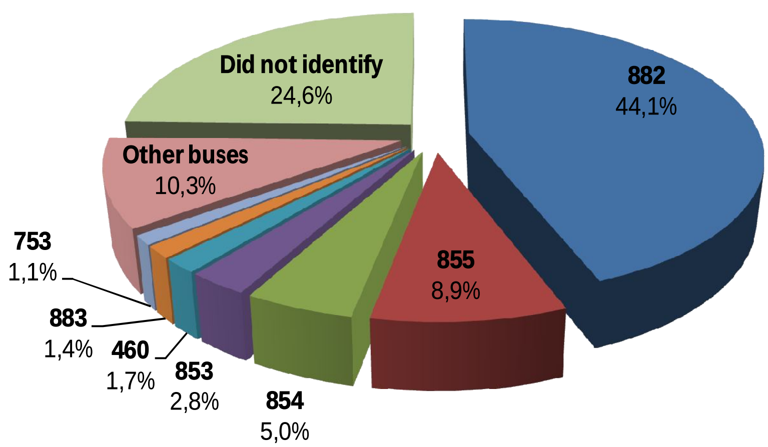


Figure 5. Complementary transportation (origin and destination)

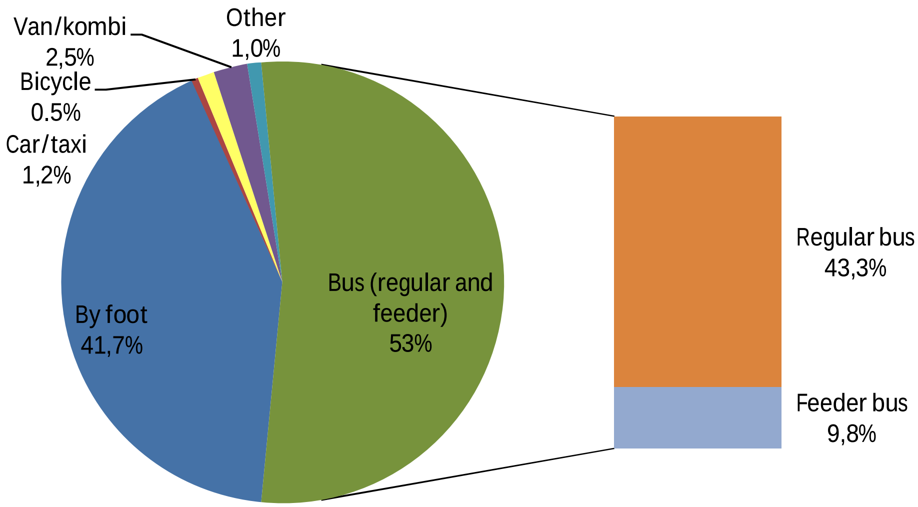


Figure 6. Service rating

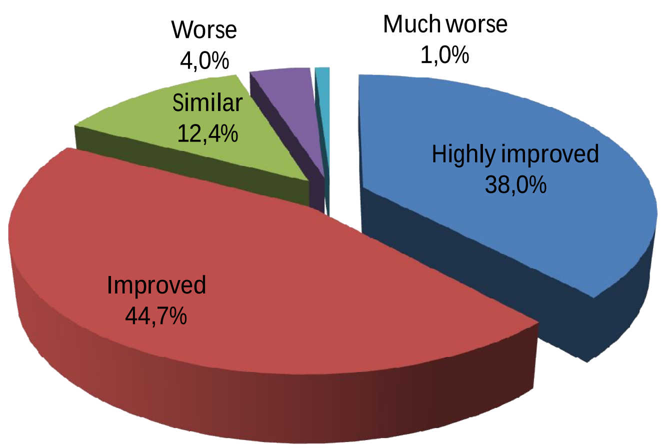


Figure 7. Bus comfort rating

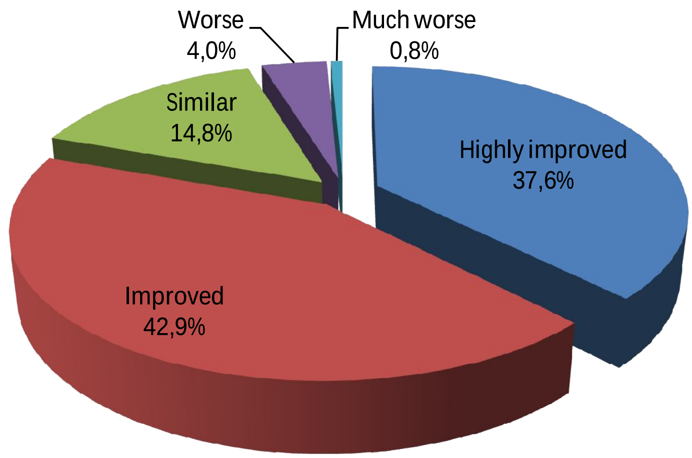


Figure 8. Station comfort rating

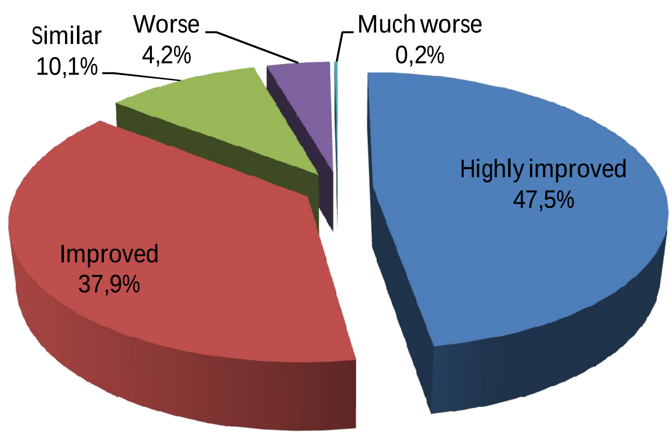


Figure 9. Recommendations

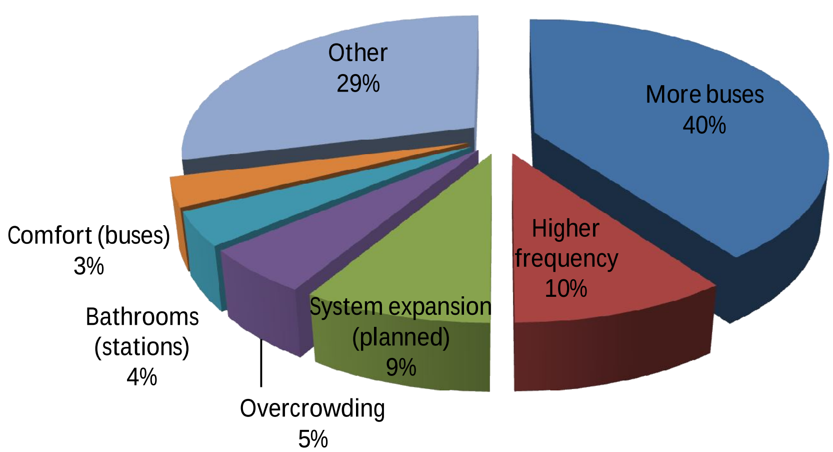


Figure 10. Capacity rating

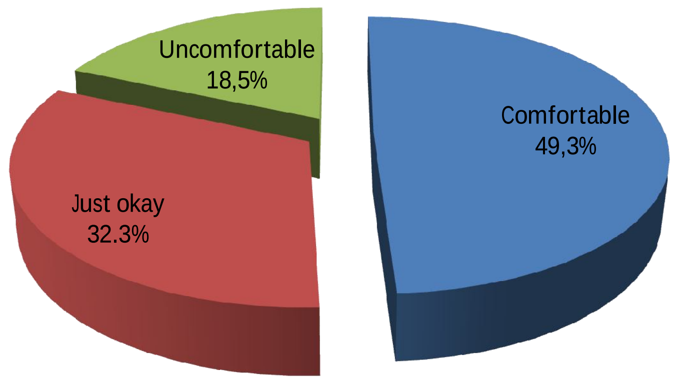


Figure 11. Do you let buses pass because they are too full?

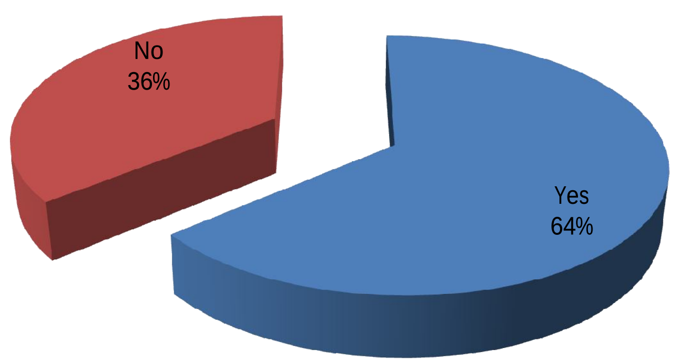
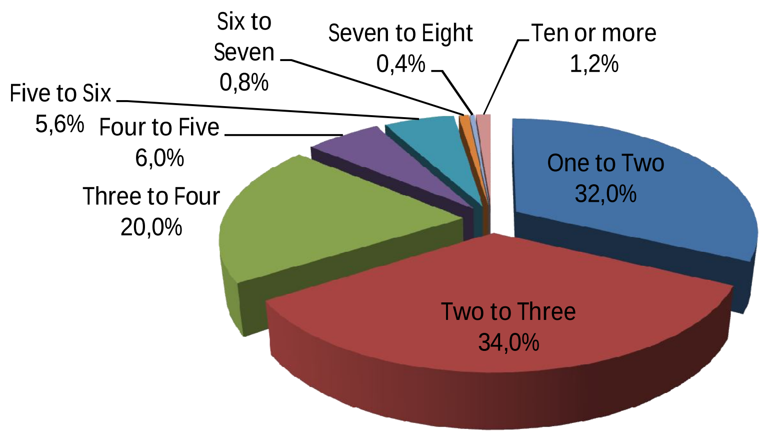


Figure 12. If so, how many buses?



Survey Results Summary

Surveys by interviewer

Interviewer	Frequency	Percentage
Eleanor	97	23.7%
Pedro	118	28.9%
Clarisse	46	11.2%
Marina	48	11.7%
Bruno	57	13.9%
Viviane	43	10.5%
Total	**409**	**100.0%**

Surveys by day

Day	Frequency	Percentage
16-Oct-12	192	46.9%
18-Oct-12	217	53.1%
Total	**409**	**100.0%**

Surveys by time

Time	Frequency	Percentage
8h	40	9.8%
9h	46	11.2%
10h	21	5.1%
11h	53	13.0%
12h	39	9.5%
13h	30	7.3%
14h	44	10.8%
15h	13	3.2%
16h	0	0.0%
17h	44	10.8%
18h	47	11.5%
19h	29	7.1%
No response	3	0.7%
Total	**409**	**100.0%**

Service

Service	Frequency	Percentage
Express	183	45.2%
Local	222	54.8%
Subtotal	405	100.0%
No response	4	
Total	**409**	

Sex

Sex	Frequency	Percentage	Percentage (out of 409)
Male	188	47.6%	46.0%
Female	207	52.4%	50.6%
Total	395	100.0%	
No response	14		3.4%
Total	409		100.0%

Number of stations traveled

Average	19.48

Trip Purpose

Response	Frequency	Percentage
Work	329	80.4%
Shopping/errand	49	12.0%
School	19	4.6%
Social	12	2.9%
Total	**409**	**100.0%**

How did you use to make this trip?

Mode	Frequency	Percentage
Regular bus	346	84.6%
Van/kombi	28	6.8%
I didn't use to make this trip	14	3.4%
Car/taxi	10	2.4%
Other	7	1.7%
Walking/biking	4	1.0%
Total	**409**	**100.0%**

Station access (complementary transportation)

Mode	Frequency	Percentage
By foot	183	44.7%
By bicycle	4	1.0%
Regular bus	160	39.1%
Feeder bus	31	7.6%
Car/taxi	9	2.2%
Van/kombi	17	4.2%
Other	5	1.2%
Total	**409**	**100.0%**

Destination access (complementary transportation)

Mode	Frequency	Percentage
On foot	156	38.6%
By bicycle	0	0.0%
Regular bus	192	47.5%
Feeder bus	49	12.1%
Car/taxi	1	0.2%
Van/kombi	3	0.7%
Other	3	0.7%
Total	404	100.0%
No response	5	
Total	**409**	

Complementary transportation (origin and destination)

Mode	Frequency	Percentage
On foot	339	41.7%
By bicycle	4	0.5%
Regular bus	352	43.3%
Feeder bus	80	9.8%
Car/taxi	10	1.2%
Van/kombi	20	2.5%
Other	8	1.0%
Total	813	100.0%
No response	5	
Total	**818**	

Average Trip Length (perceived time)

Average trip time, Local service (min)	36.4
Average trip time, Express service (min)	36.6
Average trip time, both services (min)	36.5

Perceived wait time

Service	Time (average, in minutes)
Express	13.5
Local	12.8
Both	13.1

Do you let buses pass because they are full?

Response	Frequency	Percentage
Yes	260	64.0%
No	146	36.0%
Total	406	100.0%
No response	3	
Total	**409**	

If yes, how many? (Average)

2.37

Number of buses let pass	Frequency	Percentage
One to two	80	32.0%
Two to three	85	34.0%
Three to four	50	20.0%
Four to five	15	6.0%
Five to six	14	5.6%
Six to seven	2	0.8%
Seven to eight	1	0.4%
Ten or more	3	1.2%
Total	250	100.0%

Capacity Rating

Rating	Frequency	Percentage
Comfortable	200	49.3%
Just okay	131	32.3%
Uncomfortable	75	18.5%
Subtotal	406	100.0%
No response	3	
Total	**409**	

Performance Rating (compared to previous bus service)

Rating	Frequency	Percentage	
Highly improved	153	38.0%	**82.6%**
Improved	180	44.7%	
Similar	50	12.4%	
Worse	16	4.0%	
Much worse	4	1.0%	
Subtotal	403	100.0%	
No response	6		
Total	**409**		

Bus Comfort Rating (compared to previous bus service)

Rating	Frequency	Percentage	
Highly improved	150	37.6%	**80.5%**
Improved	171	42.9%	
Similar	59	14.8%	
Worse	16	4.0%	
Much worse	3	0.8%	
Subtotal	399	100.0%	
No response	10		
Total	**409**		

Station Comfort Rating (compared to previous bus service)

Rating	Frequency	Percentage	
Highly improved	193	47.5%	**85.5%**
Improved	154	37.9%	
Similar	41	10.1%	
Worse	17	4.2%	
Much worse	1	0.2%	
Subtotal	406	100.0%	
No response	3		
Total	**409**		

Car ownership

Response	Frequency	Percentage
Yes	90	22.1%
No	317	77.9%
Total	407	100.0%
No response	2	
Total	**409**	

Where is your car now?

Response	Frequency	Percentage
Parked	60	71.4%
Someone is using it	4	4.8%
Not working at the time	19	22.6%
Other	1	1.2%
Total	84	100.0%
No response	6	
Total	**90**	

Improvements and Complaints

Suggestions	Frequency	Percentage (of respondents)	Percentage (total)
More buses	153	49.8%	37.4%
Higher frequency	38	12.4%	9.3%
System expansion (planned)	33	10.7%	8.1%
Overcrowding	20	6.5%	4.9%
Bathrooms (stations)	15	4.9%	3.7%
Comfort (buses)	13	4.2%	3.2%
Other	110	35.8%	26.9%
No response	102		24.9%
Total	**484**	124.4%	118.3%

Annex II: Transoeste Survey

TRANSOESTE SURVEY

Survey Collector: ______________________________

Date:_____________ Time:_______________

Station __________ / Express Service / Local Service

M / F

1)What city do you live in? OR At which station will you exit TransOeste? _____________________

2) What is the purpose of your trip?

a) Work
b) School
c) Errands
d) Social
e) Other task outside the house

3) How did you use to maket this trip before TransOeste?

a) Regular bus – which line? ____________
b) Car/taxi
c) Walking/biking
d) Van/Combi
e) I did not make this trip before TransOeste
f) Other ________________

4) How did you arrive to the station?

a) Walk   b) Bike   c) Bus   d) Car/taxi   e) van   f) other ________

5) How will you leave the station?

a) Walk   b) Bike   c) Bus   d) Car/taxi   e) van   f) other ________

6) Estimated trip time on TransOeste (minutes)? Express:______ Local: ________

7) How long to do you wait from the time you arrive to the station to the time your TransOeste bus departs? (minutes)? _________

8) Do you need to let buses pass because they are full? a) Sim   b) Não – How many? ________

9) How would you rate the capacity of the buses?

1 - Busesare comfortable   2 – Buses are fine   3 – Buses are too full

10) How would you rate TransOeste's transport performance compared to the previous normal bus service?

1 – Highly Improved   2- Improved   3- Similar   4 – Worse   5 – Much Worse

11) How would you rate TransOeste's level of comfort on the bus compared to the previous normal bus service?

1 – Highly Improved   2- Improved   3- Similar   4 – Worse   5 – Much Worse

12) How would you rate TransOeste's level of comfort in the stations compared to the previous normal bus service?

1 – Highly Improved   2- Improved   3- Similar   4 – Worse   5 – Much Worse

13) Do you own a car? a) Yes b) No

14) Where is your car now: A) parked   B) someone is using it   C) not working at the time D) Other ______

15) How could the TransOeste be improved?

____

PESQUISA TRANSOESTE

Pesquisador: ________________________________
Data:______________ Hora:_________________
Estação ___________/ Ônibus Expresso / Ônibus Parador
Homem / Mulher

1) Em qual cidade você mora? ______________________

2) Qual é o motivo desta viagem?

a) Trabalho
b) Escola
c) Compras
d) Social
e) Outra tarefa fora da casa

3) Como você fazia esta viagem antes do TransOeste?

a) Ônibus normal - Qual linha?_____________
b) Carro/taxi
c) A pé/de bicicleta
d) Van/Combi
e) Eu não fazia esta viagem antes do TransOeste
f) Outro _________________

4) Como você chegou na estação onde começou sua viagem?

a) A pé b) Bicicleta c) Ônibus d) Carro/taxi e) van f) outro ________

5) Como você pretende chegar ao seu destino?

a) A pé b) Bicicleta c) Ônibus d) Carro/taxi e) van f) outro ________

6) Quanto tempo de viagem estimado de ônibus (minutos)? Expresso:______ Parador: ________

7) Quanto tempo você normalmente espera entre a sua chegada na estação e a saída do seu ônibus (minutos)? _________

8) Você deixou alguns ônibus passarem porque estão cheios? a) Sim b) Não – Quantos? ________

9) Como você avalia a capacidade dos ônibus do TransOeste?

1 - Confortável 2 – Mais ou menos 3 - Insuportável

10) O que você acha do serviço do TransOeste comparado com o serviço anterior do ônibus normal?

1 – Muito melhor 2- Melhor 3- A mesma coisa 4 – Pior 5 – Muito pior

11) Como você avalia o nível de conforto do TransOeste dentro dos ônibus comparado com o serviço anterior do ônibus normal?

1 – Muito melhor 2- Melhor 3- A mesma coisa 4 – Pior 5 – Muito pior

12) Como você avalia o nível de conforto do TransOeste dentro das estações comparado com o serviço anterior do ônibus normal?

1 – Muito melhor 2- Melhor 3- A mesma coisa 4 – Pior 5 – Muito pior

13) Você tem carro? a) Sim b) Não

14) Aonde está seu carro agora: a) Estacionado b) Outra pessoa usa c) Não está funcionando no momento d) Outro ____

15) Como você acha que o TransOeste poderia melhorar?
____

Annex III: TEEMP Model Methodology for BRT

Introduction

The Transport Emissions Evaluation Models for Projects (TEEMP) model for BRT is used to evaluate existing and proposed Bus Rapid Transit (BRT) systems across the world. Due to the size, scale and variability in BRT projects, creating an estimation of their impacts can be a very complicated, data-intensive exercise. TEEMP models have been developed to streamline this process for projects in the early planning stages. The model increases the consistency of methods and assumptions, without requiring high levels of data.

Methodology Overview

In calculating the impacts of a BRT project in the TEEMP model, first a baseline scenario without a BRT intervention is established. The baseline estimation will be compared against the estimated emissions, safety and fuel-consumption improvements achieved by the BRT project. TEEMP models automatically calculate a baseline by using a market-shed analysis approach. Then the direct impacts of the BRT project scenario are calculated. The difference between the emissions, safety and fuel consumption in the BRT project scenario and the baseline scenario equals the direct impact of the project. This is the model's main output. BRT projects generally create direct impacts in five main ways:

1. Induced modal shift resulting from new or improved transit service.
2. Total transit vehicle kilometers are reduced by reorganized routes.
3. Fuel efficiency is increased due to improved transit vehicle speed and operations.
4. New or improved transit vehicles yield lower emissions per passenger-km due to more efficient vehicles and/or higher passenger capacities than the vehicles from which the passengers were drawn.

These potential benefits are also weighed against construction emissions and any special emissions caused by traffic impacts of the construction of the public transit system, which can be significant.

Impact Estimation Modes

The BRT TEEMP model offers both simplistic (Shortcut) and more complex (Full Scenario) methods for estimating the impact from BRT projects based on the modal shift and other changes they can spur in urban transportation systems. The Full Scenario Method was used for the Transoeste analysis.

The Full Scenario Method accounts for local and project-specific data for all data fields and produces a higher-confidence impact estimate of the project. While some data-points are required for the Full Scenario Method, many other data-points have default values that can be used if dependable local data is not available. However, these defaults are conservative, encouraging the collection of local data.

Data Requirements

The calculations used to find the GHG impact of mass transportation projects are based on existing bus ridership in the corridor, the quality of the transit system design and operation variables (which determine speed and shift from other modes). The basic data requirements include mode share, ridership, length of routes, frequency, passenger trip length, as well as bus capacity, engine type, fuel and average speeds currently found in the corridor. Planning information regarding the length, route, capacity and features of the proposed transit project is also required.

The model requires the following basic data about existing bus services on the planned mass transit corridor, including:

a. km or percentage of the route that overlaps the project corridor,
b. peak hour frequency and average observed occupancy on the section of the corridor most heavily utilized by buses OR total boarding and alighting counts for each bus route serving the corridor,
c. bus engine types (% of pre-Euro, Euro II, Euro III, etc.),
d. bus fuel type (petrol, diesel, CNG, LPG, hybrid, etc.),
e. bus capacity,
f. average speeds and
g. average passenger trip length.

Results

The results of the TEEMP BRT are calculated from the inputs described above and some default values. Calculated results include, but are not limited to:

a. GHG emissions reductions
b. Travel time savings
c. Expanded travel options and opportunities
d. Air pollution reductions
e. User cost savings
f. Fuel use reductions
g. Traffic injuries and fatalities reductions

Annex IV: Transoeste BRT Standard Scorecard

	Maximum	Rio de Janeiro - TransOeste
BRT Basics - Minimum score of 4 points needed	**14**	**14**
Busway alignment	7	7
Dedicated right-of-way	7	7
Service Planning	**31**	**30**
Off-board fare collection	7	7
Multiple routes	4	4
Peak frequency	3	3
Off-peak frequency	2	2
Express, limited, and local services	3	3
Control center	3	2
Located In top ten corridors	2	2
Demand Profile	3	3
Hours of operations	2	2
Multi-corridor network	2	2
Infrastructure	**20**	**18**
Intersection treatments	6	6
Passing lanes at stations	4	4
Minimizing bus emissions	3	2
Stations set back from intersections	3	3
Center stations	2	2
Pavement quality	2	1
Station Design and Station-bus Interface	**16**	**16**
Platform-level boarding	6	6
Distances between stations	2	2
Safe and comfortable stations	3	3
Number of doors on bus	3	3
Docking bays and sub-stops	1	1
Sliding doors in BRT stations	1	1
Quality of Service & Passenger Information Systems	**5**	**5**
Branding	3	3
Passenger information	2	2

Integration and Access	14	8
Universal access	3	3
Integration with other public transport	3	1
Pedestrian access	3	2
Secure bicycle parking	2	1
Bicycle lanes	2	1
Bicycle-sharing integration	1	0
TOTAL 100	**100**	**91**
BRT BASICS (MINIMUM NEEDED 20)	**33**	**33**

Point Deductions	-34	-5
Commercial Speeds	-10	0
Peak passengers per hour per direction (pphpd) below 1,000	-5	0
Lack of enforcement of right-of-way	-5	0
Significant gap between bus floor and station platform	-5	0
Station encroaches on sidewalk or busway	-3	0
Overcrowding	-3	-3
Poorly-maintained Busway, Buses, Stations and Technology Systems	-3	-2

Total Score:	86