

Figure 10.2-20 Inbound Trunk Bus Passengers on Board in 2012, Case-5 (5)

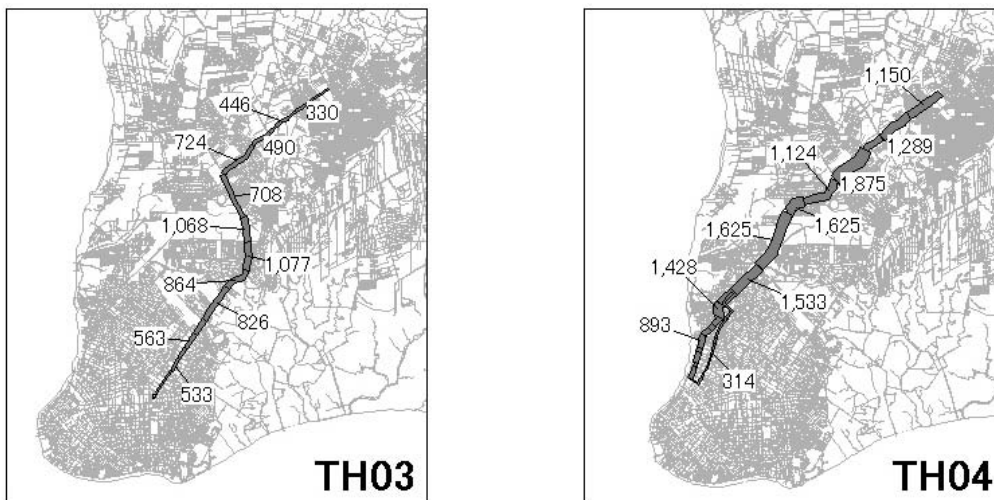


Figure 10.2-21 Inbound Trunk Bus Passengers on Board in 2012, Case-5 (6)

#### (4) Boarding and Alighting Behaviors of Trunk Bus Passengers

Figure 10.2-23 shows the peak hour boarding and alighting passengers at bus stops on major trunk bus routes in 2007 as estimated in Case-4. Figure 10.2-24 and Figure 10.2-25 do the same on major trunk routes in 2012 as estimated in Case-5. Bars indicate the boarding and the alighting passengers at each bus stop and the line shows the on-board passengers. The locations of the bus stops in these charts are indicated on the map in Figure 10.2-22.

TA01 in 2007 (Case-4) has nearly 800 boarding passengers per hour at Icoaraci Integrated Bus Terminal and picks up some passengers along the way until Rodovia Augusto Montenegro where the on-board passengers jump to nearly 2,000 per hour. After Sao Braz Terminal, passengers begin to alight, reaching nearly 400 per hour at a bus stop on Avenida Governador Jose Malcher. Some 700 passengers alight at a bus stop in the Centro. TH01 in 2007 (Case-4) has the boarding passengers of nearly 700 at Independencia 2 Integrated Bus Terminal, and by picking up passengers along the way, the route has about 3,000 on-board passengers on Rodovia Augusto Montenegro. Both boarding and alighting passengers begin to increase on Avenida Almirante Barroso, and the on-board passengers peak around 3,800 near Sao Braz Terminal. At a bus stop on Avenida Governador Jose Malcher, more than 1,100 passengers alight per hour. The alighting passengers per hour are more than 700 at a bus stop on Avenida Visconde de Souza Franco and about 1,100 at a bus stop in the Centro.

Four trunk bus routes TA01, TD01, TF01 and TH01 in 2012 (Case-5) show the same boarding and alighting behaviors of passengers as TA01 in 2007. After entering Avenida Independencia, TA02 has few boarding and alighting passengers up to the Centro where nearly 600 passengers alight per hour at a bus stop. TD02 has the boarding passengers of more than 500 at Coqueiro Integrated Bus Terminal, coasts Avenida Independencia with no boarding and alighting passenger, and unloads nearly 500 passengers per hour at one bus stop in the Centro. TF02 has the boarding passengers of about 900 per hour at Marituba Integrated Bus Terminal, picks up passengers along Avenida Independencia and unloads more than 2,000 passengers at a bus stop in the Centro. TH02 shows the same boarding and alighting behaviors of passengers as TF02.

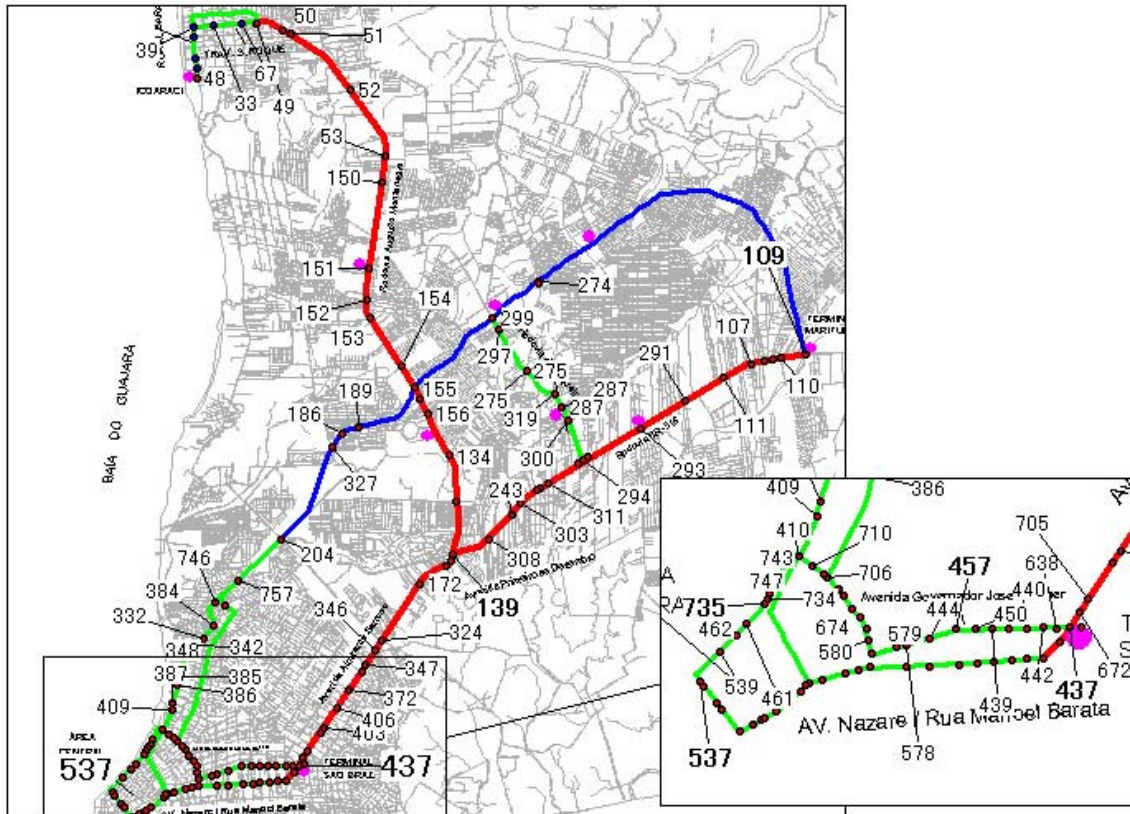
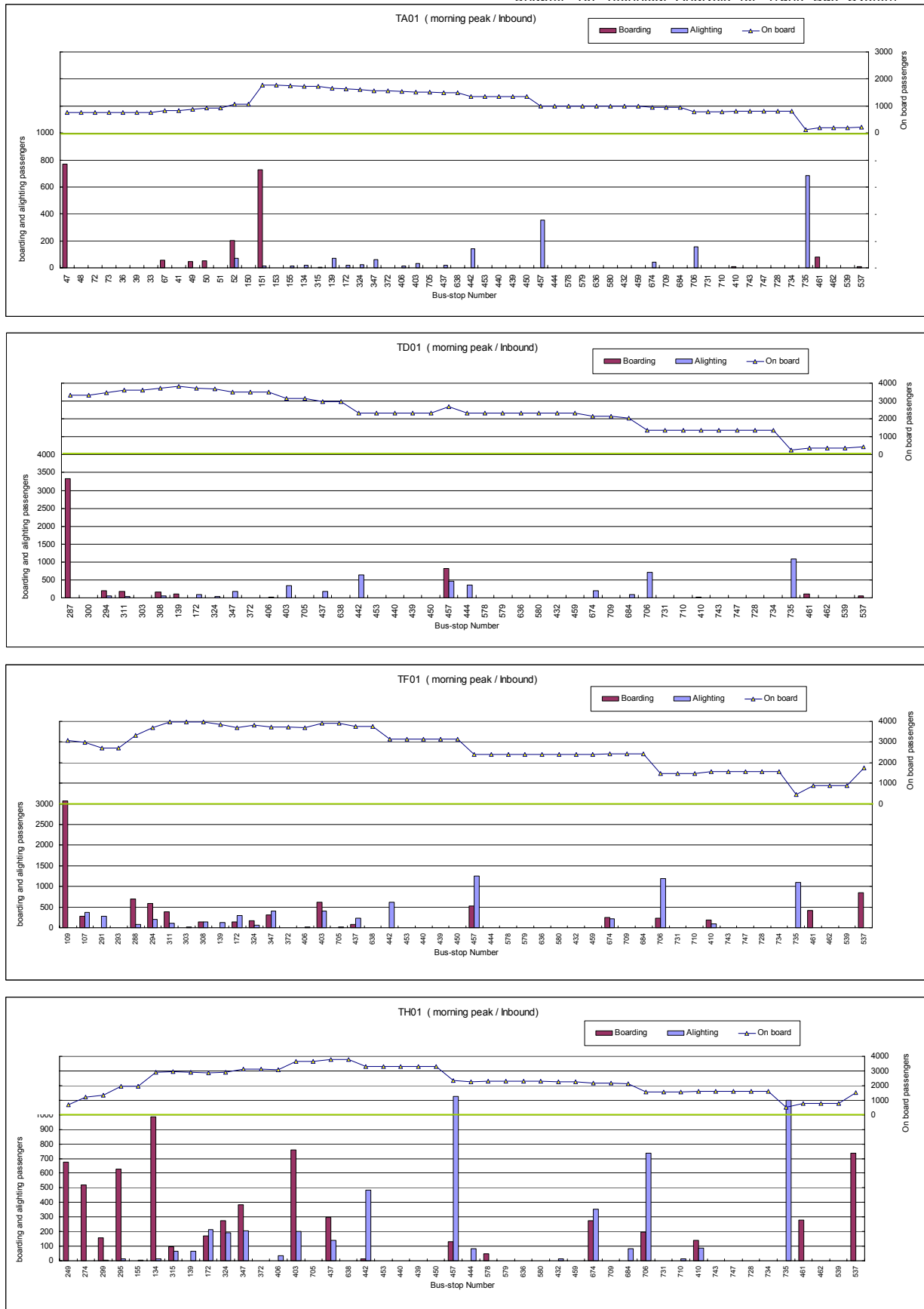


Figure 10.2-22 Locations of Trunk Bus Stops





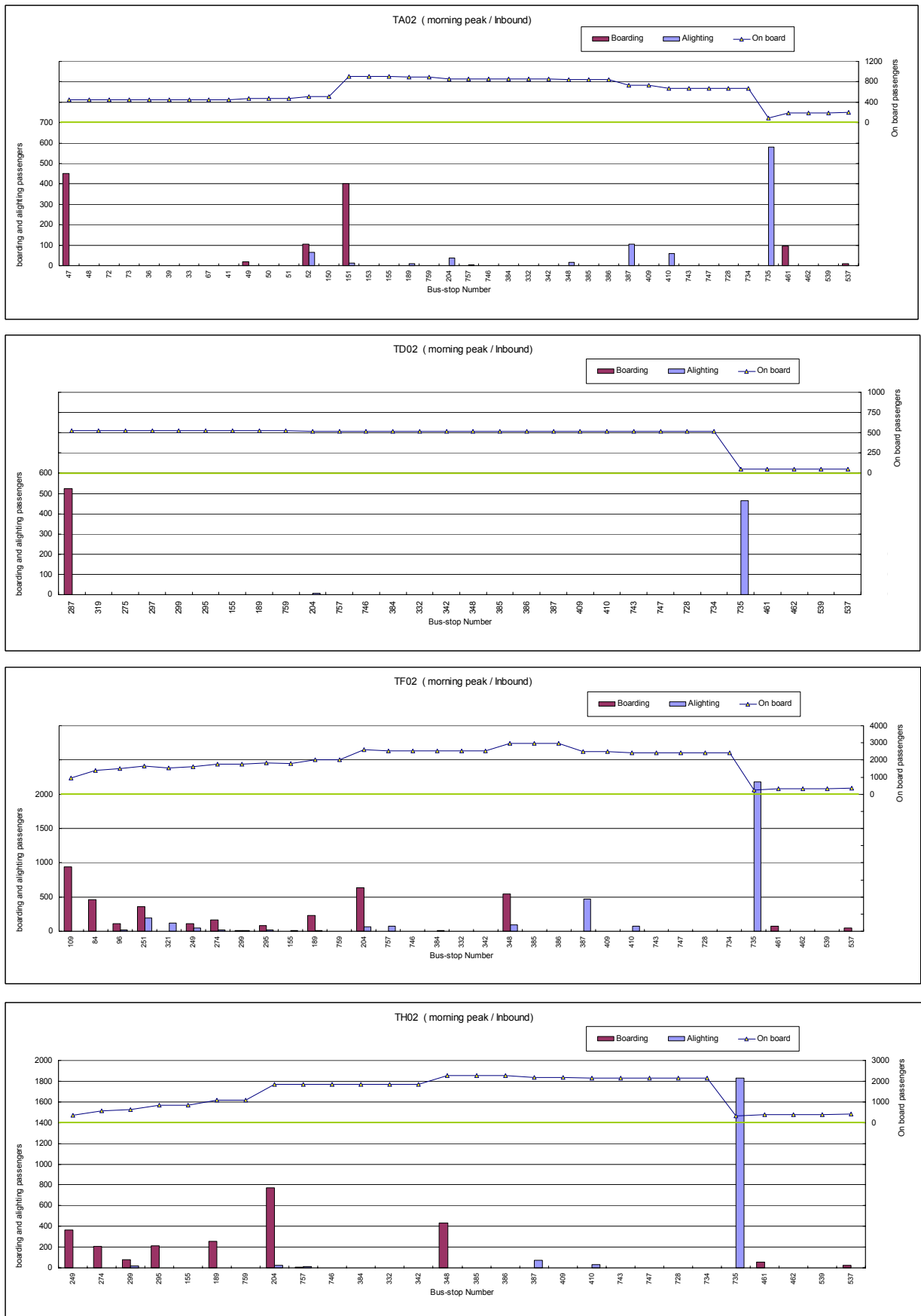


Figure 10.2-25 Behaviors of Boarding and Alighting Passengers in 2012, Case-5 (2)

### 10.2.3. BUS SERVICE FREQUENCY

#### (1) Bus Traffic

Figure 10.2-27 through Figure 10.2-29 show the conventional and the trunk bus traffic as estimated respectively in Case-1 (2002), Case-4 (2007) and Case-5 (2012). The numbers in these figures indicate the inbound bus traffic per peak hour in the morning by road segment. Table 10.2-8 summarizes the conventional and the trunk bus traffic by major road segment. The locations of road segments are shown in Figure 10.2-6.

In 2007 of Case-4, trunk buses from eight integrated bus terminals in the suburban areas converge on Avenida Almirante Barroso totaling 153 vehicles per peak hour. The service frequency on the trunk busway of this avenue is one bus every 24 seconds. Given the time needed for boarding and alighting at every bus stop and the waiting time at traffic signals, this short headway forebodes the difficulty of keeping on-schedule bus service on the avenue. The bus traffic drops to 93 vehicles per hour from Sao Braz Terminal further into the Centro, as the remaining 60 buses turn back at this terminal to their respective suburban terminals of origin.

Compared with the situation in 2002 (Case-1), the conventional bus traffic in 2007 on lanes other than the trunk busway is clearly on the decrease in all road segments. The segment ending at Entroncamento on Rodovia Augusto Montenegro has the conventional bus traffic of 122 vehicles, which means a decrease by 167 vehicles relative to the traffic in 2002. The conventional bus traffic elsewhere, for example, is 137 vehicles on Rodovia BR-316 (a drop of 181) and 200 vehicles on Avenida Almirante Barroso (reduction to one third of the volume in 2002).

Both conventional and trunk buses use the trunk bus priority lane provided on six roads in the Centro such as Avenida Nazare and Governador Jose Malcher. The combined bus traffic adds up to 441 vehicles per peak hour upon entering Avenida Governador Jose Malcher from Avenida Almirante Barroso, drops to 301 vehicles on Avenida Visconde de Souza Franco, and, after going round the inner part of the Centro, comes down to 281 vehicles per hour on reaching Avenida Nazare. Because of the introduction of trunk bus service, the volume of bus traffic on these road segments, and elsewhere as well, is smaller than the situation in 2002 despite the increase of bus passengers estimated for 2007.

In 2012 of Case-5, trunk buses originating in eight suburban terminals use either Avenida Almirante Barroso or Avenida Independencia to reach the Centro. The trunk bus traffic on the former avenue is 128 vehicles per hour (a reduction by 75 vehicles relative to 2007), while it reaches 100 vehicles on the central accessing segment of the latter. To put this in terms of service frequency, the headway is one vehicle every 28 seconds on Avenida Almirante Barroso and every 36 seconds on Avenida Independencia. This means a relative ease-up for the on-schedule trunk bus service on the former avenue, compared with the difficulty pointed out for 2007 (Case-4). The trunk bus traffic from Sao Braz Terminal further into the Centro totals 78 vehicles per peak hour, and increases to 123 vehicles on Avenida Marechal Hermes by joining with the traffic that reaches the Centro via Avenida Independencia. Of 78 vehicles passing Avenida Almirante Barroso, 50 trunk buses stop at Sao Braz Terminal to return to their respective terminals of origin. Similarly, 55 of 100 trunk buses on Avenida Independencia turn back at Avenida Visconde de Souza Franco to return to their respective terminals of origin.

The conventional bus traffic in 2012 on lanes other than the trunk busway and the exclusive trunk bus lane drops further from the situation in 2007. This is precisely the expected impact that accrues from the opening of the Centro accessing segment of Avenida Independencia.

## (2) Bus Traffic on Screen Line

Table 10.2-6 summarizes the inbound bus traffic crossing the screen line set up on five roads for 2007 in Case-2 and Case-4. The latter “with” forecast is broken down to the trunk and the conventional bus traffic. In the “without” case, the inbound bus traffic crossing the line totals 892 vehicles per peak hour in 2007. In the “with” case, the estimated bus traffic totals 666 vehicles, consisting of 153 trunk buses and 513 conventional buses. This means a reduction by 226 vehicles relative to the “without” forecast.

Table 10.2-7 similarly summarizes the inbound bus traffic crossing the screen line for 2012. The “without” forecast of Case-3 estimates the conventional bus traffic of 971 vehicles per peak hour. In the “with” forecast of Case-5, the estimated bus traffic totals 688 vehicles per peak hour, a reduction by 283 vehicles, or by almost 30%, relative to the “without” forecast.

Figure 10.2-26 compares the “with” and the “without” forecasts of inbound bus traffic on Avenida Almirante Barroso. In the “without” forecast for 2012, the conventional bus traffic totals some 700 vehicles per peak hour on the avenue. This means the headway of only five seconds, a totally impracticable proposition. In the “with” forecast for the same year, the estimated traffic consists of 130 trunk buses and 230 conventional buses, the former operating on the trunk busway and the latter on the through traffic lane. The trunk bus service is operable at the headway of 30 seconds.

Table 10.2-6 Peak Hour Inbound Bus Traffic in 2007 on Screen Line

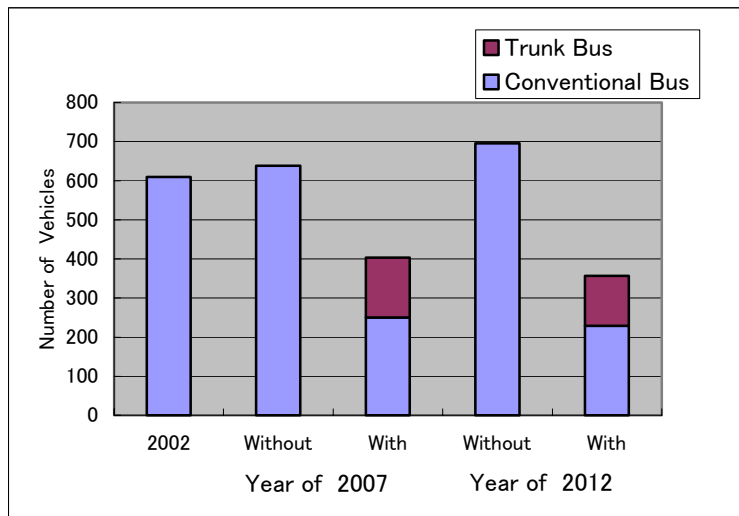
Screen-lined Road	Case-2: Without	Case-4: With			Difference of Traffic: Case-4 – Case-2
	Conventional Bus	Conventional Bus	Trunk Bus	Total	
Av. Almirante Barroso	638	250	153	403	-235
Av. Independencia	0	0	0	0	0
Av. Primeiro de Dezembro	0	24	0	24	24
Av. Pedro Alvares Cabral	207	196	0	196	-11
Rod. Arthur Bernardes	47	43	0	43	-4
Total	892	513	153	666	-226
Share (%)		77	23	100	

Note: The location of the screen line is shown in Figure 10.2-6.

Table 10.2-7 Peak Hour Inbound Bus Traffic in 2012 on Screen Line

Screen-lined Road	Case-3: Without	Case-5: With			Difference of Traffic: Case-5 – Case-3
	Conventional Bus	Conventional Bus	Trunk Bus	Total	
Av. Almirante Barroso	695	229	128	357	-338
Av. Independencia	0	0	100	100	100
Av. Primeiro de Dezembro	0	24	0	24	24
Av. Pedro Alvares Cabral	224	161	0	161	-63
Rodovia Arthur Bernardes	52	46	0	46	-6
Total	971	460	228	688	-283
Share (%)		69	34	100	





Note: The location of the screen line is shown in Figure 10.2-6.

Figure 10.2-26 Inbound Bus Traffic on Av. Almirante Barroso by Alternative Case



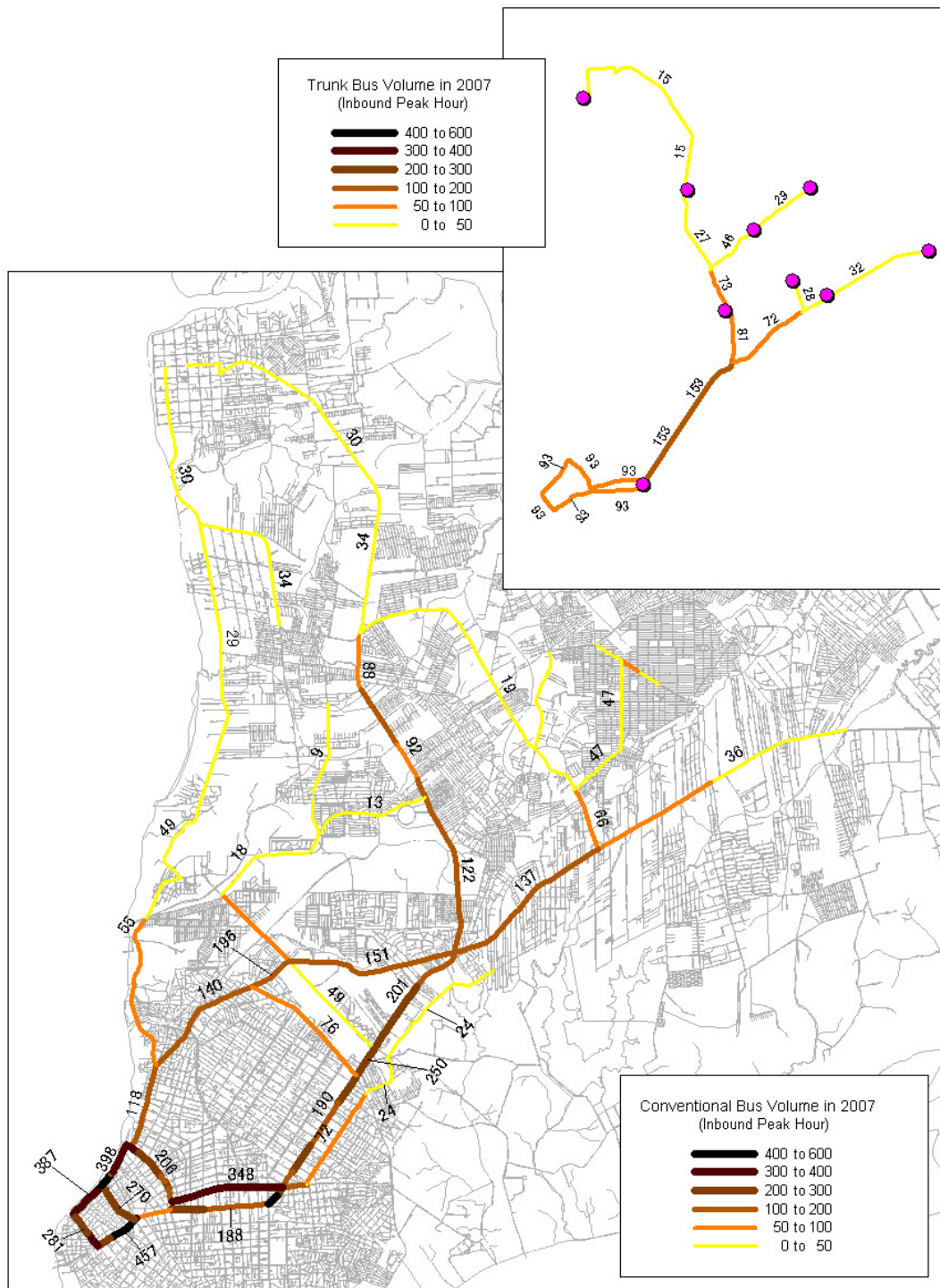


Figure 10.2-28 Peak Hour Inbound Bus Traffic in 2007: Case-4



Table 10.2-8 Peak Hour Inbound Bus Traffic by Major Road Segment

(Inbound Number of Bus Volume/Peak hour)

Segment No.	Road	2007				2012			
		Case-2	Case-4			Case-3	Case-5		
		Conventional bus	Conventional bus	Trunk bus	Total	Conventional bus	Conventional bus	Trunk bus	Total
1	Rodovia BR-16	187	36	32	68	220	34	33	67
2	Rodovia BR-16	342	137	72	209	391	89	66	155
3	Avenida Almirante Barroso	638	250	153	403	695	229	128	357
4	Avenida Almirante Barroso	545	191	153	344	593	174	128	302
5	Rodovia Augusto Montenegro	79	30	15	45	100	42	29	71
6	Rodovia Augusto Montenegro	249	101	27	128	275	110	49	159
7	Rodovia Augusto Montenegro	309	122	81	203	339	130	62	192
8	Avenida Independencia	-	-	-	-	-	-	26	26
9	Avenida Independencia	-	-	29	29	-	-	58	58
10	Avenida Independencia	-	-	-	-	-	-	100	100
11	Avenida Independencia	-	-	-	-	-	-	100	100
12	Rodovia do Coqueiro	33	15	-	15	38	21	21	42
13	Rodovia do Coqueiro	117	66	28	94	128	26	34	60
14	Av. Primeiro de Dezembro	-	24	-	24	-	24	-	24
15	Av. Pedro Alvares Cabral	164	151	-	151	181	130	-	130
16	Avenida Julio Cesar	39	49	-	49	40	44	-	44
17	Av. Pedro Alvares Cabral	207	196	-	196	224	161	-	161
18	Avenida Pedro Miranda	75	74	-	74	77	73	-	73
19	Avenida Perimetral	89	75	-	75	96	82	-	82
20	Av. Governador Jose Malcher	467	300	93	393	482	284	78	362
21	Avenida Nazare	293	154	93	247	303	152	78	230
22	Avenida Jose Bonifacio	66	60	-	60	69	62	-	62
23	Rodovia Arthur Bernardes	47	43	-	43	52	46	-	46
24	Av. Pedro Alvares Cabral	137	118	-	118	152	136	100	236
25	Boulevard Castilhos Franca	533	387	93	480	557	376	123	499
26	Av. Visconde de Souza Franco	329	206	93	299	347	191	78	269
27	Screen Line No.1	892	513	153	666	971	29,213	38,445	67,658

### (3) Trunk Bus Service Frequency

Table 10.2-9 compares the peak hour service frequency in 2007 and 2012 by trunk bus route. In 2007 (Case-4), the total trunk bus service frequency is 153 vehicles per hour, of which 60 turn back at Sao Braz Terminal to return to their respective terminals of origin. The remaining 93 proceed from Sao Braz Terminal further to Avenida Governador Jose Malcher and Avenida Visconde de Souza Franco and go round the inner part of the Centro to reach Avenida Nazare.

In 2012 (Case-5), the total service frequency rises to 228 vehicles per hour. The frequency on Avenida Almirante Barroso totals 128 vehicles per hour, of which 50 stop at Sao Braz Terminal to return to their respective terminals of origin and 78 go further into the Centro. The frequency on Avenida Independencia is 100 vehicles per hour, of which 55 turn back on Avenida Visconde de Souza Franco to return to their respective terminals of origin. The remaining 45 go further into the Centro. The service frequency is the highest at Marituba Integrated Terminal with the combined total of TF01, TF02, TF03 and TF04 adding up to 59 vehicles per peak hour.

Table 10.2-9 Trunk Bus Service Frequency

Headway / Peak hour					
Trunk Bus Route	2007	2012	Trunk Bus Route	2007	2012
	Case-4	Case-5		Case-4	Case-5
TA01	7	7	TE01	8	9
TA02	–	4	TE02	–	6
TA03	8	10	TE03	4	6
TA04	–	8	TE04	–	10
TB01	7	5	TF01	16	20
TB02	–	2	TF02	–	12
TB03	5	8	TF03	16	13
TB04	–	5	TF04	–	14
TC01	7	4	TG01	15	8
TC02	–	2	TG02	–	6
TC03	1	1	TG03	2	7
TC04	–	2	TG04	–	4
TD01	18	17	TH01	15	8
TD02	–	3	TH02	–	10
TD03	10	1	TH03	14	4
TD04	–	2	TH04	–	10
			Total	153	228

#### (4) Total Bus Service Frequency

Table 10.2-10 and Figure 10.2-30 compare the total bus service frequency forecasts of six alternative cases. The frequency per morning peak hour of conventional bus service for 2007 is lower by 526 in the “with” forecast of Case-4 than in the “without” forecast of Case-2. One reason is the discontinuation of 61 conventional bus lines by the introduction of the trunk bus system. The other reason is the shift of the passenger demand from the conventional to the trunk bus service. The decreased frequency of conventional bus service is offset by the trunk bus frequency of 189 per hour. By the introduction of the trunk bus system that operates larger buses, the total bus service frequency in Case-4 is lower by 337 than in Case-2.

Similarly, the impact of the trunk bus system is evident in 2012. The frequency of conventional bus service is lower by 648 in Case-5 than in Case-3. This drop is offset by the trunk bus frequency of 272. The total frequency of bus service in Case-5 is smaller by 376, or about 25% less, than in Case-3.

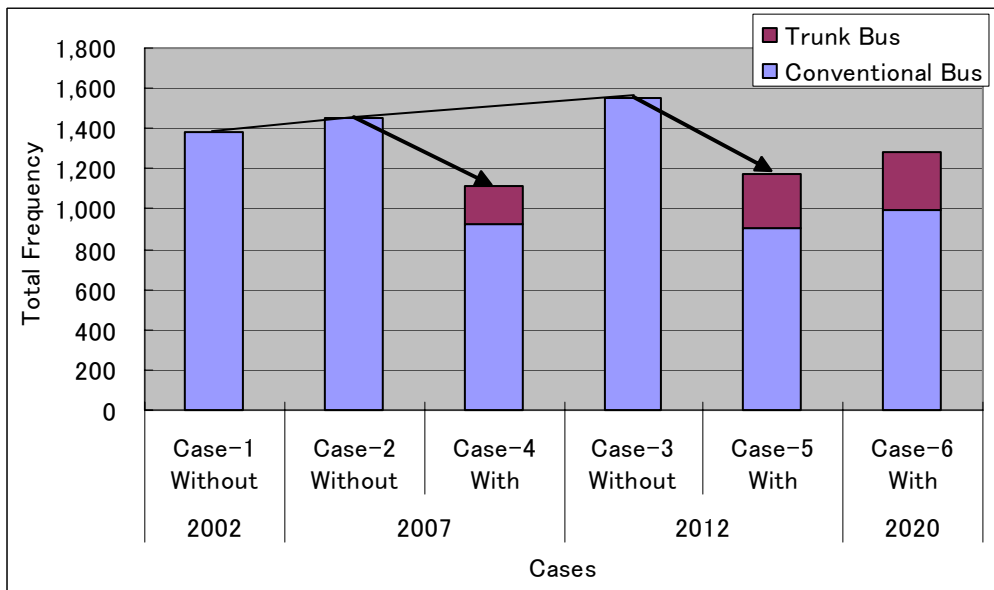


Figure 10.2-30 Peak Hour Total Bus Service Frequency by Alternative Case

Table 10.2-10 Peak Hour Total Bus Service Frequency by Alternative Case

Year/Case		Conventional Bus	Trunk Bus	Total	Ratio of With to Without	Difference of Frequency: Without minus With
2002	Case-1 Without	1,384	-	1,384	-	
2007	Case-2 Without	1,447	-	1,447	1.00	337
	Case-4 With	921	189	1,110	0.77	
2012	Case-3 Without	1,552	-	1,552	1.00	376
	Case-5 With	904	272	1,176	0.76	
2020	Case-6 With	990	296	1,286	-	

**(5) Waiting Time at Bus Stops**

Table 10.2-11 shows the waiting time at bus stops by alternative case. The waiting time is one half of the headway, when the headway is short enough. As the headway gets longer, the waiting time gets shorter than one half, because passengers consult the timetable of bus service. This tendency can be approximated by the following formula.

$$\text{Waiting time} = \text{Headway}/2 - \text{Headway}^2/200$$

At any bus stop, the waiting time gets shorter when the service frequency gets higher. The average waiting time rises from 1.88 minutes in Case-4 for 2007 to 2.34 minutes in Case-5

for 2012. This is because the completion of Avenida Independencia provides two additional routing systems to reduce the service frequency on Avenida Almirante Barroso.

Table 10.2-11 Average Waiting Time at Bus Stops by Alternative Case

2007			2012		
Case-2 (without)	Case-4 (With)		Case-3 (Without)	Case-5 (With)	
Conventional Bus	Conventional Bus	Trunk Bus	Conventional Bus	Conventional Bus	Trunk Bus
2.30	2.05	1.88	2.26	1.99	2.34

#### 10.2.4. PASSENGER BEHAVIORS AT TRUNK BUS STOPS

Figure 10.2-31 shows boarding and alighting passengers per trunk bus stop by road segment for 2007 (Case-4). Figure 10.2-32 does the same for 2012 (Case-5). The trunk bus routes are divided into 13 segments, and the boarding and the alighting passengers at the integrated bus terminals are excluded. Case-4 proposes 33 bus stops for 2007. Boarding passengers per bus stop are heaviest on Segment No.11, averaging as many as 2,100 per hour. Avenida Almirante Barroso has more alighting than boarding passengers, the former averaging 2,000 per bus stop.

Case-5 proposes 39 bus stops. Boarding passengers are heavy on Avenida Independencia, with Segments No. 11 and 13 averaging 2,600 and 2,000 respectively per bus stop. There are more alighting than boarding passengers on Avenida Almirante Barroso segments, ranging from 1,000 to 2,000 per bus stop.



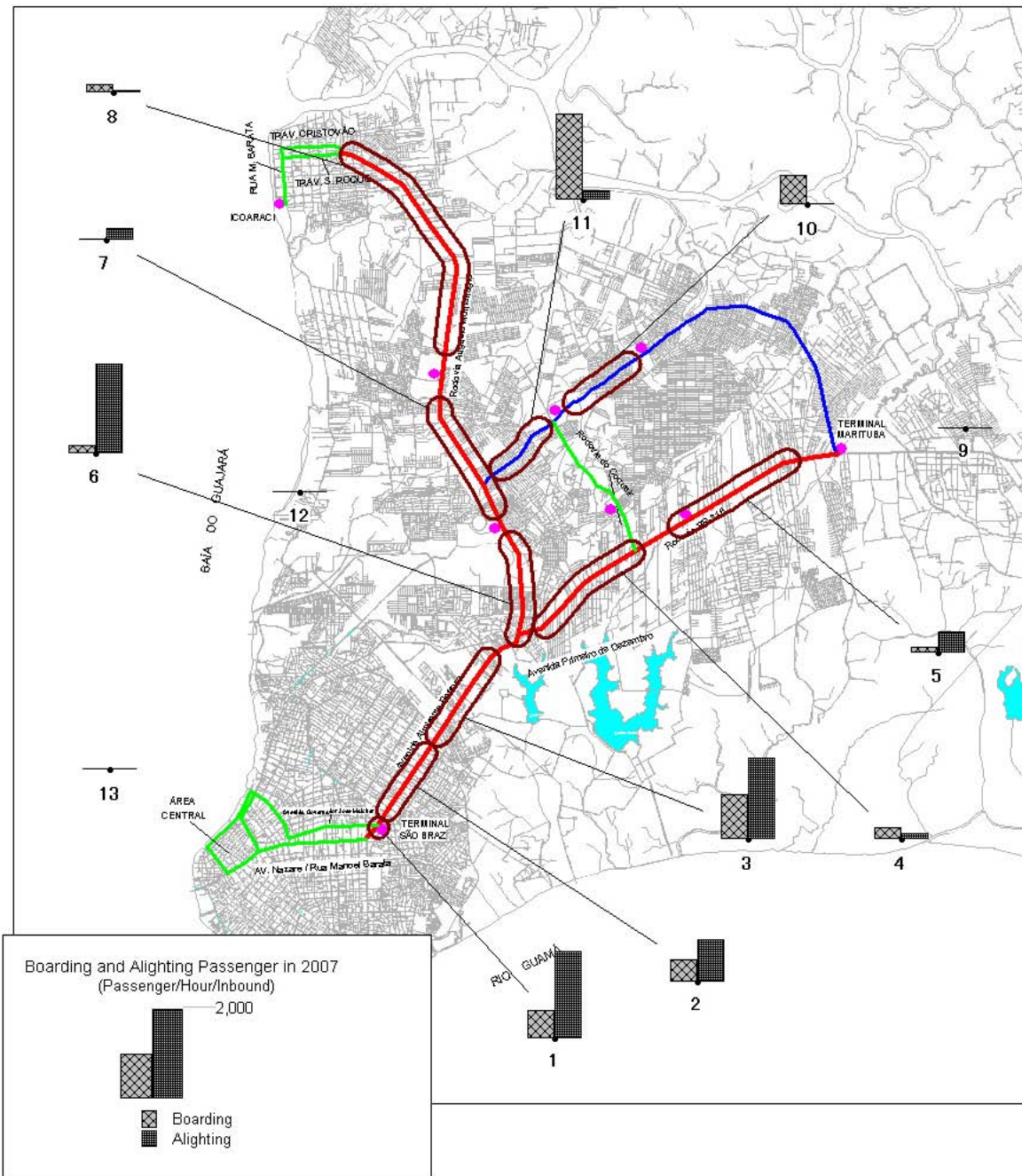


Figure 10.2-31 Boarding and Alighting Passengers per Bus Stop by Road Segment in 2007 (Case-4)

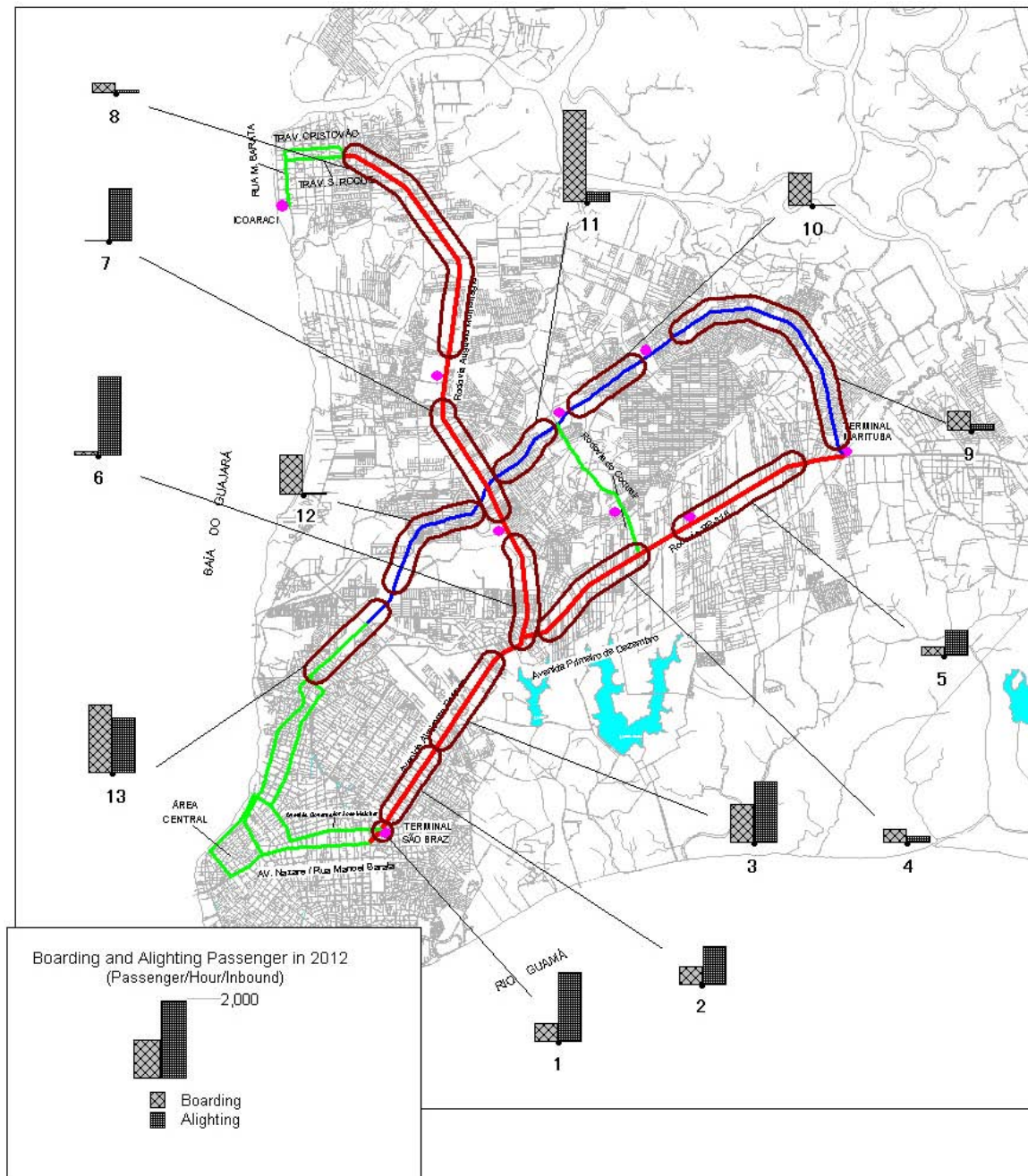


Figure 10.2-32 Boarding and Alighting Passengers per Bus Stop by Road Segment in 2012 (Case-5)

### 10.2.5. PASSENGER BEHAVIORS AT BUS TERMINALS

Table 10.2-12 shows feeder bus passengers and service frequency by integrated bus terminal. The frequency of feeder bus service is calculated from the average on-board passengers of 56 persons, or 80% of the bus capacity of 70 passengers, and the arriving and the departing passengers at the respective suburban terminals. The frequency of trunk bus service is calculated from the demand forecast using the Bus Transit Assignment Method. In the actual bus operation, the arrivals and the departures of feeder buses are equal in number, but the calculation as stated above yields a disparity between them. The columns of higher frequency requirements (arrivals) are shaded in Table 10.2-12.

Boarding and alighting passengers are heavy both in 2007 and 2012 at Mangueirao, Coqueiro and Marituba Integrated Bus Terminals. In 2007 (Case-4), a total of 9,500 passengers arrive at Mangueirao Terminal aboard 170 feeder buses per hour. These passengers depart aboard 154 trunk buses (including 8 buses originating in the terminal). In 2012 (Case-5), 11,500 passengers arrive at Marituba Integrated Bus Terminal aboard 207 feeder buses and depart aboard 59 trunk buses per hour.

Assuming the average route length of 5km and the average operating speed of 20km per hour, the frequency of feeder bus service is four vehicles per hour. The required fleet of feeder buses (capacity of 70 passengers) comes to some 180 vehicles in 2007 and 210 vehicles in 2012.

Table 10.2-12 Feeder Bus Passengers and Service Frequency by Integrated Bus Terminal

():Trunk Bus starting from Terminal

Terminal	Passengers per Peak hour				Required Service Frequency per Peak Hour					
	Case-4 (2007)		Case-5 (2012)		Case-4 (2007)			Case-5 (2012)		
	Feeder-> Terminal	Terminal-> Feeder	Feeder-> Terminal	Terminal-> Feeder	Feeder-> Terminal	Terminal-> Feeder	Trunk Bus Frequency	Feeder-> Terminal	Terminal-> Feeder	Trunk Bus Frequency
A:Icoaraci	2,608	1,555	3,534	2,200	47	28	15(15)	63	39	29(29)
B:Tapanã	4,611	3,946	5,148	4,289	82	70	42(12)	92	77	78(20)
C:Mangueirão	9,509	3,593	8,441	2,741	170	64	154(8)	151	49	123(9)
D:Coqueiro	8,738	3,920	11,119	6,072	156	70	28(28)	199	108	55(23)
E:Agua Lindas	3,855	1,755	4,861	2,397	69	31	76(12)	87	43	97(31)
F:Marituba	8,485	6,077	11,568	8,955	152	109	32(32)	207	160	59(59)
G:Independencia 1	754	168	721	225	13	3	75(17)	13	4	159(25)
H:Independencia 2	2,219	1,189	2,959	1,595	40	21	29(29)	53	28	84(32)
Total	40,779	22,203	48,351	28,474	728	396	451(153)	863	508	684(228)

### 10.2.6. FREQUENCY OF TRANSFERS

Figure 10.2-33 shows the frequency distribution of bus transfers at terminals and bus stops by alternative case. Case-4 (2007) and Case-5 (2012) include transfers between the feeder and the trunk bus services. In the “without” forecasts of Case-1 through Case-3, 70% of the total bus passengers reach their respective destinations without transfer. In the “with” forecast of Case-4, this percentage drops to 64%, and the percentage of passengers with single transfer increases a little to 29%. In the “with” forecast of Case-5, the percentage of passengers with no transfer further decreases to 62%.

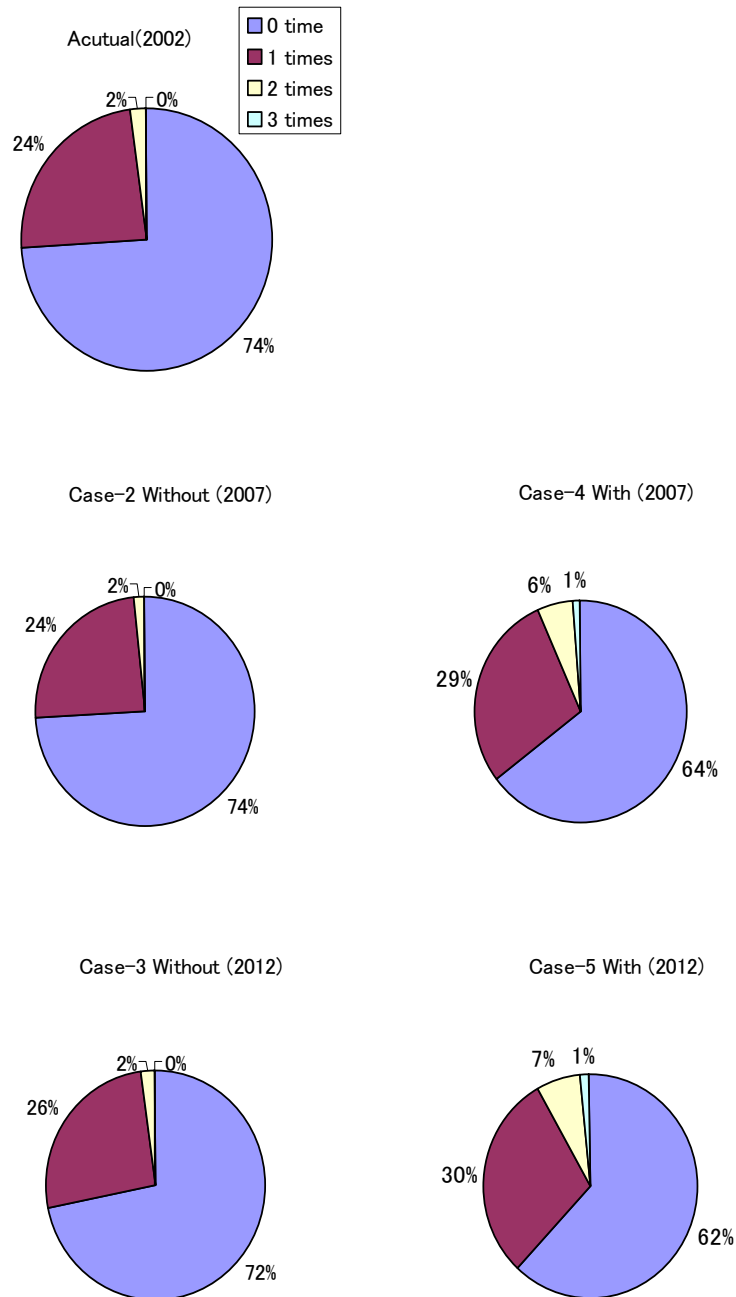


Figure 10.2-33 Frequency Distribution of Transfers in 2007 and 2012

## 10.2.7. BUS OPERATING SPEED

### (1) Total Travel Time

Figure 10.2-34 and Table 10.2-13 show total travel time by alternative case. The total time includes the time spent on feeder bus and the waiting time. Trunk buses run on the trunk busway and the exclusive trunk bus lane, while conventional buses use the through traffic lane mixed with private vehicles. The “without” total travel time of Case-2 is 59% longer,

and that of Case-3 is 126% longer, than the base year of 2002. The introduction of the trunk bus system lowers the total travel time. The total travel time in the “with” forecast of Case-4 for 2007 is 79% of the time estimated in Case-2. Similarly, the “with” total travel time for 2012 in Case-5 is 69% of the time estimated in Case-3.

The travel time per passenger in 2012 is 54 minutes without the trunk bus system and 38 minutes, or 16 minutes less, with the system.

Table 10.2-13 Total Travel Time by Alternative Case

Year/Case		Type of Bus Service	Total Travel Time (hours)	Share (%)	Ratio to Without Forecast	Travel Time per Passenger (minutes)
2002	Case-1 Without	Conventional	124,271		–	28.1
2007	Case-2 Without	Conventional	197,149		1.00	41.2
	Case-4 With	Trunk	43,106	28	–	–
		Conventional	113,500	72	–	–
		Total	156,606	100	0.79	32.7
2012	Case-3 Without	Conventional	280,358		1.00	53.5
	Case-5 With	Trunk	72,542	37	–	–
		Conventional	122,175	63	–	–
		Total	194,717	100	0.69	37.2

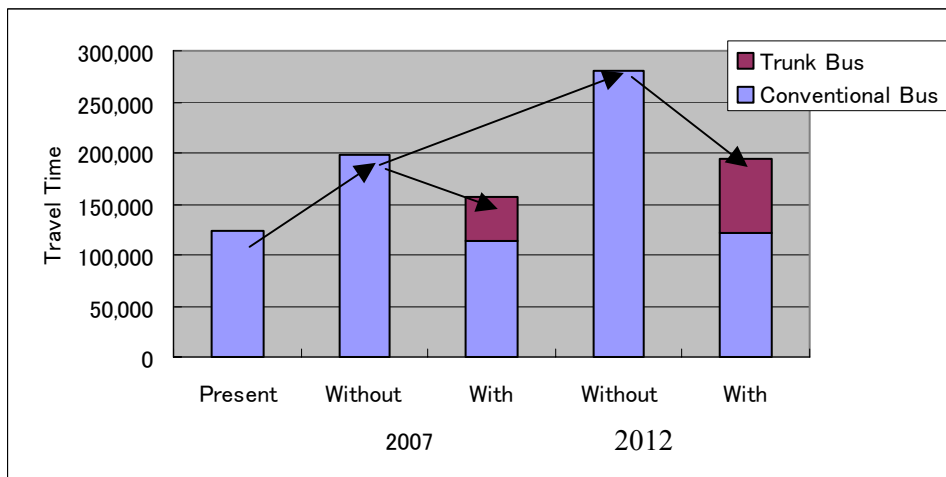


Figure 10.2-34 Total Travel Times in 2007 and 2012

## (2) Trunk Bus Operating Speed

Figure 10.2-35 shows the operating speed of inbound trunk bus service for 2007 (Case-4) and 2012 (Case-5). The operating speed is relatively fast in the Expansion Area, but slows down somewhat upon entering Avenida Almirante Barroso because of the increased trunk bus traffic on the avenue. The speed becomes even slower after Sao Braz Terminal, because trunk buses have to share the bus priority lane with conventional buses in the Centro.

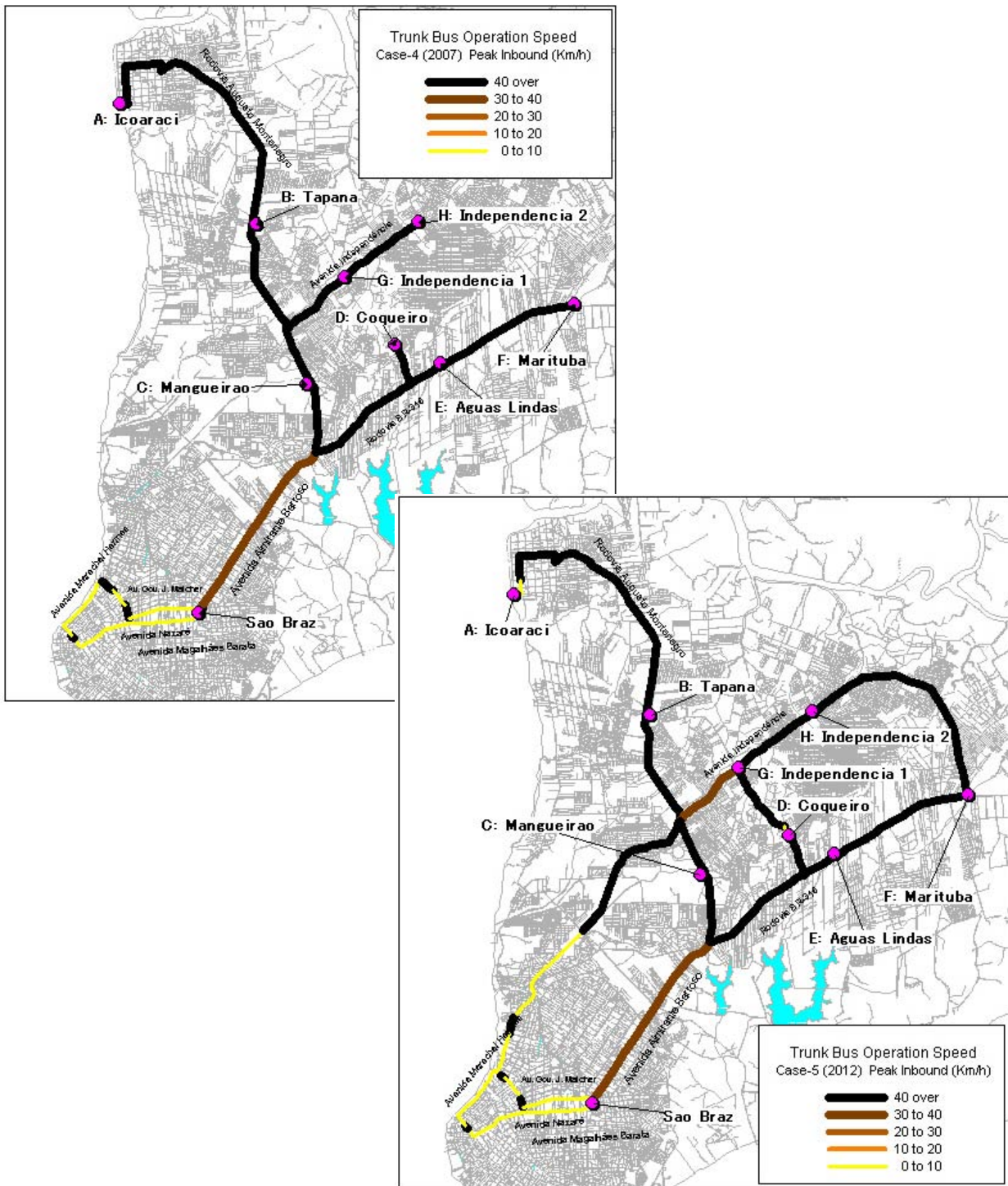


Figure 10.2-35 Trunk Bus Operating Speed in 2007 and 2012

### (3) Travel Time from Integrated Bus Terminals

Figure 10.2-36 compares the travel time during the morning peak hours from two major integrated bus terminals of origin, Icoaraci and Marituba, to two destinations, Sao Braz Terminal and the Centro. The introduction of the trunk bus system saves from 20 to 40 minutes of travel time from origin to destination.

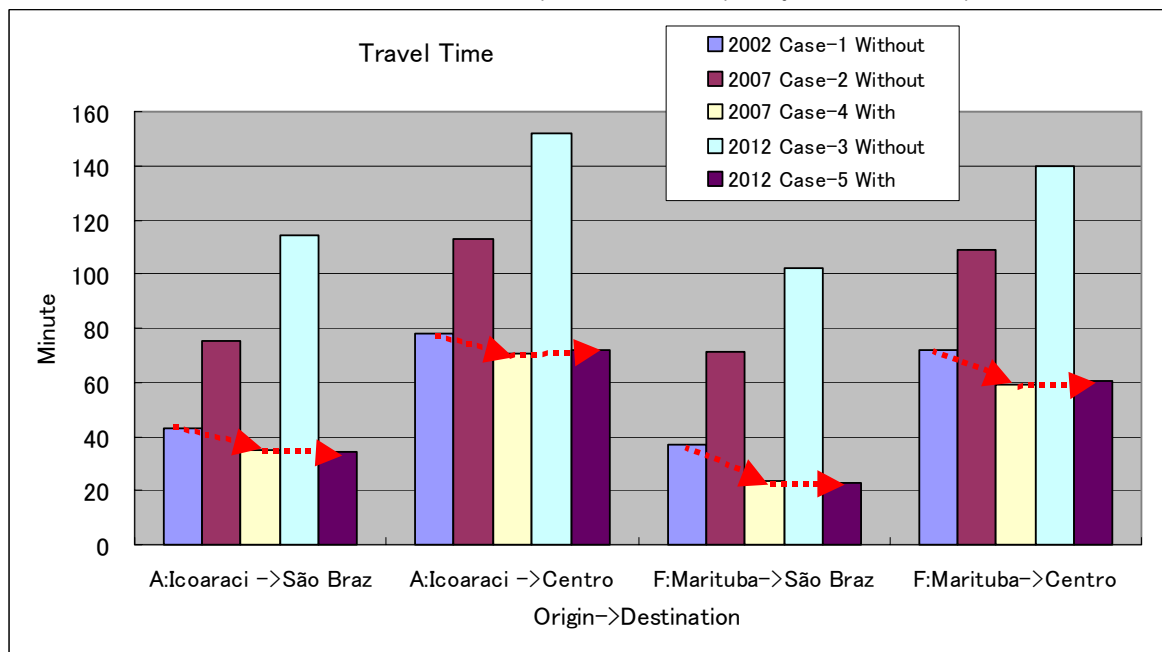


Figure 10.2-36 Inbound Travel Time from Two Major Integrated Terminals

### 10.2.8. BUS FARE REVENUE

Table 10.2-14 shows the estimated revenue from bus operation in five alternative cases. Figure 10.2-37 shows the difference in the ratio to the base year of 2002 between the “without” and the “with” cases in 2007 and 2012. The bus fare is assumed to be \$0.85 reais per trip for both the trunk and the conventional bus systems. Transfers from the feeder to the trunk bus service and vice versa and between trunk bus lines at integrated bus terminals require no extra charge. Given the expected increase in travel demand and the expected reduction of bus fleet, revenues of alternative cases are compared per vehicle service.

In the “without” cases, the revenue per vehicle service rises by 6% in 2007 and by 11% in 2012 from the base year of 2002. This is primarily because the growth of demand is larger than the increase of bus fleet. In the “with” cases, the revenue per vehicle service rises by 32% in 2007 and by 38% in 2012 from the base year of 2002.

Table 10.2-14 Total Revenue from Bus Operation by Alternative Case

Year/Case		Total Bus Trips	Total Revenue (reals\$)	Total Service Frequency	Revenue per Vehicle Service	Ratio to Case-1	Ratio of With to Without
2002	Case-1	330,617	281,024	1,384	203.1	1.00	
2007	Case-2	366,023	311,120	1,447	215.0	1.06	1.00
	Case-4	349,664	297,214	1,110	267.8	1.32	1.25
2012	Case-3	409,708	348,252	1,552	224.4	1.11	1.00
	Case-5	387,879	329,697	1,176	280.4	1.38	1.25

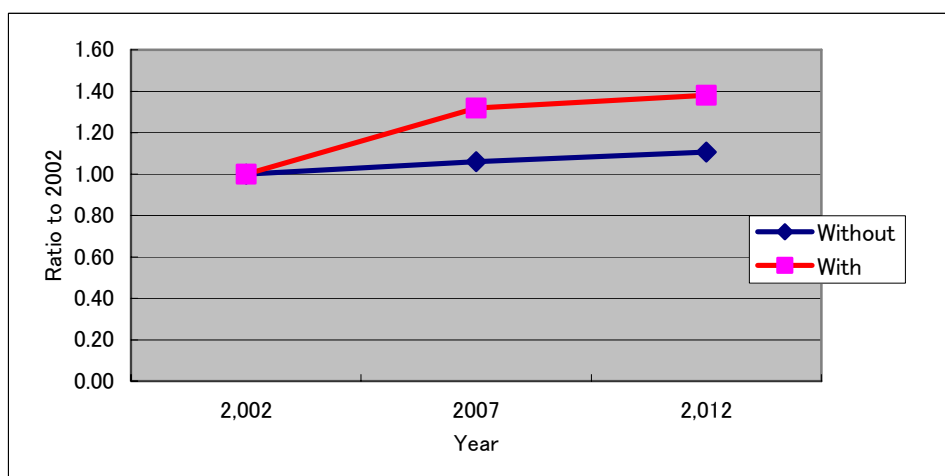


Figure 10.2-37 Growth of Revenue per Vehicle Service in 2007 and 2012

### 10.3. EFFECTIVENESS OF TRUNK BUS SYSTEM

#### 10.3.1. IMPACT ON TRANSPORTATION IN BMA

The preceding section described various operating conditions of bus service forecasted for 2007 and 2012 with and without the introduction of the trunk bus system. This section discusses the impact of the introduction on the other modes of transport, such as conventional buses and private vehicles. The trunk busway has two lanes for two-way trunk bus traffic and is closed all day to the other traffic. The introduction of the exclusive busway on both sides of the median takes two lanes off the road capacity previously available for the other modes of motorized transport. Conventional buses and private cars are left to use the remaining two to three lanes each way available on both sides of the busway. It is quite possible that the proposed trunk bus system brings some adverse impact on the other modes of transport. This section analyzes this possibility by forecasting the traffic conditions separately for trunk and conventional buses and private vehicles.

#### (1) Average Travel Speed

Table 10.3-1 compares average congestion, average travel speed or velocity, total PCU hours and total passenger hours of three transport modes by alternative case of forecast. Figure 10.3-1 through Figure 10.3-3 show for each mode the change in average velocity by



the ratio to the base year of 2002. The average travel speed of passenger cars slows down noticeably in the “without” cases, for example, by some 40% from 2002 to 2012 (Figure 10.3-1). With the introduction of the trunk bus system, the slowdown is significantly less, i.e., a reduction of velocity is only 12% from 2002 to 2012.

The average travel speed of conventional buses that share the lanes with private passenger cars changes similarly. Without the trunk bus system, their velocity drops sharply, for example, by 55% from 2002 to 2012. By the introduction of the trunk bus system, the slowdown is substantially improved to a velocity reduction of only 25% over the same period (Figure 10.3-2).

The trunk bus system uses the bus priority lane as well as the trunk busway. As shown in Figure 10.3-3, the velocity on the trunk busway is more or less steady over the period, but the average speed on the priority lane, where trunk buses mix with the traffic of conventional buses and private vehicles, drops sharply by 50% from 2002 to 2007. The velocity stays unchanged from 2007 to 2012, but again drops substantially in 2020, a velocity reduction of more than 70% relative to the base year of 2002.

Table 10.3-1 Changes of Traffic Conditions by Mode of Transport

Year/Case		Type of Vehicle	Average Congestion	Average Velocity (km/h)	Total PCU Hours	Total Passenger Hours
2002	Case-1 Without	Passenger Car	0.505	36.9	25,626	7,920
		Conventional Bus		42.3	7,920	99,795
		Trunk Bus on Priority Lane		-	-	-
		Trunk Bus on Trunk Busway	-	-	-	-
		Total Bus	-	-	7,920	99,795
2007	Case-2 Without	Passenger Car	0.695	31.1	50,618	94,655
		Conventional Bus		30.3	11,798	4,473
		Trunk Bus on Priority Lane		-	-	-
		Trunk Bus on Trunk Busway	-	-	-	
		Total Bus	-	-	11,798	4,473
	Case-4 With	Passenger Car	0.587	37.7	42,422	79,328
		Conventional Bus		34.6	6,278	94,563
		Trunk Bus on Priority Lane		21.3	391	10,249
		Trunk Bus on Trunk Busway	0.160	38.2	374	12,288
		Total Bus	-	-	7,043	117,100
2012	Case-3 Without	Passenger Car	1.019	20.9	99,550	186,159
		Conventional Bus		19.6	16,226	250,528
		Trunk Bus on Priority Lane		-	-	-
		Trunk Bus on Trunk Busway	-	-	-	-
		Total Bus	-	-	16,226	250,528
	Case-5 With	Passenger Car	0.753	32.3	76,881	143,769
		Conventional Bus		31.2	7,189	110,169
		Trunk Bus on Priority Lane		21.8	870	20,877
		Trunk Bus on Trunk Busway	0.210	39.4	510	17,085
		Total Bus	-	-	8,569	148,131
2020	Without	Passenger Car	1.856	13.72	220,713	412,733
		Conventional Bus		12.68	19,008	302,207
		Trunk Bus on Priority Lane		-	-	-
		Trunk Bus on Trunk Busway	-	-	-	-
		Total Bus	-	-	19,008	302,207
	Case-6 With	Passenger Car	1.340	19.0	204,335	382,108
		Conventional Bus		18.4	10,603	148,038
		Trunk Bus on Priority Lane		10.7	1,133	26,241
		Trunk Bus on Trunk Busway	0.230	38.8	586	18,604
		Total Bus	-	-	12,322	192,883

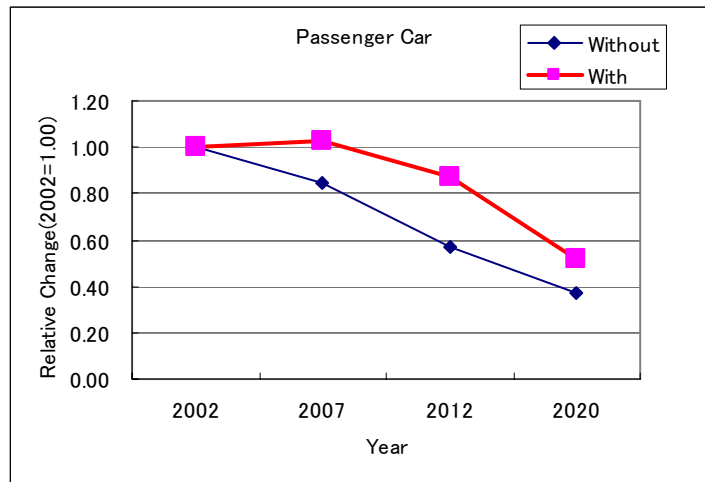


Figure 10.3-1 Relative Change in Velocity for Passenger Cars by “With” and “Without” Case

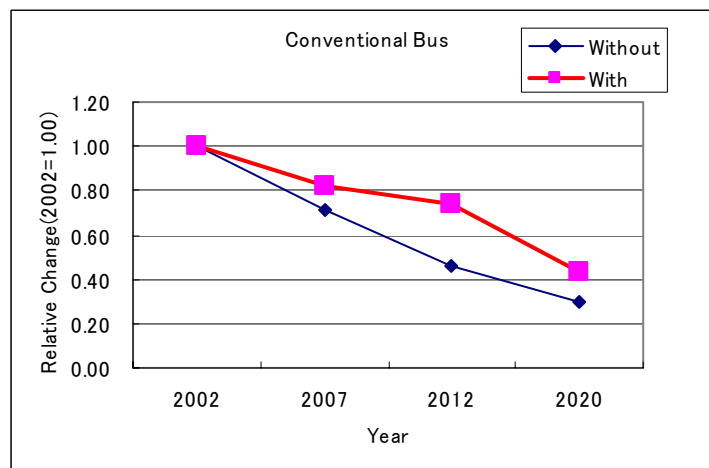


Figure 10.3-2 Relative Change in Velocity for Conventional Buses by “With” and “Without” Case

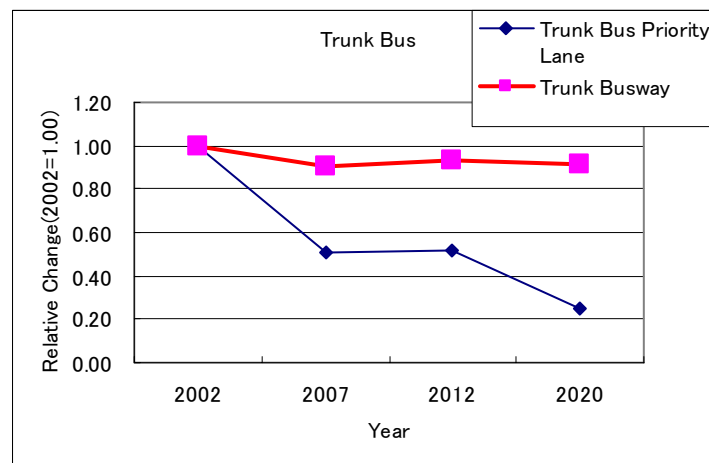


Figure 10.3-3 Relative Change in Velocity for Trunk Buses by “With” and “Without” Case

## (2) Traffic Congestion

Figure 10.3-4 shows the ratio of total traffic volume to total road capacity in the entire study area. For the “without” cases, the traffic volume consists of conventional buses and passenger cars. For the “with” cases, the traffic volume is separated into the conventional buses/cars and trunk buses.

Without the introduction of the trunk bus system, the volume to capacity ratio reaches nearly 1.00 by 2012. With the introduction, the traffic conditions for conventional buses and cars are significantly improved, with the volume to capacity ratio lower by almost 30% in the same year. The volume to capacity ratio is consistently favorable for the trunk bus traffic over the period.

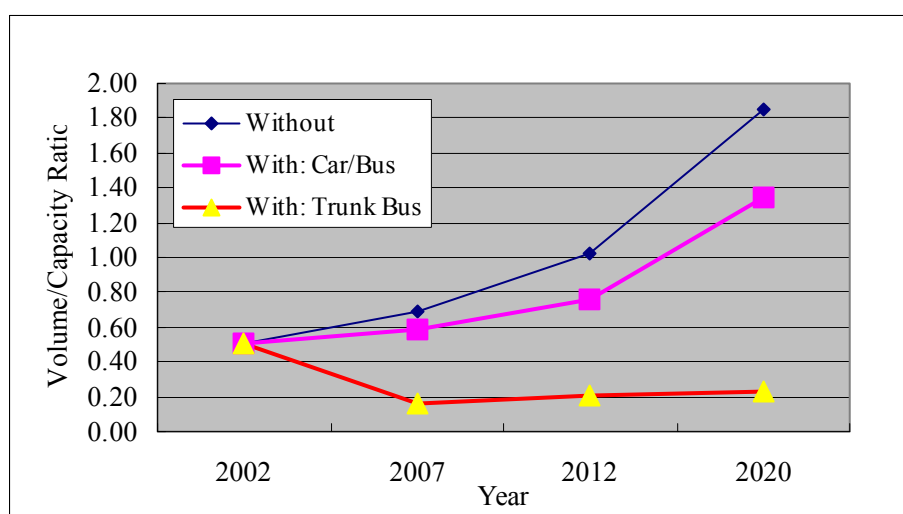


Figure 10.3-4 Volume to Capacity Ratio in the Study Area by “With” and “Without” Case

## (3) Composition of Bus Passenger Demand

Figure 10.3-5 shows the composition of the bus passenger demand in terms of passenger kilometers by alternative case of forecast. The share of trunk bus service is around 30% in 2007 (Case-4) and rises to 40% by 2012 (Case-5). The proposed trunk bus system carries 40% of the forecasted demand when expressed in passenger kilometers.

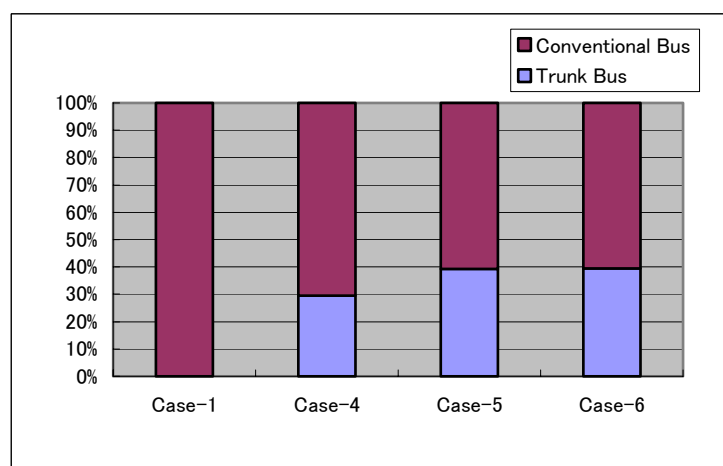


Figure 10.3-5 Share of Trunk Bus Service in Total Bus Passenger Kilometers

### **10.3.2. IMPACT ON MAJOR ARTERIAL ROADS**

The construction of the two-lane trunk busway on major arterial roads in the BMA guarantees the efficient trunk bus operation. The reduction of two lanes off the available road capacity suggests a significant drop of service level for the other modes of transport such as conventional buses and passenger cars. As pointed out in the previous section, however, the proposed trunk bus system serves to improve general traffic conditions for the other modes of transport as well. This section individually examines the impact on major arterial roads that are selected for the proposed trunk bus system.

#### **(1) Impact on Avenida Almirante Barroso**

Figure 10.3-6 shows the level of congestion by the ratio of average traffic volume to road capacity on Avenida Almirante Barroso. Specifically, the volume to capacity ratio pertains to the 5.9km segment from Entroncamento to Sao Braz. In the “without” cases, the level of traffic congestion worsens apace with the growth of demand, as indicated by the volume to capacity ratio reaching as high as 2.0 in 2012. In the “with” cases, the ratio on the through traffic lanes for conventional buses and cars is 1.00 in 2007 and 2012. The ratio is less than 1.0 on the trunk busway over the period. Even if two lanes are used for the exclusive busway, the traffic conditions on the remaining lanes in fact get better for conventional buses and passenger cars.

Figure 10.3-7 compares the inbound travel speed by mode of transport. The “without” cases separate the travel speed into conventional buses and passenger cars. The “with” cases adds the travel speed for trunk buses on the exclusive busway to the other two for conventional buses and passengers cars on the through traffic lanes. As seen from the figure, the travel speed of both conventional buses and cars stays around 10km per hour from 2007 to 2020. In the “with” cases, the trunk bus traffic keeps the travel speed of more than 35km per hour. The speed of both conventional buses and cars on the through traffic lanes is significantly improved relative to the “without” cases, viz., 30km per hour in 2007 and 20km per hour in 2012.

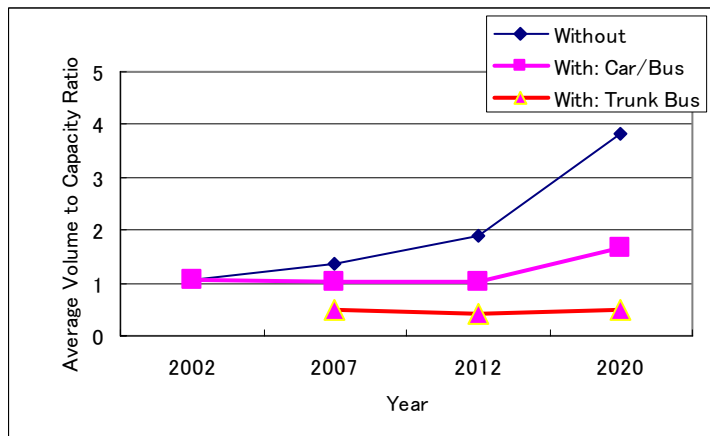


Figure 10.3-6 Average Congestion on Avenida Almirante Barroso

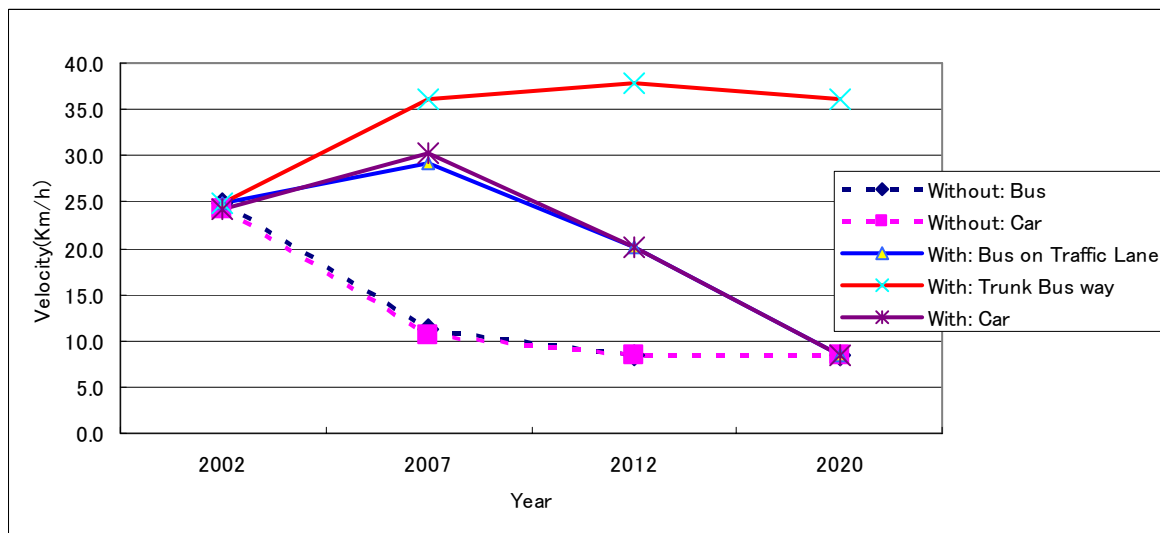


Figure 10.3-7 Travel Speed on Avenida Almirante Barroso

## (2) Impact on Rodovia BR-316

The inbound travel speed on Rodovia BR-316 from Marituba to the intersection with Avenida Mario Covas was about 40km per morning peak hour at the time of the survey in 2002. The speed slowed down to 30km on the segment from the intersection to Entroncamento. In 2002, 32 bus lines were in operation on the former segment and 46 lines on the latter segment. Approximately one half of these lines are transferred to the trunk bus system. The remaining lines, 10 lines on the former and 21 lines on the latter, continue to operate as conventional bus lines.

Figure 10.3-8 shows the level of congestion on the 9.2km segment from Marituba to Entroncamento. In the “without” cases, the traffic congestion worsens apace with the growth of demand, as indicated by the volume to capacity ratio of 1.5 in 2012. In the “with” cases, the ratio on the through traffic lanes for conventional buses and cars is less than 1.00 in 2007 and 2012. The ratio is less than 1.0 on the trunk busway over the period. Even if two lanes are used for the exclusive busway, the traffic conditions on the remaining lanes are better for conventional buses and passenger cars.

Figure 10.3-9 compares the travel speed by mode of transport. In the “without” cases, the travel speed of both conventional buses and cars slows down to 40km per hour in 2007 and to 12km per hour in 2012. In the “with” cases, the trunk bus traffic keeps the travel speed of more than 40km per hour. The travel speed of both conventional buses and cars is significantly improved relative to the “without” cases. Passenger cars travel at 50km per hour in 2007 and 45km per hour in 2012. Conventional buses travel at the speed slower by some 5km per hour than passenger cars.

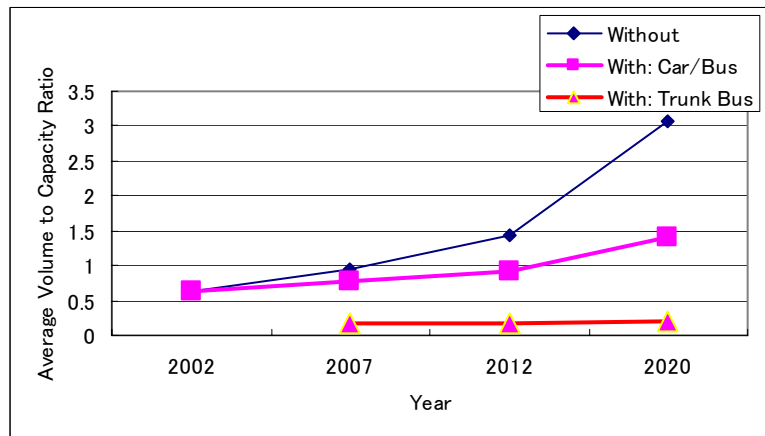


Figure 10.3-8 Average Congestion on Rodovia BR-316

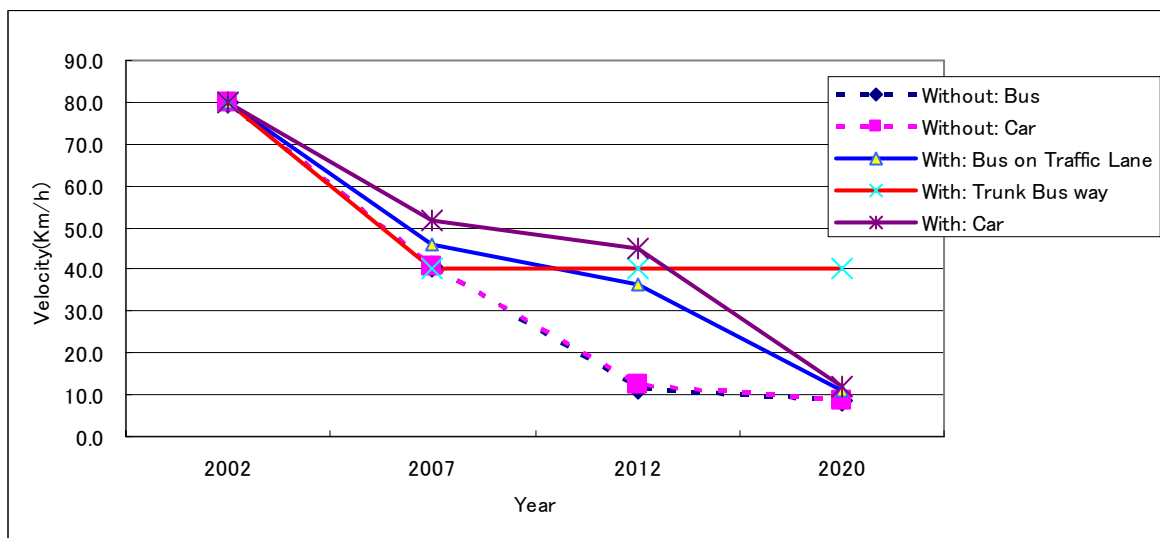


Figure 10.3-9 Travel Speed on Rodovia BR-316

### (3) Impact on Rodovia Augusto Montenegro

At the time of the survey in 2002, the inbound travel speed on Rodovia Augusto Montenegro was about 25km per hour on the two-lane segment and 40km per hour on the three-lane segment near Icoaraci. The travel speed was fast enough until it slowed down to 25km per hour near Entroncamento. In 2002, 8 bus lines were in operation near Icoaraci and 37 lines near Entroncamento. Approximately one half of these lines are transferred to the trunk bus system. The remaining lines, 5 lines near Icoaraci and 20 lines near Entroncamento, continue to operate as conventional bus lines.

Figure 10.3-10 shows the level of congestion on the 13.1km segment from Icoaraci to Entroncamento. In the “without” cases, the traffic congestion worsens apace with the growth of demand, as indicated by the volume to capacity ratio of 1.1 in 2012. In the “with” cases, the ratio on the through traffic lanes for conventional buses and cars is less than 1.00 in 2007 and 2012. The ratio is less than 1.0 on the trunk busway over the period. Even if two lanes are used for the exclusive busway, the traffic conditions on the remaining lanes are better for conventional buses and passenger cars.

Figure 10.3-11 compares the travel speed by mode of transport. In the “without” cases, both conventional buses and cars travel at about 50km per hour in 2007, but their speed slows down by 2012, to 20km per hour for the former and 30km per hour for the latter. In the “with” cases, both conventional buses and cars on the through traffic lanes show a similar slowdown in 2007 and 2012, but their respective travel speed is faster by 7km per hour for the former and 5km per hour for the latter than the “without” cases. The trunk bus traffic keeps the travel speed of about 40km per hour over the period. The positive impact of the trunk busway on the other transport modes is less on Rodovia Augusto Montenegro than on Avenida Almirante Barroso and Rodovia BR-316.

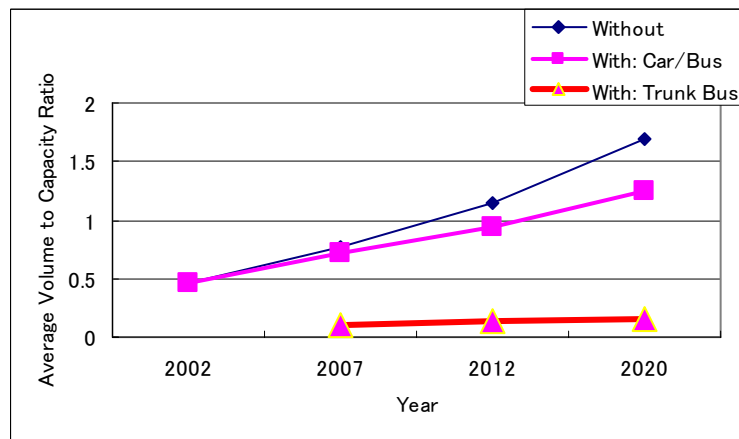


Figure 10.3-10 Average Congestion on Rodovia Augusto Montenegro

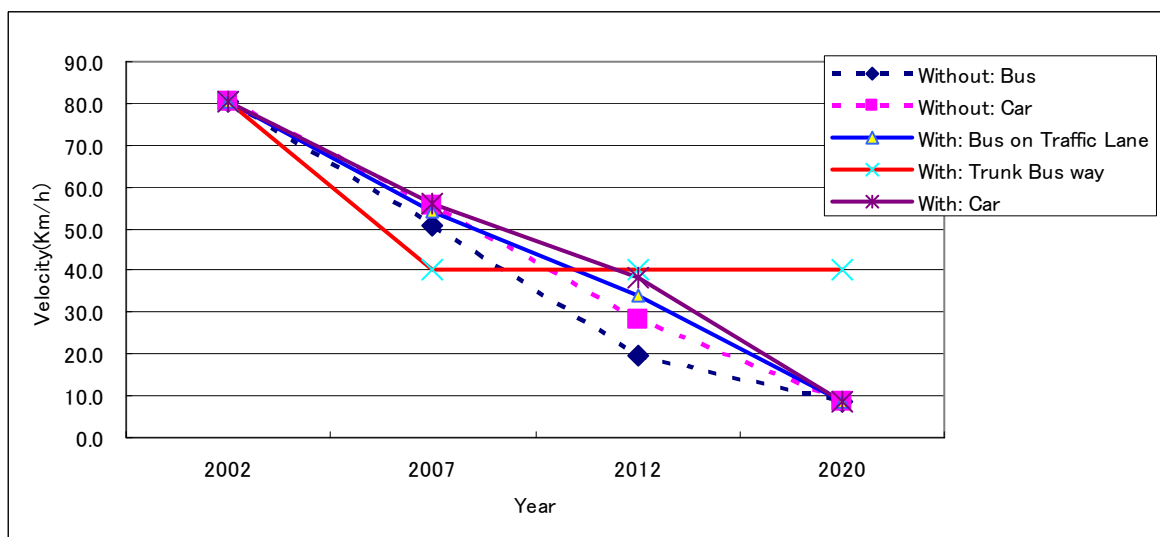


Figure 10.3-11 Travel Speed on Rodovia Augusto Montenegro



#### (4) Impact on Priority Lane in the Centro

The trunk bus priority lane starts from Sao Bras and continues on six roads such as Avenida Governador Jose Malcher, Avenida Visconde de Souza Franco and Avenida Nazare. The priority lane in the Centro is provided on the right-side lane to be used by conventional buses as well as trunk buses. One or two lanes are left for private vehicles like passenger cars. In the “with” forecast for 2007 (Case-4), 93 trunk buses and from 200 to 400 conventional buses use the priority lane per peak hour in the Centro. In 2012 (Case-5), 78 trunk buses via Avenida Almirante Barroso and 45 trunk buses via Avenida Independencia enter the Centro to join on Avenida Marechal Hermes. In addition to 123 trunk buses, from 200 to 400 conventional buses also converge on Avenida Marechal Hermes. At the time of the survey in 2002, the peak hour travel speed of conventional buses in the morning ranged from 10km to 15km per hour.

Figure 10.3-12 shows the level of congestion on the 10.4km priority lane segment in the Centro. The congestion was already apparent in 2002, as indicated by the volume to capacity ratio of over 1.0. The projected trend does not differ between the “with” and the “without” cases, the volume to capacity ratio reaching 1.5 in 2012 and 2.5 in 2020. Given the constraint of the limited rights of way in the Centro, the positive impact of the trunk bus system is hardly expected on six roads earmarked for priority lanes.

Figure 10.3-13 compares the travel speed by mode of transport. In the “without” cases, both conventional buses and passenger cars travel at about 13km per hour in 2007 and 10km per hour in 2012. In the “with” cases, both conventional buses and trunk buses travel at the same speed of 14km per hour in 2007 on priority lanes. Their speed slows down to 12km per hour in 2012. The passenger car traffic on the through traffic lanes is just as slow as buses in 2007 and 2012.

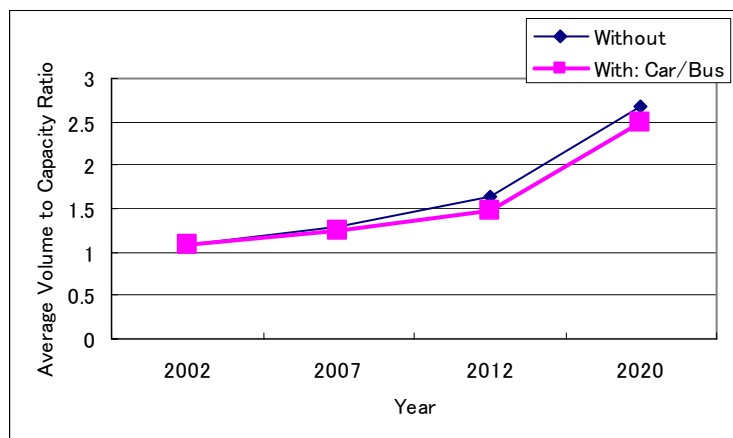


Figure 10.3-12 Average Congestion in the Centro

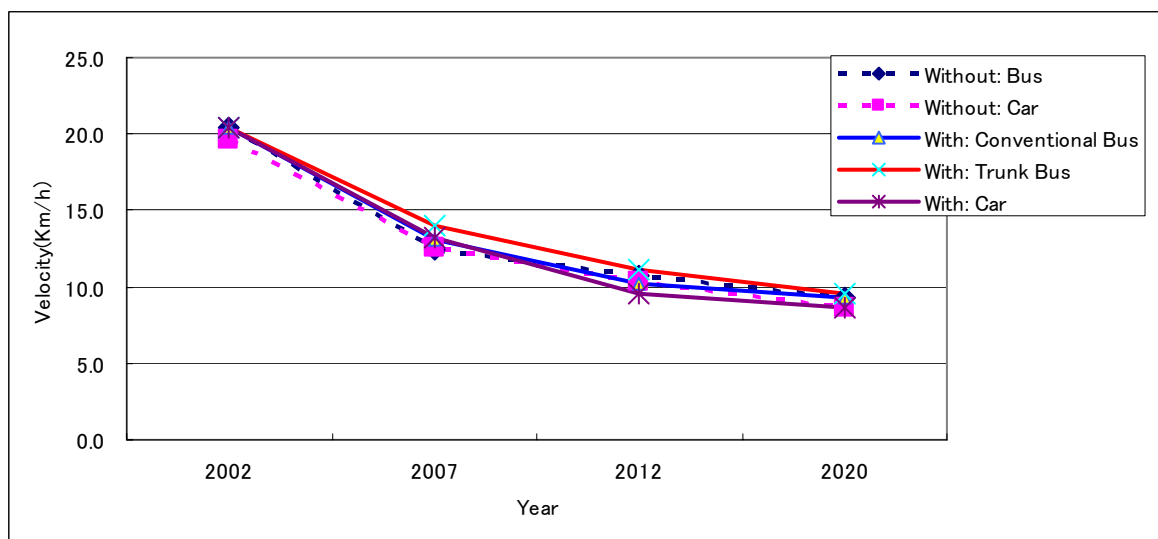


Figure 10.3-13 Travel Speed in the Centro

### 10.3.3. IMPORTANCE OF CENTRO ACCESSING SEGMENT OF AVENIDA INDEPENDENCIA

The “with” forecasts assume that the suburban segment of Avenida Independencia be available in 2007 and that the Centro accessing segment of the avenue be ready for the trunk bus system in 2012. The limited availability of alternative routes forces the inbound traffic demand in the suburbs to converge on Avenida Almirante Barroso for accessing the Centro. The impact of the absence of the said Centro accessing segment on the proposed trunk bus system is analyzed to show its crucial importance. The travel demand forecast for 2012 and the road network assumed for 2007 are used to forecast the inbound traffic of both trunk and conventional buses per morning peak hour. The result of the forecast is shown by road segment in Figure 10.3-15.

Figure 10.3-14 compares the composition of the bus traffic in 2012 on Avenida Almirante Barroso, with (Case-5) and without the Centro accessing segment of Avenida Independencia. Without the segment, the peak hour inbound bus traffic on the avenue consists of 168 trunk buses and 260 conventional buses in 2012. With the segment, the traffic drops to 128 trunk buses and 228 conventional buses. As shown in Figure 10.3-14, the inbound traffic of 168 trunk buses on a single lane means the headway of 21 seconds. Allowing for the time necessary for boarding and alighting and waiting at traffic signals, this would make it very difficult to keep the on-schedule service. It is evident that the Centro accessing segment of Avenida Independencia is indispensable for the efficient operation of the trunk bus system in 2012.

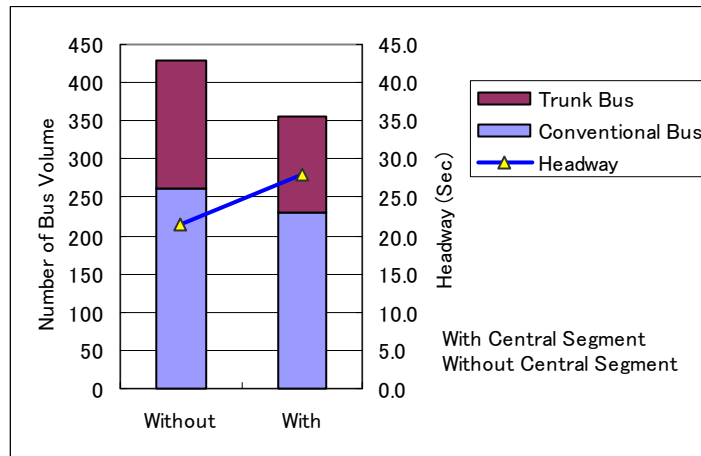


Figure 10.3-14 Peak Hour Inbound Bus Traffic on Av. Almirante Barroso in 2012:

With and Without Centro Accessing Segment of Avenida Independencia

