Chapter 4

Case Study: Simulation Analysis in Jakarta

October 2014

This chapter should be cited as

ERIA (2013), ‘Case Study: Simulation Analysis in Jakarta’, in Kutani, I. (ed.), *Improving Energy Efficiency in the Transport Sector through Smart Development*. ERIA Research Project Report 2013-27, pp.59-81. Available at: http:/www.eria.org/RPR_FY2013_No.27_Chapter_4.pdf

CHAPTER 4
Case Study: Simulation Analysis in Jakarta

Introduction

In this chapter, we will examine specific measures for promoting a modal shift from private to public transport in Jakarta. Methods of promoting a modal shift are diverse—ranging from 'soft' to 'hard'—and appear to vary in terms of benefits and costs. As such, we will apply simulation analysis to quantitatively assess the effect in reducing fuel consumption and its costs when each measure is implemented, and ultimately consider the effectiveness of each.

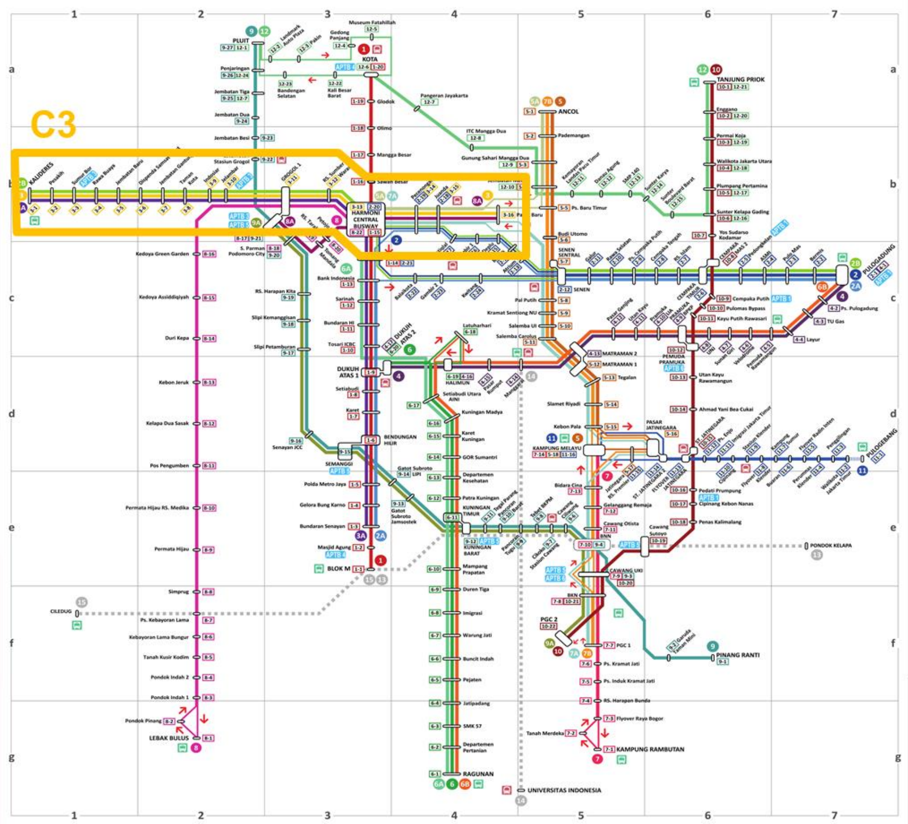
Our subject city is Jakarta, where the BRT system plays a key role in public transport. Consequently, it is necessary to improve the comparative attractiveness of the BRT and encourage its use to promote modal shift in the city. Hence, in this chapter, we will examine several methods for improving the attractiveness of the BRT and evaluate the degree to which each method encourages modal shift and the degree to which it results in reduced fuel consumption.

We will first analyze GPS (global positioning system) tracking data for Corridor 3 provided by TransJakarta to ascertain the current situation of BRT operations. Based on the results of this analysis, we will identify the specific challenges faced in BRT operations and propose solutions that may result in better operations. Then, we will calculate the amount of modal shift when each method is implemented, as well as the amount of reduction in fuel consumption, to evaluate the solutions proposed. Finally, we will discuss the results obtained.

Subject for Simulation-based Analysis

The BRT system in Jakarta began operation in 2004 under the name TransJakarta. As of April 2014, 12 so-called corridors operate within the city (Figure 4-1). TransJakarta is responsible for traffic within Jakarta, and has the combined role of linking the cities around Jakarta (Bogor, Depok, Tangerang, and Bekasi) with the central area of the city. In the study, we have selected Corridor 3—which connects Tangerang city with central Jakarta—as the target of analysis.

Figure 4-1: TransJakarta Route Map



Source: TransJakarta website, http://www.transjakarta.co.id

An overview of Corridor 3 is shown in Figure 4-2. Corridor 3 is a 19-km-long route linking Kalideres Station, close to the border with Tangerang city, with Pasar Bar Station in central Jakarta. Between these two, at Grogol and Harmoni Stations, the route intersects with Corridors 9 and 1, respectively. If we look at the number of passengers from each station in 2009 (Figure 4-3), we see that the highest numbers are at each of the terminal stations and on Corridor 1. According to this, we may expect that in the case of Corridor 3, passengers heading toward central Jakarta from around Kalideres Station and Tangerang city during the morning peak tend to use Corridor 3, and that a large number are connecting to Corridors 1 and 9 to commute to work or school. In this chapter, we will target these passengers commuting to work to determine the potential for modal shift.

Figure 4-2: Overview of Corridor 3

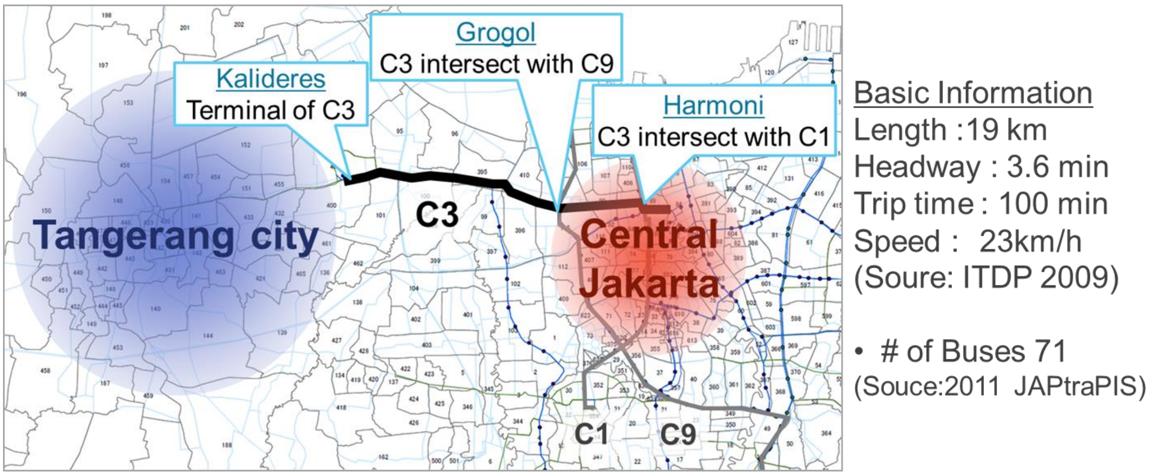
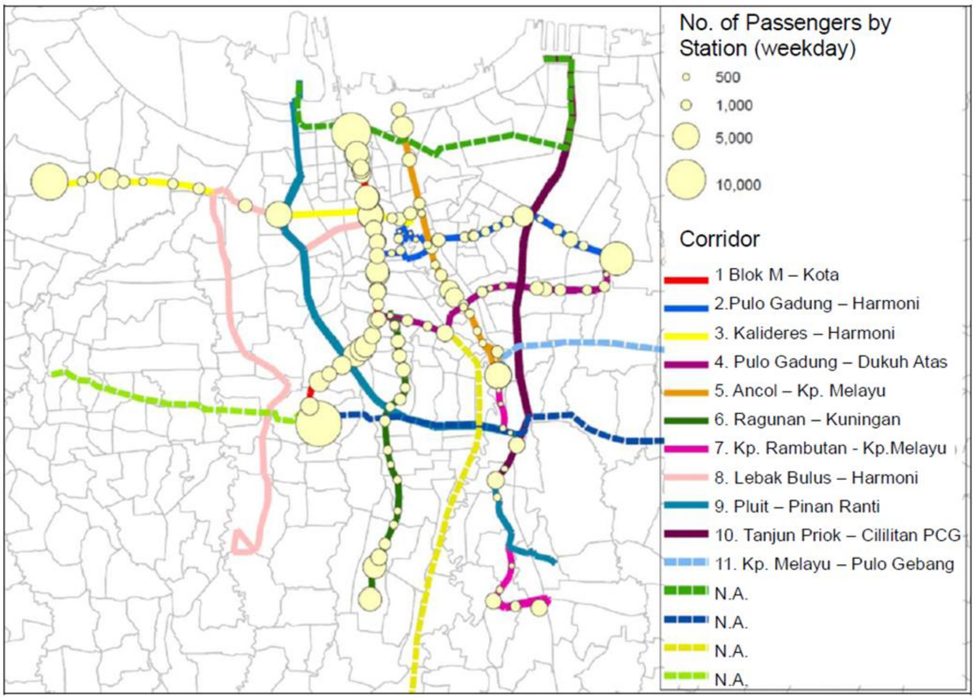


Figure 4-3: Number of Passengers/Day (weekdays) from Each Station, 2009



Source: JAPTraPIS.

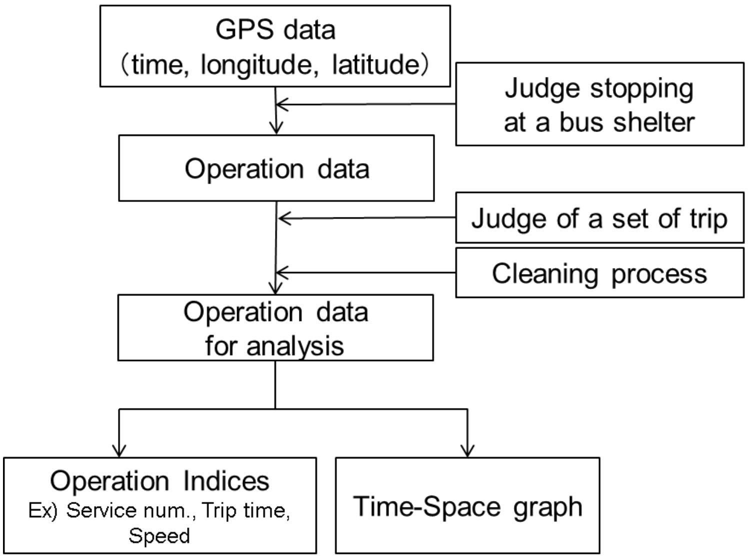
Analysis of Current BRT Operation

Method of analysis

To ascertain the current operations of Corridor 3 and deduce the challenges, we analyzed the bus GPS tracking data provided by TransJakarta. Data was compiled by measuring bus position information every 10 seconds, and so includes data on Corridor 3 operations, as well as on direct operations from Corridor 3 to Corridor 1 or Corridor 2. Data was collected for a one-month period in October 2013.

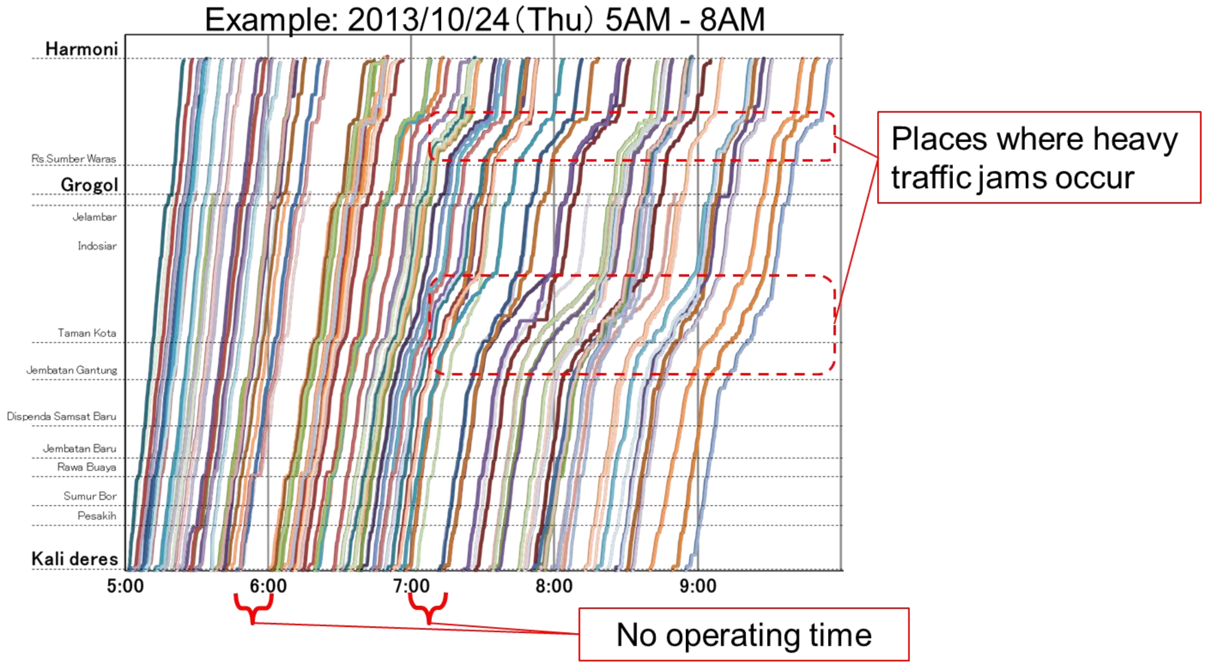
The data analysis process is shown in Figure 4-4. We produced operations data for analysis from the GPS data, and calculated time–space graphs and indices related to the operation situation (service numbers, trip times, speed, etc.).

Figure 4-4: Process of GPS Data Compilation



An example of a time–space graph we produced is shown in Figure 4-5. This uses lines to show the movement of each bus that departed from Kalideres Station between 5 am and 9 am on October 24, 2013 (Thursday). The steeper the gradient of the line, the faster the speed of the bus. Based on this time–space graph, we can see at a glance that there are sections where the operating speed drastically decreases from 7 am (morning rush hour), and that although the operating intervals are fairly spaced overall, there is a period of time before 6 am and another after 7 am when no buses operated. These are among the challenges faced in operations.

Figure 4-5: Example of Time–Space Graph

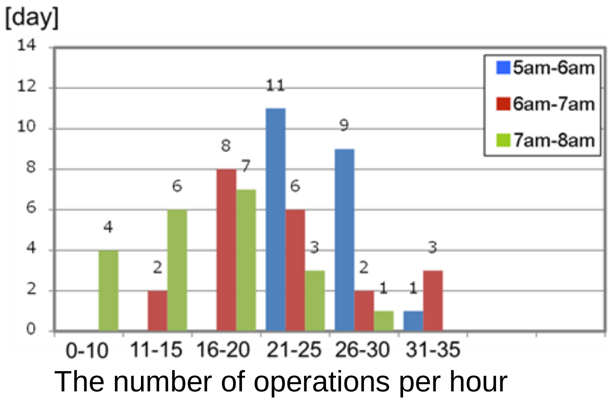


BRT operating situation

To ascertain the situation regarding BRT operations in the morning, we analyzed the time variation of the operation frequency (Figure 4-6). We can see that on weekdays, the operation frequency from 5 am to 6 am is stable, around 25 services per hour, which implies a high level of service. But during the morning peak period—6 am to 7 am and 7 am to 8 am—there is a very high degree of dispersion. For the operation frequency from 6 am to 7 am, on the day when the fewest services were running, there were 14; and on the day when most were running, there were 33, more than twice as many. Due to the relationship between service numbers and user waiting time at bus stops, we may assume that bus waiting times from day to day during the morning peak period largely vary. For service numbers on holidays, on the other hand, we see relatively smaller dispersions than those of weekdays. From the above, we may regard as a challenge the fact that the service numbers cannot be maintained as planned during the morning peak period on weekdays when there are the most users.

The variations of travel time from Kalideres to Harmoni are shown in Figure 4-7. On weekdays, the travel time in the hour from 5 am is short at around 30 minutes, and this varies very little. However, during the morning peak of 6 am to 7 am, the trip times become longer, and we see a very high degree of dispersion. The longest travel time over the period when the data was measured was 91.8 minutes, recorded on October 3 (Monday), which is extremely long. On the other hand, on holidays, the travel time stayed roughly the same as the hour from 5 am on weekdays. All these factors clearly reveal the necessity of improving the system to shorten travel times for the congested periods in the morning on weekdays, and thereby enable stable operation.

Figure 4-6: Histogram of the Operation Frequency on Weekdays (left) and on Holidays (right)



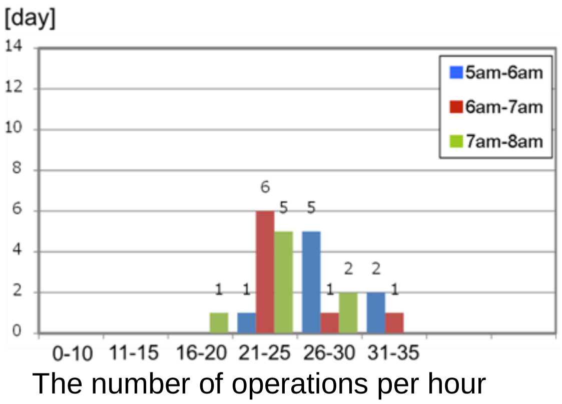
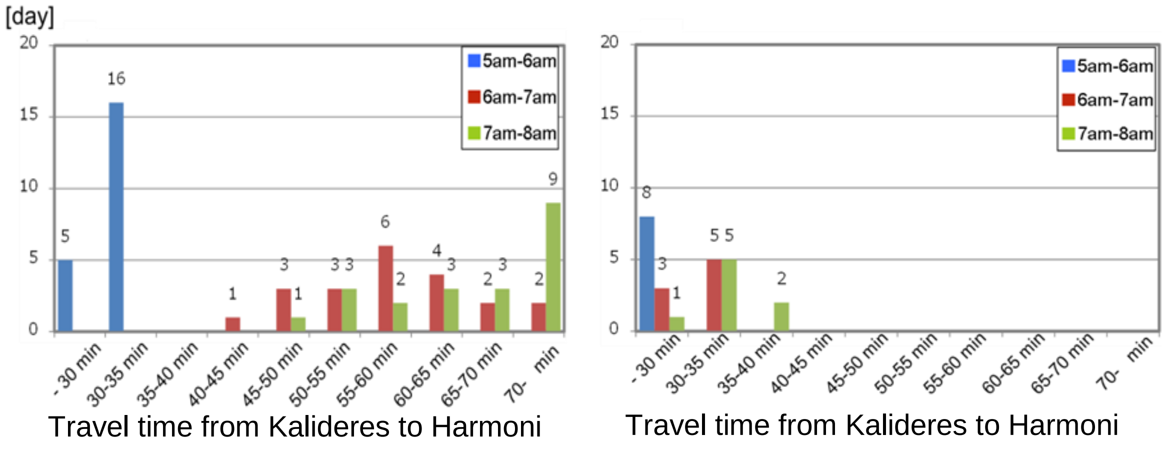


Figure 4-7: Histogram of Travel Time from Kalideres to Harmoni on Weekdays (left) and on Holidays (right)



As noted above, the operation of buses during the morning peak period is unstable. To determine the causes of this, we analyzed the average speeds and average trip times between each pair of stations (Figure 4-8). Looking first at the average speed on holidays, we find that four sections in particular have slower speeds than the others. Because these speeds are slow even on holidays when the amount of traffic is low, we can assume there is a problem in the road infrastructure. Among these four sections, the ones with the longest average travel times, and thus requiring particular improvements, are given below:

- Kalideres Station–Pesakih Station, (1) in Figure 4-8,
- Rs. Sumber Waras Station–Harmoni Station, (3) in Figure 4-8.

Looking next at the average speed on weekdays, we find that there is wide variation in travel speed depending on the time period for several sections. The speeds are reduced in the hours after 6 am and 7 am in particular; one reason could be the fact that during these hours in the morning, private transport interferes with BRT traffic (private traffic enters BRT-dedicated lanes). Of these, the sections requiring improvement that have a particularly wide variation in average travel speed are given below:

- Taman Kota Station–Indosiar Station, (2) in Figure 8;

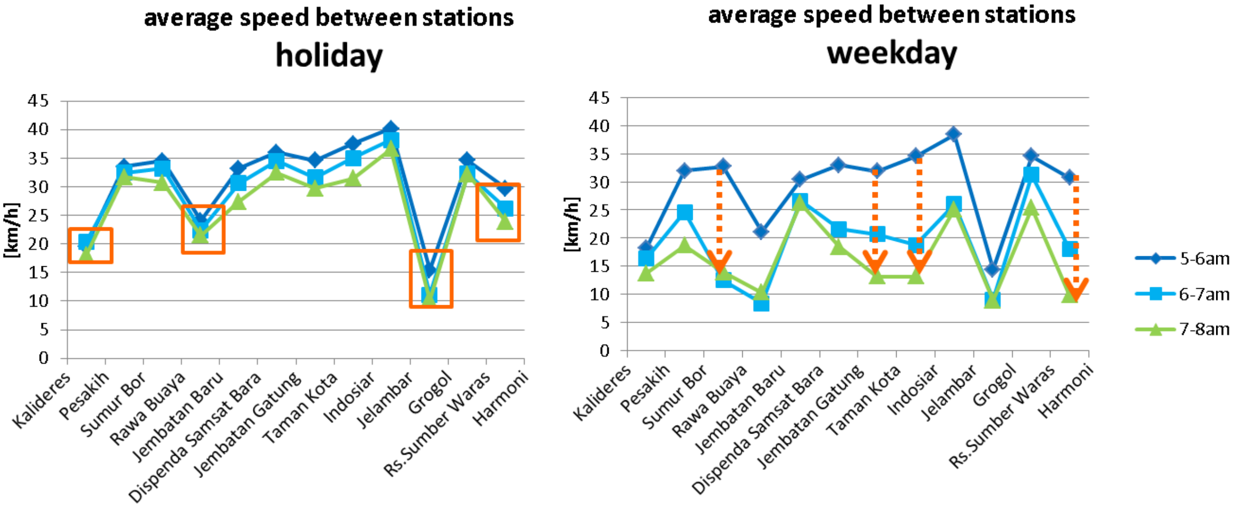
- Rs. Sumber Waras Station–Harmoni Station, (3) in Figure 8.

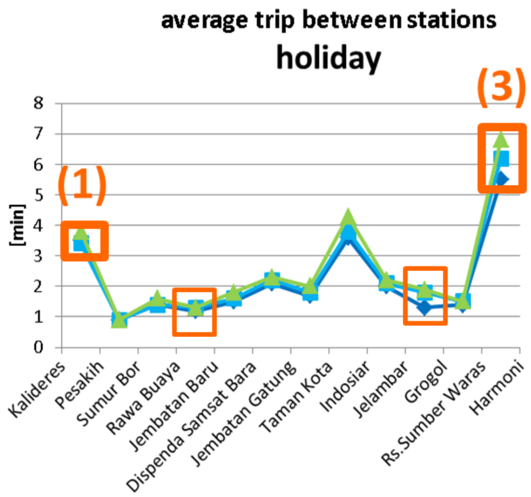
The causes of the decrease in speed on the sections mentioned above are as follows:

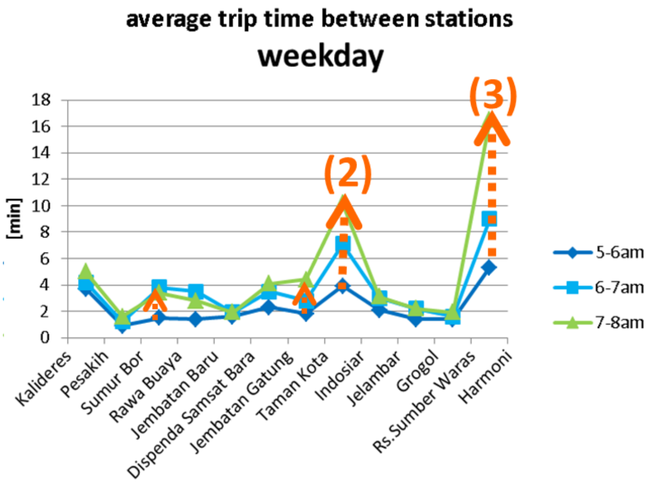
- the intersection infrastructure of the Kalideres Station exit and Daan Mogot road;
- interference with public transport on sections where there are no BRT-dedicated lanes and at their entrances/exits; and
- multiple intersection infrastructure, and interference with private transport on the bridge crossing Ciliwung River, and at its entrance/exit.

(A more detailed analysis of the average speeds between stations is given in Appendix A.)

Figure 4-8: Average Speed between Each Pair of Stations (upper) and Average Travel Time (lower) on Holidays (left) and on Weekdays (right)







Proposed Solutions

We considered solutions based on the above analysis. From the challenges deduced in section 3.2, the following improvement measures may be considered (left graph in Figure 4-9):

- construction of overpasses for sections (2) and (3) where intersection infrastructure are inadequate, and
- strengthening of the regulations for restricting inflow of private transport to BRT-dedicated lanes for sections (1) and (3) where there is a problem of interference with private transport.

Such regulations are in place even now, so priority in their implementation can be envisioned for the selected sections.

In this section, we assumed our target BRT users to be commuters travelling to work in central Jakarta from the vicinity of Tangerang city. The following methods for improvement may be considered from the perspective of improving convenience for these target users (right graph in Figure 4-9):

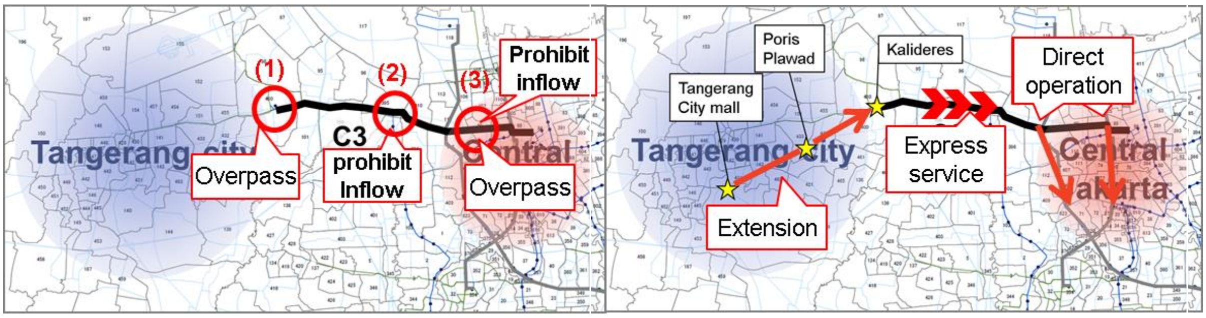
(1) Extending the route to improve access from Tangerang city. The bus stations for this extension to be applied can be envisioned as the locations proposed in JAPTraPis.[1]

[1] The Project for the Study on JABODETABK Public Transportation Policy Implementation Strategy in the Republic of Indonesia (JICA).

(2) Implementing direct operations to eliminate the loss of connection time. We will examine direct operations between the extended routes and Corridor 3, and between Corridor 3 and Corridor 1/Corridor 9.

(3) Implementing an express service on Corridor 3 to shorten trip times. Since express-service bus requires spaces for overtaking normal-service buses, overtaking spaces would be established in up to three places. As an overtaking lane at Dispenda Samsat Bara Station already exists, it would be possible to use this as well.

Figure 4-9: Locations for the Implementation of Improvement Measures



We have categorized the improvement measures listed above as either 'soft' methods, for which investment in road infrastructure is not required, and 'hard' methods, for which such investment is required. Solutions for cases A, B, C, and D in Table 4-1 are proposed. Each measure is explained as follows:

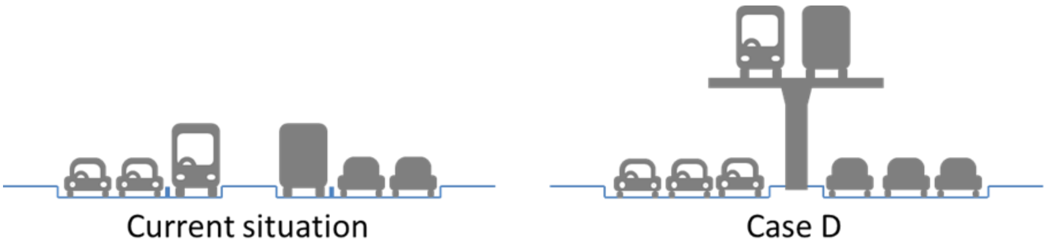
- Case A: strengthening of restrictions of private transport inflow
- Case B: implementation of all 'soft' methods
- Case C: implementation of partial improvement of infrastructure
- Case D: complete segregation of BRT and private transport, such as by elevating the entire BRT lane, and converting existing BRT-dedicated lanes into lanes for private transport (Figure 4-10).

A comparative assessment of these four measures is conducted in the next section. The basis for the cost estimates is described in Appendix B.

Table 4-1: Proposed Solutions

Measures		Case A	Case B	Case C	Case D
Soft	Strengthening restriction of inflow	✓	✓	✓	
	Express service		✓	✓	✓
	Extension + direct operation		✓	✓	✓
Hard	Overpass construction			✓	
	Total elevation				✓
Estimated Extra Cost (million USD) *Does not include land acquisition or operation costs		0	6	31	519

Figure 4-10: Illustration of "Total Elevation" in Case D



Quantitative Assessment of Proposed Measures

The results of each of the proposed measures will be assessed from the perspectives of the amount of modal shift and the amount of reduction in fuel consumption in first and second sections, respectively.

Calculating the amount of modal shift

The amount of modal shift was estimated through the following process:

1. An OD (origin–destination) zone is selected as the subject for modal shift.
2. The benefit for the BRT user when each measure is implemented is calculated. To this end, a table of operation times is produced for cases where each measure is implemented with respect to the current BRT operation situation analyzed in section 3; and factors such as the shortening of trip times required for travelling within each OD are calculated.
3. Based on the result of item 2, the utility function derived in chapter 3 is used to calculate the amount of modal shift.

The traffic heading toward central Jakarta from the vicinity of Kalideres Station and the extended stations in the morning is envisioned as the subject for modal shift, among the traffic passing through Daan Mogot road along Corridor 3. Hence, as shown in Figure 4-11, the regions of around two kilometres from the vicinity of Kalideres Station and the extended stations have been selected as the target origin zones. The regions within a radius of two kilometres of Corridor 1 and Corridor 9 stations in central Jakarta have been selected for the destination zones. The amount of traffic passing along the Daan Mogot road was determined from the result of traffic assignment based on the JUTPI[2] traffic data for 2010 (Figure 4-12).

[2] Jabodetabek Urban Transportation Policy Integration.

Figure 4-11: Selected Origin–Destination Zones

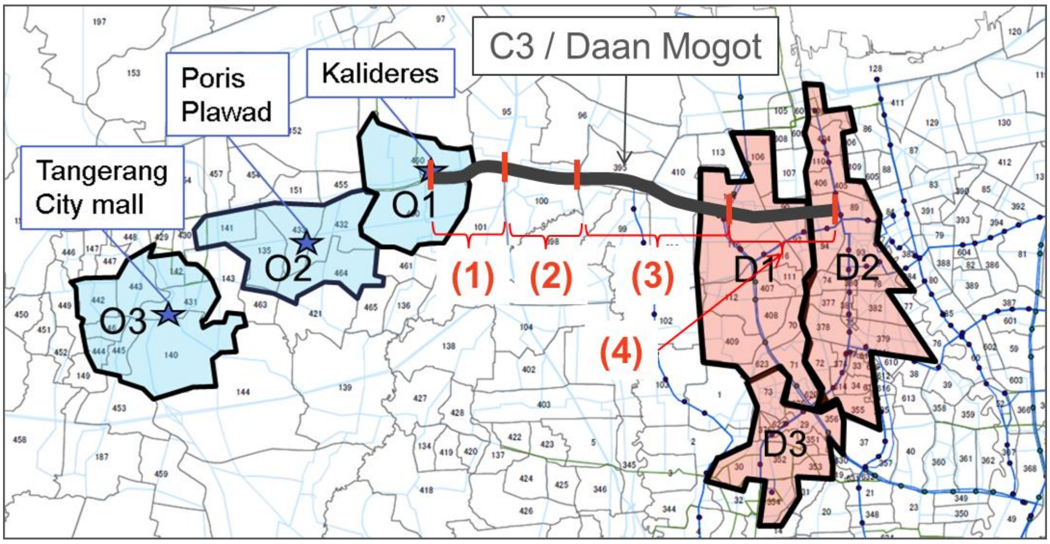
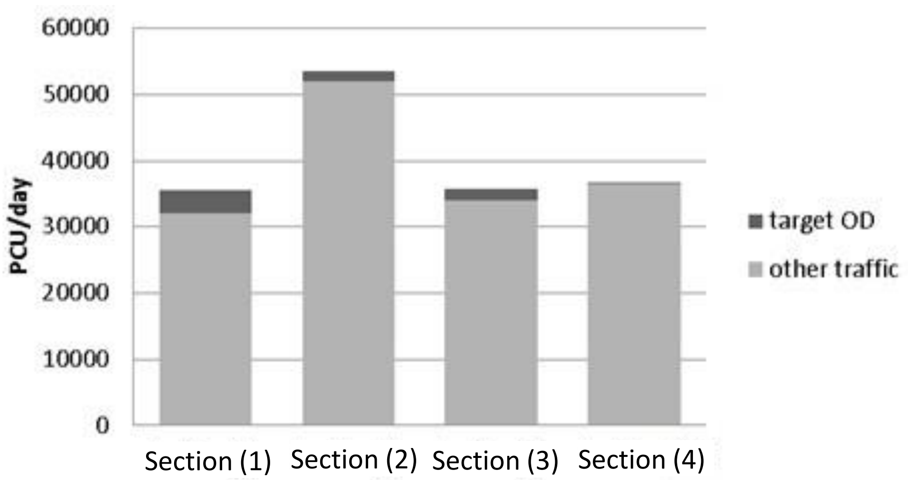
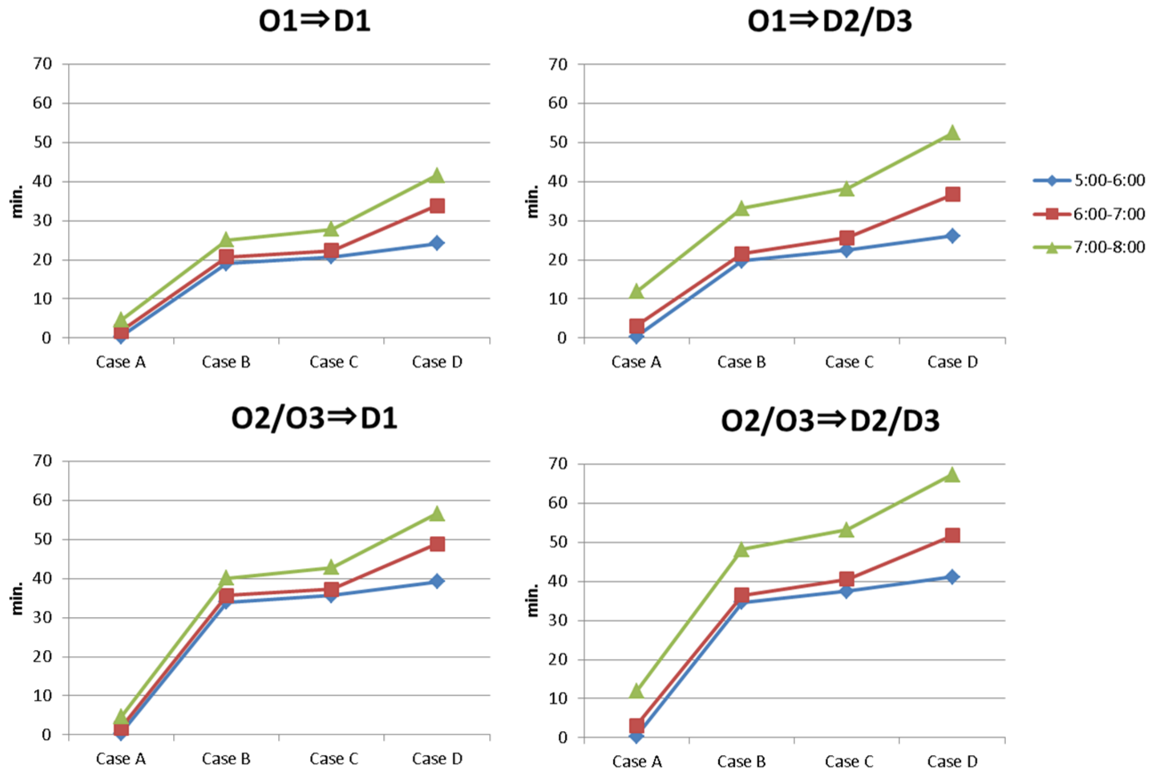


Figure 4-12: Ratio of Target Traffic Amounts in Each Road Section



The reduced trip times when each measure is implemented are shown in Figure 4-13. Regardless of the OD, the trip time is reduced in particular in cases B, C, and D. This is because direct operation is envisioned for these three cases, meaning, a reduction in connection times. The reduced trip time for cases B and C is of the same level, and although dependent on the OD, it is possible to shorten trip times by 20 to 50 minutes. In case D, the trip time can be reduced especially for the morning peak period from 6:00. Depending on the OD, there may even be reductions of 70 minutes. Details of BRT operation schedules produced are shown in Appendix C.

Figure 4-13: Reduced Trip Time for Each Origin–Destination



Note: It is assumed that in cases B, C, and D implementing direct operation, the trip times for users departing O1 would see a reduction in the time spent connecting onto Corridor 1 or Corridor 9 (15 minutes), whilst the trip times for users departing O2 and O3 would see a reduction in connection times at Kalideres Station and onto Corridor 1 or Corridor 9 (each 15 minutes; total 30 minutes).

From the above results, we used the utility function derived from chapter 3 to calculate the rate of modal shift (Figure 4-14). In cases B, C, and D where there was a large reduction in time, the rate of modal shift is high. Although the highest rate of modal shift among cases B, C, and D was found in case D, we see no substantial difference overall. Across all of the cases are particularly high rates of modal shift during the commuting period in the hour from 7 am. In terms of amount of modal shift on Daan Mogot road (Figure 4-15), naturally the largest amount is in case D but no substantial differences are evident between the three cases. Between the three, case B has the lowest costs, and from the perspective of the amount of modal shift, we may regard this as the measure having the most significant benefits with respect to costs. Because the amount of modal shift is large during 7 am to 8 am, it is important when to implement the soft measures envisaged in case B to concentrate on that within this period.

Figure 4-14: Rate of Modal Shift for Each Measure

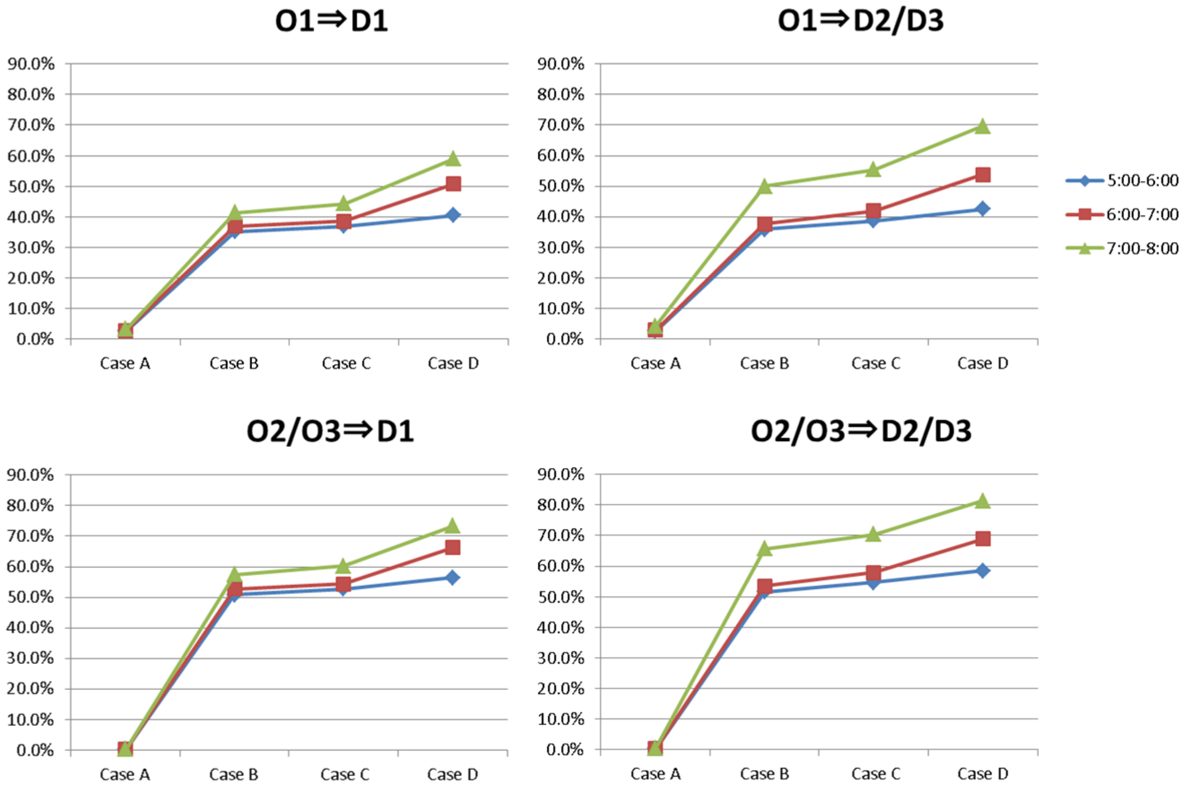
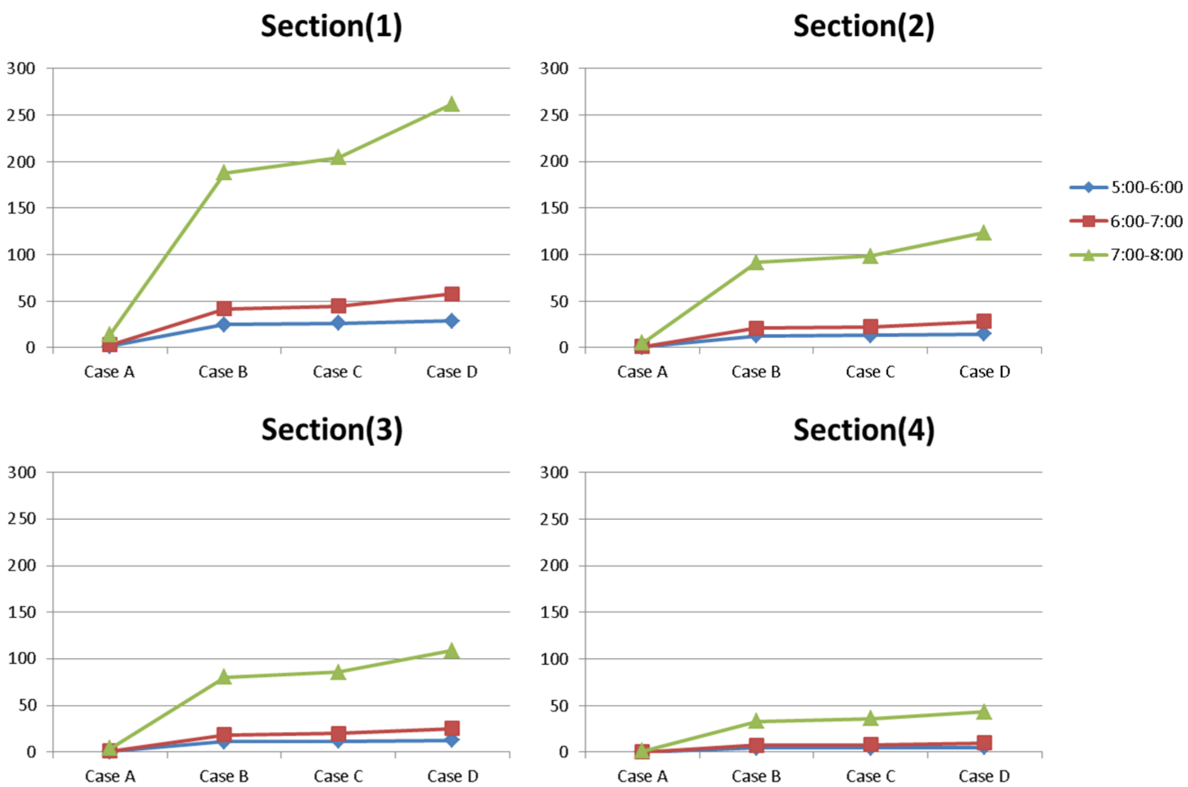


Figure 4-15: Amount of Modal Shift for Each Measure [PCU/h]

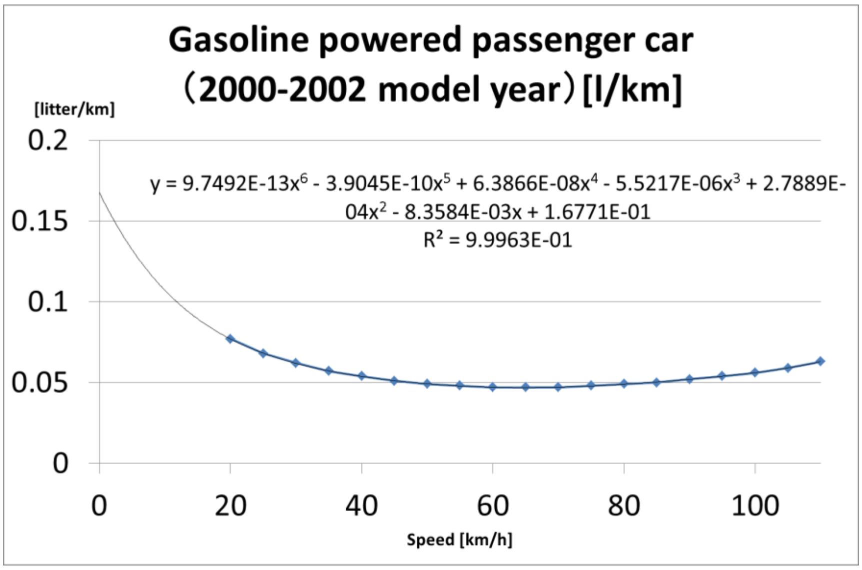


PCU/h = Passenger Car Unit or Passenger Car Equivalent per hour.

Calculating the amount of reduction in fuel consumption

We examined the amount of reduction in fuel consumption by including the direct results of decrease in private transport associated with modal shift and the effects of speed improvement due to the reduction of private transport. For the effects of speed improvement, the increase in speed due to the reduction in private transport was calculated using the BPR function,[3] and the reduction in fuel consumption according to speed was calculated based on the data of the National Institute for Land and Infrastructure Management (Figure 4-16).

Figure 4-16: Rate of Fuel Consumption when Driving an Automobile



Note: Uses a value for speeds less than 20km/h approximated by a polynomial of degree six.

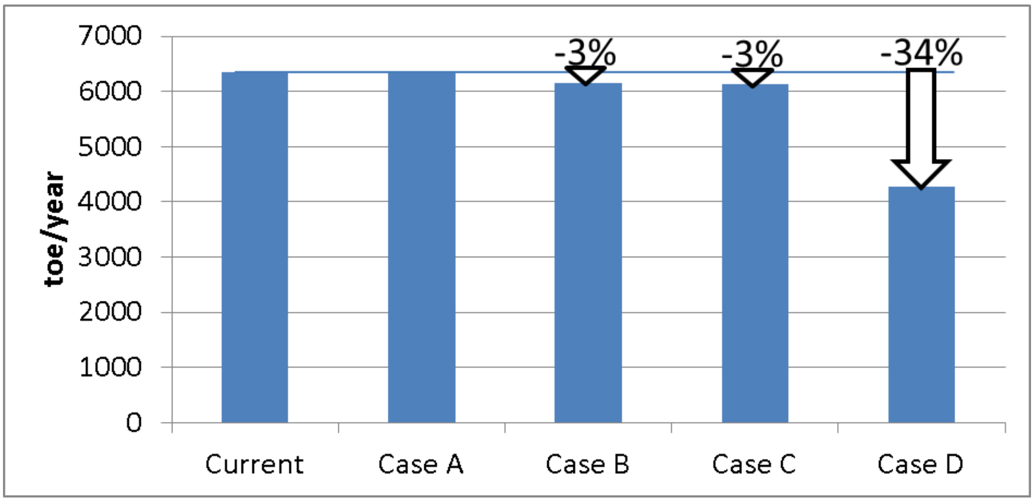
Source: Technical Note of National Institute for Land and Infrastructure Management No. 671, Grounds for the Calculation of Motor Vehicles Emission Factors using Environment Impact Assessment of Road Project, etc. (Revision of FY 2010), http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0671.htm

The results of decreased fuel consumption are shown in Figure 4-17. The largest effects were in case D, with a reduction of 1.0 ktoe/year. This results in a reduction of approximately 34 percent from the original amount of fuel consumed. The 'soft' measures of case B had a similar decreasing effect as

[3] The Bureau of Public Roads developed a link (arc) congestion (or volume-delay, or link performance) function.

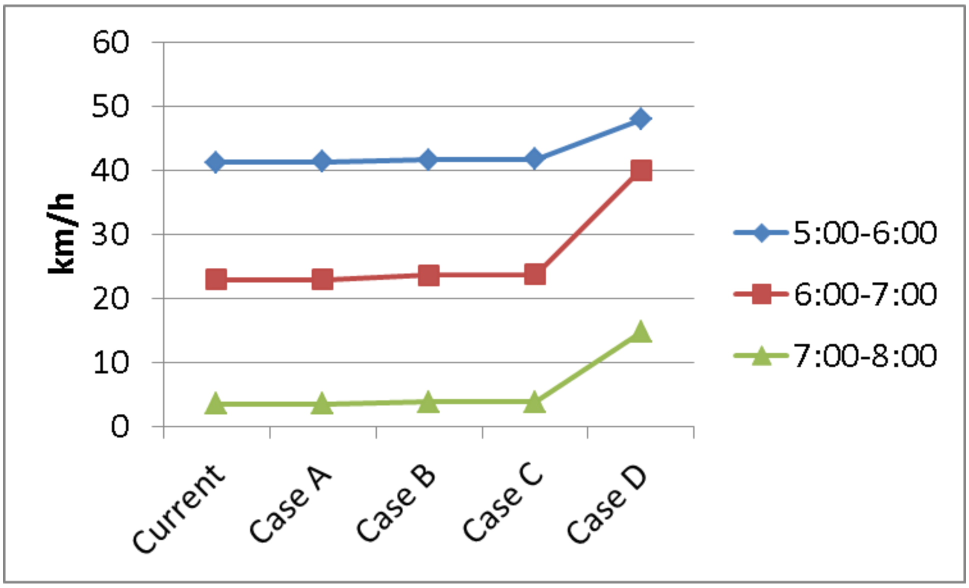
case C which includes some ‘hard’ measures, at 0.1 ktoe/year. Case A had the least effects compared with the other measures. The reason for the substantial decreasing effects in case D lies in the drastic improvement in the speed of private transport (Figure 4-18). Since the BRT-dedicated lane was converted into a lane for private transport, the speed of the latter improved, resulting in improved fuel economy.

Figure 4-17: Amount of Fuel Consumption Reduction for Each Measure



Note: The amount of decrease in fuel consumption for a year was approximated by taking the effects for three hours in the morning, multiplying this by two due to a similar effect during the evening peak, and multiplying this by 365 to get the annual amount.

Figure 4-18: Average Speed for Private Transport



What degree of effects would we expect if these measures were applied to all 12 corridors in Jakarta? Based on the results on Corridor 3, we get approximately 24.8 ktoe/year decrease in fuel consumption with case D, and approximately 2.3 ktoe/year with case B.[4] These are equivalent to approximately 1.3 percent and 0.1 percent, respectively, of the gasoline consumption in Jakarta, of 1.92 Mtoe/year.[5]

Looking forward, there are plans to increase the number of BRT routes. For example, a plan has been proposed in JAPTraPIS to increase the number of corridors to 30 by 2020. If case B or case D were to be adopted in all these 30 corridors, we could anticipate decreases in fuel consumption of 3.8 ktoe/year and 41.3 ktoe/year, respectively.

[4] Based on the effects of decreasing fuel consumption on Corridor 3, the amount expected by application to 12 corridors was estimated by multiplying by 12.

[5] Approximated from the 2013 ERIA working group data, given the product of the amount of fuel consumption in Jakarta in 2009 of 200 toe/1000 persons, and the city's population in 2010 of 9.6 million.

Figure 4-19: Decrease in Fuel Consumption if Applied to 12 Corridors

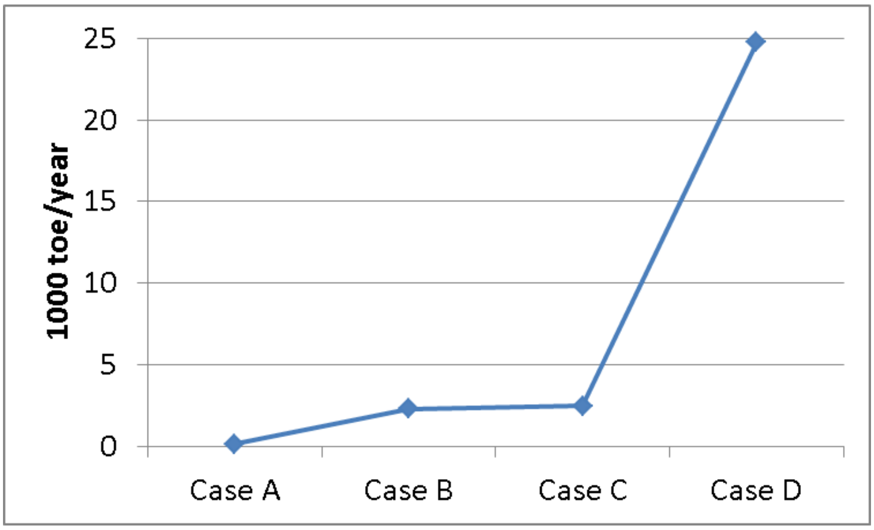
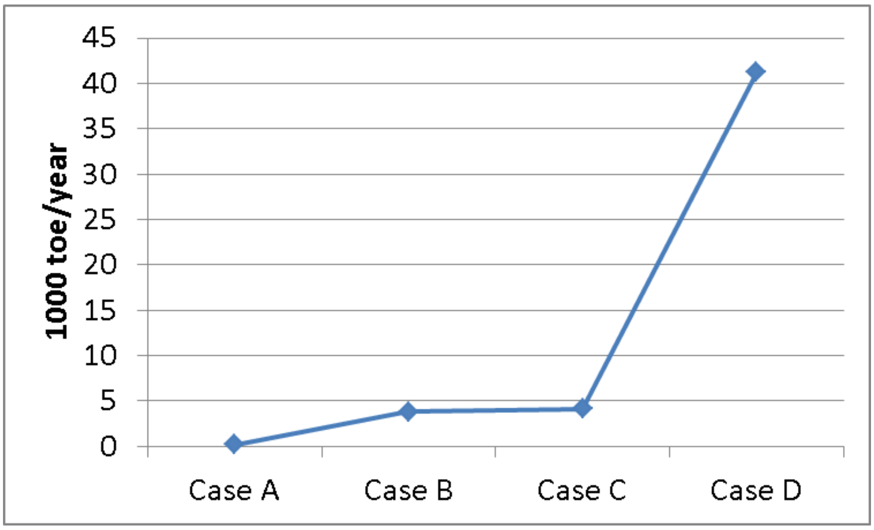


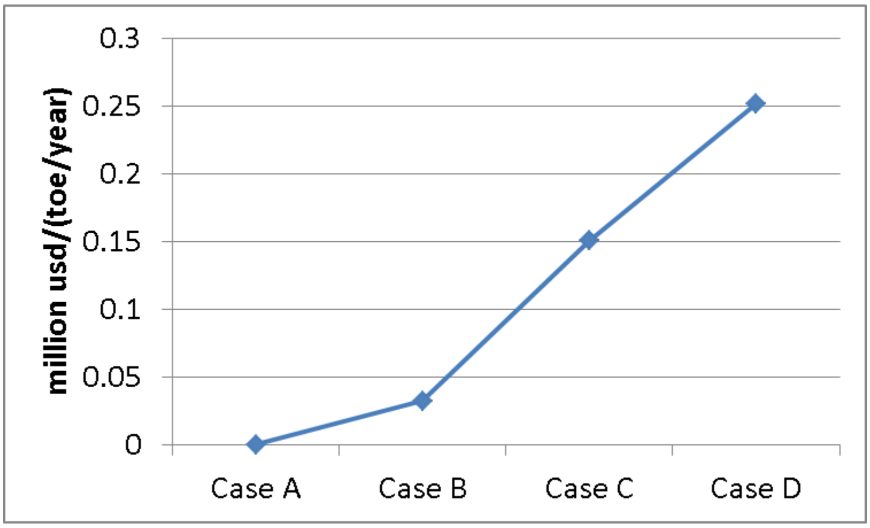
Figure 4-20: Decrease in Fuel Consumption if Applied to 30 Corridors



Cost and benefit balance

The challenge here is the expectation that the costs will be higher and more time will be required for implementing case D than the other measures. As an alternative option to case D, if those with the next highest effects in fuel consumption decrease, cases B and C, are compared in terms of cost performance (Figure 4-21), then case B would appear to be cheaper. Accordingly, whilst efforts are made to implement case D as soon as possible, it is desirable to pursue case B as an interim measure until the former starts to be implemented. Although case B is worse than case D in terms of the amount of decrease in fuel consumption, around 80 percent of the amount of modal shift of case D can be expected. Thus, by implementing case B in advance of case D, perhaps the foundation can be created for modal shift. Meanwhile, in order to discuss the cost performance accurately, it is necessary to consider the O&M (operation and maintenance) cost, attainable benefits other than decrease in fuel consumption, such as economic effects.

Figure 4-21: Cost Required for a Decrease in Fuel of 1toe/yr



Discussion

From the above analyses, we learned that the effects of decreasing fuel consumption were highest for case D. This is a measure that completely segregates private transport and the BRT to achieve faster speeds on both modes of transport. In this sense, case D may also be perceived as a measure that replaces the BRT with the MRT (metro or train). Because the MRT has a higher transport capacity than the BRT, it would appear to be more appropriate as a key transport system in cities with large traffic volumes. Based on the current situation in Jakarta, that of extremely high traffic volumes and severe congestion, we assume a sequential change from roads to the MRT is required.

Our examination in this chapter produced results suggesting that for each measure in cases B, C, and D, the rates of modal shift for the target OD are high at over 40 percent (Figure 4-14). On the other hand, the target ODs account for only a small proportion of the overall volume of traffic (Figure 4-12). Taken as a whole, the modal shift effects are somewhat limited. This means that for the total traffic in Jakarta, the ratio of coverage for the existing

BRT route network is low, and the number of potential BRT users itself is small. If the number of potential BRT users could be increased by further expanding the BRT network and developing housing in the vicinity of BRT stations, for example, and the measures proposed in this chapter are then applied, better results could be anticipated.

Key Findings

In this chapter, we used GPS tracking data to analyze actual bus operation. By so doing, we confirmed that the current operation status varies from day to day, making it difficult for users to forecast their travel times using the BRT. We specified places where the problems are caused, and deduced that these were sections that require focused improvement. By analyzing actual operation data in this way, it becomes possible to elicit the specific challenges to advance modal shift, and propose concrete solutions.

We then made a comparative assessment of the proposed measures. Various levels of measure were examined, and the following proposals were made to enhance modal shift.

1. The number of routes should be increased and a transport plan coordinated with residential planning should be implemented to increase the coverage rate of public transport. This is the foundation for improving the efficiency of all kinds of modal shift.
2. It is necessary to completely segregate public and private transport on roads and routes where the traffic load is concentrated. Doing so could maximize the benefits of public transport and encourage modal shift, whilst also making the flow of both private and public transport smoother and preventing energy waste. In Jakarta, we propose the sequential change from BRT to MRT for routes with high traffic volumes. If this were applied to the whole of Jakarta (12 corridors), then a decrease in 24.7 ktoe/year, or 1.29 percent, of gasoline consumption could be expected.
3. Until the above measures are set in place, efforts should be made to improve operation by, for example, introducing express and direct services for the BRT. Although these measures have comparatively

small effects in decreasing fuel consumption compared to the other measures above, the effects in terms of modal shift are substantial. Accordingly, this would appear to be a key move for increasing the modal shift effects when implementing large-scale measures like the MRT. We propose that express services, direct operation, and extension of routes be implemented in Jakarta; in addition to a strengthening of restrictions of private transport inflow into dedicated lanes. If these could be implemented for the whole of Jakarta (12 corridors), then a decrease in 5.7 ktoe/year, or approximately 0.3 percent, of gasoline consumption could be expected.

Measures for expanding public transport, such as items 1 and 2 above, must be executed in a way that is compatible with the rate at which traffic demand is increasing. However, further expansion of the BRT and the MRT in large cities like Jakarta, where traffic demand and chronic congestion are already extremely high, is associated with significant difficulties like further exacerbation of congestion caused by the factors below:

- BRT expansion – decrease in the number of car lanes to ensure BRT-dedicated lanes
- MRT construction – temporary interruption of traffic due to construction work, and reduction in the number of car lanes.

To promote modal shift, measures may be considered for making the benefits of public transport outweigh those of private transport due to automobile parking costs, maintenance costs, and adoption of limits on usage and speed. However, measures such as these are difficult to implement under conditions where alternative public transport systems are unable to provide adequate capacity.

Considering these factors, it is clearly necessary to guarantee public transport with sufficient capacity and wide-ranging coverage to preempt the increase in traffic demand in cities that are certain to continue developing in the future. In ASEAN countries, many cities will experience growth going forward. This implies that cities have the potential for rapid increase in traffic demand. By conducting analysis on cities like these, perhaps a more effective discussion aimed at improving the efficiency of energy usage in the transport sector will become necessary and possible.