LPEM-FEBUI Working Paper - 062
July 2021

ISSN 2356-4008

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LPEM-FEB UI Working Paper 062

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LPEM-FEB UI Working Paper 062, July 2021
ISSN 2356-4008

Quantifying the Impacts of COVID-19 Mobility Restrictions on Ridership and Farebox Revenues: The Case of Mass Rapid Transit in Jakarta, Indonesia*

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Abstract

This paper studies the impact of mobility restriction on daily mass rapid transit (MRT) ridership in Jakarta-Indonesia, and its implication for the farebox revenues during the pandemic COVID-19 outbreak. For the analysis, we primarily used the fare cost and daily passenger datasets of 156 origin-destination pair routes from April 2019 to May 2021. Three types of mobility restrictions are examined: (i) 50% of maximum passenger capacity setting, (ii) station closures, and (iii) changes in service operating hours. A panel dynamic fixed-effects regression model was fitted to quantify the economic losses on farebox revenue due to the mobility restrictions. We find that the average daily MRT ridership decrease by 56.6% due to capacity restriction, 32.6% due to station closures, and 1.7% due to a one-hour decrease in service operating hours. The station closures lead to a route diversion with a significant increase in ridership among other stations. While the effects of capacity restriction and changes in service operation hours have a larger impact during weekdays, the effect of station closure is more pronounced during the weekend. Our estimation results also reveal that the mobility restrictions during the COVID-19 pandemic have caused a loss of IDR 179.4 billion or equal to USD12.4 million in terms of potential farebox revenues to the MRT train service operator. This amount could contribute to 65.6% of total realized farebox revenues in 2019–2020. This finding suggests the importance of adjusting the tariff subsidy policy in times of crisis, considering that the company still bears the operating costs despite decreasing operating hours. It also advises the company to take this crisis as momentum to enhance operational efficiency and expand the business prospect from non-fare box revenue.

JEL Classification: L92; O18; R40

Keywords

COVID-19 — pandemic — public transport — MRT — ridership — mobility restriction

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1. Introduction

The coronavirus 2019 (COVID-19) outbreak has posed unprecedented serious threats to global society by not only affecting the health condition of people but also slowing economic growth for almost all economic sectors. To prevent the spread of the virus from getting wider and to mitigate the negative impact of COVID-19 on economic activities, many governments and authorities in cities or countries have taken a substantial number and variety of policies, including lockdowns, zonal quarantines, and social distancing at different scales over a period of months (Cheng et al, 2020). In the urban transport sector, there are imposed restrictions on people's mobility especially for those who use public transport because the public transit facilities are recognized as high-risk environments for the transmission of COVID-19 virus particles (i.e., Gutiérrez et al., 2020; Shen et al., 2020; Zhen et al., 2020). The travel restrictions thus lead to a significant decline in daily ridership (e.g., Eisenmann et al., 2021; Jenelius & Cebecauer, 2020; Tiikkaja & Viri, 2020).

Recent works of literature have examined the relationship between COVID-19 and government interventions on human mobility and public transport ridership. Park (2020) found that the social distancing decreases the mean daily number of passengers in all subway stations in Seoul, South Korea by or 40.6% by the first week of the COVID-19 pandemic. Fatmi (2020) revealed that individuals' participation in daily out-of-home activities in Canada was reduced by more than 50% during COVID-19. Almlöf et al. (2020) found that decreases in public transport use during the COVID-19 pandemic in Sweden are linked to areas with a population of high socioeconomic status. Travel satisfaction during the COVID-19 outbreak also significantly influences public transport ridership (Dong et al., 2021; Khaddar & Fatmi, 2021).

From the perspective of urban transport operators, the travel restriction and social distancing policy during the pandemic crisis clearly has influenced the financial perfor-

*The views expressed in this article are those of the authors alone and do not necessarily reflect the official views of the Institute for Economic and Social Research.

mance of transport service companies in a negative direction. Decreasing daily ridership rates due to either authorities' restrictions or travelers' own choices would imply economic losses (both directly and indirectly) for companies by generating lower farebox and non farebox revenues. The situation can be more difficult and raises awareness about the financial risks for some early-stage public transport companies, at least in the short term, especially when considering that the granted subsidy for public services obligation could become smaller and the operating cost likely remains unchanged or slightly increases.

In the context of public transport services provided by an early-stage public transport company, the case of mass rapid transit (MRT) development in Jakarta, can be a fascinating example to examine how the government policy response related to COVID-19 has a consequence on the farebox revenue of the rail-based transport operator through the ridership channel. The MRT was started to operate in March 2019, exactly one year before the first case of COVID-19 in Indonesia.

Since the national government of Indonesia and the regional government of Jakarta took one of the limited available options for Health Quarantine Action called PSBB or "Large-Scale Social Restrictions" in April 2020, the daily ridership rate of MRT in Jakarta has been dramatically declining. The limitations on operational hours and maximum seat capacity as well as station closures are three among other interventions of mobility restrictions related to COVID-19 protocol which have significantly contributed to the low ridership issue.

The aim of this paper is to estimate the impact of COVID-19 mobility restrictions on the daily MRT ridership in Jakarta and to measure the potential farebox revenue losses resulted from the implementation of three types of mobility restrictions as the response from the newly emerged rail-based company. By primarily utilizing the datasets of fare cost per trip and the daily MRT ridership from April 2019 to May 2021, our study addresses the following questions: (1) how does each type of COVID-19 related intervention on mobility restriction influence the daily MRT ridership on average? and (2) how much do the potential farebox revenue losses result from each intervention?

To the best of our knowledge, this is the first study to estimate the effect of COVID-19 related mobility restriction on ridership and to evaluate the monetary impact in terms of farebox revenue generation using a case of mass rapid transit.

The rest of the paper is organized as follows. Section 2 describes the interventions related to the COVID-19 protocol on mobility restriction for MRT users and the trend of MRT ridership during pandemic COVID-19. Section 3 describes the data and the methodology used to estimate the impacts. Section 4 presents the estimation results. The last section concludes the paper.

2. Mobility Restrictions and the Trend of Daily MRT Ridership During the COVID-19 Pandemic

The MRT has been projected as a promising rail-based urban transport mode and it has the potential to become the backbone of integrated public transportation systems in a metropolitan city like Jakarta. The infrastructure of MRT are relatively newly established and still have more than two phases of development for the next 5-10 years. In 2019, the average daily MRT ridership is approximately 86,200 passengers per day and grew by about 2.8% percent per month and by a long-term projection the average daily MRT ridership in Jakarta will reach one million passengers in 2030 (MRT, 2020a).

Figure 1 shows the matrix of share of the daily passengers of MRT by the origin-destination pair routes in 2019. The red-highlighted cells indicate the most popular origin-destination pair routes (i.e., 1.5 times above the standard deviation of total daily ridership). It can be shown that the passenger flows are less dispersed across routes. The reason is that some of these routes are not only connected to larger employment and shopping centers but also other mass public transport facilities. For example, a public bus terminal or a commuter train station. At the station level, Lebak Bulus Grab and Bundaran HI are the two busiest MRT stations. A combined share of these two stations is equal to as much as one-third of the total daily passenger.

Since the beginning of its full commercial operation in 2019, the MRT train service is available from 05:00 to 24:00. In a normal pre-COVID19 situation, the MRT train headway departures every 5 minutes during rush hours at 07:00-09:00 (only from Monday to Friday) and every 10 minutes during normal hours. However, to respond to the implementation of the PSBB due to the COVID-19 pandemic outbreak in Jakarta, the MRT operator company has set adjustments in terms of 50 percent of maximum capacity load, station closures, and operational hours of MRT train fleets. Few stations were shut down gradually and the adjustments of operating hours were varied along with the upward and downward trends of COVID-19 infections in the city. We summarize the sequence of station closures and adjustments of operating hours in Table 2 and Table 3, respectively. Due to the pandemic COVID-19 outbreak, the average daily MRT ridership dropped by about 68%. The rate of ridership is equal to 27,100 passengers per day in 2020.

Figure 2 shows the changes in the trend of average daily MRT ridership before and after the implementation of PSBB in Jakarta (separated by the red line) for each station during weekdays and weekends. All stations are visually having a similar pattern but with various gaps. Before the PSBB was implemented, there was a significant difference between weekdays and weekends. The average ridership per day for weekdays is 1.3 times as higher as for weekends. The ratio increases to 2.1 after the PSBB was implemented. It suggests that the work and school commuters play a critical role in shaping the gap of travel demand for MRT train service as the real impact exceeds the actual 50% maximum capacity restriction. Changes in people behavior for doing their daily routine activities such as work, school, and shop-

Departure from:		Arrival at:													
	STATION	Lebak Bulus Grab	Fatmawati	Cipete Raya	Haji Nawi	Blok A	Blok M BCA	ASEAN	Senayan	Istora Mandiri	Bendungan Hilir	Setiabudi Astra	Dukuh Atas BNI	Bundaran Hotel Indonesia	TOTAL BY ARRIVAL
	Lebak Bulus Grab	-	0.12%	0.22%	0.17%	0.22%	1.31%	0.31%	1.39%	1.02%	1.82%	0.96%	1.21%	5.81%	14.55%
	Fatmawati	0.12%	-	0.09%	0.09%	0.13%	0.61%	0.20%	0.95%	0.71%	1.22%	0.61%	0.60%	1.93%	7.25%
	Cipete Raya	0.29%	0.07%	-	0.05%	0.05%	0.32%	0.06%	0.42%	0.25%	0.44%	0.27%	0.32%	1.01%	3.54%
	Haji Nawi	0.23%	0.07%	0.05%	-	0.03%	0.20%	0.03%	0.25%	0.13%	0.28%	0.17%	0.25%	0.65%	2.35%
	Blok A	0.27%	0.13%	0.06%	0.03%	-	0.26%	0.06%	0.23%	0.12%	0.25%	0.19%	0.29%	0.63%	2.51%
	Blok M BCA	1.62%	0.70%	0.43%	0.25%	0.30%	-	0.12%	0.55%	0.33%	0.60%	0.48%	1.20%	2.55%	9.15%
	Asean	0.38%	0.21%	0.10%	0.06%	0.09%	0.19%	-	0.11%	0.06%	0.13%	0.08%	0.34%	0.37%	2.12%
	Senayan	1.47%	0.88%	0.51%	0.30%	0.24%	0.68%	0.09%	-	0.15%	0.44%	0.35%	1.41%	1.34%	7.86%
	Istora Mandiri	1.15%	0.74%	0.36%	0.20%	0.16%	0.54%	0.06%	0.19%	-	0.68%	0.50%	1.91%	1.35%	7.84%
	Bendungan Hilir	1.80%	1.22%	0.56%	0.39%	0.27%	0.87%	0.13%	0.61%	0.52%	-	0.16%	1.29%	0.92%	8.73%
	Setiabudi Astra	1.04%	0.63%	0.34%	0.24%	0.20%	0.75%	0.10%	0.59%	0.48%	0.20%	-	0.88%	0.85%	6.30%
	Dukuh Atas BNI	1.23%	0.56%	0.35%	0.28%	0.28%	1.26%	0.34%	1.47%	1.49%	0.94%	0.76%	-	0.91%	9.88%
	Bundaran HI	5.44%	1.78%	1.10%	0.71%	0.58%	2.95%	0.34%	1.56%	1.05%	0.70%	0.61%	1.07%	-	17.89%
	TOTAL BY DEPARTURE	15.05%	7.11%	4.17%	2.77%	2.53%	9.95%	1.84%	8.30%	6.32%	7.72%	5.15%	10.76%	18.32%	

Figure 1. Share of Daily Passenger of MRT Jakarta (Phase 1) by Origin-Destination Route, 2019

Source: MRT Jakarta, unpublished data (authors' calculation)

ping into work-from-home (WFH), distance learning, and online shopping explain why the real impact is beyond than expected.

Table 1. MRT Station Closures in 2020

Station	Period	Length of Days
Haji Nawi	20 April 2020–4 June 2020	45 days
Blok A	20 April 2020–4 June 2020	45 days
ASEAN	20 April 2020–4 June 2020	45 days
Istora Mandiri	23 April 2020–4 June 2020	42 days
Setiabudi Astra	23 April 2020–4 June 2020	42 days
Senayan	27 April 2020–4 June 2020	38 days
Bendungan Hilir	27 April 2020–4 June 2020	38 days

Source: Annual Report of PT MRT Jakarta (2020, pp. 173)

3. Data and Methodology

3.1 Dataset

For the purpose of analysis in this study, we construct and combine the dataset from various sources. First, the main interest of data is the amount of ridership at each of 13 stations of the North-South Line MRT Jakarta (Phase 1). We obtained the ridership data from the MRT operator company. The daily ridership is based on passenger counting data. The data we use for the analysis covers the period from April 2019 to May 2021 on a daily basis. Next, the information about the time of station closures and changes in MRT operating hours during pandemic COVID-19 outbreak were obtained from the Annual Report 2019–2020 of the Mass Rapid Transit Jakarta Ltd. For the period beyond 2020, we obtain the information from the company's official press release, which can be found at MRT Jakarta's website (https://jakartamrt.co.id/id/siaran-pers).

We also collect additional information regarding the fare cost per trip and the list of the date of public holidays. The fare cost per trip for each origin-destination route was publicly available to download from the MRT Jakarta Website at https://jakartamrt.co.id/id/tarif-mrt-jakarta, while the list of public holidays in 2019–2021 can be retrieved from https://publicholidays.co.id.

Using google maps, we manually record the latitude and longitude location of MRT stations in order to be able to calculate the geographical distance to the nearest station of other two urban mass transport mode facilities in the Jakarta area (i.e., TransJakarta - Bus Rapid Transit bus stop and KRL Commuter Line - train station). We provide a brief summary and the descriptive statistic of variables in Table 1 and 2, respectively.

3.2 Empirical Model

We employ a panel dynamic regression estimator with origin-destination (OD) pair route and daily fixed effects as the main strategy in our analysis. We choose the fixed-effects estimator to control for time-invariant heterogeneity of OD pair routes and time-variant shocks that may simultaneously affect all the OD pair routes in order to be able to reduce any potential endogeneity issue.

In addition, OD pair route fixed-effects capture any selection biases which may arise due to the over-representation of popular routes in the ridership data distribution as a result of their location characteristics. For example, the accessibility to other mass public transit facilities, distance to employment and shopping centers, etc.

Daily fixed-effects arrest the effects of time-varying factors common to all OD pair routes such as the period of COVID-19, the implementation of PSBB, the application of three types of intervention on mobility restriction. Time-fixed effects are jointly significant. Errors are clustered at OD pair route level as the daily ridership is not evenly distributed across OD pair routes and also to obtain robust standard errors a remedial measure for heteroscedasticity.

Given the availability of data, our analysis is restricted to the time period 1 April 2019–31 May 2021. Note that, in some cases, we also shorten the period of observations and aggregate the daily ridership data of each OD pair route into station level and line level to conduct appropriate analysis. Our model covers 13 MRT stations and 156 OD pair routes.

To answer our first research question, we use a model of the panel dynamic fixed-effects regression method that

Table 2. Adjustments to the Operational Hours of MRT Trains in 2020–2021

Year	Month	Period	Operating Hours		Length of Operating Hours	
			Weekdays	Weekend	Weekdays	Weekend
2020	April	1–9 April	06:00–20:00	06:00–20:00	14 hours	14 hours
		10–19 April	06:00–18:00	06:00–18:00	12 hours	12 hours
		20–30 April	06:00–18:00	06:00–18:00	12 hours	12 hours
	May	1–31 May	06:00–18:00	06:00– 18:00	12 hours	12 hours
	June	1–4 June	06:00–18:00	06:00–18:00	12 hours	12 hours
		05–June	05:00–21:00	05:00–21:00	16 hours	16 hours
		6–30 June	05:00–21:00	06:00–20:00	16 hours	14 hours
	July	1–31 July	05:00–21:00	05:00–20:00	16 hours	15 hours
	August	1–31 August	05:00–22:00	06:00–20:00	17 hours	14 hours
	September	1–16 September	05:00–22:00	06:00–20:00	17 hours	14 hours
		17–20 September	05:00–20:00	05:00–20:00	15 hours	15 hours
		21–30 September	05:00–19:00	05:00–19:00	14 hours	14 hours
	October	1–11 October	05:00–19:00	05:00–19:00	14 hours	14 hours
		12–31 October	05:00–21:00	06:00–20:00	16 hours	14 hours
	November	1–30 November	05:00–21:00	06:00–20:00	16 hours	14 hours
	December	1–17 December	05:00–21:00	06:00–20:00	16 hours	14 hours
		18–31 December	05:00–20:00	06:00–20:00	15 hours	14 hours
2021	January	1–10 January	05:00–20:00	06:00–20:00	15 hours	14 hours
		11–25 January	05:00–20:00	06:00–20:00	15 hours	14 hours
		26–31 January	05:00–21:00	06:00–20:00	16 hours	14 hours
	February	1–10 February	05:00–21:00	06:00–20:00	16 hours	14 hours
		11–28 February	05:00–22:00	06:00–20:00	17 hours	14 hours
	March	1–9 March	05:00–22:00	06:00–20:00	17 hours	14 hours
		10–31 March	05:00–22:00	06:00–21:00	17 hours	15 hours
	April	1–18 April	05:00–22:00	06:00–21:00	17 hours	15 hours
		19–30 April	05:00–23:00	06:00–21:00	18 hours	15 hours
	May	1–20 May	05:00–23:00	06:00–21:00	18 hours	15 hours
		21–23 May	05:00–22:00	06:00–21:00	17 hours	15 hours
		24–31 May	05:00–21:30	06:00–21:00	16,5 hours	15 hours

Source: Annual Report of PT MRT Jakarta (2020, pp. 163) and authors' compilation of MRT official press releases during 2021

Table 3. List of Variables

Dependent variable	
ridership	Total daily ridership counts (in persons)
Independent variables	
hour	Length of MRT operation hours at day *i*-th (hours)
fare	Fare cost per trip per person (in IDR)
pandemic	Dummy for COVID-19 outbreak/PSBB declaration (since March 2020)
closure	Dummy for station closure at day *i*-th
pubholiday	Dummy for public holiday at day *i*-th
access_brt	Dummy for access to TransJakarta bus stop within a radius of 500 m
access_rail	Dummy for access to KRL Commuter Line train station within a radius of 500 m

Table 4. Descriptive Statistic of Variables

Variable	Observations	Mean	Std. Dev.	Min	Max
ridership	114,494	294.86	547.52	0	15,648
hour	114,494	17.39	2.18	12	19
fare	114,494	6,615.39	2,949.29	3	14
pandemic	114,494	0.65	0.48	0	1
closure	114,494	0.05	0.21	0	1
pubholiday	114,494	0.11	0.31	0	1
access_brt	114,494	0.15	0.36	0	1
access_rail	114,494	0.15	0.36	0	1

can be written into the following equation:

$$\begin{aligned}\ln(ridership_{it}) \quad = \quad & \beta_0 + \beta_k \sum_{k=1}^{7} \ln(ridership_{i,t-k}) \\ & + \beta_8 . \ln(fare_i) + \beta_9 . hour_t \\ & + \beta_{10} . pandemic_t + \beta_{11} . closure_{it} \\ & + \beta_{12} . pubholiday_t + \beta_{13} . access\_brt_j \\ & + \beta_{14} . access\_rail_j + \theta_i + \theta_j + \theta_t \\ & + \theta_m + \theta_y + \varepsilon_{it} \qquad (1)\end{aligned}$$

$ridership_{it}$ is the total daily ridership counts (measured in persons) in OD pair route i for day t. We included seven periods lagged of total daily ridership as explanatory variables because it can reasonably be assumed that the ridership level is determined by its past level and to defend the existence of autocorrelation in the regression. One may argue that the use of a lagged dependent variable in the fixed effects estimator may cause a serious problem as by construction lagged dependent variable and error term are correlated. The negative biases on estimates for positive coefficients may arise in short panels with small time periods. Since our daily dataset is a panel with long time periods, we thus can address the negative bias issue. Moreover, we still obtain consistent results when the specification is modeled without including the lagged dependent variable.

$fare_i$ is the fare cost per trip per person (in IDR unit) for a trip of OD pair route i, while $hour_i$ is the number of MRT operation hours for day t. In addition, $pandemic_t$ is a dummy variable equal to one if the observation is measured during the period of COVID-19 outbreak or after the first day of PSBB declaration in March 2020 and zero other-

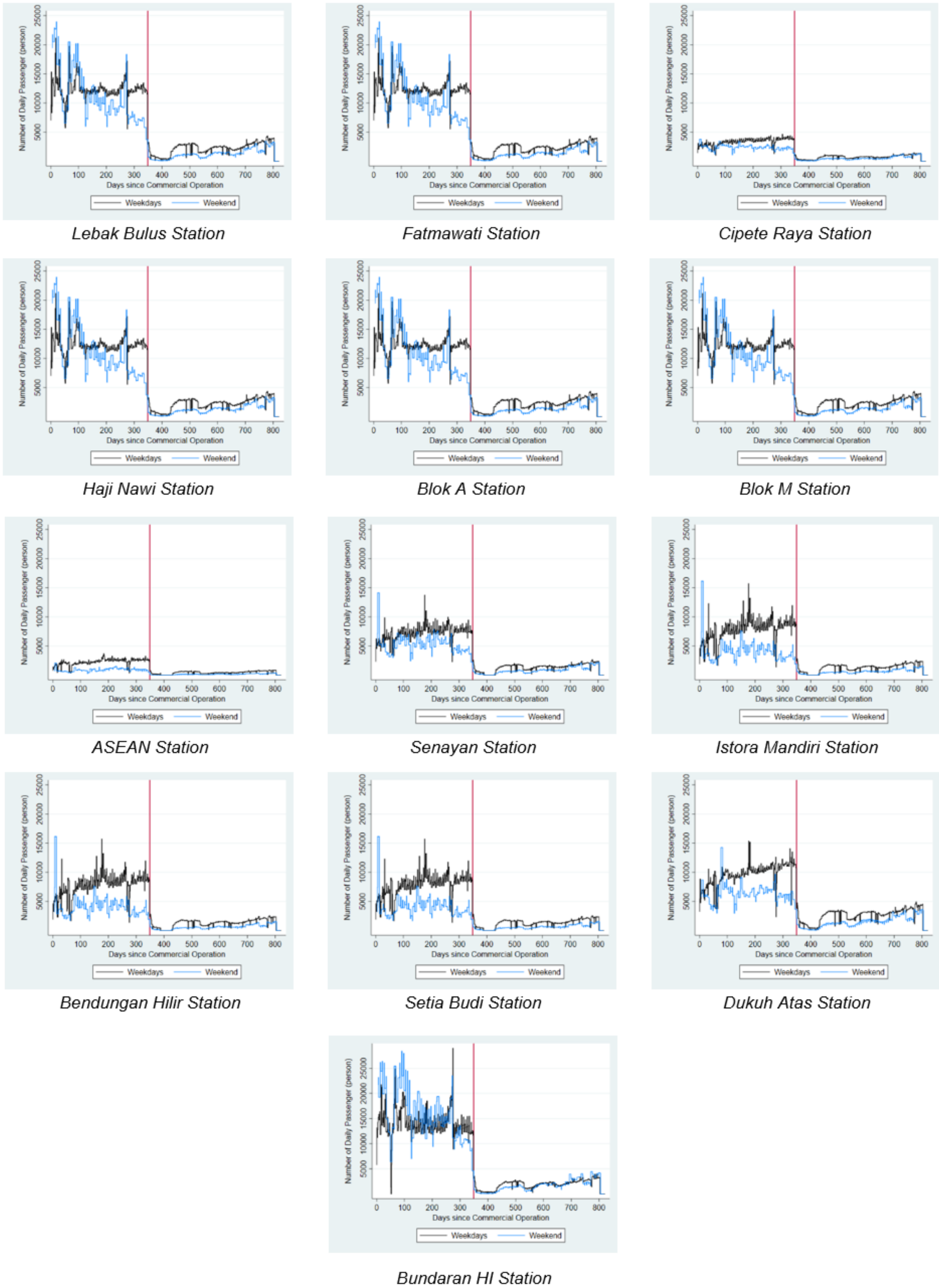

Figure 2. The Trend of the Daily Boarding Passenger in Each MRT Station During Weekdays and Weekends (Before and After the Declaration of PSBB in April 2020)
Source: PT. MRT Jakarta, unpublished data (authors' calculation)

wise. A consequence of the large-scale social restriction is to put the capacity restriction for public transport sector – that is, allowing the public transit vehicle to operate only at 50% of maximum passenger capacity. Hence, we employ $pandemic_t$ as a variable indicating the implementation of capacity restriction during the period of COVID-19 outbreak.

$closure_t$ is a dummy variable equal to one if the trips for OD pair route i not available due to station closure at day t and zero otherwise. $pubholiday_t$ is a dummy variable equal to one if the day t is a public holiday and zero otherwise. $access\_brt_j$ and $access\_train_j$ are dummy variables which equal to one if the station j is accessible from a Transjakarta BRT bus stop and a KRL Commuter Line train station within a radius of 500 meters and zero otherwise, respectively. Terms θ_i, θ_j, θ_t, θ_m, and θ_y are sequentially the OD pair route, station, day, month, and year fixed effects. ε_{it} is the independently and identically error term.

An additional dependent variable is required in order to be able to answer our second research question. We later compute the farebox revenue generated from OD pair route i at day t by multiplying the number of ridership counts and the fare cost per trip per person. Therefore, we rewrite Equation (1) as follows:

$$\begin{aligned} revenue_{it} \quad = \quad & \beta_0 + \beta_k \sum_{k=1}^{7} \ln(revenue_{i,t-k}) + \beta_8.hour_{jt} \\ & + \beta_9.pandemic_t + \beta_{10}.closure_{it} \\ & + \beta_{11}.pubholiday_t + \beta_{12}.access\_brt_j \\ & + \beta_{13}.access\_rail_j + \theta_i + \theta_j + \theta_t + \theta_m \\ & + \theta_y + \varepsilon_{it} \qquad (2) \end{aligned}$$

For the case of estimating the effect of changes in MRT operation hours on the potential farebox revenue losses, we first set a standard of 15-hours of operating time. This standard follows the restrictions under the implementation of PSBB for the public transport sector. A variance resulted from the difference between the standard and actual MRT train operation hours will be treated as the multiplying factor to compute the potential gains or losses of farebox revenue. That is, the gains or losses which should be generated if the MRT operation hours deviate from the standard.

4. Results

4.1 The Effect of COVID-19 Capacity Restriction on Daily MRT Ridership

Table 3 reports the panel fixed-effect estimation results of the effect of COVID-19 capacity restriction – which applied under the implementation of large-scale social restriction, on the average daily MRT ridership at three different periods (i.e., 2019–2020, 2020–2021, 2019–2021) and three different levels (i.e., origin-destination pair routes-level, station-level, and line-level) with robust standard errors. The different estimation periods will help to identify whether the effect of capacity restriction is increasing along with the trend of COVID-19 infections in the city, while the different estimation levels will enable us to examine to what extent the scale of such effect could be consistent.

Our estimation results confirm that the COVID-19 capacity restriction has an extremely negative effect on daily MRT ridership for all estimation levels and their magnitudes are significantly increasing over time. At the line level, the daily MRT ridership on average decreases by 68.6% during 2019-2020 and 85.6% during 2020–2021. The average estimated effect decreases to 56.6% as we expand the period of observations. The effect is also more pronounced at the station and origin-destination pair routes levels, which are respectively about 5% and 6% higher than the line level. It indicates that the magnitude of the effect of COVID-19 capacity restriction on daily ridership is disproportionally distributed over stations and origin-destination pair routes. For example, the reduction in total daily passengers will be smaller for any MRT station connected or nearly located to other urban mass transit facilities (e.g., train stations or BRT bus stops) within a radius less than 500 meters.

In Table 4, we divide the estimation results based on weekdays and weekends. On average, the COVID-19 capacity restriction reduces the daily MRT ridership by 61% and 50.6% at the line level during weekdays and weekends, respectively. In contrast with the station and line levels, the magnitude at the origin-destination pair routes level is almost similar between weekdays and weekend trips. It suggests that the implementation of COVID-19 capacity restriction under the PSBB scheme causes an indifferent effect for all origin-destination pair routes regardless of the day of trips.

4.2 The Effect of Station Closures on Daily MRT Ridership

Table 5 shows our estimation results for the effect of station closures during the COVID-19 outbreak on daily MRT ridership at three different levels based on weekdays and weekends. We limit the estimation to the period of 1 Jan 2020–31 Dec 2020 as the sequence of station closures in our dataset took place in 2020 only. In addition, we drop the temporarily closed stations from the observations to obtain more accurate effect estimates as our interest in the first place is to know the consequences for the remaining opened or active stations.

The results show that the station closures have decreased the daily MRT ridership in other active stations by approximately 32.6% at the line level. The size is still reasonable because the share of passenger in all six temporarily closed stations is around 34.6%.

At the station level, the impact of station closures on ridership rate for remaining opened stations is about 10.2% lower on average than compared to days where all MRT stations were fully operated. In contrast to our previous estimation results in Table 5, the magnitudes for both estimation levels are lower during the weekdays (17.7%–40.2%) relative to weekends (27.1%–44.2%). One plausible reason is that the MRT users who travel to/from the closed stations might have a set of preferences (e.g., trip profile, travel motivation) toward a weekend trip and such preferences are correlated to the location-specific unobserved characteristics. We admit that we are unable to explain the pattern because there is no information available about the trip profile and travel motivation from the dataset.

Surprisingly, the impact of station closure on ridership rate is positive at origin-destination pair routes-level among active stations. It is easily understood that the station closure has led to a route diversion for a short-term period and hence increase the ridership for the remaining active stations by 11.8%. When a station closure occurs, the MRT users choose the nearest alternative departure/arrival station given the additional travel cost. The fact that the ridership rate increases by about 9% during the weekdays imply that the route diversion effect is stronger for work commuters.

4.3 The Effect of Changes in MRT Operation Hours on Daily Ridership

Table 6 presents the estimation results of the effect of changes in MRT operation hours on the average rate of daily MRT ridership, followed by the implementation of

Table 5. Effects of COVID-19 Capacity Restriction on Daily MRT Ridership

Dependent variable:	Ridership at OD Pair Route Level			Ridership at Station Level			Ridership at Line Level (Phase 1)		
ln(ridership)	2019/21 [a)]	2019/20 [b)]	2020/21 [c)]	2019/21 [a)]	2019/20 [b)]	2020/21 [c)]	2019/21 [a)]	2019/20 [b)]	2020/21 [c)]
COVID19	-0.626***	-0.778***	-0.958***	-0.618***	-0.738***	-0.949***	-0.566***	-0.686***	-0.856***
	(0.042)	(0.038)	(0.045)	(0.050)	(0.044)	(0.052)	(0.014)	(0.012)	(0.008)
Constant	1.072***	0.580***	1.841***	1.508***	0.711***	2.479***	1.785***	0.842***	2.804***
	(0.115)	(0.133)	(0.100)	(0.187)	(0.178)	(0.130)	(0.083)	(0.025)	(0.049)
Observations	114,494	91,235	72,902	114,494	91,235	72,902	114,494	91,235	72,902
R^2	0.924	0.931	0.899	0.943	0.951	0.924	0.960	0.965	0.947
R^2 Within	0.882	0.893	0.853	0.934	0.942	0.919	0.959	0.964	0.946

Note: [a)] Between 1 Apr 2019–31 May 2021, [b)] Between 1 Apr 2019–31 Dec 2020, [c)] Between 1 Jan 2020–31 May 2021.
Clustered standard error at station level in parentheses. Included control variables are not shown.
Significance level: * $p < 0.01$, ** $p < 0.05$, *** $p < 0.01$.

Table 6. Effects of COVID-19 Capacity Restriction on Daily MRT Ridership During Weekdays and Weekends

Dependent variable:	Ridership at OD Pair Route Level		Ridership at Station Level		Ridership at Line Level (Phase 1)	
ln(ridership)	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
COVID19	-0.609***	-0.606***	-0.642***	-0.540***	-0.610***	-0.506***
	(0.042)	(0.056)	(0.046)	(0.066)	(0.024)	(0.008)
Constant	1.245***	0.265*	1.963***	0.559**	2.312***	0.830***
	(0.073)	(0.123)	(0.101)	(0.210)	(0.128)	(0.056)
Observations	81,773	32,721	81,773	32,721	81,773	32,721
R^2	0.925	0.914	0.941	0.957	0.964	0.971
R^2 Within	0.896	0.886	0.941	0.957	0.964	0.970

Note: All estimates are between 1 Apr 2019–31 May 2021. Clustered standard error at station level in parentheses.
Included control variables are not shown. Significance level: * $p < 0.01$, ** $p < 0.05$, *** $p < 0.01$.

Table 7. Effects of Station Closure on Daily MRT Ridership

Dependent variable:	Ridership at OD Pair Route Level			Ridership at Station Level			Ridership at Line Level (Phase 1)		
ln(ridership)	All	Weekdays	Weekends	All	Weekdays	Weekends	All	Weekdays	Weekends
Station closure	0.118***	0.090**	-0.084**	-0.102**	-0.177***	-0.271***	-0.326***	-0.402***	-0.442***
	(0.022)	(0.026)	(0.029)	(0.036)	(0.039)	(0.033)	(0.001)	(0.002)	(0.001)
Constant	1.539***	1.941***	0.417**	2.274***	3.039***	0.647**	3.640***	4.272***	1.907***
	(0.160)	(0.166)	(0.118)	(0.182)	(0.168)	(0.235)	(0.004)	(0.007)	(0.009)
Observations	24,098	17,226	6,872	24,098	17,226	6,872	24,098	17,226	6,872
R^2	0.927	0.916	0.915	0.955	0.945	0.973	0.968	0.965	0.989
R^2 Within	0.900	0.905	0.919	0.954	0.954	0.984	0.967	0.964	0.989

Note: All estimates are for the period from 1 Jan 2020 to 31 Dec 2020, when the sequence of station closure was implemented.
Only active OD pair routes are estimated. Clustered standard error at station level in parentheses.
Included control variables are not shown. Significance level: * $p < 0.01$, ** $p < 0.05$, *** $p < 0.01$.

PSBB during the COVID-19 outbreak. We again separate the analysis into three different estimation levels based on weekdays and weekends. We expand the period of estimation from 1 Jan 2020 to 31 May 2020 as the changes in MRT operation hours still were continued until May 2021.

The results show that the average rate of daily MRT ridership would increase by approximately 1.7%–2.1% when the MRT train service operates for a one-hour deviation above the standard of 15-hours operation hours during the implementation of PSBB. Our estimation results are consistent and have similar patterns at the station and OD pair routes levels.

The effect is even more substantial if the MRT operator changes the operating hours during the weekdays (i.e., 5.1%–8.4%). A contradictory situation occurs if the changes in operation hours take place during the weekends, where the average rate of daily MRT ridership would decrease by 10.2%–13.8%. With the increasing gap in the average rate of daily MRT ridership between weekdays and weekend periods, these findings would justify a reason for the MRT operator to set shorter operation hours to optimize the daily MRT ridership during the weekend.

4.4 Implications of COVID-19 Mobility Restrictions for Farebox Revenues

Table 7 presents our results in estimating the potential farebox revenue losses due to public transport maximum capacity restriction during the COVID-19 outbreak. The farebox revenue losses occur because the MRT train service cannot load passengers at its full capacity. The estimation results would reflect the annual farebox revenue that could be generated as if the pandemic COVID-19 either outbreak or the large-scale social restriction did not exist.

We estimate that the MRT operator company have lost the potential farebox revenues by approximately IDR413 million (USD28,480) per day due to the capacity restriction during the COVID-19 outbreak. This amount is equal to IDR183.4 billion (USD12.7 million) during the period of 2020–2021. In 2020, the potential farebox revenue losses due to the capacity restriction during the COVID-19 out-

Table 8. Effects of Station Closure on Daily MRT Ridership

Dependent variable:	Ridership at OD Pair Route Level			Ridership at Station Level			Ridership at Line Level (Phase 1)		
ln(ridership)	All	Weekdays	Weekend	All	Weekdays	Weekend	All	Weekdays	Weekend
Operating hours	0.021**	0.051***	-0.108***	0.026***	0.073***	-0.138***	0.017***	0.084***	-0.102***
	(0.007)	(0.006)	(0.013)	(0.007)	(0.006)	(0.014)	(0.002)	(0.001)	(0.010)
Observations	37,163	26,441	10,722	37,163	26,441	10,722	37,163	26,441	10,722
R^2	0.859	0.828	0.822	0.886	0.825	0.935	0.924	0.914	0.968
R^2 Within	0.743	0.696	0.699	0.870	0.840	0.943	0.921	0.909	0.967

Note: All estimates are for the period from 1 Jan 2020 to 31 May 2021, when adjustment of operating hours was implemented.
All OD pair routes are estimated. Clustered standard error at station level in parentheses.
Intercept and included control variables are not shown. Significance level: * $p < 0.01$, ** $p < 0.05$, *** $p < 0.01$.

break is approximately IDR 399 million (USD27,515) per day or IDR117 billion (USD8.1 million) in total. This economic loss is equal to 142.6% and 61.1% of total realized farebox revenues in 2020 and 2019, respectively. Nevertheless, it is important to note that we still have not excluded the farebox revenue losses by the effects of station closures and changes in MRT operation hours from these estimates.

The potential farebox revenue loss at the rate of weekdays trips is 2.5–3.1 times higher as much as the rate of weekends trips. If the MRT daily ridership can persistently increase at the rate of weekdays trips for a full year, the potential farebox revenue losses could be equal to IDR199.1 billion (USD13.7 million) at maximum. Meanwhile, if the MRT daily ridership can persistently increase at the rate of weekend trips for a full year, the potential farebox revenue losses only reach IDR78.9 billion (USD5.4 million) at maximum.

Table 8 provides our results in estimating the potential farebox revenue losses per day due to a sequence of MRT station closures during the year 2020. The potential farebox revenue losses occur because of unavailable trips from and to the closed stations. Thus, it is important to note that our estimation results reflect the indirect impact of station closures on other remaining active stations.

We estimate that the MRT operator company have lost the potential farebox revenue losses by approximately IDR 848,000 (USD58.5) per day for each remaining active station until the temporarily closed stations are reopened. The potential farebox revenue losses from weekdays trips is larger than weekend trips because the previous estimation results show that there is a difference in ridership rate between the two groups of travel days. The potential potential farebox revenue losses from weekdays trips is almost twice higher as much as from weekdays trips.

In aggregate, the MRT operator's decision to temporarily close several stations during the year 2020 has lost the potential farebox revenue by approximately IDR2.5 billion in total. This amount is equal to 3.1% and 1.3% of total realized farebox revenue in 2020 and 2019, respectively.

We admit that our estimation might produce a little underestimated results in the first place because we have not taken into account the potential farebox revenue losses on zero ridership for any trip from the closed station. Yet our interest is to measure the indirect impact of station closure, the estimation results are still convincing and consistent in describing the potential farebox revenue losses borne by other remaining active stations.

To obtain full-size impact of station closure, we extend the analysis by calculating the average farebox revenues per day for all temporarily closed stations as if there was no closure at any period – which is equal to IDR32.9 million (USD2,269) per day. By combining both direct and indirect impacts of station closure in 2020, we reveal that the total potential farebox revenue losses reached IDR3.8 billion (USD0.3 million). Given that the realized farebox revenues in 2019 and 2020 were IDR191.6 billion (USD13.2 million) and IDR82 billion (USD5.7 million) (MRT, 2020b), the total potential farebox revenue losses is respectively equal to 4.7% and 2.0% of total actual farebox revenues in 2020 and 2019.

Table 9 presents our estimation results on the potential farebox revenue losses per day due to changes in MRT operation hours during the COVID-19 pandemic outbreak. The potential farebox revenue losses occur because of unavailable trips during certain time periods. In that case, the users may cancel their trips as the MRT operator changes train operation hours periodically.

We find that that the MRT operator company have lost the potential farebox revenues by approximately IDR311,000 (USD21.5) per one-hour deviation below the standard of 15-hours operation hours for each OD pair route, vice versa. As previously mentioned, the effect of changes in MRT operation hours is going in a different direction if the estimation was separated between weekdays and weekends. During the weekdays, a one-hour deviation below the standard of 15-hours operation hours for each OD pair route will lead to a potential farebox revenue loss by IDR211,000 (USD14.6) (vice versa). Meanwhile, the farebox revenues losses during the weekends will occur only if there is a one-hour deviation above the standard of 15-hours operation hours for each OD pair route – which is almost equal to IDR191,000 (USD13.2) (vice versa). These findings would justify a reason for the MRT operator to act differently – that is, by setting a shorter operating hour during the weekends to reduce the size of economic losses on farebox revenues.

In aggregate, the MRT operator decision to changes the train operation hours periodically due to the implementation of the COVID-19 mobility restriction (i.e., by operating below and above the standard of 15-hours operation hours during weekdays and weekends respectively) has caused the potential farebox revenue losses by around IDR5.4 billion (USD0.4 million) in 2020 and IDR7.2 billion (USD0.5 million) until end of May 2021. The potential farebox revenue losses in 2020 is equal to 6.6% and 2.8% of total realized farebox revenues in 2020 and 2019, respectively.

However, it is noteworthy that – at a particular time – the MRT operator also gained potential benefits on farebox revenues by operating above and below the standard

Table 9. Indirect Impact of COVID-19 Capacity Restriction on Potential Farebox Revenue Losses

Dependent variable: Farebox revenue per day (million IDR)	2020			2020–2021		
	All	Weekdays	Weekend	All	Weekdays	Weekend
COVID-19 public transport capacity restriction	- 399.156*** (0.483)	- 566.216*** (0.578)	-180.794** (0.089)	-413.044**** (0.227)	-545.527*** (0.807)	-216.249*** (0.191)
Observations	49,643	35,489	14,154	72,902	51,981	20,921
R^2	0.960	0.981	0.993	0.957	0.978	0.971
R^2 Within	0.960	0.981	0.993	0.957	0.978	0.971

Note: All estimates are for the period from 1 Jan 2020 to 31 May 2021. All OD pair routes are estimated.
Clustered standard error at station level in parentheses. Intercept and included control variables are not shown.
Significance level: * $p < 0.01$, ** $p < 0.05$, *** $p < 0.01$.

Table 10. Indirect Impact of Station Closures on Potential Farebox Revenue Losses

Dependent variable: Farebox revenues per active station per day (IDR)	All	Weekdays	Weekend
Station closure	-848,594*** (0.201)	-945,301*** (0.279)	-472,917** (0.185)
Observations	37,163	26,441	10,722
R^2	0.895	0.913	0.856
R^2 Within	0.814	0.820	0.797

Note: All estimates are for the period from 1 Jan 2020 to 31 Dec 2020, when the sequence of station closure was implemented.
Only active OD pair routes are estimated.
Clustered standard error at station level in parentheses.
Intercept and included control variables are not shown.
Significance level: * $p < 0.01$, ** $p < 0.05$, *** $p < 0.01$.

of 15-hours operation hours during weekdays and weekends. The estimated benefit of such a reverse decision is approximately IDR9.7 billion (USD0.7 million) in 2020 and IDR27.1 billion (USD1.9 million) in 2021. Therefore, the changes in MRT train operation hours actually result in positive net benefits of farebox revenues by IDR4.3 billion (USD0.3 million) in 2020 and IDR 19.9 billion (USD1.4 million) in 2021.

Based on the estimation results from Table 8, 9, and 10, we are finally able to calculate the aggregate potential farebox revenue losses borne by the MRT operator due to the implementation of three types of mobility restrictions during the pandemic COVID-19 outbreak. Table 10 provides the summary of our calculations.

5. Conclusion

From the perspective of urban transport operators, the COVID-19 related travel restrictions have been significantly affecting people's mobility which directly leads to a decrease in the public transit ridership as well as the financial performance of transport service companies, particularly for the fare-box items. Lower ticket revenues could bring unwanted consequences to the financial health of public transport companies and the government who provide funding to support the public transport services.

In this paper, we investigate the effect of mobility restriction on daily mass rapid transit (MRT) ridership and its implication for the farebox revenues after the implementation of the Health Quarantine Action called PSBB or "Large-Scale Social Restrictions" as the response to the pandemic COVID-19 outbreak in Jakarta (Indonesia). We employ the datasets of fare cost and passenger counting for 156 origin-destination pair routes across 13 stations within MRT Line Phase 1 in the period from April 2019–May 2021. Our study is the first to estimate the effect of COVID-19 related mobility restriction on ridership and to evaluate the monetary impact in terms of farebox revenues generation using a case of mass rapid transit in Jakarta, Indonesia.

We examine three types of mobility restrictions implemented during the pandemic COVID-19 outbreak. The first restriction is the limitation on maximum passenger capacity where public transport providers are only allowed to load passengers at 50% of maximum vehicle capacity. The next restriction is the closure events of few MRT stations. The last restriction is the changes in MRT train service operating hours. For the purpose of analysis, we develop a panel dynamic fixed-effects regression model to quantify the potential economic losses on farebox revenues due to these mobility restrictions.

Based on the estimation results, we have three main findings regarding the impacts on daily MRT ridership. First, the restriction on maximum passenger capacity has significantly decreased the daily MRT ridership at the line level by 56.6% on average. The magnitude of the effect is disproportionally distributed over stations as well as origin-destination pair routes and tends to increase over time. The accessibility from the MRT station to other mass transit facilities is the key to offset the negative effect of capacity restriction on the daily ridership. Secondly, the station closures have significantly decreased the daily MRT ridership at the line level by 32.6% on average but simultaneously created a trip route diversion which is indicated by a significant increase in ridership at the origin-destination pair route level for other remaining active stations by 11.8%. Lastly, the one-hour reduction of the standard of 15-hours in MRT train service operation hours under the COVID-19 protocol significantly influences the daily MRT ridership at the line level by 1.7% on average with a positive impact for weekday trips, but negative for weekend trips.

Table 11. Impacts of Changes in MRT Operation Hours on Potential Farebox Revenue Losses

Dependent variable: Farebox revenues per hour deviation (IDR)	All	Weekdays	Weekend
Operating hours	311,308*** (0.015)	211,403*** (0.010)	-190,892*** (0.007)
Observations	37,163	26,441	10,722
R^2	0.879	0.860	0.936
R^2 Within	0.877	0.855	0.934

Note: All estimates are for the period from 1 Jan 2020 to 31 May 2021, when adjustment of operating hours was implemented.
All OD pair routes are estimated. Estimates are at line level.
Clustered standard error at station level in parentheses.
Intercept and included control variables are not shown.
Significance level: * $p < 0.01$, ** $p < 0.05$, *** $p < 0.01$.

Table 12. Aggregated Potential Farebox Revenue Losses Due to COVID-19 Mobility Restrictions

Type of COVID-19 related mobility restrictions	Year 2020		Year 2021	
	Economic Losses on Farebox Revenue*)	Ratio to Realized Farebox Revenue in 2019**)	Economic Loss on Farebox Revenue	Ratio to Realized Farebox Revenue in 2020**)
Capacity restriction on public transport	107.8	56.3%	55.2	67.3%
Station closures	3.8	2.0%	-	-
Changes in operation hours	5.4***)	2.8%	7.2***)	8.8%
Total	117	61.1%	62.4	76.1%

Note: *) Measurement unit in IDR biilion
**) Based on the Annual Report of PT MRT Jakarta (2020, pp. 187), the realized farebox revenues were IDR191.55 billion (2019) and IDR82.03 billion (2020).
***) Exclude the estimates of economic gains

Our estimation results also reveal that the mobility restriction during the COVID-19 pandemic has caused the MRT train service operator to lose the potential farebox revenues of IDR179.4 billion (USD12.4 million) in total from March 2020 until May 2021. The potential farebox revenues are considered as economic losses because they reflect the annual farebox revenues that could be generated as if the pandemic COVID-19 either outbreak or the large-scale social restriction did not exist. Such economic losses occur because of the inability of MRT train fleets to load passengers at the full capacity, the unavailability of providing services from and to the closed stations, and the unavailability of providing trips for certain time periods. Regarding the size of the potential farebox revenue losses during the period of COVID-19 outbreaks, the capacity restriction has the largest effect followed by changes in operating hours and the station closure event.

Finally, this study provides evidence of the negative impact of COVID-19 on the transportation sector. However, these findings also illustrate how the decline in economic activity of MRT passengers, especially in the trade, retail, financial, and corporate services sectors, which are the primary industries on the current MRT route. Additionally, the results show that the restriction policy has decreased the potential revenue of the MRT by almost 66 percent from the farebox. Hence, it is suggested that the burden should be shared between the local government and the company. Local governments can consider the subsidy reformulate in times of crisis, considering that the MRT still bears the operational and maintenance costs. As the pandemic continues, there is a serious concern about the financial risk of lower ticket revenues. The provincial government of Jakarta has been granted a subsidy through a public service obligation scheme is equivalent to IDR534.1 billion (USD36.8 million) in 2019 and IDR620.8 billion (USD42.8 million) in 2020 to support the operation of MRT train services in the short term.

On the other hand, the MRT must continuously improve its operational efficiency by taking the crisis period as momentum in carrying out business strategies, especially for earning revenue from non-farebox opportunities. Finding innovations of business strategies to balance ticket revenues with non-farebox revenue sources while keeping the high levels of service and reducing the COVID-19 transmission risks at the same time will be challenging for the MRT operator company. To support this, further analysis to understand the implication of COVID-19 on the non-farebox revenues is still required. We leave the research for future work.

Acknowledgements
The authors are greatly indebted to PT. MRT Jakarta for providing the daily ridership dataset under the consideration of non-disclosure agreement in the framework of cooperation between respective parties. The authors are grateful for many valuable, and constructive comments to Muhammad Halley Yudhistira, Andhika Putra Pratama, and academic colleagues from the Research Cluster of Urban and Transport Economics.

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