IMPACT OF JAKARTA MASS RAPID TRANSIT ON LOCAL AIR QUALITY

(Dampak Moda Raya Terpadu Jakarta Terhadap Kualitas Udara Lokal)

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Abstrak

Moda Raya Terpadu Jakarta, atau MRT Jakarta merupakan transportasi publik berbasis kereta perkotaan pertama di Indonesia dengan beberapa jalur bawah tanah. Sejak 24 Maret 2019, MRT Jakarta Fase 1 (koridor Utara-Selatan) resmi beroperasi dan memiliki panjang jalur sekitar 16 kilometer yang terdiri dari tujuh stasiun layang dan enam stasiun bawah tanah. Motivasi penelitian ini bermula dari kenyataan bahwa pada tahun 2019 Jakarta menduduki peringkat pertama sebagai ibu kota dengan tingkat polusi udara tertinggi di Asia Tenggara, di mana sektor transportasi darat menjadi salah satu sumber utama. Investasi pemerintah cukup besar untuk mengembangkan angkutan umum yang diharapkan dapat mengatasi kegagalan pasar ini. Namun, hasil penelitian untuk membuktikan manfaat pengoperasian MRT terhadap kualitas udara lokal masih terbatas, terutama untuk wilayah perkotaan di negara berkembang seperti Jakarta. Penelitian ini menggunakan metode Difference-in-Difference dan Indeks Standar Polusi Udara (ISPU) sebagai proksi kualitas udara dengan mengontrol beberapa faktor-faktor, seperti kondisi cuaca, penetapan hari libur nasional, akhir pekan, kebijakan pembatasan sosial berskala besar (PSBB) di masa pandemi Covid-19 yang melanda seluruh belahan dunia, penetapan tarif MRT secara bertahap, dan dengan memperhitungkan periode pembangunan jalur MRT. Penelitian ini mengungkapkan dua temuan utama. Pertama, beroperasinya MRT Jakarta Fase 1 di koridor 1 berdampak pada penurunan tingkat polusi udara sebesar 27,4 persen di area yang terdekat dengan jalur MRT. Kedua, hasil estimasi menunjukkan bahwa dampaknya terhadap penurunan polusi udara terjadi lebih kecil pada akhir pekan.

Kata kunci: kualitas udara, MRT Jakarta, ISPU

Abstract

Moda Raya Terpadu Jakarta, or MRT Jakarta, is the first urban rail-based public transportation in Indonesia with several underground lines. Since March 24, 2019, MRT Jakarta Phase 1 (North-South corridor) has officially operated and has a line length of about 16 kilometres consisting of seven elevated stations and six underground stations. The motivation for this research stems from the fact that in 2019 Jakarta occupied ranked first as the capital city with the highest level of air pollution in Southeast Asia, where the land transportation sector is one of the primary sources. Government investment is significant enough to develop public transport, which is expected to overcome this market failure. However, research evidence to prove the benefits of MRT operation on local air quality is still limited, especially for urban areas in developing countries such as Jakarta. This study uses the Difference-in-Difference method and the Air Pollution Standard Index (ISPU) as air quality proxies by controlling several factors, such as weather conditions, determination of national holidays, weekends, and large-scale social restriction (PSBB) policies during the Covid-19 pandemic that hit all parts of the world, the gradual determination of MRT fares, and the period of construction of the MRT line. This study reveals two main findings. First, the operation of MRT Jakarta Phase 1 in corridor 1 resulted in a 27.4 per cent reduction in air pollution levels in the area closest to the MRT line. Second, the estimation results show that the impact on reducing air pollution is negligible on weekends.

Keywords: air quality, MRT Jakarta, ISPU

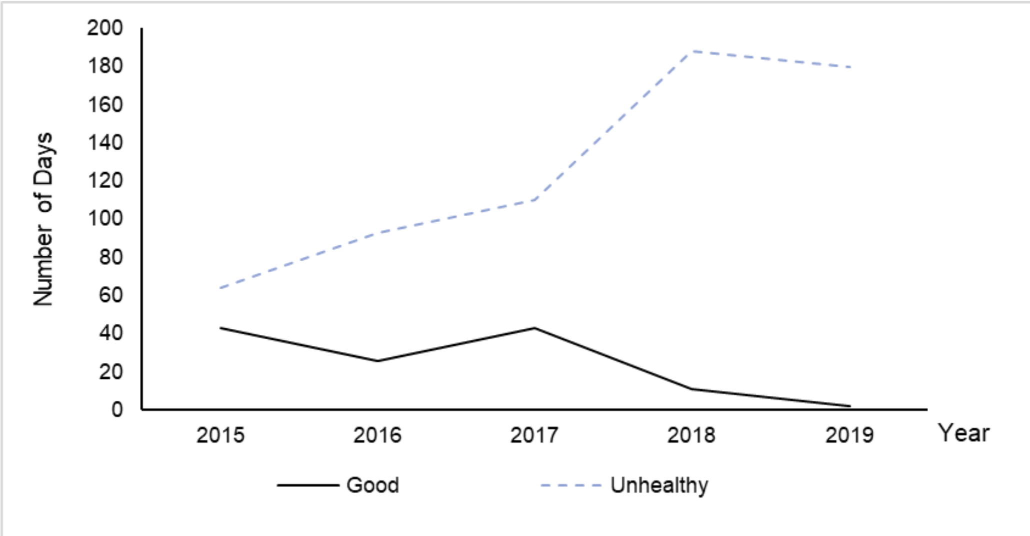
INTRODUCTION

Deteriorating air quality is a severe problem in urban areas. More than 80 percent of the urban population is exposed to air pollution with air quality that exceeds the WHO threshold (WHO, 2017). In 2019, Jakarta ranked the most polluted capital city in Southeast Asia (IQAir, 2019). In addition, about 181 percent the number of days in the unhealthy air quality category tends to increase from 2015 to 2019 with an increase of around 181 percent (64 days in 2015 to 180 days in 2019), as shown in Figure 1 below.

High exposure to air pollution can cause various health impacts, such as an increased risk of respiratory infections, heart disease, and lung cancer (WHO, 2019), and causes 3.3 million premature deaths per year, mainly in Asia (Lelieveld et al., 2015) including the long-term health impacts of ozone and fine particulate matter with a diameter smaller than 2.5 micrometres (PM2.5. In 2010, 57.8 percent of people in Jakarta suffered from various air pollution-related illnesses and paid IDR38,5 trillion to treat them (Ministry of Environment and Forestry of the Republic of Indonesia, 2010).

One of Jakarta's leading sources of air pollution is road transportation (Environment Agency of DKI Jakarta and Vital Strategies, 2019). In 2015, the results of the emission inventory showed that road transport contributes to 57 percent of the Nox emission load and 93 percent of C.O. pollutants and comes from the use of private vehicles (Lestari et al., 2020). To overcome this problem, the DKI

DOI: 10.22212/jekp.v13i1.1988



Source: Environment Agency of DKI Jakarta, 2015-2019

Figure 1. Number of Days of Air Quality Index (ISPU)

Jakarta Provincial Government encourages people to switch to using public transportation modes through Governor's Instruction Number 66 of 2019.

Public transportation can be an option to reduce road traffic externalities (Adler & van Ommeren, 2016; Anderson, 2014; Fageda, 2021; Lichtman-Sadot, 2019)a reduction in car congestion externalities, the so-called congestion relief benefit, using quasi-natural experimental data on citywide public transit strikes for Rotterdam, a city with mild congestion levels. On weekdays, a strike induces travel times to increase only marginally on the highway ring road (0.017. min/km. It can mitigate private transportation dominance (Nguyen-Phuoc et al., 2018; Sohoni et al., 2017)power outages, and personnel strikes. This paper explores the network-wide impacts of PT strikes (train, tram, and bus strikes and reduce air pollution (Chenyihsu & Whalley, 2012; Guo & Chen, 2019; Salehi et al., 2016). One type of public transportation used in urban areas is rapid mass transit (MRT) (MRT, 2020).

Since March 24, 2019, MRT Jakarta Phase 1 (North-South corridor) has officially operated and has a line length of about 16 kilometres, consisting of seven elevated stations (Lebak Bulus, Fatmawati, Cipete Raya, Haji Nawi, Blok A, Blok M, and Sisingamangaraja) and six underground stations (Senayan, Istora, Bendungan Hilir, Setiabudi, Dukuh Atas, and Hotel Indonesia Roundabout). The Government to Government (G2G) loan scheme between the Government of Indonesia and the Government of Japan through the Japan International Cooperation Agency (JICA) is used to finance MRT Jakarta Phase 1 with a loan value of ¥125,237,000,000.

This study deals with the literature on the impact of public transport on air quality (Beaudoin & Lawell, 2016; Bel & Holst, 2018; Nugroho et al., 2011; Salehi et al., 2016; Wöhrnschimmel et al., 2008). However, only a few studies have explored the impact of public transportation in the form of urban rail, particularly on local air quality (Chenyihsu & Whalley, 2012; Park & Sener, 2019). Overall, this research contributes in three ways. First, this research only focuses on the effect of the operation of urban trains only on local air quality at locations traversed by the MRT and those further away from the MRT line in the same city. Second, this research uses the Difference in Difference method that was developed by the previous study (Bel & Holst, 2018; Chenyihsu & Whalley, 2012) with some modifications and the latest data of the air pollution standard index from the Environment Agency of DKI Jakarta and weather data from Meteorology, Climatology, and Geophysical Agency of the Republic of Indonesia, NASA Giovanni, and CHRS data. Third, this study also shows the impact of MRT operations on local air quality daily.

METHODS

Types and Sources of Data

This study used daily data of the Jakarta air pollution standard index from the Environment Agency of Jakarta and the sets of meteorological variables to provide the local weather conditions that affect air pollution. The sample of this study was taken from January 1, 2018, to December 31, 2020. We used air pollution data from January 1, 2015, to December 31, 2017, obtained from the same source for the placebo treatment.

1. Air Pollution Data

This study uses the daily Air Quality Index or Indeks Standar Pencemaran Udara (ISPU) published by the Environment Agency of Jakarta as a proxy for air quality in Jakarta. Under the Minister of Environment and Forestry Regulation No.P.14/MENLHK/SETJEN/KUM.1/7/2020, Air Pollution Index Standard (ISPU) is calculated based on seven major air pollutants: Carbon monoxide (C.O.), Nitrogen dioxide (NO_2), Ozone (O_3), Particulate Matter (PM_{10} and $PM_{2,5}$), Sulfur dioxide (SO_2) and Hydrocarbon (H.C.).

As the ISPU increases, air pollution concentrations increase, and their adverse health effects are more severe, as shown in Table 1 below. So, negative and significant results are expected from this study.

Table 1. Range and Category of Air Pollution Standard Index (ISPU)

Range	Category	Health Implication
0-50	Good	Does not have an effect on the health of living things such as humans, animals and plants and does not have an impact on buildings or aesthetic value
51-100	Moderate	Has no effect on human or animal health but has an impact on sensitive plants and aesthetic value
101-199	Unhealthy	Detrimental to humans or sensitive animal groups or can cause damage to plants or aesthetic values
200-299	Very Unhealthy	Can be detrimental to the health of some segments of the exposed population
> 300	Dangerous	Dangerous air quality levels which, in general, can be seriously detrimental to health

Source: Ministry of Environment and Foresty, 2020.

2. Weather Data

Local weather conditions significantly affect air pollutant concentrations, and to describe it, we use climate data such as air temperature, air humidity, sunshine, rainfall, and wind speed (Bel & Holst, 2018; Liu et al., 2020; Viard & Fu, 2015). In addition, we also added precipitation data; the level of precipitation also significantly reduces the number of pollutants in the air through the rainfall it generates (Kim et al., 2014).

Weather data were obtained from the Indonesian Meteorological, Climatological, and Geophysical Agency station, NASA Giovanni, and the Center for Hydrometeorology and Remote Sensing with the closest location to the air quality monitoring station and MRT line. Air temperature, air humidity, sunshine, and wind speed are obtained from the website https://dataonline.bmkg.go.id/ belongs to the Meteorology, Climatology, and Geophysical Agency.

Air Pollution Standard Index and weather data are obtained from the different sources and stations, so we did the matching. We use a weather monitoring station closest to the air quality monitoring station. In addition, for the location of rainfall and precipitation, we also use the coordinates closest to the location of the air quality monitoring station with the assumption that the weather conditions in the nearest area are not too different. The data is measured by climate monitoring stations such as Kemayoran Station, Tanjung Priok Station, South Tangerang Climatology Station, Tangerang Class 1 Geophysical Station, and Soekarno Hatta Station. Meanwhile, for the daily precipitation data, we use NASA Giovanni's data (see https://giovanni.gsfc.nasa.gov/giovanni/) with the locations that have the closest coordinates to the Jakarta air quality monitoring station. Rainfall data were obtained from the Center for Hydrometeorology and Remote Sensing (see https://chrsdata.eng.uci.edu/) (Table 2).

Table 2. List of Air Quality and Weather Monitoring Station

No.	Station Name	Distance to Nearest MRT Phase 1 Line
1.	Air Quality Monitoring Station DKI 1 - Bundaran HI	154,40 m
2.	Air Quality Monitoring Station DKI 2 - Kelapa Gading	10,67 km
3.	Air Quality Monitoring Station DKI 3 - Kebon Bibit Jagakarsa	8,70 km
4.	Air Quality Monitoring Station DKI 4 - Museum Lubang Buaya	12,55 km
5.	Air Quality Monitoring Station DKI 5 - RPTRA Kebon Jeruk	5,07 km
6.	Meteorological, Climatological, and Geophysical Agency	4,46 km
7.	Tanjung Priok Maritime Meteorological Station	11,34 km
8.	South Tangerang Climatology Station	4,08 km
9.	Tangerang Geophysics Station	19,77 km
10.	Soekarno-Hatta Meteorological Station	19,44 km

Source: Authors' calculations from Google Earth and Google Map

The local event also affects the local air quality. The Covid-19 pandemic in early 2020 forced the Regional Government of Jakarta to implement a policy to reduce the number of infected with the virus called large-scale social restrictions (PSBB). The implementation of PSBB will impact community activities, and the use of motorized vehicles will contribute to the level of air pollution. Therefore, we also include a dummy variable for the initial period of implementing the PSBB policy.

Dust particles in the construction process can impact air quality (Font et al., 2014). To capture the possible impact of the MRT construction process on air quality in locations closest to the MRT line, we include a dummy variable for the MRT construction period from October 10, 2013, to March 23, 2019 (MRT, 2019).

The public transportation ticket fares also affect the air quality (Yang & Tang, 2018). To capture it, we also add three dummies to differentiate the timing of MRT ticket fare fixing. Dummy free for days with free ticket assignments during the MRT trial period (12 to March 31 2019), dummy 50 for the moment when the tariff discount is set at 50 per cent (April 1 to May 12 2019), and dummy full for the time when the total rate is determined (May 13, 2019, to December 31 2020) (MRT, 2020). In addition, we also included several other variables, such as the dummy for national holidays following the Joint Ministerial Decree of the 3 Ministers and the dummy variable for weekends, especially Saturdays and Sundays.

Table 3 below presents summary statistics for the main variables pre-MRT operated and post MRT operated. The mean of the daily ISPU shows a lower value in the post MRT Jakarta operated period than in the pre-MRT Jakarta operated period.

Research Method

Empirical Model

Following the literature (Bel & Holst, 2018; Kellogg & Auffhammer, 2011), this study use difference in difference method with modification to estimate the effect of operating MRT on local air quality in Jakarta. The baseline empirical model for this study is given by equation (1) below, in which Yit denotes the value of ISPU as recorded at station *i* on date t.

$$\log Y_{it} = \beta_0 + + \beta_1 MRTOperate_t + \beta_2 Stattreat_i + \beta_3 Operate_{it} + \gamma X'_{it} + \eta_i + \delta_{iy} + \delta_{id} + \delta_{im} + \alpha_t + \theta_1 T_{it} * MRToperate_t + \theta_2 T_t^2 * MRToperate_t + \theta_3 T_t^3 * MRToperate_t + \varepsilon_{it} \quad (1)$$

Where:

$MRTOperatet$ is an indicator for periods after the MRT operation, 1 for March 24, 2019, and 0 otherwise. $\mathrm{Stattreat}_i$ is an indicator for treatment and control station.

Table 3. Descriptive Statistics

Variable	MRT Operational Status					
	Pre-Operated			Post Operated		
	N	Mean	Std. Dev	N	Mean	Std. Dev
ISPU	4123	78.64	34.95	1280	68.91	24.87
Operate (1 for MRT start operating; 0 otherwise)	4182	0	0	1298	1	0
Weekend (1 for Saturday and Sunday; 0 for otherwise)	4182	0.28	0.45	1298	0.286	0.452
Holiday (1 for holiday ; 0 otherwise)	4182	0.05	0.22	1298	0.051	0.22
PSBB (1 for implemented of large-scale social restriction policy; 0 otherwise)	4182	0.19	0.39	1298	0.41	0.492
Infrastructure Period	4182	0.53	0.49	1298	0	0
Daily Average Air Temperature	4081	28.17	1.03	1267	28.537	.999
Daily Maximum Air Temperature	3944	32.46	1.46	1266	32.761	1.407
Daily Minimum Air Temperature	3886	25.01	1.32	1224	25.301	1.155
Daily Average Precipitation	4182	5.92	11.02	1297	6.436	12.81
Daily Average Air Humidity	4078	80.29	116.90	1267	76.119	7.085
Daily Average Windspeed	4103	2.19	1.11	1272	1.51	0.642
Daily Maximum Windspeed	4103	4.71	1.58	1272	4.245	1.351
Daily Sunshine	3993	5.43	2.93	1263	5.239	2.659
Rainfall	4161	8.48	17.08	1298	8.664	21.645

Source: author's calculations

$Operate_{it}$ is the variable of interest, 1 for the area in the air quality monitoring station that has an operated MRT on day t. When ISPU is expressed as a log in the model, the coefficient on an operational MRT (β_3) is interpreted by multiplying by 100 and interpreted as the percentage difference in ISPU, holding all other factors fixed (Wooldridge, 2016). Negative and statistically significant is expected.

X'_{it} is for control variables include dummy weekend, dummy holiday, a dummy for infrastructure period, PSBB policy during Covid-19 pandemic, the dummy for the variations of MRT ticket fare (free, 50 per cent discount, and full ticket fare), and weather control (daily average temperature, daily maximum temperature, daily minimum temperature, daily average precipitation, daily average humidity, daily average wind speed, daily maximum wind speed, daily sunshine, daily rainfall).

The η_i is station fixed effect (F.E.).

The δ_{iy} is for the interaction of the five air quality monitoring stations each year. This interaction captures unobserved year-to-year shocks common to both treated and non-treated monitors (Station-Year F.E.).

The δ_{id} for the interaction of the five air quality monitoring stations i with each day of the week, and it captures unobserved day-to-day shocks that are common to both treated and non-treated monitors (Station-Day of Week F.E.). δ_{im} for the interaction of the five air quality monitoring stations i with each day of the month to capture unobserved day-to-day shocks common to treated and non-treated monitors in a month (Station-Day of Month F.E.).

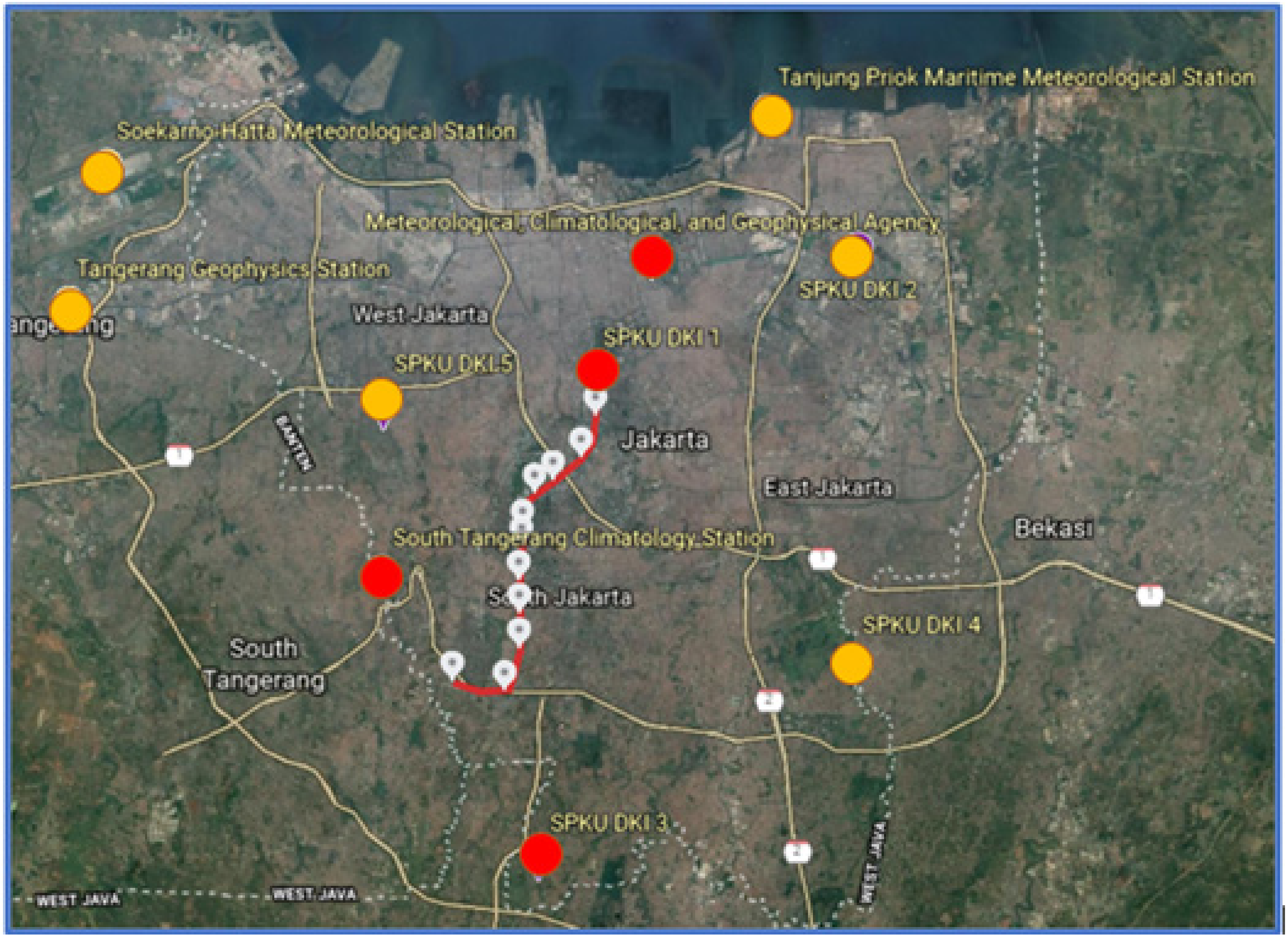
The α_t are time-specific fixed effects consisting of a year fixed effect, a month of year fixed effect, and day of week fixed effect, a day of the month, and a week of the month – it controls the trend around each monitoring station.

$\theta_1 T_{it} * MRToperate_t$ is the interaction between the dummy variable of $MRToperate_t$ and the linear daily time trend.

$\theta_2 T_t^2 * MRToperate_t$ is the interaction between the $MRToperate_t$ dummy variable and the quadratic linear daily time trend.

$\theta_3 T_t^3 * MRToperate_t$ is the interaction between the $MRToperate_t$ dummy variable and the cubic linear daily time trend. This control captures the possible time trends in the pollution that differ in the two periods of the opening date.

ε_{it} represents unobservable disturbances.



Source: Authors' calculations from Google Earth and MRT Jakarta.

Figure 2. Map of MRT Jakarta Phase 1 and the Location of Air Quality Monitoring Station

This study's treatment and control groups are based on the distance between the air quality monitoring station and the MRT station. The distance determination uses the coordinates of the air quality monitoring station and the coordinates of the location of the MRT station with *Google Maps* and *Google Earth*. The treatment group is air quality monitoring stations within fewer than 10 kilometres around the MRT Stations (Bel & Holst, 2018). Moreover, the control group is air quality monitoring stations within a radius more than 10 kilometres away from the MRT Stations.

The treatment consists of "Bundaran Hotel Indonesia Station" (DKI-1) and "Jagakarsa Station" (DKI-3). Meanwhile, the control group consists of DKI-2 air quality monitoring stations "Kelapa Gading", "Lubang Buaya "(DKI-4), and" Kebon Jeruk "(DKI-5). The treatment and control group location is shown in Figure 2, where red dots and control stations mark treated stations are marked yellow, and the red line indicates MRT Jakarta Phase 1 line.

The impact of MRT on air quality might daily differ. This study also aims to capture it and use the difference-in-difference method with modification of literature (Yudhistira et al., 2019)

$$\log Y_{it} = \beta_0 + \sum_{t=1}^{7} \beta_1\, Operate_{it} + \gamma X'_{it} + \eta_i + \delta_{iy} + \delta_{id} + \delta_{im} + \alpha_t + \theta_1 T_{it} * MRToperate_t + \theta_2 T_t^2 * MRToperate_t + \theta_3 T_t^3 * MRToperate_t + \varepsilon_{it} \quad \text{.. (2)}$$

Where $\sum_t{}^7 =_1 \beta_1$ Operate$_{it}$ equal to 1 for the area closest to the air quality monitoring station that has an operated MRT on day of week t.

Table 4. DiD Estimation Result - Impact of MRT Jakarta on Local Air Quality

	Dependent Variable: Logarithm ISPU			
	(1)	(2)	(3)	(4)
MRT Operation	-0.298***	-0.307***	-0.309***	-0.274***
(1 for MRT Start Operating; 0 otherwise)	(0.0263)	(0.0381)	(0.0398)	(0.0285)
Control:				
Weekend	Yes	Yes	Yes	Yes
Holiday	Yes	Yes	Yes	Yes
Ticket Fare Controls:				
Free Ticket Fare	No	Yes	Yes	Yes
50 Percent Discount Rate	No	Yes	Yes	Yes
Full Ticket Fare	No	Yes	Yes	Yes
Infrastructure Period	No	Yes	Yes	Yes
PSBB	No	No	Yes	Yes
Weather Control	No	No	No	Yes
Time Trend:				
MRT Operate*Linear Daily Time Trend	No	No	No	Yes
MRT Operate*Quadratic Daily Time Trend	No	No	No	Yes
MRT Operate*Cubic Daily Time Trend	No	No	No	Yes
Observations	5,394	5,394	5,394	4,472 (?)
R-squared	0.302	0.312	0.324	0.405
Number of stations	5	5	5	5

Notes: The dependent variable is the Log of Air Pollution Standard Index (ISPU) as a proxy for air quality. Standard error clustered by the station. The sample uses data from January 2018 through December 2020. All regression include station F.E., year F.E., a month of year F.E., day of week F.E., day of month F.E., week of F.E., station-year F.E., station-day of week F.E., and station-day of month F.E. Lockdown is a large-scale social restrictions dummy. Weather control includes daily average temperature, daily maximum temperature, daily minimum temperature, daily average precipitation, daily average humidity, daily average wind speed, daily maximum wind speed, average daily sunshine, and daily rainfall. All dependent variables are from the Environment Agency of DKI Jakarta. All-weather data are from the Meteorology, Climatology, and Geophysical Agency of the Republic of Indonesia. Daily average precipitation from NASAGiovanni. Rainfall data from the Center for Hydrometeorology and Remote Sensing. The station in parentheses clusters robust standard errors.

*** Significant at the 1 per cent level
** Significant at the 5 per cent level
* Significant at the 10 per cent level

Source: Author's Calculation.

RESULTS AND DISCUSSION

Impact of MRT on Local Air Quality (Baseline)

By estimating Equation (1), the results are shown in Table 4. Table 4 shows several steps to obtain the specification of the preferred model in this study. The dependent variable in every column is the Log of Air Pollution Standard Index (ISPU) as a proxy for air quality. All regression include station F.E., year F.E., a month of year F.E., day of week F.E., day of month F.E., the week of F.E., station-year F.E., station-day of week F.E., and station-day of month F.E.

The first column only uses the primary explanatory variable in the form of MRT operation and only adds two control variables in the model. The following columns add more control. Column (4) with all control variables is the specification of the preferred control mode in this study.

The estimation results of the main explanatory variable in the form of MRT operations show that the operation of MRT is associated with a 27.4 per cent decrease in the ISPU level in the closest area to the MRT Jakarta line. However, this study does not display the coefficients of the estimated control variables for each model specification (column 1 to column 4).

Although it does not display the estimated coefficients on the control variables, this study will provide an overview based on all models regarding the effect of these control variables on the estimation results. The control variables in this study showed different directions and significant results.

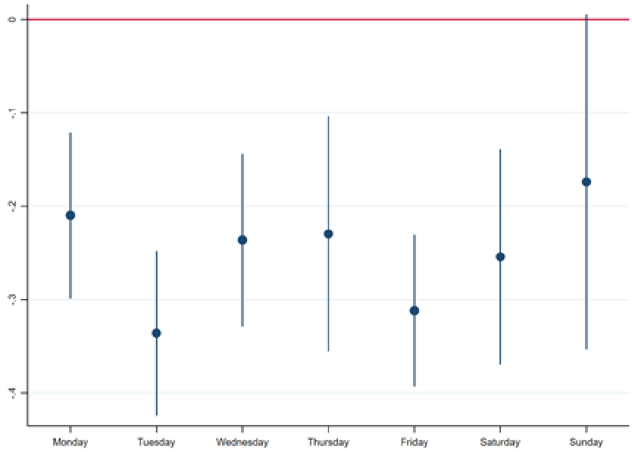
Several variables statistically have a significant relationship to the increase or decrease in the number of passengers at the ISPU level. These variables are weekends, holidays, determination of free MRT tickets, and the MRT construction period. The weekend is negatively related to ISPU by 1.5 to 7 percent. National holidays are negatively related to pollution levels by 8.9 to 10.7 percent, which is significant at the 1 per cent significance level. Free MRT tickets impact reducing pollution by 24.4 percent to 35.3 percent. The MRT construction period has a positive relationship at the ISPU level of 25.7 percent.

Based on the estimation results above, several important points of the existence of MRT Jakarta to local air quality can be simplified as follows:

1. Air quality is significantly related to several variables such as weekends, holidays, PSBB, and free ticket prices (Yang & Tang, 2018).
2. The MRT construction process has a positive impact on increasing pollution levels (Font et al., 2014)
3. Weather conditions such as humidity levels, rainfall and wind speed have an important role in reducing air pollution levels (Viard & Fu, 2015).

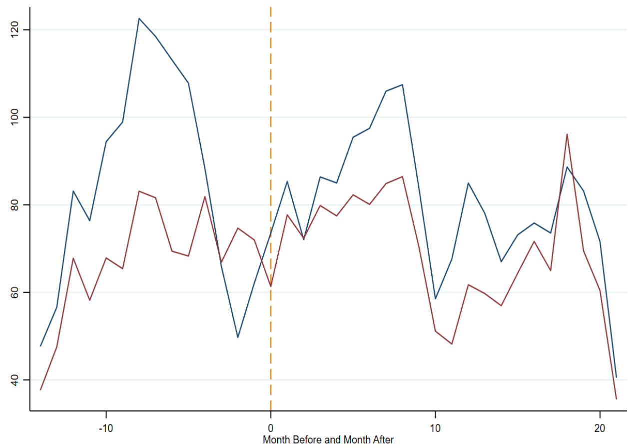
Daily Impact of MRT on Local Air Quality

The estimation results in Equation (2) are shown in Figure 3 below and the results show that the operation of the MRT reduces air pollution every day and Tuesday is the day that experiences the most reduction in air pollution.



Note: The point estimate shows the daily impact of MRT Operations at a 95 per cent confidence interval. The intervals are represented by bars derived from the point estimate. The point estimate is statistically different from zero if the bar does not cross the horizontal line at 0.

Figure 3. Daily Impact of MRT Jakarta on Local Air Quality



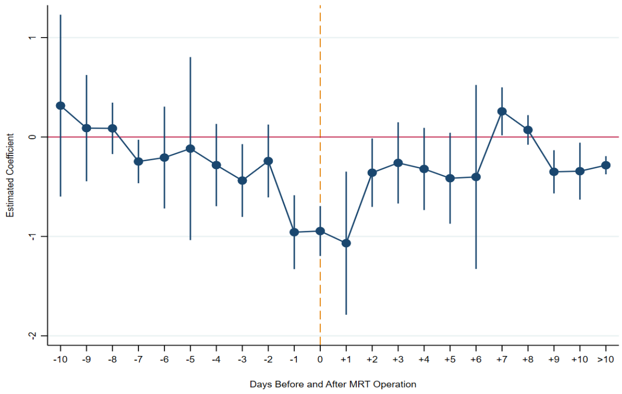
Note: A yellow dotted line represents the initial period of operation of the MRT. The treatment group is marked in red, and the control group is marked in blue.

Figure 4. Change in Air Quality Month Before and After MRT Operation

To test the parallel trend assumption more sure, this research is going to run the following regression to get the trend of air pollution for different times, ten days before the operation of MRT and ten days after the starting operation, as follows:

$$\log(Y_{it}) = \sum_{t=0}^{10} \beta_{-1}\, Operate_{it-1} + \sum_{t=1}^{10} \beta_{+1}\, Operate_{it+1} + \gamma X'_{it} + \eta_i + \delta_{iy} + \delta_{id} + \delta_{im} + \alpha_t + \theta_1 T_{it} * MRToperate_t + \theta_2 T_t^2 * MRToperate_t + \theta_3 T_t^3 * MRToperate_t + \varepsilon_{it} \quad (3)$$

As shown in Figure 5 below, the trend of the estimated coefficient of ISPU critical value before the operation of MRT is mainly near the zero value before the operation of MRT. These results show that treatment and control groups before the MRT measures have the same trend (Wang et al., 2021).



Note: The vertical dashed yellow line represents the start of MRT Jakarta.

Figure 5. Tests on Parallel Trends Assumption

Robustness Check

The critical assumption of the Difference-in-Difference estimates is that the treated and control groups indicate similar equal trends before implementing the policy. To test this assumption, we used the Karimah & Yudhistira (2020) method by imitating the estimation of the dependent variable by changing the original ISPU 2018-2020 to ISPU 2015-2017. In addition, we also randomize the MRT operating time from our basic estimate.

As the Karimah & Yudhistira's (2020) study results, there is no treatment effect on this placebo test, which is statistically insignificant as shown in Table 5 below.

Table 5. Placebo Treatment

	Dependent Variable: Logarithm ISPU	
	Placebo Output	
	(1) 2015-2017	(2) Random Timing
Operate	-0.0142	
	(0.123)	
Rand		0.003
		(0.007)
Observations	4,466	4,472
Number of station	5	5
R-squared	0.321	0.396

Notes: All specifications were the same as in the last column of Table 2. Columns (1) & (2) are placebo treatment estimates. The dependent variable in column (1) uses the maximum ISPU value for 2015-2017. Column (2) uses randomization of MRT Jakarta operation time. Stations in parentheses group strong standard errors.
*** Significant at the 1 per cent level
** Significant at the 5 per cent level
* Significant at the 10 per cent level

Source: Author's Calculation.

CONCLUSION

This study evaluates the impact of MRT on the pollution level (nearest area to the line of MRT Jakarta Phase 1). Using the ISPU critical value as an indicator of air quality, this study contributes to recent literature in two folds. First, it only focused on estimating the impact of local air quality in the area traversed by the line of MRT Jakarta Phase 1. Second, this study uses the Difference in Difference method and the latest data.

After controlling for factors such as weather conditions, holidays, weekends, large-scale social restriction policy (PSBB), MRT fare difference determination, and the dummy for the MRT construction period, this study finds that the effect of the operating of MRT Jakarta Phase 1 reveals two findings. First, the operation of MRT Jakarta Phase 1 is associated with a 27.4 percent decrease in air pollution levels in the closest area to the line of MRT Jakarta Phase 1. Second, the estimation result shows that the impact has a lower magnitude on the weekend.

Overall, the result of this study suggests that the operation of MRT has an impact on improving air quality, so to get an enormous effect, the policymakers need to improve MRT facilities, ease of access to the MRT, and continue the construction of the Transit-Oriented Development. This measure should motivate people to switch from private vehicles to public transport. In addition, there are some limitations to this study. First, this study does not add the concentration of air pollutants (Particulate Matter, Sulfur dioxide, Carbon monoxide, Ozone, and Sodium dioxide) as the dependent variable, so the study results cannot indicate which pollutants are most affected by the operation of the MRT. Second, because of the limitations of obtaining data on the number of private vehicles that pass around the MRT line, this study does not capture the impact of MRT operations on the use of private vehicles. So further research is expected to use more complete data in the form of air pollutant concentrations and the number of vehicles that pass around the MRT line.

ACKNOWLEDGEMENT

Thanks to the supervising lecturers, DKI Jakarta Provincial Government, *Environment Agency of DKI Jakarta,* PT MRT Jakarta, and other parties who have helped in this research.

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Attachment

Table 1. Definition of Variable

Variable	Definition	Source
ISPU	Daily Maximum of Air Pollution Standard Index (ISPU critical value)	https://data.jakarta.go.id/dataset/indeks-standar-pencemaran-udara-ispu
Weather:	The weather variable consists of daily average air temperature (in degrees Celsius), daily average air humidity (in per cent), and daily average wind speed (in meters per second)	https://dataonline.bmkg.go.id/ courtesy of the Meteorological, Climatological, and Geophysical Agency
	The average daily precipitation data	https://giovanni.gsfc.nasa.gov/giovanni/
	The average rainfall	http://chrsdata.eng.uci.edu/.
Operate	is a binary variable: 1 if the MRT is operated in the nearest area to the line of MRT Jakarta Phase 1; 0 otherwise	P.T. MRT Jakarta.
PSBB	A binary variable, one of the large-scale social restrictions are implemented; 0 otherwise.	DKI Jakarta Governor’s Decree No. 380 (2020).
Holiday	A binary variable: 1 is holiday and 0 otherwise and based on three ministerial decrees issued every year.	
Weekend	A binary variable: 1 for Saturday and Sunday; 0: otherwise	
Dummy_free	1 for the day of free ticket assignment; 0 otherwise	MRT Jakarta
Dummy_50	is a binary variable: 1 for the day of 50 per cent discount tariff of MRT ticket assignment; 0 otherwise	MRT Jakarta
Dummy_full	1 for a full day ticket pricing ; 0 otherwise	MRT Jakarta
Dummy_infra	is a binary variable, 1 for the MRT construction process; 0 otherwise	MRT Jakarta