Assessing the influence of mobility behavior on the Covid-19 transmission: a case in the most affected city of Indonesia

Najirah Umar [a,1]; Hamdan Gani [b,2,*]; Sitti Zuhriyah [c,3]; Helmy Gani [d,4]; Feng Zhipeng [e,5]

[a] Department of Informatics Engineering, STMIK Handayani, Makassar, Indonesia
[b] Graduate School of Computer System, STMIK Handayani, Makassar, Indonesia
[c] Department of computer system, STMIK Handayani, Makassar, Indonesia
[d] Department of Industrial Hygiene and Occupational Health, Akademi Hiperkes Makassar, Makassar, Indonesia
[e] Hangzhou Normal University, China
[1] najirah@handayani.ac.id; [2] hamdangani@handayani.ac.id; [3] zuhriyahi@handayani.ac.id ; [4] helmy.gani@mail.com; [5] fengzp@ustb.edu.cn
* Corresponding author

Abstract

An emerging outbreak of Covid-19 has now been detected across the globe. Referring to the current pandemic condition, the robust estimation reports are urgently needed. Therefore, this study aimed to analyze the impacts of community mobility (before, during, and after the lockdown period) on the spread of the Covid-19 in Jakarta, Indonesia. The secondary data was derived from surveillance data for Covid-19 daily cases from the Health Office of DKI Jakarta Province and the Ministry of Health. The community mobility indicators were retrieved from the Google website. Our results showed that in the pre-lockdown period, the Covid-19 daily cases rapidly increased, while community mobility significantly dropped. The increasing number of Covid-19 daily cases was significantly affected by the number of Covid-19 tests per day rather than community mobility. During the mobility restriction period, the number of Covid-19 tests per day, and community mobility statistically affected the decreasing number of Covid-19 daily cases. Meanwhile, after the lockdown period, the number of Covid-19 daily cases rapidly increased, which significantly has a direct relationship with the increasing level of community mobility. Overall, community mobility and the number of tests per day are the essential variables that explain the number of Covid-19 daily cases in Jakarta, Indonesia. Additionally, this study did not observe any impact of average air temperature and air pollution on the spread of Covid-19. This study figures out that community mobility could potentially explain the progression of Covid-19.

Keywords: Covid-19; Community Mobility; average air temperature; air pollution; Indonesia.

Introduction

At the end of 2019, China's government reported a new type of pneumonia disease [1], [2]. The International Committee on Taxonomy of Viruses (ICTV) named the virus as SARS-CoV-2 and Covid-19 disease [3]. The rapid spread of this respiratory disease has led the WHO to declare a global pandemic [4]. With respect to combat the Covid-19 pandemic, the researchers have investigated their characteristics from every possible angle. In recent months, several works have identified various factors which can influence the Covid-19 transmission, such as host defense potential [5], underlying health conditions [6], host behavior [7], age [8], and public health consciousness [9]. Moreover, Socio-economic and environmental factors, such as population density, air temperature, and air pollution, are also observed to affect the disease spread [10]–[12].

Although researchers have shown advances in defining the Covid-19, a study involving community mobility related to the spread of Covid-19 cases has not been profoundly studied, and those studies were not done in Indonesia. As we know, Jakarta is one of the most densely populated cities in the world [13] and the most densely populated city in Indonesia [14]. Jakarta is the center of several industrial sectors and oversees high mobility where people work in and around the region [15]. On 2 March 2020, Indonesia's government reported the first case of Covid-19 in Jakarta, and the number of cases rapidly increased across the country [16]. As of 14 July 2020, 15.064 cases were confirmed in Jakarta, with 701 total deaths. Currently, Indonesia is the highest Covid-19 mortality rate in Asia [17], and Jakarta is the central pandemic city in Indonesia [18]. On 5 June 2020, the transition period from

large-scale social restrictions (partial lockdown: from 10 April to 4 June 2020) triggered the city back to normal activities (called: new normal) [19]. This condition presents a high risk of transmission in Jakarta. The more outdoor/indoor activities, the higher chance of people being infected by the disease. At the same time, the number of cases accelerates after reopening (Fig.1) [20]. Thus, with concern to Jakarta as a representation of a high densely populated area and the effect of reopening, studying the impacts of community mobility on the spread of Covid-19 in the more recent observation time would be beneficial for the current understanding related to the disease.

More recently, several studies have been investigated the potential use of community mobility and its effect related to the spread of Covid-19 cases. Community mobility has been used to explain the spread infection in the United States [21], China [22], and Italy [23]. Also, it has been used to explain the effect of lockdown in India [24]. Although researchers have shown advances in defining the Covid-19, a study involving community mobility related to the transmission cases have not been deeply studied, and the location of the studies were not in Indonesia.

Our study aimed to analyze the impacts of community mobility on the spread of the Covid-19 in Jakarta (before, during, and after the lockdown period). Estimates were made by using the Ordinary Least Square (OLS) regression model, correlation test, and trend analysis test linking to the community mobility indicators (e.g., CMI), epidemiological variables (e.g., the number of daily positive cases, the number of Covid-19 tests taken daily), and environmental variables (e.g., average air temperature, air pollution).

Method

A. Study Area

Jakarta, the capital city of Indonesia, situated in the Java island in the maritime of southeast Asia. It covers approximately an area of 662.33 km^2. It is owing to its geographical location (6^0 12' South latitude and 106^0 48' East longitude). Jakarta has a population of 11.063.324, with a population density of 16.704 people per km2 [14].
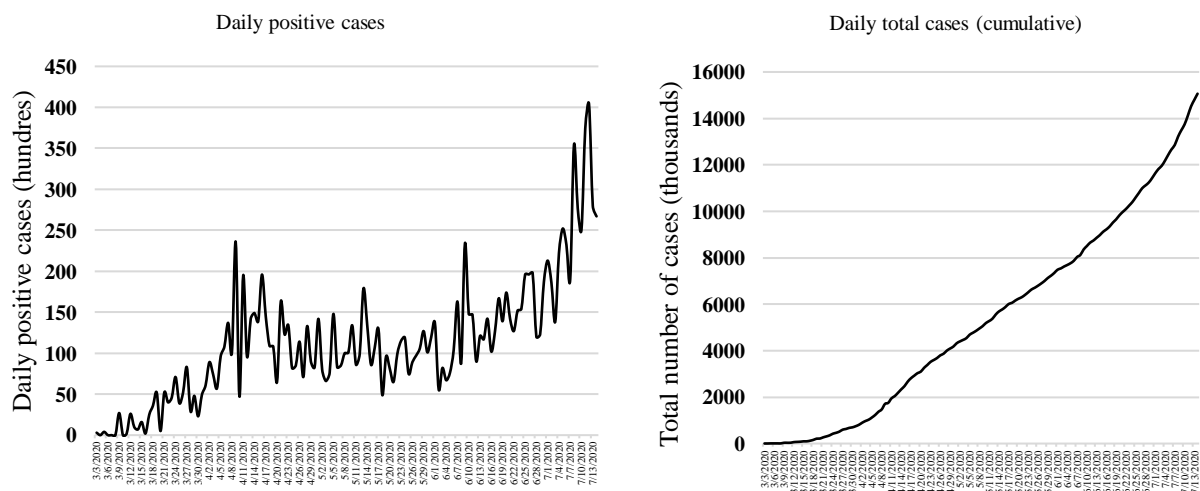

Figure 1. Covid-19 daily positive cases and daily total cases in Jakarta. The data period is from 3 March to 14 July 2020.

On 2 March 2020, the first case of Covid-19 was officially declared by Indonesia's government in Jakarta, and the number of cases continually rose. As of 14 July 2020, a total of 15.064 cases were confirmed in Jakarta, with 701 total deaths. The change period from large-scale social restrictions (partial lockdown: from 10 April to 4 June 2020) generated the city back to normal activities and presented the increasing number of Covid-19 daily cases in Jakarta as shown in **Figure 1**.

B. Data types and sources

Secondary data from surveillance data for Covid-19 was obtained from the Health Office of DKI Jakarta Province and the Ministry of Health of the Republic of Indonesia [25], while the environmental data was obtained from an online archives database [26]. The community mobility indicators (CMI) were gathered from the Google community reports website [27]. The data was obtained from 3 March to 14 July 2020 (N = 134 observation days). For epidemiological variables, the daily positive cases and the number of tests per day (NTPD ($\pm$ 14.000 tests/day)) were chosen. The particulate matter (PM^{25} (μg/m3)) and the average air temperature (Avg. temp (^{0}C)) were chosen for environmental variables as Jakarta is one of the most polluted cities in the world [28] and also has the characteristic of hot temperature (Tropical climate). Thus, it is interesting to study the effect of those variables on the spread of Covid-19.

The CMI reports were developed by people's location-tracking that measures changes in community mobility concerning a baseline (e.g., shop, work, sports, parks, transit activities). CMI reports present daily data that include several types of mobility indicators (e.g., retail and recreational, grocery and pharmacy, parks, transit stations, workplaces, and residential). This study excluded the residential mobility indicator as it showed the mobility in the direction of places where people stayed at home. This study only used five indicators that showed the outdoor/indoor activities outdoor activities and have a highly possible to transmit. CMI reports estimated a relative volume (-80 - +80) of directions requests per region, sub-region, or country compared to a baseline volume during the specific period. The baseline value was 0, which showed the boundary of increasing or decreasing the community activities at a specific location. For data analysis and visualization, the baseline value was changed to 100. More than 100 showed the regular activities and explains the increase of people's activities, while less than 100 indicates the decrease in people's activities compared to a baseline.

The detail of observation variables was presented as follows: Community behavior: the community mobility indicators (CMI); Epidemiological variables: daily cases and the number of tests per day (e.g., NTPD); Environmental variables: the average temperature (e.g., Avg. temp) and the PM^{25} (e.g., PM^{25}).

C. Equations

First, a non-parametric correlation test (Kendall rank correlation) was used to analyze the relationship between CMI and Covid-19 daily cases. The bivariate, two-tailed analysis at 95% confidence value was used. If we did not get a strong association, the non-parametric trend analysis test (Mann-Kendall trend test) was conducted to explain the changing trend of the specific variables. This test was used to determine the magnitude of the trend, either increase or decrease. Second, an OLS regression model equation (1) was developed to examine the impacts of independent variables on dependent variables.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e \qquad (1)$$

Y was the outcome or the dependent variable; here, the number of daily positive cases. $X1$ through $X4$ (respectively CMI, NTPD, Avg. temp, and PM^{25}) were predictor or independent variables. β_0 is the intercept and β_1 through β_4 are constants (slope) or regression coefficient, and e is an error term. The estimation results were interpreted in the results and discussion section by explaining the significant coefficient (p-value). The assumption test was conducted for OLS regression; a multicollinearity test was done while the normal distribution test was not fulfilled. Thus, a Box-Cox method was applied for the transformation data [29].

Results and Discussion

This section presents the empirical estimations obtained from the experiment test. First, the results of correlation and trend analysis tests were presented to show the association between CMI and the spread of Covid-19 daily cases (pre, during, and post lockdown). Second, the results of the OLS model were explained to show the impacts of independent variables (e.g., CMI, NTPD, Avg. temp, PM^{25}) on the spread of Covid-19 daily cases.

A. Correlation and trend analysis test results

In the pre-lockdown period, this study found that Covid-19 daily cases had statistically negative correlation with the CMI (r = -0.586; p < .01) and daily cases were significantly climbed (τb = 0.726; p < .01). The number of daily cases dramatically increased from 3 cases to 236 cases. On the other hand, CMI dropped from the baseline around -50 %, 27 days before lockdown, and the trend test showed a substantial decline (τb = -0.758; p < .01) (**Figure 2** and **Table 1**).

During the lockdown period, this study did not observe any correlation between CMI and the daily cases (Table 1). The number of daily cases slightly decreased (τb = -0.165), and there was a slightly increased level of CMI (τb = 0.005). According to **Figure 2**, CMI was stable in the range of -50%.

After lockdown period, the CMI indicated statistically positive correlation with the increase number of daily cases (r = 0.520; p < .01) and CMI increased significantly to a baseline value (τb = 0.767, p < .01). Meanwhile, the daily cases (τb = 0.597, p < .01) significantly climbed. (**Figure 2** and **Table 1**).

Table 1. Correlation test and trend analysis test results (CMI and daily cases of Covid-19)

	Variables	Kendall's coefficient	Mann-Kendall Tau
Pre-lockdown (3 March - 9 April)	Daily cases		0.726** (↑)
	CMI	-0.586**	-0.758** (↓)
Lockdown (10 April - 4 June)	Daily cases		-0.165 (↓)
	CMI	0.044	0.005 (↑)

	Variables	Kendall's coefficient	Mann-Kendall Tau
Post-lockdown (Start on 5 June)	Daily cases		0.597** (↑)
	CMI	0.520**	0.767** (↑)

* Significant at the 0.05 level
**Significant at the 0.01 level
(↑) Increasing trends
(↓) Decreasing trends

B. Ordinary least square regression results

Several OLS models have been tested, and the significant model formulation was obtained based on the validation tests (R^2 and adj. R^2). The R^2 of the OLS model was relatively good to explain the effect of independent variables on the dependent variable (more than 0.451) except for the model in Table 2(b). The results of the model were presented in **Table 2** and **Table 3**. The significance column (p-value) interpreted whether the independent variables had a statistically significant relationship with the dependent variable.

At the early phase of the pandemic, the increased number of daily cases had a statistically significant relationship with NTPD at a 95 % level of confidence (Table 3(a)). In the restriction period, CMI and NTPD indicated a significant relationship with daily cases at a 90 % level of confidence (Table 3(b)). In the post-lockdown period, CMI (95 % level of confidence) was the most significant variable among the five independent variables and showed a statistically significant relationship with the number of daily cases (Table 3(c)). Concerning the observation within the study period from 3 March to 14 July 2020, the NTPD had a statistically significant relationship with the daily cases at a 95 % level of confidence (Table 3(d)). Overall, the NTPD and CMI were the most significant variables among the five independent variables. Their standardized coefficient of beta values was the highest compared to the strength of the effect of each of the independent variables.

Table 2. Estimation results of OLS model regression (pre-lockdown and lockdown period)

Variables	B values	Standardized coef. of Beta	P-value	Std. error	Variables	B values	Standardized coef. of Beta	P-value	Std. error
Constant	12807.65				Constant	-18004.1			
CMI (0% - 100%)	-18678.37	-0.22	0.2	0.169	CMI (0% - 100%)	26478.16	0.284	0.036*	0.132
NTPD (±14.000/day)	1.887	0.609	0.001**	0.168	NTPD (±14.000/day)	-0.958	-0.315	0.024*	0.136
Avg.temp (0^C)	-1.417	-0.092	0.432	0.116	Avg.temp (0^C)	2.004	0.18	0.2	0.139
PM^{25} (µg/m3)	-3.793	-0.045	0.696	0.113	PM^{25} (µg/m3)	9.702	0.155	0.234	0.129

Dependent variable: Daily positive cases

Number of observations: 38 days

R-Squared: 0. 590

Adj. R-squared: 0. 540

*Significant relationship at the 90 % level

** Significant relationship at the 95 % level

(a) Pre-lockdown (3 March - 9 April 2020)

Dependent variable: Daily positive cases

Number of observations: 56 days

R-Squared: 0.201

Adj. R-squared: 0.138

*Significant relationship at the 90 % level

** Significant relationship at the 95 % level

(b) Lockdown (10 April - 4 June 2020)

Table 3. Estimation results of OLS model regression (post-lockdown and study period)

Variables	B values	Standardized coef. of Beta	P-value	Std. error	Variables	B values	Standardized coef. of Beta	P-value	Std. error
Constant	-154255.1				Constant	-11370			
CMI (0% - 100%)	12.617	0.057	0.675	0.134	CMI (0% - 100%)	10.335	0.103	0.257	0.091
NTPD (±14.000/day)	226083.16	0.576	0.001**	0.152	NTPD (±14.000/day)	16485.63	0.139	0.044*	0.068
Avg.temp (0^C)	0.458	0.078	0.6	0.148	Avg.temp (0^C)	2.049	0.804	0.001**	0.104
PM^{25} (µg/m3)					PM^{25} (µg/m3)				

Dependent variable: Daily positive cases

Number of observations: 134 days

R-Squared: 0. 453

Adj. R-squared: 0. 373

Dependent variable: Daily positive cases

Number of observations: 134 days

R-Squared: 0.548

Adj. R-squared: 0.530

*Significant relationship at the 90 % level   *Significant relationship at the 90 % level

** Significant relationship at the 95 % level   ** Significant relationship at the 95 % level

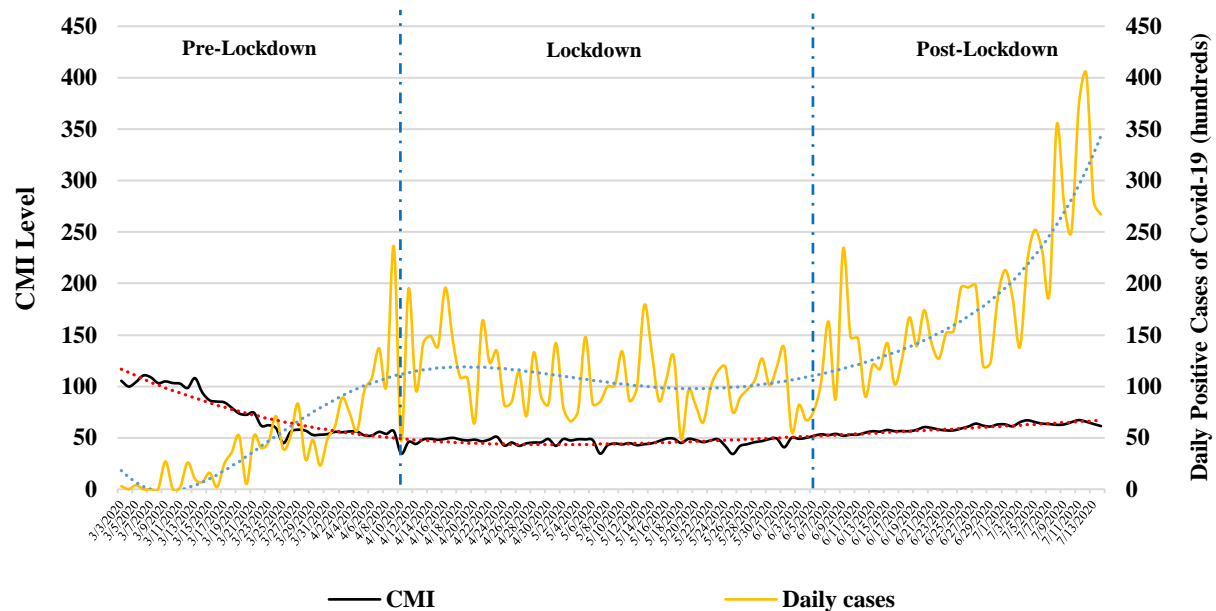(a) Pre-lockdown (5 June - 14 July 2020)   (b) Lockdown (3 March to 14 July 2020)

Figure 2. Display of Covid-19 daily cases and CMI. Normalized data was used for CMI. CMI-baseline: (100 - shows normal activities) and (less than 100 - decreasing activities. The data period is from 3 March to 14 July 2020.

C.   Discussion

This study presents the relationship pictures between community mobility and the spread of the Covid-19 pandemic by comparing the time series data (for 134 observation days) of community behavior (CMI) and other variables (Avg. temp, PM^{25}) with the increasing number of Covid-19 daily cases. The key insight obtained from this study were explained in this section and compared with findings from the previous literature to examine the main implications.

In the early phase of Covid-19 transmission, 38 days before lockdown, Covid-19 daily cases increase exponentially ($\tau b = 0.726$; $p < .01$), from 3 cases to 236 cases. On the other hand, CMI dropped from the baseline around -50 % ($\tau b = -0.758$; $p < .01$) (Table 1). The hypothesis was that the CMI dropped because, after the first cases reported on 2 March 2020, Indonesia's government urged society to stay at home or at least reduce their activities in the public area to control the spread of Covid-19 [30]. Moreover, during the period, Indonesia's government started the massive Covid-19 tests [31], and consequently, the number of positive cases also rose. According to the results of the OLS model, the increased number of daily cases had statistically significant relationship with NTPD at a 95 % level of confidence (Table 3(a)). That result showed the condition of the pandemic; the more tests are performed, the higher is the probability of obtaining positive cases. Contrary, this study did not observe any significant impacts of CMI on the increasing number of daily cases (Table 3(a)). The significant decreasing level of CMI (-50%) ($\tau b = -0.758$; $p < .01$), and the increasing number of daily cases ($\tau b = 0.726$; $p < .01$) may affect that condition.

During the restriction period, 56 observation days, CMI significantly impacts daily cases based on OLS results (Table 3(b)). CMI was stable in the range -50% as people mostly stayed home and had fewer outdoor activities, and the number of daily cases slightly decreased ($\tau b = -0.165$) (Fig. 2 and Table 1). Indicating the enforcement of lockdown was slightly reduced the transmission of Covid-19 at the early period (e.g., from 236 cases on 9 April to 47 cases on 10 April just gone one day). Despite the positive effect of the restriction, their implementation was not entirely successful in reducing the spread of Covid-19 [32]. The number of daily cases fluctuated (around 50-180 cases in Fig. 2), and the daily cases raised significantly at the end of the period. Several factors may contribute that condition, including the people violating the rules. Disobedience of lockdown regulation and outside activities are still occurring during the implementation of lockdown [33]. Industrial factories could continue their business if they obtain a permit from the Industrial Ministry and strictly apply health procedures [34]. Thus, implementation of lockdown will likely fail if local government policies do not enforce the rules through the strict limitation of people's movement.

After lockdown, 40 observation days after lockdown, the CMI (τb = 0.767, p < .01) moved to a baseline value. Contrary, the daily cases (τb = 0.597, p < .01) rocketing (Fig. 2 and Table 1). The influence of transition to the new normal may affect the increased number of Covid-19 daily cases. In this period, CMI (95 % level of confidence) was the most significant variable that explains the increasing number of daily cases, based on the OLS model (Table 3(c)). The increased number of Covid-19 daily cases can be influenced by the infected people during the restriction period where the incubation period was 14 days. CMI results may support that indication. CMI level slightly increased (τb = 0.005), and the cases fluctuated around 50-180 cases (Table 1 and Fig. 2 in the center), meaning that there were outdoor/indoor activities during the lockdown period, as we said on the abovementioned (e.g., person or group of people infected during their activities). Similarly, in the pre-lockdown period, the people might be infected several days before the first case was confirmed on 2 March 2020, where the level of CMI was still on the baseline (100), meaning normal activities (Fig. 2 on the left side) before CMI suddenly decreased on 13 March 2020. As we hypothesized, the more outdoor activities, the higher chance of people infected by the disease.

Overall, this study observed that NTPD and CMI are the essential variables among the five independent variables that significantly correlate with the number of daily cases during the study period. Several recent studies have identified that population density is a significant trigger of the increased number of Covid-19 cases [10]. That might explain why the pandemic is getting worse in a number of the highly densely populated region over the world, such as Lombardy in Italy [23], several provinces in Iran [35], Madrid in Spain, New York in the United States, and San Paulo in Brazil as mentioned by [36]. Thus, they support our findings as Jakarta is one of the most densely populated cities in the world [13]. With concern about the association between community mobility and population density, it is suggested that the cities/regions with high community mobility and a high population should more precisely control their policy to control the spread of the disease.

Furthermore, this study did not observe any significant impact of the air pollutant (PM^{25}), where Jakarta has poor air quality, on Covid-19 daily cases. One hypothesis could be that the concentration of air pollution might be decreased due to the restriction rules where there were fewer outdoor activities and closures of industrial sectors. The previous work has identified that air pollution significantly declined during the Covid-19 period in the USA [37]. Thus, this study may not observe any effects of air pollution on Covid-19 daily cases.

Regarding average air temperature, previous work has observed that they correlate with the spread of Covid-19 cases during the early phase of the pandemic from January to 29 March 2020 in Jakarta [38]. Although our study extends the observation period (134 days; start from the first case; 3 March to 14 July 2020), this study did not observe any effect of average air temperature on the spread of Covid-19. The different methods may affect those findings. The previous work used a correlation test while our study applied the OLS regression model. The correlation test may not indicate substantial causation without considering any other factor that probably verifies the spread of Covid-19 besides climate factors.

Although showing a significant relationship between community mobility and the Covid-19 pandemic in Jakarta, this study has the following limitations. First, the spread of Covid-19 is influenced by many factors, such as public health consciousness and socio-economic factors. Second, as we did not observe any significant effect of air pollutants on the spread of Covid-19, further studies are needed to investigate those effects using a robust experiment method. Finally, the findings of our study are an estimation, and more comprehensive research is urgently needed to get a better understanding of the characteristics of the Covid-19 pandemic.

Conclusion

This study aimed to analyze the impacts of community mobility on the spread of the Covid-19 in Jakarta, Indonesia. Our results showed that people mobility could potentially contribute to the spread of Covid-19. The number of tests per day and community mobility have a direct relationship with Covid-19 daily cases. They are essential variables that strongly influence the number of Covid-19 daily cases. Additionally, this study did not observe any significant impact of average air temperature and PM25 on the spread of Covid-19.

Our study suggests that the cities or regions with high people mobility and high population density should more precisely control their policy in order to control the spread of the disease. The impact of air pollution or other environmental variables on Covid-19 cases is needed to explore the effect of long-term exposure to get better conclusions. Moreover, there are no indications that the spread of Covid-19 may decrease at a warm temperature. Finally, the polynomial regression line (Figure2) shows an increasing trend of Covid-19 daily cases and human mobility in Jakarta. Thus, the local government should pay more attention due to the transmissibility of the disease. This study shows that community behavior is a promising infodemiology tool and could be considered material for decision-making in preventing the spread of Covid-19 and other similar pandemics.

References

[1] M. A. Shereen, S. Khan, A. Kazmi, N. Bashir, and R. Siddique, "COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses," *J. Adv. Res.*, vol. 24, pp. 91–98, 2020, doi: 10.1016/j.jare.2020.03.005.

[2] Y. Chen, Q. Liu, and D. Guo, "Emerging coronaviruses: Genome structure, replication, and pathogenesis," *J. Med. Virol.*, vol. 92, no. 4, pp. 418–423, Apr. 2020, doi: 10.1002/jmv.25681.

[3] C. C. Lai, T. P. Shih, W. C. Ko, H. J. Tang, and P. R. Hsueh, "Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges," *Int. J. Antimicrob. Agents*, vol. 55, no. 3, p. 105924, 2020, doi: 10.1016/j.ijantimicag.2020.105924.

[4] WHO, "Coronavirus disease 2019 (COVID-19) situation report – 41. Retrieved from.," 2020. https://www.who.int/docs/default-source/coronaviruse/situation-reports/%0A20200301-sitrep-41-covid-19.pdf?sfvrsn=6768306d_2. (accessed Jul. 14, 2020).

[5] WHO, "WHO Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. Retrieved from.," World Health Organization, 2020. [Online]. Available: https://www.who.int/internal-publications-detail/clinical-management-of-severe-acute-respiratory-infection-when-novel-coronavirus-(ncov)-infection-is-suspected%0Ahttp://apps.who.int/iris/bitstream/10665/178529/1/WHO_MERS_Clinical_15.1_eng.pdf.

[6] B. E. Young *et al.*, "Epidemiologic Features and Clinical Course of Patients Infected with SARS-CoV-2 in Singapore," *JAMA - J. Am. Med. Assoc.*, vol. 323, no. 15, pp. 1488–1494, 2020, doi: 10.1001/jama.2020.3204.

[7] J. Riou and C. L. Althaus, "Pattern of early human-to-human transmission of Wuhan 2019 novel coronavirus (2019-nCoV), December 2019 to January 2020," *Eurosurveillance*, vol. 25, no. 4, p. 2000058, 2020, doi: 10.2807/1560-7917.ES.2020.25.4.2000058.

[8] Z. Wu and J. M. McGoogan, "Characteristics of and Important Lessons from the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72314 Cases from the Chinese Center for Disease Control and Prevention," *JAMA - J. Am. Med. Assoc.*, vol. 323, no. 13, pp. 1239–1242, 2020, doi: 10.1001/jama.2020.2648.

[9] A. Wilder-Smith and D. O. Freedman, "Isolation, quarantine, social distancing and community containment: Pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak," *J. Travel Med.*, vol. 27, no. 2, p. taaa020, 2020, doi: 10.1093/jtm/taaa020.

[10] J. Rocklöv and H. Sjödin, "High population densities catalyse the spread of COVID-19," *J. Travel Med.*, vol. 27, no. 3, p. taaa038, 2020, doi: 10.1093/jtm/taaa038.

[11] S. K. Pani, N. H. Lin, and S. RavindraBabu, "Association of COVID-19 pandemic with meteorological parameters over Singapore," *Sci. Total Environ.*, vol. 740, p. 140112, 2020, doi: 10.1016/j.scitotenv.2020.140112.

[12] Y. Zhu, J. Xie, F. Huang, and L. Cao, "Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China," *Sci. Total Environ.*, vol. 727, p. 138704, 2020, doi: 10.1016/j.scitotenv.2020.138704.

[13] World Population Review, "World Cities," 2020. https://worldpopulationreview.com/world-cities (accessed Jul. 14, 2020).

[14] Data.jakarta.go.id, "Data Penduduk DKI Jakarta," 2020. https://data.jakarta.go.id/organization/dinas-kependudukan-dan-catatan-sipil (accessed Jun. 17, 2020).

[15] Jakarta.go.id, "Jakarta Infografis," 2020. https://jakarta.go.id/infografis (accessed Jul. 14, 2020).

[16] CNN Indonesia, "Jokowi Umumkan Dua WNI Positif Corona di Indonesia CNN Indonesia Senin, 02/03/2020 11:36," *CNN Indonesia*, 2020. https://m.cnnindonesia.com/nasional/20200302111534-20-479660/jokowi-umumkan-dua-wni-positif-corona-di-indonesia (accessed May 31, 2020).

[17] The Johns Hopkins Coronavirus Resource Center (CRC), "Mortality in the most affected countries," 2020. https://coronavirus.jhu.edu/data/mortality (accessed Jul. 14, 2020).

[18] Kemkes, "https://covid-monitoring.kemkes.go.id/," 2020. https://covid-monitoring.kemkes.go.id/ (accessed May 31, 2020).

[19] The Jakarta Post, "Transitional PSBB a deciding chapter for jakarta's new normal," 2020. https://www.thejakartapost.com/news/2020/06/09/transitional-psbb-a-deciding-chapter-for-jakartas-new-normal.html (accessed Jul. 14, 2020).

[20] The Jakarta Post, "Jakarta extends transition phase postponing further relaxation by 14 days," 2020. https://www.thejakartapost.com/news/2020/07/01/jakarta-extends-transition-phase-postponing-further-relaxation-by-14-days.html (accessed Jul. 14, 2020).

[21] A. Paez, "Using Google Community Mobility Reports to investigate the incidence of COVID-19 in the United States," *Transp. Find.*, pp. 1–8, 2020, doi: 10.32866/001c.12976.

[22] M. U. G. Kraemer *et al.*, "The effect of human mobility and control measures on the COVID-19 epidemic in China," *Science (80-.).*, vol. 368, no. 6490, pp. 493–497, 2020, doi: 10.1126/science.abb4218.

[23] A. Carteni, L. Di Francesco, and M. Martino, "How mobility habits influenced the spread of the COVID-19 pandemic: Results from the Italian case study," *Sci. Total Environ.*, vol. 741, p. 140489, 2020, doi: 10.1016/j.scitotenv.2020.140489.

[24] J. Saha, B. Barman, and P. Chouhan, "Lockdown for COVID-19 and its impact on community mobility in India: An analysis of the COVID-19 Community Mobility Reports, 2020," *Child. Youth Serv. Rev.*, vol. 116, p. 105160, Sep. 2020, doi: 10.1016/j.childyouth.2020.105160.

[25] DKI Jakarta Province, "Corona Jakarta," 2020. https://corona.jakarta.go.id/ and https://kawalcovid19.id/ (accessed Jul. 14, 2020).

[26] The World Air Quality Index Project, "AQICN," 2020. https://aqicn.org/data-platform/covid19/ (accessed Jul. 14, 2020).

[27] Google, "Google Community Mobility," 2020. https://www.google.com/covid19/mobility/ (accessed Jun. 14, 2020).

[28] IQAIR, "World most polluted cities," 2020. https://www.iqair.com/world-most-polluted-cities (accessed Jul. 14, 2020).

[29] R. M. Sakia, "The Box-Cox transformation technique: a review," *J. R. Stat. Soc. Ser. D (The Stat.*, vol. 41, no. 2, pp. 169–178, 1992.

[30] The Jakarta Globe, "Indonesia rules out lockdowns as covid19 new cases growth slows down," 2020. https://jakartaglobe.id/news/indonesia-rules-out-lockdowns-as-covid19-new-cases-growth-slows-down (accessed Jul. 14, 2020).

[31] The Jakarta Globe, "Jokowi calls for massive covid19 rapid testing in indonesia," 2020. https://jakartaglobe.id/news/jokowi-calls-for-massive-covid19-rapid-testing-in-indonesia-as-market-rupiah-are-routed (accessed Jul. 14, 2020).

[32] Tempo, "Covid 19 task force head psbb in jakarta is not effective yet," 2020. https://en.tempo.co/read/1333550/covid-19-task-force-head-psbb-in-jakarta-is-not-effective-yet (accessed Jun. 17, 2020).

[33] Kompas, "Residents still ignoring psbb," 2020. https://kompas.id/baca/english/2020/04/16/residents-still-ignoring-psbb/ (accessed Jun. 17, 2020).

[34] The Jakarta Post, "Ministry allows 11000 companies operate during psbb," 2020. https://www.thejakartapost.com/news/2020/04/22/no-choice-but-to-keep-economy-running-ministry-allows-11000-companies-operate-during-psbb.html (accessed Jun. 17, 2020).

[35] M. Jahangiri, M. Jahangiri, and M. Najafgholipour, "The sensitivity and specificity analyses of ambient temperature and population size on the transmission rate of the novel coronavirus (COVID-19) in different provinces of Iran," *Sci. Total Environ.*, p. 138872, 2020.

[36] S. Copiello and C. Grillenzoni, "The spread of 2019-nCoV in China was primarily driven by population density. Comment on 'Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China' by Zhu et al.," *Sci. Total Environ.*, vol. 744, no. 3, p. 141028, Nov. 2020, doi: 10.1016/j.scitotenv.2020.141028.

[37] J. D. Berman and K. Ebisu, "Changes in U.S. air pollution during the COVID-19 pandemic," *Sci. Total Environ.*, vol. 739, p. 139864, 2020, doi: 10.1016/j.scitotenv.2020.139864.

[38] R. Tosepu *et al.*, "Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia," *Sci. Total Environ.*, vol. 725, p. 138436, 2020, doi: 10.1016/j.scitotenv.2020.138436.