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Time-based Geospatial Analysis of Night-Time Light Data and Citizen Movement Restriction During Covid-19 Period

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ABSTRAK

Pembatasan kegiatan masyarakat atau di beberapa daerah disebut juga dengan *lockdown* sudah banyak dijalankan oleh beberapa negara demi menekan angka penyebaran Covid-19. Dalam penelitian ini, menggunakan foto satelit di malam hari, atau biasa disebut dengan *Night Time Light* (NTL) Data. Setelah itu diambil sample titik koordinat sebanyak 381 tempat umum di Jakarta dan diambil datanya menggunakan dataset VIIRS *Stray Light Corrected Nighttime Day/Night Band Composites Version* 1 selama kurun waktu Q1 2019 sampai dengan Q2 2022. Dari hasil foto satelit ini kemudian dikonversikan ke dalam bentuk numerik, dikorelasikan dengan *timeline* pembatasan kegiatan masyarakat di Indonesia dan juga *data mobility* untuk wilayah Jakarta. Hasilnya adalah ditemukan penurunan intensitas cahaya saat memasuki masa pembatasan kegiatann masyarakat sebanyak 1% - 16% di berbagai sektor. Penurunan intensitas ini tidak berkorelasi dengan kuat dengan *data mobility* untuk beberapa sektor yang menunjukkan perubahan penurunan aktivitas hingga 60%.

Kata Kunci:

Analisis Geospasial, *Night Time Light Data,* Pembatasan Kegiatan Masyarakat

Keywords **:**

Citizen Restriction, Geospatial Analysis, Mobility Report, Night Time Light Data

ABSTRACT

Restrictions on community activities or in some areas also called lockdowns have been carried out by many countries in order to reduce the spread of Covid-19. Various methods are used to monitor the implementation of these restrictions, this study uses a new approach by using satellite imagery at night commonly called Night-Time Light (NTL) Data. This research using a sample of 381 coordinate points was taken in public places in Jakarta. The data was collected using the VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1 dataset from Q1 2019 to Q2 2022. The results of these satellite photos were then converted into numerical form and correlated with the timeline for the restriction of community activities in the Jakarta area. The result is there is a slightly decreasing in light intensity when entering a period of Covid-19 at the beginning of 2020 until 2022 with a percentage of around 1% - 16% in various sectors. This decreasing light intensity has a slight correlation with mobility data for several sectors. The mobility data show a huge difference at the beginning of Covid-19, which shows a decrease in the activity of up to 60%.

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INTRODUCTION

Since Covid-19 began in 2019, there have been many efforts from various countries to prevent the spread of this virus. One of the prevention measures taken is to limit people's activities, or for extreme restrictions, it is commonly called a lockdown (Syuhada et al., 2021). In one of the countries in Asia, namely Indonesia, the local government also places restrictions on community activities which are commonly referred to as Restrictions on Community Activities. This limitation is regulated in a ministerial decree which also limits the opening hours and capacity of several public areas such as offices, malls, terminals, and several other places. During this period of restriction on community activities, many things changed, such as the air quality index, community mobility, and preferences for using public transportation (Jakob et al., 2022; Samuel Ady & Suyoto, 2022). Even though there are restrictions on people's space for movement, there are still many places that do not follow this call. There are already several ways to control this decision by carrying out police patrols, CCTV monitoring, or community reports. So, in this study, a new approach will be used to monitor community activities in general, especially during restrictions using satellite data by using Night Time Light Data released by Google. This NTL data will later be used to analyse geospatially in the time dimension from the pre-pandemic period to the time of the pandemic. It is hoped that there will be a pattern that shows changes in community activities at night as restrictions on community activities are imposed at night. Several previous studies have used satellite data for various things such as: monitoring the development of a region from year to year; changes in the forest being converted into agricultural land; the process of sea level rise and land narrowing due to global warming; as well as use to view post-disaster events (Alzu'bi & Alsmadi, 2022; Gibson et al., 2019; Y. Ouyang et al., 2023).

Research on the effects of Covid-19 and also lockdowns or restrictions on community activities in Indonesia have also been carried out for several parameters. One of them is the effect of the lockdown on improving air quality, but it is not significant because there is the influence of weather and climate (Jakob et al., 2022). In general, community activities are also affected by this restriction, with a decrease in mobility in the Workplaces, Grocery, Transit stations, and Retail sectors in Asia including Indonesia (Samuel Ady & Suyoto, 2022). In some research, using satellite data both during the day, at night or real images has been carried out for a number of things ranging from observing economic developments, and monitoring post-disaster developments, to predicting income. The economic development of a country is usually measured by an increase in Gross Domestic Product (GDP). Night Light data also can be used to measure economic development and also make predictions of GDP based on the light intensity, where the brighter an area indicates that the area has a higher economy than the dim one, which is more closely related to urban areas with lots of lights at night (Chen & Nordhaus, 2019; Gibson et al., 2019). This is also reinforced by other research which shows that there is a link between NTL and socio-economic development in an area such as population, GDP, road networks, and also carbon emissions (Han et al., 2022). Apart from that, Night Light data can be used to monitor the situation after natural disasters such as the earthquake that occurred in Nepal, which can differentiate affected areas using the Visible Infrared Imaging Radiometer Suite (VIIRS) nightlight data (Gao et al., 2020; Tveit et al., 2022). The use of satellite data to find out the development of civilization from time to time in an area, by looking at changes in the lights at night with indicators the more lights, the more developed an area is (Ch et al., 2021). Deforestation can also be identified using satellite data to find out which green areas have been transformed into industrial land or urban areas (Alzu'bi & Alsmadi, 2022). Or the process of abrasion on an island over a long period of time or rising sea levels causes a reduction in the area of an island (Z. Ouyang et al., 2022). From various studies that have been published, this research will propose how the intensity of light during the Covid-19 period in Indonesia, especially when there are restrictions on people's movements by the government.

RESEARCH METHODOLOGY

Dataset

There are several data used to support this research, including Night Time Light Data (NTL data) (Elvidge et al., 2021); Google Mobility Data (Google, n.d.); as well as local data for research support. NTL data is retrieved from Google Earth Engine API which can be accessed publicly by querying the coordinates and what type of data to choose (Elvidge et al., 2013, 2017, 2021). The data on Google Earth Engine is not limited to Night Light Time Data, but also various types such as Surface Temperature, Climate, Atmospheric, Weather, Landsat, Sentinel, and several other types (Eskandari & Ali Mahmoudi Sarab, 2022). But in this study, NTL data was taken because it will focus on imposing curfews during the Covid-19 pandemic in Indonesia, especially in the capital city of Jakarta. Actually, there are several versions of NTL data available, but in this study, the Visible Infrared Imaging Radiometer Suite (VIIRS) was chosen because the Defense Meteorological Satellite Program (DMSP) dataset has several weaknesses such as blurring, top-coding, lack of calibration, and variations in sensor amplification which breaks comparability over time and space. Some of these weaknesses are corrected in more recent data, namely from the Visible Infrared Imaging Radiometer Suite (VIIRS) (Gibson et al., 2019). Comparison of the use of VIIRS and DMSP is also used for several studies such as testing electricity consumption, mapping urban dynamics, and also CO2 emissions (Hu et al., 2022; Lv et al., 2020; Zhao et al., 2020).

Framework and Workflow

To carry out this research, there is a workflow described in Figure X. Starting from collecting sample coordinates in several public places such as: terminals, malls, buildings and hotels. After the coordinate point dataset from several sample places in Jakarta is collected, the next step is to take photos from VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1 during the observation period and as many coordinate points as have been selected. This Google Earth data will later be in the form of satellite photo images over a certain period of time, which can then be extracted for the level of light intensity at the coordinates and the area of that point. This data will not only be taken at one time period, but will be taken periodically from 2019 to 2022, which will produce Night Time Light Data by Date.

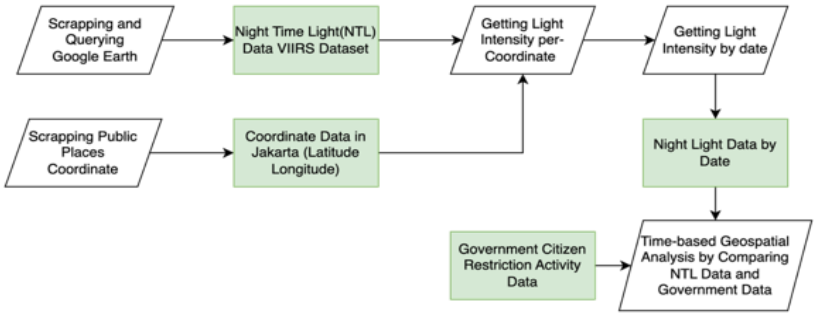


Figure 1. Framework and Workflow of this Research

This NTL Data by Date will later be analyzed by comparing it with the government's timeline of limiting people's movements. The final results of this analysis will see the correlation and also the effect of these restrictions on the light intensity of the samples over a certain period of time. This aims to see which areas and also what types of buildings are affected by the imposition of this restriction.

RESULTS AND DISCUSSION

Dataset

This study took a sample of one province in Indonesia, namely the capital city of Jakarta. This sampling is because Jakarta is one of the big cities that has the highest light intensity

throughout Indonesia. In addition, the application of restrictions on people's movements always starts from Jakarta because it has the highest mobility. Several coordinate points taken are attached in Tale 1, namely: Building, Hotel, Mall, Market, and Terminal. This sampling also consists of 5 cities in Jakarta, namely: Cental Jakarta, East Jakarta, North Jakarta, South Jakarta, and West Jakarta.

Table 1. Location Sampling for Light Intensity

District	Building	Hotel	Mall	Market	Station
Central Jakarta	30	22	17	33	1
East Jakarta	0	1	13	30	7
North Jakarta	5	2	15	27	3
South Jakarta	55	14	25	24	5
West Jakarta	9	3	13	24	4

From a total of 381 coordinate points taken, in Figure 2 is a representation of Latitude and Longitude on Maps in Jakarta. The coordinate points are scattered so that random sampling can represent areas in Jakarta. The dataset of several coordinate points is taken from Google API which provides services to get latitude and longitude based on the given place name.

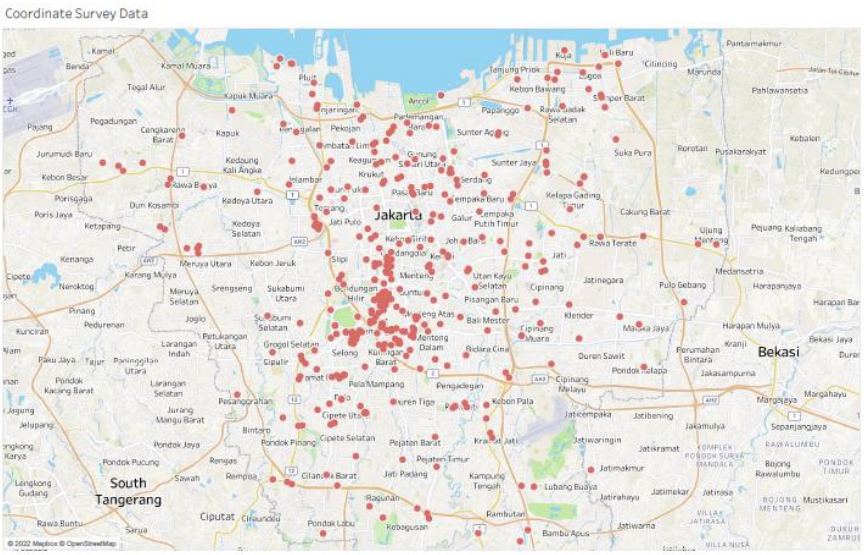


Figure 2. Sample Coordinate Latitude and Longitude in Jakarta Maps

Then in Figure 3 there is travel timeline data on how activity restrictions occur in Indonesia, especially for the Java and Bali regions. In this dataset, it can be seen that Indonesia has started implementing activity restrictions from April 2020 to 2022. This difference in levels indicates that the higher the level, the stricter the restrictions on community activities. For 2022, the level of restrictions on activities will decrease because most Indonesian people have been vaccinated.

After obtaining the coordinate point data, Google Earth data will be collected using Night Time Light Data using the VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1 version as shown in Figure 4. This dataset is taken every month by taking the monthly average radiance composite. images using nighttime data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB). This Night Time Light data was taken from January 2019 to June 2022. In addition to the initial dataset for several places in Jakarta, there is also data from the Google Mobility Report which observes people's movements starting from the beginning of the pandemic in February 2020 which is also referred to as the baseline. Google Mobility Data describes the activities of the people of Jakarta from 2020 to 2022 in several

categories, such as: Retail and Recreation; Grocery and Pharmacy; Parks; Transit Stations; Workplaces; Residential. This data on Google Mobility is referred to as "percent change from baseline", which means there is a change in a positive or negative direction compared to 2020 in February. The latest dataset used is the timeline for limiting community activities in Indonesia based on regulations issued by the government. So that later this government regulatory reference will be used to compare how it correlates with light intensity during the pre-Covid period and also when Covid took place.

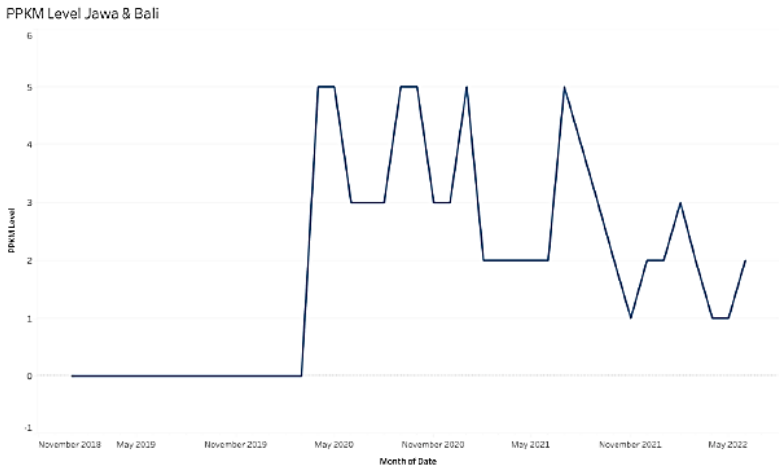
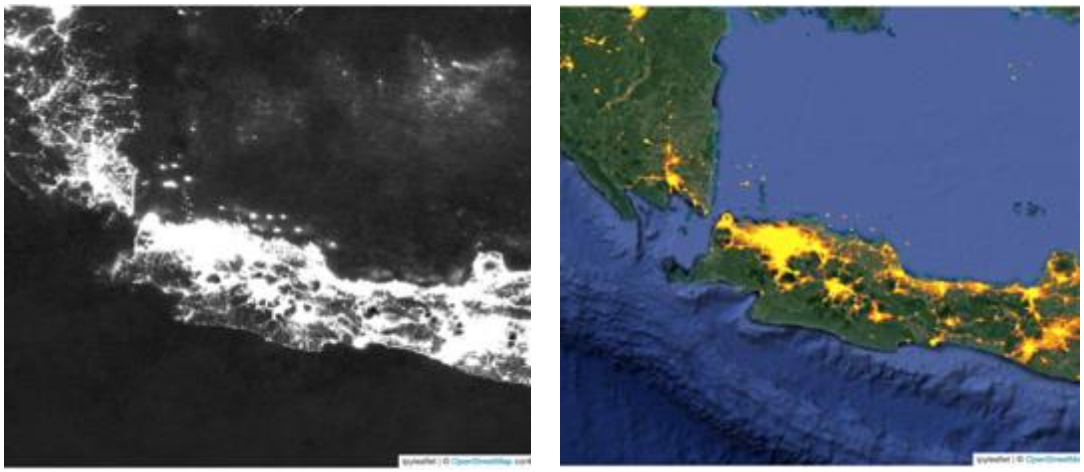


Figure 3. Timeline Level PPKM(Citizen Acitivity Restriction) in Indonesia.



(a) Initial Satelite Image **(b) Processed Image**

Figure 4. Example Night-Time Light(NTL) Image Dataset from Google Earth

Time-Based Geospatial Analysis

Based on the dataset that was taken from the previous satellite, it will then be converted to each coordinate point to obtain light intensity at a certain time. For example, in figure X is a timeline of light intensity over a certain period of time for one of the biggest malls in Jakarta, namely Grand Indonesia Mall. The figure shows that there has been a drastic decrease from when community activities restriction started to be implemented in late 2020 until 2022. When the proportion of vaccinations in Indonesia is large, and the government begins to relax restrictions on activities, light intensity patterns slowly begin to recover.

Figure 5. Example of Light Intensity by Time: Grand Indonesia Mall

In addition to one sample at the Grand Indonesia Mall, in Figure 6 there is data on changes in light intensity over time divided into several categories of places: Buildings, Hotels, Malls, Markets and Transit Stations. From 2019 to 2020 there was a decrease in the amount of light intensity because in the first quarter of 2020, Covid-19 began to enter Indonesia and restrictions on community activities began to be imposed. In addition, by comparison in Figure 7, it can also be seen that Central Jakarta has a higher light intensity compared to other cities in Jakarta. There are also similarities between areas of the city of Jakarta which also experienced a significant decrease in light intensity starting from Q4 2019 to Q1 2020.

The final analysis of this study is to compare the mobility data with the light intensity on the sample coordinate points that have been taken. This analysis is observed in general by taking the median of all sample coordinates for each point in time which can be seen in Figure 7. In Figure 7 it is also illustrated that the decrease in light intensity is not as extreme as the decrease in the mobility number of up to tens of percent. From these results, it was found that Covid-19 and also restrictions on people's movements greatly affected mobility in the retail, pharmaceutical, or transit station sectors. The purple line in Figure 7, Median Value, is the light intensity over time taken as the median value.

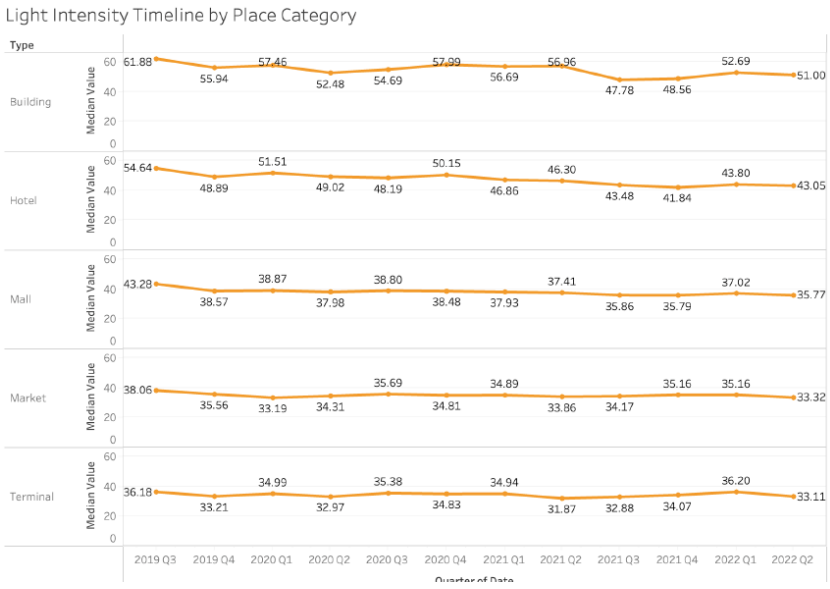


Figure 6. Light Intensity Timeline by Place Category

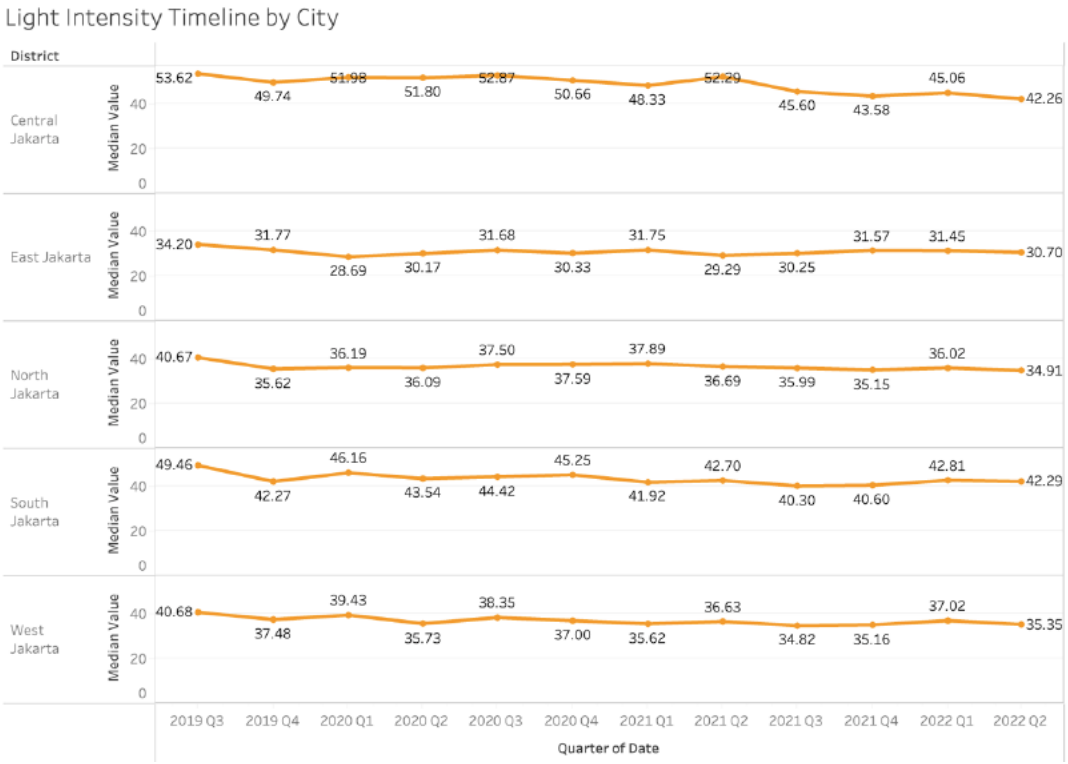


Figure 7. Light Intensity Timeline by City

Table 2. Location Sampling for Light Intensity and YoY Percent Change

Quarter of Date		Type				
		Terminal	Market	Mall	Hotel	Building
2019	Q1	37.51	36.85	43.13	53.01	58.58
	Q2	0.33%	5.11%	5.87%	4.24%	10.57%
	Q2	37.63	38.74	45.66	55.26	64.77
	Q3	-3.84%	-1.76%	-5.21%	-1.12%	-4.46%
	Q3	36.18	38.06	43.28	54.64	61.88
	Q4	-8.22%	-6.57%	-10.88%	-10.52%	-9.60%
	Q4	33.21	35.56	38.57	48.89	55.94
2020	Q1	5.37%	-6.67%	0.78%	5.36%	2.71%
	Q1	34.99	33.19	38.87	51.51	57.46
	Q2	-5.79%	3.38%	-2.29%	-4.83%	-8.66%
	Q2	32.97	34.31	37.98	49.02	52.48
	Q3	7.29%	4.04%	2.16%	-1.69%	4.21%
	Q3	35.38	35.69	38.8	48.19	54.69
	Q4	-1.54%	-2.47%	-0.82%	4.06%	6.03%
	Q4	34.83	34.81	38.48	50.15	57.99
2021	Q1	0.33%	0.22%	-1.42%	-6.54%	-2.24%
	Q1	34.94	34.89	37.93	46.86	56.69
	Q2	-8.81%	-2.95%	-1.38%	-1.22%	0.48%
	Q2	31.87	33.86	37.41	46.3	56.96

	Q3	3.19%	0.90%	-4.14%	-6.08%	-16.12%
	Q3	32.88	34.17	35.86	43.48	47.78
	Q4	3.62%	2.90%	-0.18%	-3.78%	1.63%
	Q4	34.07	35.16	35.79	41.84	48.56
2022	Q1	6.25%	0.00%	3.43%	4.70%	8.50%
	Q1	36.2	35.16	37.02	43.8	52.69
	Q2	-8.55%	-5.22%	-3.38%	-1.72%	-3.21%
	Q2	33.11	33.32	35.77	43.05	51

In this study, it was also found that light intensity was only slightly affected by this pandemic and restrictions. It was found that during the pandemic, the light intensity decreased by around 1%-16% which is written in detail in Table 2 with the time dimension and also the type of public places. The biggest decline was in buildings and malls because in general, these places produce a lot of light, then during a pandemic there were curfew restrictions for malls and also Work From Home (WFH) for buildings so there was an effect of reducing light intensity.

From the detailed results in Table 2, it can also be seen that in Q2 2022 the light intensity for several places has not fully returned to what it was before the pandemic took place. However, based on mobility data trends, the country of Indonesia is one of the countries in Asia that is experiencing good recovery so that in the future it is predicted to return to normal as before the pandemic occurred.

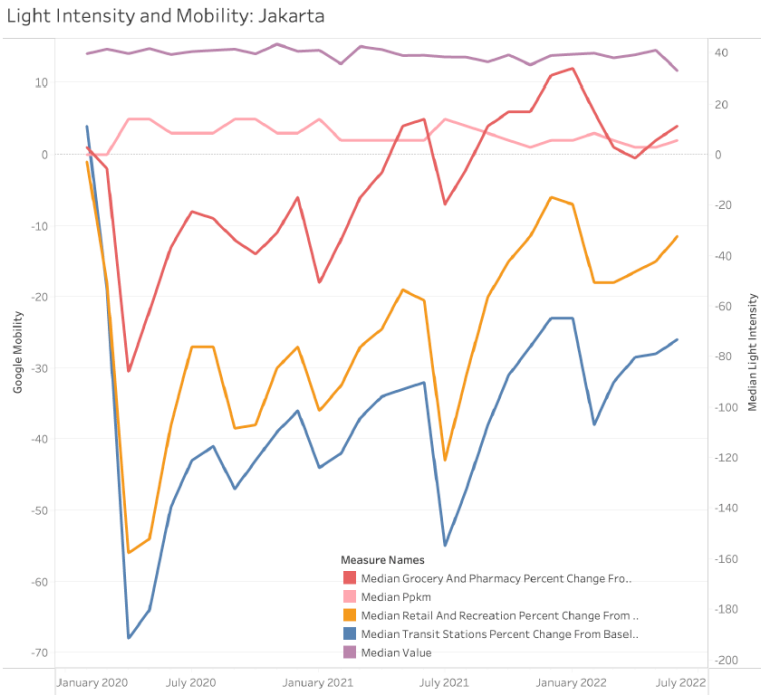


Figure 8. Light Intensity Timeline by Place Category

CONCLUSION AND RECOMENDATION

From the results of light intensity analysis using NTL Data by taking samples at several coordinate points and within a certain time, it was concluded that there was a decrease in the amount of light intensity when Covid-19 entered Indonesia by 1% - 16%. This is also supported by

an extreme decrease in the level of people's mobility based on Google data, which has almost reached -70% from the initial conditions before the pandemic. However, the level of restriction on community activities does not have such a large effect on the change in light intensity because a high level of restriction does not necessarily reduce the level of light intensity. Then there are also things to consider, namely several weather factors that can affect the intensity of light at night such as clouds, rain, fog or floods. So that the light intensity captured by the satellite camera becomes distorted. However, with this research, it becomes a new perspective to see how human life patterns on earth can be monitored using satellite photos, especially for community monitoring in certain cases such as this pandemic. In future research, it is expected to be able to utilize this satellite photo to monitor an event by combining satellite photos at night and also satellite photos during the day.

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