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THE IMPACT OF ACTIVITY DENSITY ON THE INCREASE IN AIR POLLUTION IN BANDUNG CITY SQUARE

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Abstract

Air pollution in the city of Bandung resulting from traffic congestion has disrupted the environmental balance, causing physical harm to the community. As these consequences are linked to material aspects, individual interests and rights are also compromised and adversely affected. The purpose of this research is to determine how vehicle and individual density impact air pollution. In this study, we analysed and collected data samples in Bandung, one of the largest cities. We conducted this at various times by counting the number of passing vehicles. Another factor contributing to air pollution is the increasing population density in the city centre of Bandung. The research findings indicate that vehicle density is lower during the daytime than in the morning, and vehicle density in the evening is also lower than during the daytime.

Keywords: Air pollution, Bandung city square, Population density, Vehicle density.

1. Introduction

The term "vehicle density" refers to the number of vehicles present at a specific point in time in a particular area or road. These factors are of great importance in traffic and transportation and can impact traffic efficiency, air pollution, road safety, and the quality of life in specific regions [1]. Bandung, one of the largest cities in Indonesia, has experienced rapid growth in recent decades [2]. While this growth has been beneficial for development and the economy, it has also been detrimental to the environment, particularly in terms of air pollution. In such circumstances, the number of vehicles and the population residing in the urban centre, such as Bandung City Square, is a crucial factor in discussions about air quality decline [3].

This research aims to examine how the number of people living in Bandung and the number of vehicles affect air quality and pollution in Bandung City Square. The city square serves as the hub of urban activities and functions as a microcosm that reflects common issues faced by many major cities worldwide. Vehicle density can change daily and in specific locations depending on various factors, such as working hours, seasons, and special events [4]. When vehicle density increases, traffic congestion can occur. Conversely, when vehicle density decreases, traffic flow can improve [5].

Vehicle density, including both private cars and public transportation, has significantly increased in metropolitan cities like Bandung. This has led to increased emissions of exhaust gases and hazardous particles, which are major contributors to air pollution [6]. The increase in population and vehicle density are two primary causes of air pollution escalation. This study explores how the population growth in Bandung City Square affects air pollution and the efforts that can be made to mitigate its adverse effects and maintain good air quality. More people mean more human activities, more energy consumption, and more ways to get around.

Many population-related issues, such as the number, distribution patterns, and density, need to be examined and reevaluated [7]. The purpose of doing this is to understand the causes of uneven population distribution patterns and density on the Earth's surface as population growth continues. People generally tend to cluster in areas with abundant resources and essential facilities for life [8]. As population growth conditions change, the activities of the population become increasingly concentrated, such as engaging in activities or gathering at specific places at specific times because Bandung City Square is renowned as a tourist destination and attracts many visitors, even causing significant density. Location, timing, season, and specific events can influence the extent of activities people undertake.

Data on the volume of human activities is often used by governments, urban planners, businesses, and research institutions to make better decisions regarding resource and urban environmental management, improving the quality of life, and making better adaptations to changes.

Masrul and Utami [9] found that significant traffic congestion occurs on the streets of Surabaya during peak hours. Consequently, traffic density increases during busy hours in the city of Surabaya. Many drivers do not adhere to traffic rules, there are instances of wrong-way driving, unregulated intersections without traffic lights, and pedestrians not using pedestrian bridges, all contributing to traffic congestion. As a result, traffic density in Surabaya not only leads to air pollution but also causes noise pollution due to the exhaust emissions from motorized vehicles [10]. Exhaust fumes worsen the air quality due to a higher concentration of chemicals than its natural composition. Consequently, health problems such as eye irritation, respiratory issues or lung problems, dizziness, nausea, fatigue, and more emerge, affecting the lives of those in the vicinity [11].

Andini et al. [12] stated that at intersections with Traffic Signal Lights (TSL) near the Primary Arterial Roads, namely Perintis Kemerdekaan Street and Setiabudi Street, which is the location of the study. This intersection consists of Karangrejo Street, Sukun Raya Street, and Ngesrep Timur V Street in Semarang City. The locations along Karangrejo Street, Sukun Raya Street, and Ngesrep Timur V Street are used for business, education, and residential purposes. According to field observations, there is a considerable flow of private vehicles, public transport, and motorcycles traversing Karangrejo Raya Street, Sukun Raya Street, and Ngesrep Timur V Street. Public transport frequently uses these roads in the city. Traffic lights are devices equipped with lights installed at intersections to control traffic flow.

Air pollution in large cities is a complex issue to resolve, and the primary cause of pollution is transportation. Industries, transportation, and household activities are the primary sources of air pollution in major cities. Over time, the types of vehicles used, and the fuels utilized have changed [12]. When vehicle emissions and exhaust gases are not monitored, air quality deteriorates [13]. Consequently, the primary source of Nitrogen oxide (NO_x) air pollution is the exhaust emissions from stationary power generators or engines using fossil fuels such as diesel and kerosene. Nitrogen oxide (NO_x) is a group of atmospheric gases composed of Nitric oxide (NO) and Nitrogen dioxide (NO_2) [14].

This research is based on prior studies to understand vehicle density, human activities, and air pollution caused by traffic congestion. This stems from the fact that the population in metropolitan cities in Indonesia, such as Jakarta, Surabaya, and Bandung, is extremely busy, to the extent that they do not consider using the streets for their daily needs or other activities [15, 16].

By gaining a deeper understanding of how vehicle and population density impact air pollution in Bandung City Square, this research aims to provide valuable insights for addressing pressing environmental issues and laying the foundation for efforts to improve air quality resulting from vehicle density and the well-being of the urban population in this area.

2. Research Method

This research employs a descriptive quantitative approach. Data collection occurred at three different times at 08:20 AM, 11:40 AM, and 1:47 PM Western Indonesia Time (WIB) on Saturday, October 7, 2023, with each session lasting 10 minutes. The day and the times were chosen based on the public activities happening at the city square. The choice of the city square itself was decided because it is a bustling location every day and a well-known tourist attraction and family recreation site. Some companies in Bandung employ a five-day workweek while others employ a six-day workweek. Therefore, it is the time when some people do recreation while others still going to work. At 08:20 AM, it is the usual time for family recreation and for the workers to go to work. At 11:40 AM, it is the time for the lunch break and for some workers to go home. Lastly, 1:47 PM is for office workers to go home.

Several instruments were used in this study, traffic density was counted using a mobile traffic counter application whereas air quality was measured using one AQMO2 (8-in-1 Air Quality Monitor) and one HT 2000 (CO_2 meter). The study was conducted around Bandung City Square, which was divided into three areas: Dalem Kaum Street, Asia Afrika Street, and the centre of the City Square (as shown in Fig. 1). As shown in Fig. 1, the first point was situated at Dalem Kaum Street, point two was located at Asia Afrika Street, both streets are one-way streets, and then the third point was located at the centre of the City Square.

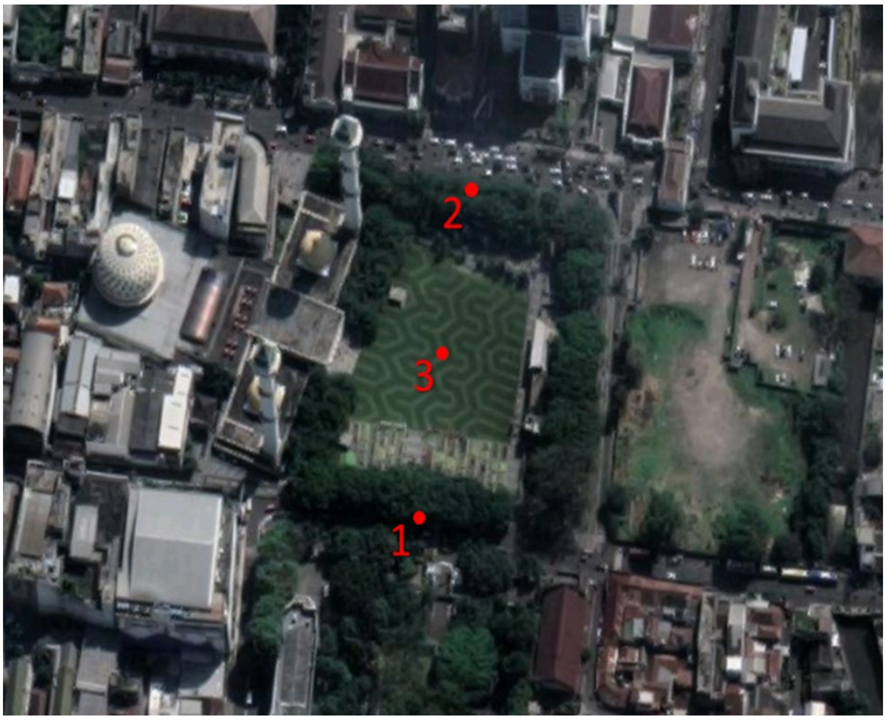

Fig. 1. Location of data collection: Alun-alun (City Square) Bandung.

3. Results and Discussion

In the first point, there were 831 motorcycles, 161 cars, 37 trucks, and 4 buses in 08:20. In 11:45, there was a noticeable decrease in the number of motorcycles to 576 and trucks to 15, while there was an increase in the number of cars to 247 and buses to 10 as shown in Fig. 2. However, there was an increase in the number of motorcycles to 642 and cars to 276, but there was a decrease in the number of trucks to 15, and buses to 5 at 13:47.

Meanwhile, at point 2, the result of the traffic counter showed that there were 878 motorcycles, 241 cars, 24 trucks, and 9 buses at 08:20 as shown in Fig. 3. Then, at 11:45, there was a decrease in the number of motorcycles to 790 and trucks to 15 while there was an increase in the number of cars to 393 and buses to 10. Lastly, there is a significant increase in the number of motorcycles to 929 while the rest decreased from cars to 2, as well as trucks and buses to 0. In addition to the traffic density, Tables 1 to 3 show the air quality around the city square.

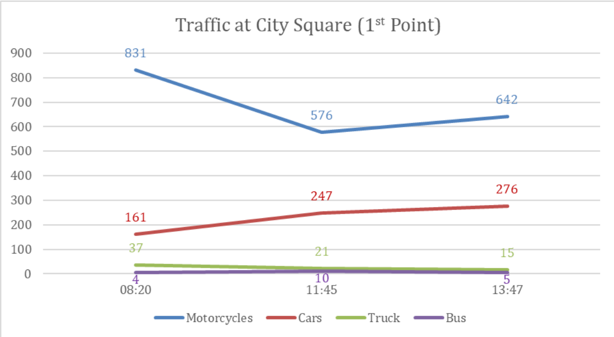

Fig. 2. Amount of traffic at Asia-Afrika street.

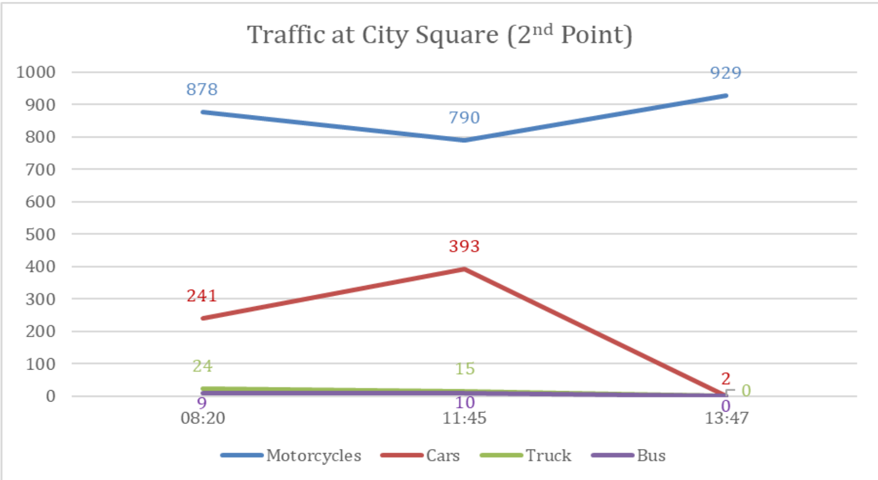

Fig. 3. Amount of traffic at Dalem Kaum street.

At point 1, from 08:20 to 08:30 AM WIB, the AQMO2 and HT-2000 were activated for 10 minutes and indicated that the air properties on Jl. Dalem Kaum had PM2.5 at 33 ppm, PM1.0 at 19 ppm, PM10 at 42 ppm, HCHO at 0.013 ppm, TVOC at 0.735 ppm, CO_2 at 598 ppm, a temperature of 26.1°C, and humidity at 58% as depicted in Table 1. Then, at 11:45 to 11:55 AM WIB, PM2.5 increased to 44 ppm, PM1.0 to 26 ppm, PM10 to 56 ppm, CO_2 to 650 ppm, and the temperature rose to 31.2°C. However, HCHO remained at 0.041 ppm, while TVOC decreased to 0.129 ppm, and humidity dropped to 44%. Finally, measurements taken from 13:47 to 13:57 WIB showed a decrease in PM2.5 to 29 ppm, PM1.0 to 16 ppm, PM10 to 36 ppm, TVOC to 0.054 ppm, CO_2 to 621 ppm, and humidity to 34%. On the other hand, there was an increase in HCHO to 0.022 ppm and the temperature rose to 32.9°C.

Table 1. Air quality at Dalem Kaum street (1st point).

Time	PM2.5	PM1.0	PM10	HCHO	TVOC	CO_2	Temperature	Humidity

	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ºC)	(%)
08:20	33	19	42	0.013	0.735	630	26.1	58%
11:45	44	26	56	0.013	0.129	650	31.2	44%
13:47	29	16	36	0.022	0.054	621	32.9	34%

At point 2, at 08:20, the HT-2000 and AQMO2 were activated for 10 minutes. Table 2 shows the measurement results indicating the air properties on Jl. Asia-Afrika, with PM2.5 at 32 ppm, PM1.0 at 18 ppm, PM10 at 40 ppm, HCHO at 0.041 ppm, TVOC at 0.016 ppm, CO_2 at 630 ppm, a temperature of 23.8°C, and humidity at 60%. There was an increase in the values at 11:55, with PM2.5 rising to 44 ppm, PM1.0 to 28 ppm, PM10 to 58 ppm, TVOC to 0.389 ppm, CO_2 to 650 ppm, and the temperature increasing to 29.8°C. However, HCHO and humidity decreased to 0.010 ppm and 45%, respectively. At 13:57, the HT-2000 and AQMO2 indicated an increase only in HCHO to 0.011 ppm, while PM2.5 increased to 35 ppm, PM1.0 to 20 ppm, PM10 to 44 ppm, HCHO to 0.011 ppm, TVOC to 0.298 ppm, CO_2 to 621 ppm, the temperature to 29.6°C, and humidity to 42%.

Table 2. Air quality at Asia-Afrika street (2nd point).

Time	PM2.5 (ppm)	PM1.0 (ppm)	PM10 (ppm)	HCHO (ppm)	TVOC (ppm)	CO_2 (ppm)	Temperature (ºC)	Humidity (%)
08:20	32	18	40	0.041	0.016	630	23.8	60
11:45	44	28	58	0.010	0.389	650	29.8	45
13:47	40	24	52	0.011	0.244	621	29.7	42

At point 3, the HT-2000 and AQMO2 were activated for 10 minutes starting at 08:20, and measurements revealed that the air properties at that point consisted of PM2.5 at 23 ppm, PM1.0 at 14 ppm, PM10 at 29 ppm, HCHO at 0.012 ppm, CO_2 at 533 ppm, TVOC at 0.310 ppm, a temperature of 32.4°C, and humidity at 45% (as shown in Table 3). At 11:45, there was a decrease in air properties, with PM10 dropping to 27 ppm, HCHO to 0.009 ppm, TVOC to 0.065 ppm, CO_2 to 531 ppm, and humidity to 31%. However, PM2.5 increased to 36 ppm, and the temperature rose to 40°C. Lastly, at 13:47, there was a reduction in PM2.5 to 28 ppm, PM1.0 to 16 ppm, and the temperature dropped to 36.9°C, while PM10 increased to 36 ppm. HCHO increased to 0.014 ppm, TVOC increased to 0.255 ppm, and CO_2 increased to 621 ppm, while humidity remained at 31%.

Table 3. Air quality at the centre of city square (3rd point).

Time	PM2.5 (ppm)	PM1.0 (ppm)	PM10 (ppm)	HCHO (ppm)	TVOC (ppm)	CO_2 (ppm)	Temperature (ºC)	Humidity (%)
08:20	23	14	29	0.012	0.310	533	32.4	45%
11:45	36	23	27	0.009	0.065	531	40	31%
13:47	28	16	36	0.014	0.255	621	36.9	31%

The research data analysis results from the two points show a significant difference, with motorized vehicles tending to pass more frequently on Jl. Asia-Afrika compared to Jl. Dalem Kaum. In the first session, the concentration of particulate matter PM2.5 and PM1.0 was slightly higher at points 1 and 2 during the morning session. The TVOC concentration at point 2 was also lower than at point 1, and the CO_2 concentration at point 2 was higher than at point 1. In the second session, the locations had the same concentrations of PM2.5 and PM1.0, but the PM10 concentration at point 2 was slightly higher. At point 2, there was also a significantly higher TVOC concentration than at point 1, and the CO_2 concentration was also higher at point 2. Moreover, carbon monoxide levels, humidity, and temperature also differed at the two locations.

In the third session, at the first point, the instruments were used for 10 minutes, generating research data with AQMO2 measurements of PM2.5 at 20 ppm, PM1.0 at 16 ppm, PM10 at 36 ppm, HCHO at 0.022 ppm, TVOC at 0.054 ppm, a temperature of 32.9°C, and humidity at 34%. At the second point, the instruments were used for 10 minutes, producing research data with AQMO2 measurements of PM2.5 at 35 ppm, PM1.0 at 20 ppm, and PM10 at 44 ppm.

4. Conclusion

The objective of this research is to measure and identify various factors, including air pollution levels, humidity levels, CO2 levels, and oxygen levels, as well as vehicle density at two different points within the Bandung City Square area. From the gathered information above, it can be concluded that the density of vehicles passing through the city square leads to an unstable air temperature along the roadside. However, in the central open area, sunlight and population density contribute to an increased temperature.

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