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The Relationship of Fire Incident and Area Vulnerability: Case Study of West Jakarta Municipality, Indonesia

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Abstract. *Fire incident has a great impact on the loss of lives and financial loss due to property damage. Areas with high population density, densely physical building conditions, and irregular building patterns commonly form congested residential slum areas are vulnerable to fire hazards. The capital city of Jakarta is the most populous city in Indonesia and the most densely populated city, with an average of 15,900 people per sq km. In 2019, there was 2,109 fire incident recorded, and nearly 20% of them occurred within the West Jakarta Municipality area. This study investigates the relationship of population density and building density, which are considered vulnerability factors of an area, to fire incidents within the West Jakarta Municipality area in 2019. This study investigates 56 villages within the eight subdistricts of West Jakarta Municipality. This study is an ecologic study, and the bivariate test used is Spearman's rank correlation. The fire incident was significantly correlated with the building density (p -value=0,0001; r =-0,533) and the population density (p -value=0,04; r =-0,276). The distribution of densely populated and high building density villages is dominant in West Jakarta Municipality's east region. In contrast, the villages with high fire incident are dominant in West Jakarta Municipality's west region.*

Keywords: *Fire Incident, Area Vulnerability, West Jakarta*

1. Introduction

Fire incident significantly impacts the loss of lives and financial loss due to property damage, as mentioned in the research conducted in Canada, India, and Indonesia (Asgary *et al.*, 2010; Singh *et al.*, 2021; Sufianto and Green, 2011; Rahardjo and Prihanton, 2020). Globally, over 300,000 deaths are caused by fire annually, the fourth-largest cause of accidental injury (after road accidents, falls, and drowning). One of the significant urban disasters due to high population density and economic value

are fires in high-rise buildings and residential complexes due to the high population density and high economic value of buildings and the property within the buildings (Masoumi *et al.*, 2019).

The rapid building construction in Jakarta, following the rapid economic growth of Indonesia within the last two decades, has caused fire problems (Sufianto and Green, 2011). Urban sustainable development is adversely affected by structure fires. Structure fires threaten property within or surrounding the building, continuity of operations, the protection of environment around structures, and life safety of residents (Singh *et al.*, 2021; Setiawan *et al.*, 2020). Areas with densely physical building conditions and irregular building patterns commonly form congested residential slum areas are vulnerable to fire hazards (Setiawan *et al.*, 2020; Sudiana *et al.*, 2018). Structure fires pose a substantial negative impact on the buildings and also on economic and social aspects. Residents who are victims of urban fires are likely to face food, health, psychological, and financial challenges and are subject to living in refugee camps (Rahardjo and Prihanton, 2020).

As the capital city of Indonesia, Jakarta is the most populous city in Indonesia and the most densely populated city, with an average of 15,900 people per sq km (BPS, 2020b). As can be seen from the density of settlements, the population growth of Jakarta Province is due to urbanization and the high birth rate in the area (Amin and Alisjahbana, 2018). The growth of the population has driven the urban development and the development of densely populated residential areas in Jakarta Province. Some areas developed into slum areas that are vulnerable to urban fires (Sudiana *et al.*, 2018). West Jakarta Municipality is an administrative area within the Province of Jakarta. The rapid development of West Jakarta Municipality with increasing population and building public facilities and infrastructures to support community activities pose a threat to the potential fire disasters in densely settlements areas in West Jakarta (Setiawan *et al.*, 2020). In 2019, there were 2,109 fire incidents recorded in the Jakarta Province, and nearly 20% of them occurred within the West Jakarta Municipality area (BPS, 2020a). This study examines the relationship between fire incident, population density, and building density in the West Jakarta Municipality.

2. Research Methodology

2.1. Study Design and Study Area

The study design used for this research is ecological study (Morgenstern, 1998). The population in this study is the entire villages located within the West Jakarta Municipality, consisting of 56 villages. The fire incident, population density, and building density data are secondary data collected from relevant institutions. The fire incident data is from the Fire Department and Disaster Management of Jakarta Province, and the population density is from the Statistics Bureau of Jakarta Province (BPS, 2020). The building density data comes from aggregating the data of building structures with administrative boundaries from the Jakarta One Data Geoportal (<https://jakartasatu.jakarta.go.id>) (PemprovDKI, 2020).

2.2. Data Analysis

The data analysis consists of univariate and bivariate analysis. A normality test was performed on all the data. When the data normality test (p-value) result is <0.05 , a non-parametric test is used for the bivariate analysis. Spearman's rank correlation is a non-parametric test; therefore, it is used for the bivariate analysis. Spearman's rank correlation test is used to investigate the magnitude and the direction of the relationship between two numeric variables which are not normally distributed. Alpha 5% is used in the study, and a relationship between two variables is considered significantly associated if the $p\text{-value} < 0.05$ (Pagano and Gauvreau, 2018). This study has passed the ethical approval conducted by the

3. Results and Discussion

The fire incident variable has a minimum value of 0 and the maximum value of 21 fire incidents. The standard deviation is 5.2758, the median value is 5, and the mean value with the 95% Confidence Interval is 6.857 (5.44—8.27), meaning that 95% of fire incident in the population is between the range of 5.44 to 8.27. The result of the normality test using the Kolmogorov-Smirnov shows the p-value of 0.002, which indicates that fire incident is not normally distributed with the skewness of +0.842. The population density variable has a minimum value of 7,168 persons per km² and a maximum value of 95,078 persons per km². The standard deviation is 19,032.3 persons per km², the median value is 22,175.5 persons per km², and the mean value with the 95% Confidence Interval is 29,281.5 (24184,59 - 34378,38) persons per km², meaning that 95% of population density in the population is between the range of 24,184.59 to 34,378.38 persons per km². The result of the normality test using the Kolmogorov-Smirnov shows the p-value of 0.0001, which indicates that population density is not normally distributed with the skewness +1.391. The building density variable has a minimum value of 25.5% and the maximum value of 59.54%. The standard deviation is 9.08%, the median value is 42.35%, and the mean value with the 95% Confidence Interval is 42.29% (39.86%—44.72%), meaning that 95% of building density in the population is between the range of 39.86% to 44.72%. The result of the normality test using the Kolmogorov-Smirnov shows the p-value of 0.2, which indicates that building density is generally distributed with the skewness +0,096 (Table 1).

Table 1. Univariate Analysis of Fire Incident and Vulnerability Factors, West Jakarta, 2019

Variable	N	Min-Max	Mean	Median	SD	95% CI Mean	Kolmogorov-Smirnov p-value
Fire incident	56	0--21	6.857	5	5.2758	5.44--8.27	0.002
Population density	56	7168--95078	2928	22175.5	19032.34	24184.59--34378.38	0.0001
Building density	56	25.50--59.54	42.29	42.35	9.0817	39.86--44.72	0.2

The mapping of fire incidents in West Jakarta Municipality points out that the villages with a high fire incident are predominantly located in the western region of the West Jakarta Municipality and symbolized with dark color. Villages with more than 16 fire incidents (the darkest red color) dominate the north-western region villages, namely Kamal, Kali Deres, and Cengkareng Timur. The villages with the second-highest number of fire incidents (13-16 fire incidents) symbolized by dark pink color, also located in the western villages of West Jakarta Municipality, namely Pegadungan, Cengkareng Barat, Duri Kosambi, Rawa Buaya, Kembangan Utara, and Kembangan Selatan. On the other hand, the villages with the minor fire incident during the year 2019 (less than five incidents) dominate in the eastern villages of the West Jakarta Municipality administrative area (light pink pastel color), namely Pekojan, Roa Malaka, Tambora, Angke, Jembatan Lima, Glodok, Mangga Besar, Kerendang, Keagungan, Kali Anyar, Duri Selatan, Krukut, and Maphar. The villages with the second-lowest number of fire incidents (5-8 fire incidents) are symbolized by the lighter-orange color in the eastern region, namely Grogol, Duri Utara, Tangki, and Taman Sari (Figure 1).

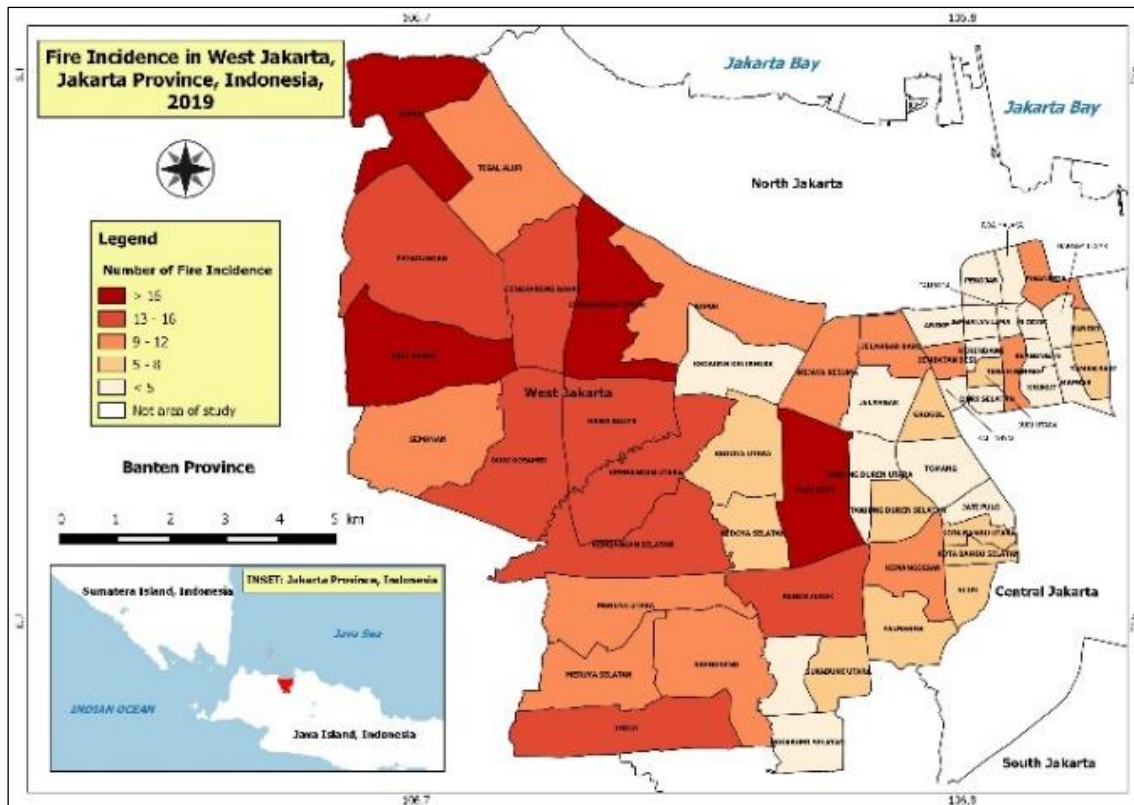


Figure 1. Distribution of fire incident in West Jakarta, Jakarta Province, Indonesia, 2019

The mapping of population density in West Jakarta Municipality indicates that the villages with darker colors dominate the eastern region. The village with more than 80,000 persons per km² (the darkest purple) is located in the north-eastern region of the area, namely Kali Anyar. The villages with the second-highest number of persons per km² (65,001-80,000) during the year 2019 symbolized by the darker purple color, also predominantly located in the eastern region of West Jakarta Municipality Jembatan Besi, Kerendang, and Keagungan. On the other hand, the villages with the lowest population density during the year 2019 (less than 25,000) dominate in the western region of the study area (light purple pastel color), namely Kamal, Pegadungan, Kali Deres, Semanan, Tegal Alur, Cengkareng Barat, and Duri Kosambi. The lighter-blueish color symbolizes the villages with the second-lowest population density (25,000-40,000), are predominantly located in the center region of the study area, namely Kapuk, Kembangan Utara, Jelambar Baru, Jelambar and also located in the southern region, namely Palmerah, Sukabumi Utara, and Sukabumi Selatan (Figure 2).

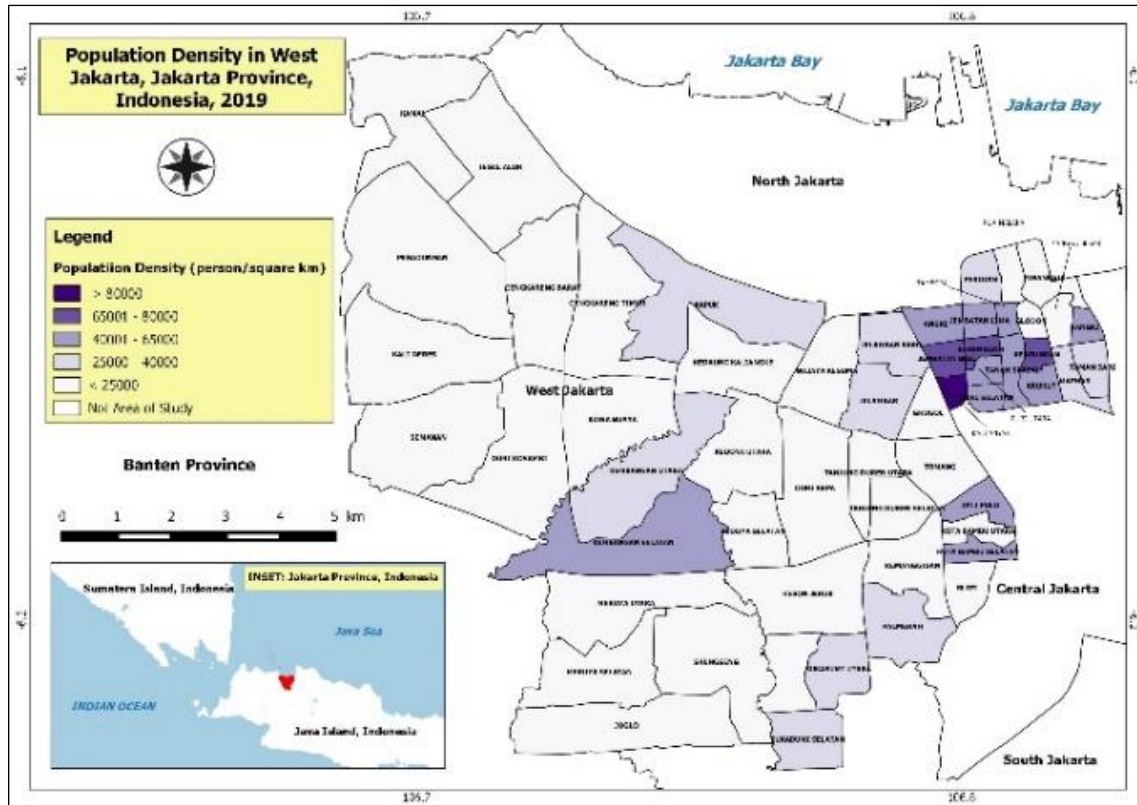


Figure 2. Distribution of the population density in West Jakarta, Jakarta Province, Indonesia, 2019

The mapping of building density in West Jakarta Municipality points out that the villages with the darker color dominate the area's eastern region. The village with more than 45% (the darkest green) is located in the north-eastern region of the area, namely Jelambar Baru, Jelambar, Angke, Jembatan Besi, Kali Anyar, Pekojan, Jembatan Lima, Kerendang, Duri Utara, Duri Selatan, Roa Malaka, Tambora, Tanah Sereal, Glodok, Keagungan, Krukut and Mangga Besar. The villages with the second-highest building density (40,1-45%) during 2019 symbolized by the darker green color, also predominantly located in the eastern region of West Jakarta Municipality, Tangki, Maphar, Grogol, Wijaya Kesuma, and Duri Kepa. On the other hand, the villages with the lowest building density during 2019 (less than 30%) dominate the center region of the West Jakarta Municipality administrative area, namely Kedaung Kaliangke, Kembangan Selatan, Meruya Selatan, Srengseng, and Joglo. The villages with the second-lowest building density (30-35%) symbolized by the lighter-greenish color dominate the center region of the West Jakarta Municipality administrative area, namely Duri Kosambi, Rawa Buaya, Kembangan Utara, Kedoya Selatan, and Meruya Utara (Figure 2).

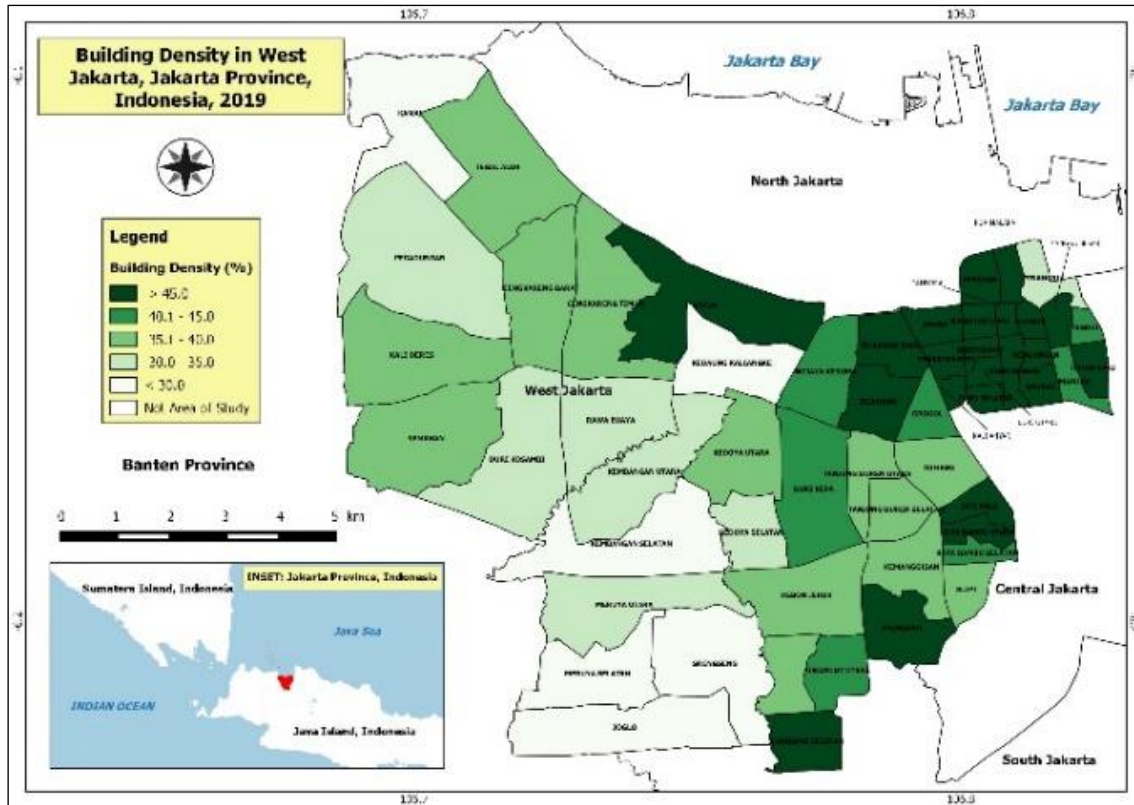


Figure 3. Building density in West Jakarta, Jakarta Province, Indonesia, 2019

The bivariate analysis of fire incidents with population density and fire incidents with building density indicated negative linear correlations of $r=-0.343$ (population density) and $r=-0.625$ (building density). Both variables mentioned above are significantly correlated with fire incidents ($p\text{-value}<0.05$) with a moderate to strong magnitude of correlation (Table 2).

Table 2. Bivariate Analysis of Fire Incident with Vulnerability Factors, West Jakarta, 2019

Variable	N	r	p-value
Population density	56	-0.343	0.016
Building density	56	-0.625	0.0001

The result of the bivariate analysis suggests that the less dense the population density and building density in the West Jakarta Municipality area, the higher the fire incident, or in other words; the higher the population density and the building density, the lower the fire incident in the West Jakarta Municipality area. The result is not in line with the research conducted by Asgary *et al.* in Toronto, Canada, which suggested that the lowest fire incident intensity for all categories is found in areas with low population densities, newer developments, and higher incomes (Asgary *et al.*, 2010). Setiawan *et al.* mentioned that high-class residential fires dominate the Cengkareng Subdistrict, West Jakarta Municipality, probably the case within the whole West Jakarta Municipality area (Setiawan *et al.*, 2020). According to Kumar *et al.*, the vulnerable population, buildings, and nearby surroundings (e.g., high-density commercial) affects the occurrence of the fire incident hot spots in Mumbai, India, which also corresponds with Proag that mentioned the physical vulnerability relates to buildings and also to infrastructure (Kumar *et al.*, 2020; Proag, 2014).

4. Conclusions

The fire incident in the West Jakarta Municipality during 2019 is significantly correlated with the building density and the population density. The fire incident in the West Jakarta Municipality during 2019 mainly occurred in areas with lower building density and less densely populated areas. The densely populated and high building density villages are dominant in West Jakarta Municipality's eastern region. In contrast, the villages with high fire incidents are dominant in the western region of West Jakarta Municipality. Further studies using a more detailed unit analysis and classification will provide a clearer picture of the typology of buildings or settlements prone to fire incidents.

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