Fire risk based on building density in dense settlement

M I R Winandari*, P Wijayanto and Faradila
Architecture Department, Universitas Trisakti, Jl. Kyai Tapa No. 1, Jakarta, Indonesia

*mi.ririk@trisakti.ac.id

Abstract. Fire disaster occurs commonly in densely populated settlements mostly due to a large number of inhabitants. Among the various types of disasters, those related to fire outbreak, need to be avoided. Therefore, it is important to determine the building density, and street conditions, with the availability of fire extinguishers to prevent fire disaster mitigation. This research examined the risk of fire disaster based on building density in a dense settlement. The research was carried out in 9 village communities in Kali Anyar Sub-district, using the case study method. Aspects of total area, number of building units, and fire accidents location were used to evaluate the cases. The result showed that the rate of fire outbreak was not always related to the building density. However, physical arrangement related to fire risk in all building is necessary to minimize the possibility of its occurrence.

1. Introduction
Disasters are classified into two broad categories, namely natural and man-made. Fire disaster is a man-made disaster that can be avoided in settlements and other parts of the environment. This is the 4th largest man-made disaster in the world and Indonesia [1]. Between 2000 and 2020, there were 2402 fire incidents in Indonesia with electricity and candles attributes to its occurrence in residential areas [2]. In dense settlements, fire is a disaster that can cause a lot of causalities and material loss. Its high risk is influenced by population and building densities, building quality, road conditions, and the availability of fire extinguishers. However, not all areas with high building density are at a high risk of fire outbreak [3]. Therefore, it is important to determine the relationship between building density and fire incidence in an area.

Involvement and capacity of community in disaster mitigation play a significant role in reducing disaster associated risk [4]. However, socio-political, and economic conditions, especially in low-income communities, exacerbate the risk of fire outbreak [5]. Furthermore, physical environmental control is indispensable in mitigating disasters, therefore, control can be carried out by determining the availability of disaster evacuation routes [6,7], open space, the position of infrastructure, number of buildings [7], width of roads [8,9], and availability of fire extinguishers [10,11]. This physical condition is presented in the form of a fire risk map which includes the position of fire-prone infrastructure, entry and evacuation routes, fire hydrant positions, building access, and fire systems [7]. Various studies indicate that fire problems occur majorly in settlements with high building densities. This led to the implementation of various policies to ensure that there are maximum evacuation routes, such as reducing the number of parked vehicles on the street, optimized land usage, and developing roads with a width of more than 2.5 meters [8,11]. However, despite these policies, fires still occur, due to the difficulty in obtaining the right data on the number of buildings and population in dense settlements, especially the lower middle class [1].
This study was carried out to demonstrate the risk of fire disasters in densely populated settlement using a sub-district in Jakarta, as a case study. The result showed that this situation can occur in big and medium cities. In contrast to other studies, this research also reveals a relationship between building density and the incidence of fire in Kali Anyar Sub-district, which has the most densely populated settlements in Jakarta. This situation is very suitable to be used to determine the trends in similar problems in other urban areas.

2. Methods
The case study method was used to explore the relationship between building density and the occurrence of fire disasters. This method is considered the most appropriate research tool because it uses propositions as an initial reference when going into the field, with the unique exploration used for further analysis [12].

The research was carried out in nine neighborhood associations or Rukun Warga (RW) at Kali Anyar, which is one of the eleven Sub-districts in Tambora District. The area is administratively located at West Jakarta with a total area of 0.32 km² or 5.90% of Tambora District (542.09 ha). The area was chosen because it is the most densely populated settlement in Jakarta. Fire is not the only type of disaster that occurs in this Sub-district. Another disaster that occurs is flooding because of its close location to Krendang river.

The unit of analysis, which is the basis for data retrieval consists of the number of building units and the fire incidence. Data obtained through literature reviews, urban village archives, and field observations, showed that building density analysis was carried out by manually counting the number of building units in each RW based on a digital base map of Jakarta. Furthermore, the number of fire incidents was obtained through literature and archives belonging to the office of the sub-district, such as Map of Disaster-Prone Area or Peta Area Rawan Kebakaran. The data obtained from the building density were cross analyzed with fire accidents that occurred at each RW in Kali Anyar Sub District.

3. Results and discussion
Indonesia is the fourth most populous country in the world and the 83rd position in terms of settlement density. Similar to other big cities in the world, the majority of Indonesia populations live in urban areas, and it is predicted that by 2050, approximately 85% will relocate to cities.

Regarding risk disaster, Indonesia is ranked 37th in the World Risk Index, due to its very high exposure, and vulnerability [13]. However, its position is still better than other countries in the South East Asia region, such as Brunei Darussalam (7th), Philippines (9th) and Cambodia (17th). These countries are in the highest risk class because of their very high exposure.

The high-risk index is directly proportional to the population size and the occurrence of disasters in an area. Out of all the cities in Indonesia, Jakarta, which is the capital city and the province with the smallest area, has the highest population density. Meanwhile, in terms of districts, Tambora is the area with the highest population density of 43,930 persons per km². One of its sub-districts known as Kali Anyar is the area with the highest population density and the second smallest area in Jakarta. Located in West Jakarta District, this sub-district consists of 9,603 households, with 29,728 people living on a 0.32 km². Furthermore, approximately 92,900 people live in a km², thereby making the area a sub-district with the highest density [14]. Kali Anyar consists of nine RW with varying total area and number of building units. The type of building used in the area is mostly house or residential with a unit consisting of 2-3 stories and occupied by several households. Many houses located in one of the areas known as Tambora are used as convection factory, therefore, the area is known as convection home industry.

3.1. Fire risk based on building density
Fire risk is a type of man-made disaster-related to fire hazard, particularly caused by uncontrolled flames. Other kinds of man-made disasters are accidents due to transportation or structural failure. Fire risk can be assessed by examining the possibility of a fire outbreak and predicting its impacts. Measuring the possibility of a fire risk can be checked by determining the information of fire frequency. On the
other hand, one way of measuring fire risk vulnerability is through building density obtained by dividing the number of buildings against the area. The variation of the total area in each RW ranges from 1.6 km² to 5.5 km² while the number of units’ ranges from 133 to 258 units [14]. The largest total area is RW 08, with 258 units while the smallest is RW 05 with 133 units. Furthermore, the highest number of building units is RW 08, while the least is RW 06. Based on the data on land area and the number of building units in each RW, the variation in building density in each unit ranges from 47 units/ha to 116 units/ha. RW with the highest building density is RW 05 while the lowest is RW 08.

Fire risk vulnerability is indicated by the number of building density of an area. Building density between 32-57 units/ha is classified as moderate susceptibility, while more than 57 units/ha is classified as high vulnerability [15]. Most of buildings in RW 07 are attached to each other with a distance between buildings including the street width approximately 0-2 meters (as seen in figure 1). The short width is exacerbated by the placement of vehicles and furniture on both street side. This condition shows the high vulnerability density in RW 07.

Table 1 shows that the fire risk vulnerability in Kali Anyar falls into two categories, namely high or moderate level. There are 4 RW with the number of units less than 57 per ha, including RW 03, RW 04, RW 06 and RW 47. Five RWs, namely RW 01, RW 02, RW 05, RW 07, and RW 09 are classified as high level with the highest fire risk at RW 05 (116 unit/ha), and the lowest is RW 09 (69 unit/ha). The other four RWs, namely RW 03, RW 04, RW 06, and RW 08 are classified as moderate fire risk vulnerability group with the highest fire risk is RW 06 (55 unit/ha), and the lowest is RW (47 unit/ha).

| RW | Total area (ha) | unit | unit/ha | Vulnerability level |
|----|----------------|------|---------|---------------------|
| 01 | 3.2            | 253  | 84      | High               |
| 02 | 2.5            | 201  | 80      | High               |
| 03 | 5              | 258  | 52      | Moderate           |
| 04 | 2.8            | 143  | 53      | Moderate           |
| 05 | 1.6            | 186  | 116     | High               |
| 06 | 2.4            | 133  | 55      | Moderate           |
| 07 | 1.8            | 151  | 84      | High               |
| 08 | 5.5            | 258  | 47      | Moderate           |
| 09 | 2              | 137  | 69      | High               |
3.2. Fire risk and fire accident analysis
Tambora District experience frequent fire outbreaks, which ranges from 3 to 4 events per year. According to the General Guidelines for Disaster Risk Assessment BNPB published in 2015, a frequency of more than three events in an area is included in the high criteria [4]. Fire incidents in Kali Anyar sub-district are bound to occur several times a year, this encouraged the government to improve the system by providing fire hydrants. Currently, there are 2 RW equipped with fire hydrants, with one of them located at RW 08.

Figure 2 shows the mapping of fire locations and fire-prone areas from 2013-2019. The mapping was the results of previous research and archives collected at the office of sub-district or RW, which indicates 12 locations of fire events [3,16]. The map shows the occurrence of fire irrespective of the place, whether near the main street or in the middle of sub-district. It also happens that the location of fire events is next to the others, as shown on the map, which also indicates 3 fire-prone areas with high risk.

A total of nine RW are in Kali Anyar sub-district, and all have experienced fires at least once. In those events, a short circuit was often the cause of the fire, with the most serious location at RW 08, followed by RW 01 and RW 09. Cross-analyzed findings of fire incidents with fire risk vulnerability are shown in table 1, which indicates that RW 08 with the highest fire incidence was moderate while RW 01 and RW 09 were at a high level.

Fire incidence can be reduced by providing an extinguisher [11]. Ironically, RW 08 as one of 2 RW with fire hydrants in the area with the highest fire incidence. This condition indicates that the areas with the highest incidence are not always in areas with a high level of vulnerability.

4. Conclusion
The fire risk disasters occur in densely populated settlements, as shown in the case of Kali Anyar sub-district. However, there is not always any relationship between building density and the incidence of fire in the densely populated settlements.

Furthermore, the nine RW in Kali Anyar sub-district indicates that the level of building density and the rate of fire incidence in an area does not have a very strong relationship. The highest fire incidence was in areas with moderate building density. Although one of the 3 fire-prone locations determined by the government has a high level of vulnerability, it is still lower than the other locations.

Nevertheless, the focus needs to always be in disaster risk management during the development process. Furthermore, disaster risk mitigation in dense settlements related to the physical environment
needs to be prepared. Furthermore, the capacity of the community is also needed to reduce the risk of fire disasters.

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References
[1] Twigg J, Christie N, Haworth J, Osuteye E and Skarlatidou A 2017 Improved methods for fire risk assessment in low-income and informal settlements *International journal of environmental research and public health* **14** 2 139

[2] Badan Nasional Penanggulangan Bencana BNPB 2020 *Jumlah Kejadian Bencana* [Online] (Jakarta: Badan Nasional Penanggulangan Bencana) Retrieved from: http://bnpb.cloud/dibi/graflk1a, Accessed on 2020 Sept 05

[3] Sutanti N, Tjahjono B and Syaufina L 2020 Analisis Risiko Bencana Kebakaran di Kecamatan Tambora Kota Administrasi Jakarta Barat *TATALOKA* **22** 2

[4] Rahmawati D, Pamungkas A, Aulia B U, Larasati K D, Rahadyan G A and Dito A H 2016 Participatory mapping for urban fire risk reduction in high-density urban settlement *Procedia-Social and Behavioral Sciences* **227** 395-401

[5] Smith H M 2005 The relationship between settlement density and informal settlement fires: Case study of Imizamo Yethu, Hout Bay and Joe Slovo, Cape Town Metropolis *In Geo-information for disaster management* **1333**-1355 (Springer, Berlin, Heidelberg)

[6] Winandari M I R 2018 Public open space for disaster mitigation in Tangerang housing estates *IOP Conference Series: Earth and Environmental Science* **106** 1 012021

[7] Masoumi Z, van L Genderen J and Maleki J 2019 Fire risk assessment in dense urban areas using information fusion techniques *ISPRS International Journal of Geo-Information* **8** 12 579

[8] Januandari M U, Rachmawati T A and Sufianto H 2017 Analisa Risiko Bencana Kebakaran Kawasan Segiempat Tunjungan Surabaya *Jurnal Pengembangan Kota* **5** 2 149-158

[9] Mtani I W and Mbuya E C 2018 Urban fire risk control: House design, upgrading and replanning *Jambá: Journal of Disaster Risk Studies* **10** 1 1-8

[10] Setiawan C and Handawati R 2020 Analysis of Influence Settlement Density on the Fire Hazards Settlement at Cengkareng Subdistrict, West Jakarta *412* 1 012011

[11] Isfani I, Ismail A B and Nizamuddin N 2019 Study of Community Capacity Enhancement in Fire Disaster Mitigation in Kuta Alam Sub-District, Banda Aceh *International Journal of Multicultural and Multireligious Understanding* **6** 2 331-338

[12] Yin R K 2003 *Case Study Research: Design and Methods* (London: Sage Publications)

[13] Day S J, Forster T, Himmelsbach J, Korte L, Mucke P, Radtke K, Thielborger P and Weller D 2019 *World Risk Report 2019* [Online] (Berlin: Bündnis Entwicklung Hilft) Retrieved from: https://reliefweb.int/sites/reliefweb.int/files/resources/WorldRiskReport-2019_Online_english.pdf, Accessed on 2020 Aug 02

[14] BPS 2019 *Tambora District in Figures 2019* [Online] (Jakarta: Badan Pusat Statistik) Retrieved from: https://jakbarkota.bps.go.id/publication/2019/09/26/7c4bbcd01184899a025ba0da/kecamatan-tambora-dalam-angka-2019.html, Accessed on 2020 Aug 02

[15] Permana A Y, Susanti I and Wijaya K 2019 Kerentanan Bahaya Kebakaran di Kawasan Kampung Kota. Kasus: Kawasan Balubur Tamansari Kota Bandung *Jurnal Arsitektur ZONASI* **2** 1 32-45

[16] Kali Anyar Subdistrict 2019 *Peta Area Rawan Kebakaran di Kelurahan Kali Anyar* (Jakarta: Kali Anyar Subdistrict)