Assessment of potential locations for evacuation in Depok Municipality using images from UAV

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Abstract. This study aims to perform assessment of public facilities in Perumnas Depok Utara, Depok Municipality, Indonesia for evacuation locations using images from UAV. A UAV device, a DJI Phantom 4 was flown at 100 metres height to capture seven locations of public facilities located within Perumnas Depok Utara residential area. Raw images from DJI Phantom 4 underwent image processing and georeferencing process to generate smooth aerial images. Public facilities locations were identified from acquired images and later digitized to generate layers of assessment parameters. Each locations were scored based on rating of all criteria’s parameters. Seven criteria serve as foundation layers for evacuation assessment namely size, ownership, availability, capacity, infrastructure, transportation and safety. Study result shows that Jawa Soccer Field is the first rank of potential evacuation location while Balai Rakyat Meeting Place is the least potential evacuation location. Total area for potential evacuation locations around 43,000 m² and can accommodate 28,961 people or equal to 60.5% of Beji Village’s population.

1. Introduction
The growing attention to plan and prepare the shelter in urban areas for evacuation during natural disaster events such as earthquakes and floods has been discussed in various recent publications. This is reflected by incorporating quickest time to reach the evacuation and emergency shelters [1], and the assessment of evacuation location based on several parameters [2]. Consequently, the planning of emergency shelters and evacuation locations should consider strategic location where it can be reached timely and accommodate more people conveniently. Such considerations are not easy to fulfill especially in dense urban environment where not much open spaces or public facilities are strategically located. One of the first public facilities developed within residential areas in Indonesia was Perumnas housing projects in Depok Municipality. Built around 1974 [3], Perumnas Depok I and II were equipped with strategically public facilities such as playgrounds, soccer fields, badminton fields and green open spaces. These facilities still can be seen today in Perumnas Depok I, II and Utara where mostly located in the centre of residential units. However, these public facilities have not been assessed for their availability as emergency shelters and evacuation locations. This assessment is really important, since emergency readiness in the wake of disasters can save many lives. In addition, detail assessment of public facilities needs holistic mapping which can be provided by remote sensing technologies. When [4] performed a comprehensive literature review to provide guidelines for the use of Unmanned Aerial Systems (UAS) in flood emergency response, it was identified that UAS can be used in all three phases of the emergency response namely; pre, during and post. One of the UAS application in pre-emergency response phase is to conduct flood risk assessment such as determining terrain elevations, flood extent modelling, evacuation’s routes identification and flood warning [4]. Unmanned aerial vehicle (UAV) is a device of...
remote sensing which can capture images with very high spatial resolution and rapid time. Previously, UAV aerial mapping has been conducted by [5] in Batuhiu and Pangandaran Beach, West Java Province in order to plot post-tsunami buildings’ spatial distribution in 2006. The spatial distribution of buildings developed after 2006 tsunami which was captured by UAV then compared with buildings before 2006 tsunami event generated from satellite imagery. The information come from differences of building spatial distribution before and after 2006 tsunami event were formulated to analyze tsunami risk, and use it for proposing proper mitigation to reduce the impact. By observing those previously demonstrated capabilities of UAV in gathering spatial data to be used in disaster risk assessment, therefore this study employs UAV aerial mapping to capture spatial characteristics of assessed public facilities in Perumnas Depok Utara. Hence, the process of capturing spatial data using UAV will be described in this paper as well as the study objective which is to perform assessment of public facilities in Perumnas Depok Utara for evacuation locations.

2. Methods
The study flowchart can be observed in Figure 2. Firstly, a UAV device namely DJI Phantom 4 was flown at 100 metres height at public utilities locations within Perumnas Depok Utara residential area. Six locations were identified as potential locations for emergency evacuation to be evaluated based on assessment parameters. After image processing and georeferencing, very high resolution images from UAV were acquired to compute the size of each public facility location. The data derived from UAV images were classified further to be assessment parameters based on previous study [2] namely size, ownership, availability, capacity, infrastructure, transportation and safety. The resulted assessment of every parameters indicated the suitable location for evacuation in Perumnas Depok Utara.
2.1. Study location
The study location is known as Perumnas Depok Utara. It was built in 1975 and commissioned later in 1976 for residential use [6]. In this study, the public facilities are Balai Rakyat Meeting Place, Jawa Soccer Field, Cemetery I and II, schools of SDN Beji 6, SDN Beji 4 and SMP Muqorobin (Figure 1).

2.2. Image processing
Acquired UAV images from DJI Phantom 4 were processed using Agisoft Photoscan. Imported photos were input in a single project name. Stored photos underwent alignment process to generate 3D model. For georeferencing, acquired photos were referenced with high spatial resolution images which were downloaded from Google Earth. Resulted RMSE was observed to see the accuracy of georeferencing process. Georeferencing process was performed using ArcGIS software.

2.3. Public utilities location identification and digitization
In this study, images from UAV were used for identification of the size of each public facility locations. Area measurement menu within ArcGIS was employed to estimate the size of each facility. During field survey for aerial photo, interviews with local around those public facilities were conducted primarily to seek information whether those facilities are public or private. In addition, the existence of pedestrian, supply water, electricity and sewage system were surveyed around the target locations. Hence, once all information were complete, they input into spatial attribute table of each location using ArcGIS. Digitization of all acquired images from UAV were performed in ArcGIS to delineate all public facilities potentially as evacuation locations.

2.4. Assessment of potential location for evacuation
After all potential places of evacuation were digitized in form of vector map, rating of each parameter from all criteria were input into spatial attribute table within ArcGIS (Figure 3). In this paper, score of 1 indicates that the acquired parameter value for each location less potential than those with score of 2. Therefore, the bigger score means that input value is the better or more potential to become a location for evacuation. Consequently, it is better not to use 0 to represent less potential because the parameter is not empty but rather indicate more potential or not. However, for capacity criterion because the values were calculated from size of each location divided by $1.5 \, \text{m}^2/\text{person}$ therefore ranking method for each
location was applied to indicate which one was the biggest. Hence, for capacity criterion input for spatial attribute table was converted from rank using following equation [7]:

$$w_j = \frac{n - r_j + 1}{\sum_{j=1}^{n} n + r_j + 1}$$

where $w_j$=the weight of $j$-th attribute, $r_j$=rank of $j$-th criteria, dan $n$=number of criteria with circumstance that rank 1 is given to the most important criteria. Moreover, all six criteria and its parameters for potential rating can be observed in Table 1. Especially for capacity criterion, 1-2 scale is replaced with ranking method. Rank 1 is given for the biggest value of capacity criterion while the smaller

| Criteria       | Parameters                                                                 | Scoring (the bigger the better) |
|----------------|----------------------------------------------------------------------------|---------------------------------|
| Size           | 500-<2,000 m²                                                             | 1                               |
|                | 2,000- 10,000 m²                                                          | 2                               |
| Ownership      | Private                                                                    | 1                               |
|                | Public                                                                     | 2                               |
| Availability   | School, sport facility, green areas, playgrounds, outdoor sport areas,     | 2                               |
|                | other open areas                                                           |                                 |
|                | Others                                                                     | 1                               |
| Transportation | Pedestrian access                                                          | 2                               |
|                | No pedestrian access                                                       | 1                               |
| Capacity       | Calculated from size divided by 1.5 m²/person                              | Rank 1 for the biggest value     |
|                |                                                                             | followed by the smaller capacity |
| Safety         | Building risks                                                             | 1                               |
|                | No Building Risks                                                          | 2                               |
| Infrastructure | Water supply, sewage system, electricity                                    | 2                               |
|                | None above                                                                 | 1                               |

In detail, the process of value scoring for every potential location using spatial attribute table in ArcGIS and final summed values can be observed in Figure 3.

![Figure 3. Parameters’ score computation using spatial attribute table in ArcGIS.](image-url)
3. Results and Discussion

3.1. UAV images
After the raw images from UAV underwent image processing and georeferencing, ready to be analysed image is shown in Figure 4. Three potential locations for evacuation namely Jawa Soccer Field, Balai Rakyat Meeting Place and Cemetery were identified and later be digitized. When combined together all of these three locations have approximately area around 24,000 m².

![UAV image of the study area](image_url)

*Figure 4. UAV image of the study area: (a) Jawa Soccer Field, (b) Balai Rakyat Meeting Place, (c) Public Cemetery*
3.2. Potential location identification and digitization

Once potential locations for evacuation are identified, the process of digitization from images to become vector maps begin. It can be seen from Figure 4, the Jawa Soccer Field and Cemetery have no secondary hazard risks caused from the building unlike the Balai Rakyat Meeting Place. On the contrary, cemetery has no water supply, electricity and sewage system thus make it low rating score in infrastructure criterion when compared to schools and meeting place. Vector maps in Figure 5 resulted from digitization process can be measured to provide size information and later capacity. Interestingly, the biggest size is cemetery with an area around 16,000 m² followed by the second cemetery around 11,000 m².

3.3. Potential location for evacuation

Calculation result shows Jawa Soccer Field is the first rank for potential evacuation while cemetery is the second. Though cemetery has the bigger size than Jawa Soccer Field but it lacks of water supply, electricity and sewage system. In addition, it can be observed in Figure 5 that all school buildings are ranked lower than open spaces. It because of school buildings have risks during earthquake while open spaces are relatively safer. Furthermore, all of these seven locations are closely located to each other it offers better strategic locations during emergency because all supports can be allocated in one single location. Not to mention it is located in the center of Perumnas Depok Utara, where all residents from all directions can reach this site relatively fast. This strategic location of public facilities in Perumnas Depok Utara has fulfilled the first step towards urban resilience planning, which according to [1], reflected by quickest evacuation to assembly points and shelters in the wake of the disasters.

![Figure 5. Rank of potential evacuation location based on parameters’ assessment](Data processing using image downloaded from Google Earth).

With the total capacity around 28,961 people, these all seven potential locations during earthquake can support 60.5% of total population in Beji Village [8]. However, certain places like cemeteries need to be equipped with water supply, electricity and sewage system. Though schools offer multiple floors to
accommodate more people inside the building, they also have secondary hazard risks especially during earthquake. For further study, these all seven locations need further assessment whether they are close to water source to prevent from flooding risks during evacuation process. In prior study related to evacuation shelter planning [9], existing shelter locations in Pangandaran area prepared for tsunami hazards consist of public facilities such as mosques, fields, regent offices, and halls. In addition, [9] added potential shelter locations for tsunami mitigation included various types of buildings i.e. mosques, schools, public health centers, government buildings, and shopping centers. Presumably, public facilities have the advantages of large space to accommodate refugees in disaster events, not to mention the ownership of those facilities belong to the government which can be used instantly compare to private-owned facilities.

4. Conclusion
Using seven criteria and its parameters, the assessment of public facilities in this study has found that Jawa Soccer Field is the most potential evacuation location while Balai Rakyat Meeting place is the least potential for evacuation location. Though Cemetery I and II are very potential for evacuation location, they need to be equipped with more facilities such as water supply, electricity and sewage system. For further research, these potential locations need more assessment particularly in flood risks.

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