Multi-criteria Decision Analysis for Readiness of COVID-19 Referral Hospital in Jakarta

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Abstract. In early March, Indonesia had reported the first two cases of COVID-19 and this was the beginning for the spread of the COVID-19 outbreak in Indonesia. The need for health services is increasing along with the increasing number of COVID-19 cases in Indonesia. DKI Jakarta is the capital city of Indonesia and is a city with a dense population, causing the transmission of the COVID-19 to be faster than other areas. An assessment of the capacity of health facilities which includes infrastructure and resources is very important to determine the ability of health facilities to manage the rate of spread of COVID-19. This study aims to evaluate the capability of health facilities using the COVID-19 referral hospital readiness index in DKI Jakarta. The data used is the availability of human resources and infrastructure for COVID-19 referral hospitals. Analysis of Geographic Information Systems and Multi-criteria was used to map the readiness index of COVID-19 referral hospitals. The results show that there are no referral hospitals with a high readiness index. There are only 10 referral hospitals with a medium and 92 referral hospitals with a low readiness index. The lack of referral hospitals with a medium readiness index in areas of high vulnerability can have serious consequences in handling COVID-19 cases. Most of the referral hospitals have a low readiness index. However, referral hospitals are capable to reach almost all areas of DKI Jakarta in an emergency condition. It can be concluded that most of the referral hospitals do not have adequate facilities for handling COVID-19 patients.

1. Introduction
On December 31, 2019, the Chinese government reported a case of pneumonia to the World Health Organization [1]. Most cases of pneumonia came from the activities of the Huanan seafood and live animal market in Wuhan City, Hubei Province, China [2], [3]. The pneumonia case was caused by a new Corona virus which was later called coronavirus disease 2019 (COVID-19). COVID-19 is an acute respiratory syndrome in humans caused by infection with the novel coronavirus-2 CC [4]. Compared with SARS and MERS, COVID-19 has a higher transmission and spread rate [5]. This virus has spread rapidly in numerous countries around the world since the first case in China [6]. Furthermore, World Health Organization (WHO) declared COVID-19 a global pandemic in early March 2020 [7].
In early March, Indonesia had reported the first two cases of COVID-19 and this was the beginning for the spread of the COVID-19 outbreak in Indonesia [8]. Therefore, the need for health services is increasing along with the increasing number of COVID-19 cases in Indonesia. At the beginning of the pandemic, the Ministry of Health through the Decree of the Minister of Health No. HK.01.07/MENKES/169/2020 decided eight COVID-19 referral hospitals in Jakarta. However, the spread of the COVID-19 is getting out of control. In early 2021, the number of COVID-19 cases has increased to 185,691 cases in DKI Jakarta [9]. DKI Jakarta, as Indonesia's capital and a densely populated city, has a higher rate of COVID-19 virus transmission than other areas [10].

Many countries are currently attempting to defeat COVID-19. Due to the increasing number of COVID-19 cases, health facilities are approaching critical status. The death rate from COVID-19 rises when health facilities approach criticality. As a result, in order to respond pandemic, health facilities must be prepared by understanding their resources and geographic distribution [7]. The ability of the hospital to serve the surrounding population is a major factor in determining its placement. The availability of COVID-19 hospitals is critical in this situation, especially in determining the areas ability to deal with the current COVID-19 outbreak.

The readiness of referral hospitals is crucial for handling infectious diseases [11], [12]. An assessment of the readiness of health facilities which includes infrastructure and resources is very important to determine the ability of health facilities to deal with the rapid spread of the COVID-19 virus [13]. As a result, the purpose of this study is to evaluate the capability of health facilities using the COVID-19 referral hospital readiness index in DKI Jakarta. The COVID-19 referral hospital readiness index is a useful tool for determining a region's capacity to respond with the spread of the COVID-19 virus.

2. Method
The research area is located in DKI Jakarta. DKI Jakarta is bordered by the Java Sea to the north, Jawa Barat province to the east and south, and Banten province to the west. DKI Jakarta is divided into 6 administrative areas, namely Kepulauan Seribu, Jakarta Utara, Jakarta Selatan, Jakarta Barat, Jakarta Timur, and Jakarta Pusat. Kepulauan Seribu region was not included in this study because the COVID cases in this region were under control. In addition, most of the referral hospitals are located in 5 main administrative areas. DKI Jakarta has an area of about 664.01 km$^2$ with a population of 11,100,929 people [14].

In this study, the data used were data on the availability of human resources (HR) and hospital infrastructure to assess the readiness of a COVID-19 referral hospital. In addition, the hospital readiness assessment uses Multi-Criteria Decision Analysis to determine what infrastructure a COVID-19 referral hospital requires. Then, the results of hospital readiness are visualized using a Geographic Information System (GIS). Geographic Information System is known as a device that has the ability to store, manipulate, analyze, and visualize spatial data for decision making. Meanwhile, Multi-criteria Decision Analysis provides a large collection of procedures and algorithms for formulating decision problems, designing, evaluating, and prioritizing alternative decisions. The combination of GIS and MCDA methods has been widely used in recent years [15]. In this study, GIS is used for visualization and makes it easier to allocate hospital resources spatially.

2.1 Pairwise Comparison
Pairwise comparison matrices are a powerful interference tool and knowledge acquisition technique. The pairwise comparison matrix produces the relative importance of each criterion against predetermined criteria and the criteria are measured by an expert or group of experts [16]. Pairwise comparison matrices can be seen in equation 1.

$$ A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad \text{Equation (1)}$$

$a_{ij}$ indicates the relative importance of criterion $i$ to criterion $j$, which can be indicated on a numerical scale of 1 to 9. A scale of 1 indicates equal importance, while a scale of 9 indicates that criterion $i$ is...
very important. This study uses 6 criteria to be compared in pairs, which consist of 3 criteria related to infrastructure and 3 criteria related to the human resources of the COVID-19 referral hospital. Based on [17], isolation rooms, Intensive Care Unit (ICU), and ventilators are instances of hospital infrastructure that must be available for the treatment of COVID-19 patients with medium to severe symptoms. Furthermore, based on [18] and [19], pulmonary doctors, internal medicine doctors, and nurses are hospital human resources who have an important role in handling COVID-19 patients. Therefore, this study uses these 6 criteria to determine the readiness index of a COVID-19 hospital in Jakarta. In this case, information on the availability of ventilators, ICU rooms, and isolation rooms can be obtained from Jakarta government website (https://corona.jakarta.go.id/id). Meanwhile, information related to the number of pulmonary doctors, internal medicine doctors, and nurses was obtained from Indonesian Health Ministry website (http://bppsdmk.kemkes.go.id). Update information related to the availability of ventilators, ICU rooms, and isolation rooms in each hospital is different. Then, hospital infrastructure uses a time span from September 2020 to May 2021, based on the latest update available on the Jakarta government website.

2.2 Multi-Criteria Decision Analysis

Multi-criteria Decision Analysis (MCDA) is a decision-making method to determine the best alternative from a number of spatial alternatives that are evaluated based on certain criteria [20], [21]. One method of decision making is the Simple Additive Weighting method. The Simple Additive Weighting (SAW) method is also known as the weighted aggregate method [22]. The basic concept of the Simple Additive Weighting method is to find a weighted sum of performance on each alternative on each attribute. The Simple Additive Weighting method is a method commonly used in decision making that has many attributes, so that by applying the SAW method to a decision support system, the completion of various decision-making processes can be easily [23]. The calculation of the SAW matrix, weight matrix, and total alternative value are presented in equations 2 to 4, respectively.

\[ r_{ij} = \frac{x_{ij}}{\max (x_{ij})} \] \hspace{1cm} Equation (2)

\[ W = \frac{c_i}{c_1 + \ldots + c_n} x 100\% \] \hspace{1cm} Equation (3)

\[ V_i = \sum_{j=1}^{n} \frac{l w_j r_{ij}}{\sum_{j=1}^{n} l w_j} \] \hspace{1cm} Equation (4)

This study applies the SAW method in determining the readiness index of the COVID-19 referral hospital in Jakarta. The data used in this stage is the weight of the pairwise comparison results. Each criterion is divided into 5 classes, class 1 indicates incomplete variables and class 5 indicates very complete variables. Then the class criteria and the weights of the pairwise comparison results are used to calculate the readiness index of the COVID-19 referral hospital in DKI Jakarta. The COVID-19 referral hospital readiness index consists of 3 classes, namely high, medium, and low. The readiness index's output will finally show that the COVID-19 referral hospital has appropriate facilities and human resources to handle symptomatic COVID-19 patients.

3. Result and Discussion

3.1 Pairwise Comparison

Health workers who were respondents in the assessment of the questionnaire consisted of doctors, nurses, and nutritionists. These health workers are directly involved in handling COVID-19 patients. The results of the questionnaire were processed using Microsoft excel software to get the weights for each criterion. Each respondent must show consistency of assessment. This can be seen from the Consistency Index value. If the Consistency Index value is less than or equal to 10% (0.1), then the inconsistency is acceptable [24]. Only four of the nine respondents who completed the survey obtained a Consistency Index value. Then the results of the weights of the four respondents are combined to get the total weight of each criterion. From the result, the Consistency Index value is 0.08. According to
expert judgment, the availability of ventilators is the most important criterion in handling COVID-19 at a referral hospital. Then followed by the availability of the ICU, isolation rooms, pulmonary doctors, internal medicine doctors, and nurses. The weight values for the 6 paired criteria can be seen in Table 1.

Table 1. Pairwise comparison result

| Criteria               | Weight number |
|------------------------|---------------|
| Ventilator             | 0.260         |
| ICU                    | 0.214         |
| Isolation rooms        | 0.181         |
| Pulmonary doctors      | 0.134         |
| Internal medicine doctors | 0.113     |
| Nurses                 | 0.098         |
| **Consistency Index**  | **0.080**     |

3.2 Multi-Criteria Decision Analysis

The DKI Jakarta government has issued many restrictions regarding hospitals designated as COVID-19 referral hospitals in response to the rise in daily COVID-19 patients. The most recent regulation for appointing a COVID-19 referral hospital is the Governor of Jakarta Decree Number 14 of 2021, there are 101 COVID-19 referral hospitals in DKI Jakarta. Table 3 shows the distribution of 101 COVID-19 referral hospitals in the five administrative areas of DKI Jakarta. Jakarta Timur is the area with the highest number of referral hospitals. There is no referral hospital with a high readiness index from the 101 referral hospitals. Figure 1 shows the distribution of referral hospitals with a medium to low readiness index. There are 10 referral hospitals with medium readiness index, and 92 referral hospitals with low readiness index. Figure 2 shows the vulnerability of the COVID-19 area in DKI Jakarta. Vulnerability area are obtained from age groups that are at high risk of death caused by COVID-19 [25]. The highest vulnerabilities are in Jakarta Timur, Jakarta Selatan, Jakarta Barat, and Jakarta Utara. Most referral hospitals are in the Jakarta Timur area. However, most of the referral hospitals in the Jakarta Timur area have a low readiness index. There are only two referral hospitals with a medium readiness index in the Jakarta Timur and Jakarta Selatan areas. For the Jakarta Barat and Jakarta Utara areas, there is one referral hospital with a medium readiness index. The lack of referral hospitals with a medium readiness index in areas of high vulnerability can have serious consequences in handling COVID-19 cases, because there are no adequate facilities for treating COVID-19 patients. When there are no adequate health facilities, it is possible to refer patients to hospitals with a higher readiness index.

Other studies related to the hospital readiness index have been carried out by [26]. From the mapping of the readiness index of the referral hospital and the mapping of the reach of the referral hospital, it was found that areas with high active positive cases but not reachable even there were no referral hospitals. This must be a concern for regional policy makers to determine the next steps in dealing with the COVID-19 outbreak. Alternative mapping of referral hospitals was carried out to produce new referral hospitals that were strategically seen from the number of active positive cases and existing referral hospitals so that if there was a spike in COVID-19 cases, the nearest referral hospital could immediately handle it. Apart from adding hospital infrastructure, other solutions What can be done by local governments is to strictly implement Large-Scale Social Restrictions (PSBB).

Many countries have conducted research related to hospital readiness in dealing with COVID-19. In Nepal, most hospitals have not allocated an ICU to treat COVID-19 patients, as well as for the human resources needed to treat COVID-19 patients. Government support related to COVID-19 is not evenly distributed across provinces; infrastructure and resources for health facilities are less in some provinces than in others. It is very important to conduct research related to hospital readiness in dealing with the COVID-19 pandemic so that local governments can act early and proactively during a health emergency and not wait until the disease disrupts their health system [27].
On the other hand, the referral hospital facilities will be unable to treat patients if the increase in cases continues. As a result, expanding the capacity of referral hospitals is essential [28]. Assessment of the hospital's readiness index in dealing with the COVID-19 pandemic is very important to improve mitigation capabilities against the pandemic. This assessment will be an important guide to reducing the impact of the outbreak and improving the training of disaster preparedness personnel, organizing material management activities during the epidemic period, accelerating the response to the outbreak, and managing human resources appropriately [29]. The DKI Jakarta government needs to expand referral hospital facilities so that symptomatic COVID-19 patients can be adequately treated.

Table 2. Referral hospital distribution

| Administration   | Number of referral hospital |
|------------------|-----------------------------|
| Jakarta Utara    | 17                          |
| Jakarta Selatan  | 19                          |
| Jakarta Timur    | 25                          |
| Jakarta Barat    | 19                          |
| Jakarta Pusat    | 22                          |
Figure 1. COVID-19 referral hospital readiness index map.
Figure 2. COVID-19 vulnerability map.

4. Conclusion
Based on the results of the pairwise comparison, according to expert adjustment of the 6 paired criteria, the availability of ventilators is the most important criterion that must be available at the COVID-19 referral hospital. Ventilators have a vital role in treating COVID-19 patients because the function of the ventilator is to help someone who has difficulty breathing.

On the other hand, based on the readiness index of referral hospitals in DKI Jakarta, most of the referral hospitals have a low readiness index. This demonstrates that the majority of referral hospitals lack adequate capacity to handle symptomatic COVID-19 patients. As a result, local governments must make considerable effort to improve health-care facilities. The availability of these health facilities can reduce
the mortality rate in an area. Symptomatic patients will receive adequate medical care, so that deaths from COVID-19 can be suppressed as much as possible. The criteria used in this study were limited to 6 variables, namely isolation rooms, ICU, ventilators, pulmonary doctors, internal medicine doctors, and nurses. If there are more variables in the readiness index, the results will be better. In addition, the latest data related to the availability of hospital infrastructure and human resources is needed to describe the real condition of the COVID-19 referral hospital.

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