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The application of K-means clustering for province clustering in Indonesia of the risk of the COVID-19 pandemic based on COVID-19 data

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Abstract
This study was conducted with the aim to the clustering of provinces in Indonesia of the risk of the COVID-19 pandemic based on coronavirus disease 2019 (COVID-19) data. This clustering was based on the data obtained from the Indonesian COVID-19 Task Force (SATGAS COVID-19) on 19 April 2020. Provinces in Indonesia were grouped based on the data of confirmed, death, and recovered cases of COVID-19. This was performed using the K-Means Clustering method. Clustering generated 3 provincial groups. The results of the provincial clustering are expected to provide input to the government in making policies related to restrictions on community activities or other policies in overcoming the spread of COVID-19. Provincial Clustering based on the COVID-19 cases in Indonesia is an attempt to determine the closeness or similarity of a province based on confirmed, recovered, and death cases. Based on the results of this study, there are 3 clusters of provinces.

Keywords COVID-19 · Clustering · K-means clustering

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1 Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease that is currently circulating around the world (Ahmar and Rusli 2020; Atuahene et al. 2020; Gupta et al. 2020). COVID-19 was first reported in the city of Wuhan, Hubei Province, China in December 2019. COVID-19 is an infectious disease caused by a newly discovered coronavirus—severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)—which was first identified in Wuhan (Ahmar and Boj 2020; Azarafza et al. 2021). The first COVID-19 cases in Indonesia were detected on 2 March 2020 in Jakarta. Over time, the pandemic has spread to various provinces in Indonesia. As of 19 April 2020, more than 6575 cases of COVID-19 have been reported in 34 provinces in Indonesia. On April 19, 2020, 6,575 confirmed were cases, 686 recovered while 582 died in Indonesia. Based on COVID-19 data from the Worldometer, last updated: 20 April 2020, 07:53 GMT, Indonesia has the highest confirmed cases of COVID-19 among the Association of Southeast Asian Nations (ASEAN) member states (Worldometer 2020).

Evaluation of the development of COVID-19 cases per province is one of the bases for monitoring the development of COVID-19 cases in Indonesia. However, to date there has been no provincial grouping based on confirmed cases, recoveries, and deaths conducted on this data. The K-means clustering algorithm is a popular unsupervised technique used to identify similarities between objects based on distance vectors suitable for small data sets (Sreedhar et al. 2017). This technique by definition is a kind of cluster algorithm, and has several advantages including briefness, efficiency and celerity (Li and Haiyan 2012). Meanwhile, the purpose of cluster analysis are (1) investigate underlying structure of data, (2) classification: to determine the degree of similarity among data points and (3) compression: a method for organizing and summarizing data into understandable groups (Govender and Sivakumar 2020).

Armstrong, et.al. (2012) said that the K-means algorithm was helpful in segmenting a heterogeneous recovery client population into more homogeneous subgroups and K-means offers a better view of applicant characteristics and needs, which may lead to more targeted rehabilitation options for people in home care. This is in line with Kusrini (2015) that K-means clustering is used since the number of clusters needed for item categorization has already been determined and in addition, Fotouhi & Montazeri-Gh (2013) said that K-means clustering needs less computing than the SAPM process, which benefits the method's capability for accurate traffic grouping. Furthermore, Al-Wakeel and Wu (2016) show that for strongly correlated load profiles, a limited number of clusters is suggested.

By using data mining methods such as the K-means clustering, it is possible to find the main characteristics of each potential province which can be used in an effort to predict future COVID-19 cases based on the provincial data similarity.

2 Methods and Statistical Analysis

This study was conducted using data obtained on 19 April 2020 from the Indonesian COVID-19 Acceleration Task Force website (https://covid19.go.id/peta-sebaran). Data were analyzed using the K-Means Clustering method as a technique for performing data groupings. Furthermore, the data classification procedure was based on the degree of each component's membership (Ahmar et.al., 2018). This analysis was performed by using R Software version 3.6.3. as described on the website (https://uc-r.github.io/) and this study, we using R Software version 3.6.3.

The research steps were carried out as follows:

(1) Data on the confirmed, recovered, and death cases were obtained from the Indonesia COVID-19 website (https://covid19.go.id/peta-sebaran).
(2) This data were extracted into 3 parts which include the confirmed, recovered, and death according to the different provinces.
(3) When there is a predominant data compared to others then, that particular set is made into 1 group and excluded from the analysis process.
(4) The following packages were Installed and executed; tidyverse (version 1.3.0), cluster (version 2.1.0), and factoextra (version 1.0.7) of R Software version 3.6.3.
(5) Data obtained in stage 2 were further loaded on the R Software.

```
library("readxl")
data <- read_excel("C:\\datacovid19indonesia.xlsx")
```

(6) Data Preparation:

(a) Rows are observations, columns are variables.
(b) Any missing values of the data are deleted or estimated.
To remove any missing value that might be present in the data, type this:

```
data <- na.omit(data)
```

(c) The data were standardized (i.e. scaled) in order to make variables comparable.
To scale/standardize data using the R function scale:

```
data <- scale(data)
head(data)
```

(7) Clustering distances measurement was carried out using Euclidean distances.

```
euclidean <- get_dist(data)
fviz_dist(euclidean, gradient = list(low = "#00AFBB", mid = "white", high = "#FC4E07"))
```

(8) The K-means analysis process can be described as follows:

(a) Determinine the number of clusters (k) using optimal clusters. The three (3) most popularly used optimal clusters, include:

(1) Elbow method

```
set.seed(123)
fviz_nbclust(data, kmeans, method = "wss")
```

(2) Silhouette method

```
set.seed(123)
fviz_nbclust(data, kmeans, method = "silhouette")
```

(3) Gap statistic

```
set.seed(123)
fviz_gap_stat(gap_stat)
```

The optimal cluster is seen from the fviz_nbclust function of each method. Furthermore, the optimal cluster value in the Elbow Method is the *k* value which drops drastically on the visualization graph meanwhile, in the Silhoute and Gap statistics, it appears automatically on the graph.

(b) Extracting results

Based on the optimal cluster method approach in the previous step, the optimal cluster will be obtained. The number of clusters was used to calculate the k-means clustering value.

For example, in the previous stage, the value of $k = 2$ was obtained.

```
set.seed(123)
endkmeans <- kmeans(data, 2, nstart = 25)
print(endkmeans)
```

Based on these results, k-means clustering results will be obtained. This result can be visualized using the code:

```
fviz_cluster(endkmeans, data = data)
```

3 Result and Discussion

Based on the descriptive statistical analysis (Table 1) out of the 34 provinces in Indonesia, the maximum confirmed cases were 3032 with 234 recovered and 287 death cases meanwhile, there were provinces without recovered and deaths cases. On average, the number of confirmed cases was 193 with a standard deviation of 528.

In Fig. 1, Jakarta obviously had more cases hence, the province became the epicenter of data center therefore, Jakarta formed one special group and was not included in the data clustering process (Pamula et al. 2011). Epicentrum is based in Jakarta because it is the capital of the country and the center of the economy in Indonesia.

Moreover, the optimal number of k groups was determined using the three(3) most commonly used approaches namely Elbow, Silhouette, and Gap Statistics. The results can be seen in Fig. 2a, b, and c.

Based on Fig. 2, the Elbow method obtained optimal k at $k=2$, the Silhouette method obtained many optimal clusters at $k=2$, and the Gap statistics obtained optimal k value to form clusters at $k=2$.

Therefore, based on the results from these methods, it can be concluded that the optimal k value to form a cluster is 2. Furthermore, the Clustering analysis results using K-means with $k=2$ are presented in Table 2.

As shown in Table 2, it can be seen that Cluster 1 consists of 5 provinces and Cluster 2 consists of 28 provinces. When combined with the DKI Jakarta Cluster, there will be 3 provincial clusters in Indonesia based on COVID-19 data (Fig. 3).

This study is consistent with Zarikas, et.al. (2020), which showed that clustering active cases in a region is useful for drawing conclusions about the disease impact which spreads rapidly in an area. Furthermore, Azarafza et al. (2021) stated that the

Table 1 Descriptive statistics of COVID-19 in Indonesia

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Confirmed	34	0	34	1	3032	193	528
Recovered	34	0	34	0	234	20	43
Deaths	34	0	34	0	287	17	50

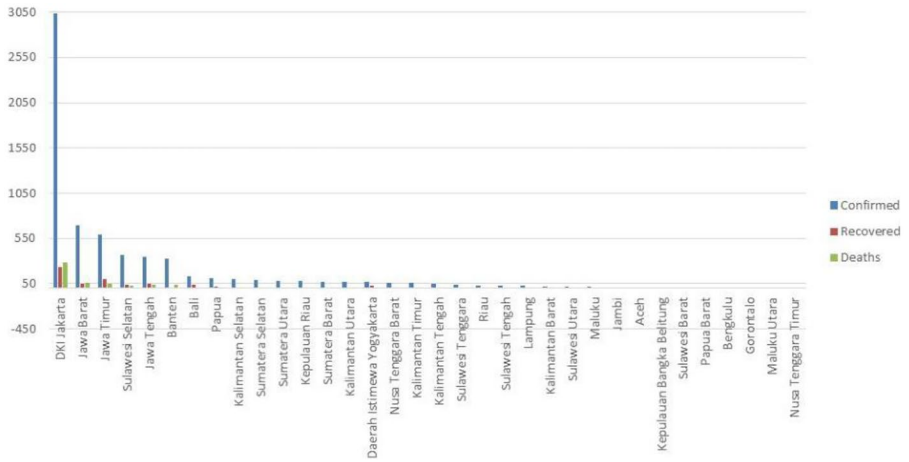
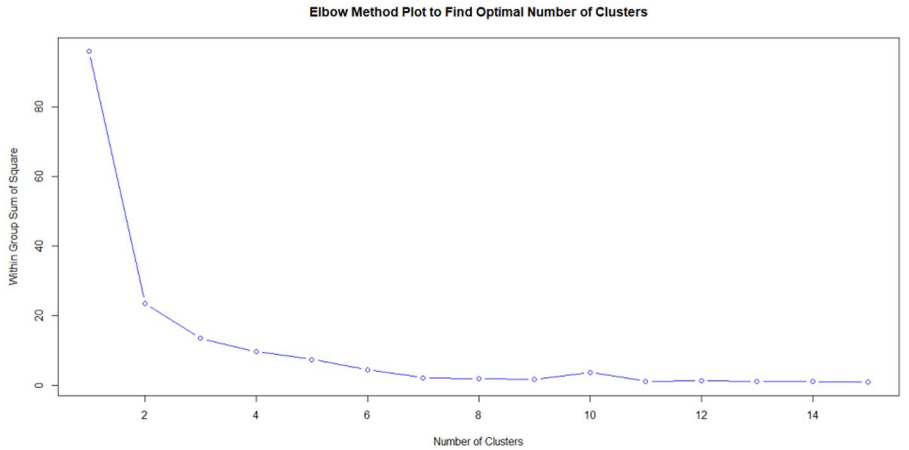


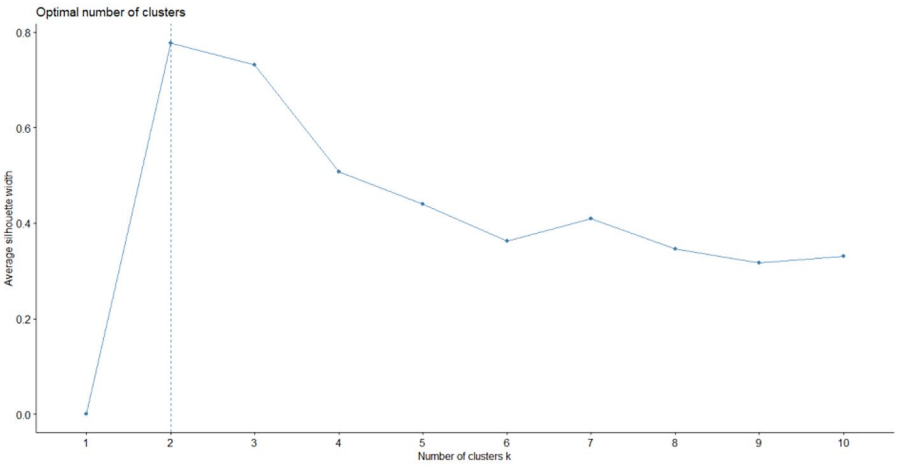
Fig. 1 Number of COVID-19 cases each Province in Indonesia



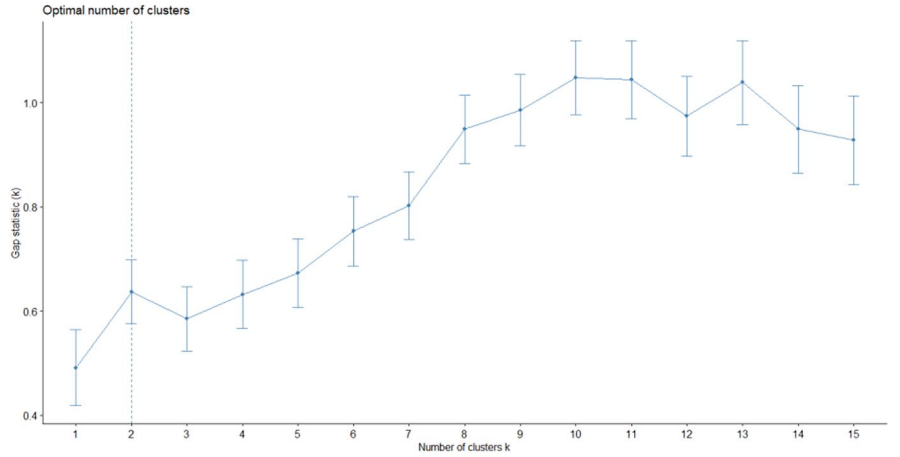
(a)

Fig. 2 Result of **a** Elbow, **b** Silhouette, and **c** Gap Statistic to find k optimal

pattern of transmitting infection between provinces was estimated using the clustering method. Therefore, based on these opinions, it can be concluded that by conducting provincial clusters, one is being provided with an overview of disease spread patterns and solutions related to this distribution pattern.



(b)



(c)

Fig. 2 (continued)

4 Conclusion

Provincial grouping/clustering based on the COVID-19 cases in Indonesia is an attempt to determine the closeness or similarity of a province based on confirmed cases, recovered cases, and deaths cases. Based on the results of this study, there are 3 clusters of provinces, each consisting: **Clusters 1** (Jawa Barat, Jawa Timur, Sulawesi Selatan, Jawa Tengah); **Cluster 2** (Bali,Papua, Kalimantan Selatan, Sumatera Selatan, Sumatera Utara, Kepulauan Riau, Sumatera Barat, Kalimantan Utara, Daerah Istimewa Yogyakarta, Nusa Tenggara Barat, Kalimantan Timur, Kalimantan Tengah, Sulawesi Tenggara, Riau, Sulawesi Tengah,

Table 2 Results of provincial clustering in Indonesia with K-Means clustering*

Province	Cluster
Jawa Barat	1
Jawa Timur	1
Sulawesi Selatan	1
Jawa Tengah	1
Banten	1
Bali	2
Papua	2
Kalimantan Selatan	2
Sumatera Selatan	2
Sumatera Utara	2
Kepulauan Riau	2
Sumatera Barat	2
Kalimantan Utara	2
Daerah Istimewa Yogyakarta	2
Nusa Tenggara Barat	2
Kalimantan Timur	2
Kalimantan Tengah	2
Sulawesi Tenggara	2
Riau	2
Sulawesi Tengah	2
Lampung	2
Kalimantan Barat	2
Sulawesi Utara	2
Maluku	2
Jambi	2
Aceh	2
Kepulauan Bangka Belitung	2
Sulawesi Barat	2
Papua Barat	2
Bengkulu	2
Gorontalo	2
Maluku Utara	2
Nusa Tenggara Timur	2

*Does not include Province of DKI Jakarta

Lampung, Kalimantan Barat, Sulawesi Utara, Maluku, Jambi, Aceh, Kepulauan Bangka Belitung, Sulawesi Barat, Papua Barat, Bengkulu, Gorontalo, Maluku Utara, Nusa Tenggara Timur); and **Cluster 3** (DKI Jakarta). The results of the provincial cluster are expected to provide input to the government in making policies related to restrictions on community activities or other policies in overcoming the spread of COVID-19.

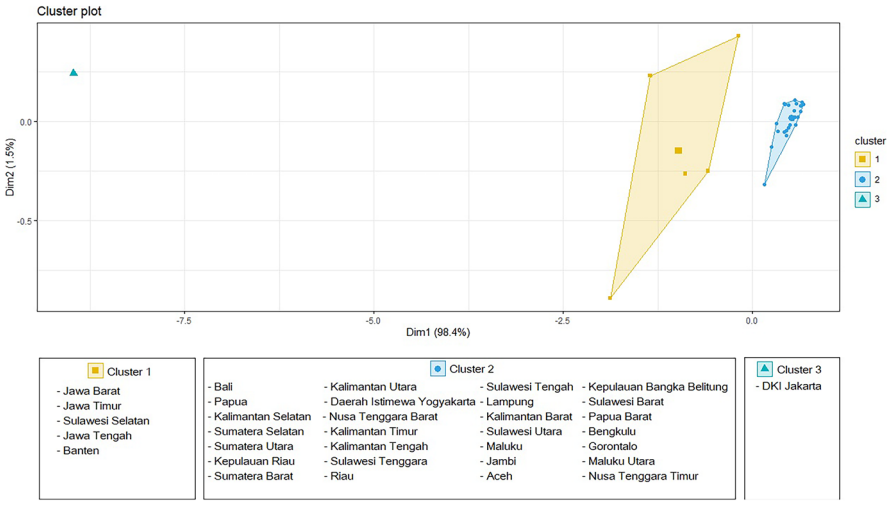


Fig. 3 Results of Provincial Clustering in Indonesia with K-Means Clustering

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Author contributions Authors contributed to the manuscript equally.

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Data availability The data in this study can be accessed at: Website of COVID-19 of Indonesia (https://covid19.go.id/peta-sebaran) or Harvard Dataverse (https://doi.org/10.7910/DVN/JUSYYX).

Declarations

Conflict of interest The author declares that there is no conflict of interest.

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