Implementation of Clustering and Association for Early Warning of Disasters in Bojonegoro

by Dewi Novianti

Submission date: 06-Sep-2024 04:50PM (UTC+0700)
Submission ID: 2296269123
File name: 11933-Article_Text-61509-1-2-20240722.docx (153.27K)
Word count: 3768
Character count: 21310

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Author(s)

***Abstract* –** This research was conducted to measure the likelihood of different disasters occurring and to increase awareness and understanding of disasters in Bojonegoro Regency. Mapping, clustering using the K-Means algorithm, and association rule using the Apriori algorithm are the techniques used in this research. The Bojonegoro District Disaster Management Agency provided secondary data, including eight disaster categories. Based on the research findings, using the K-Means model, the Bojonegoro District data was divided into five groups of 28 sub-districts. Each of the four groups has the following sub-district members: thirteen in Group 0, one in Group 1, four in Group 2, six in Group 3, and four in Group 4. Four association rules were generated from the association analysis, with a minimum support of 10% and a minimum confidence of 50%. Recommendations from this study indicate that Ngasem and Bojonegoro sub-districts require greater attention; of the four association rules generated, the fourth rule has the most significant confidence value, at 78.79%. There will be catastrophic forest and land fires if there is a drought.

Keywords: Disaster, Mapping, K-Means, Association Rule

I. INTRODUCTION

A disaster is a sequence of occurrences that impact people's lives and means of subsistence while causing misery to humans, property loss, environmental harm, and damage to infrastructure and facilities (Ahmed et al., 2022). Events or series of events that upset and endanger people's lives and means of subsistence that are caused by both natural and man-made factors are referred to as disasters. They can result in fatalities, destruction of the environment, loss of property, and psychological repercussions (Morganstein & Ursano, 2020).

A disaster is defined as an event or sequence of events that endanger and disrupt people's lives and livelihoods due to natural or unnatural factors and other human factors and result in death, harm to humans, the environment, loss of property, and psychological effects (Udori & Miranti, 2019). This definition is based on Article 1, Paragraph 1 of Law No. 24 of 2007 concerning disaster management. Planning is essential for any potential calamity that could happen at any time. Law No. 24 of 2007 concerning disaster management, Article 1, paragraphs 2, 3, and 4, lists three categories of disasters: natural disasters, non-natural disasters, and social disasters. Natural disasters include earthquakes, tsunamis, volcanic eruptions, floods, droughts, hurricanes, and landslides (Udori & Miranti, 2019).

Non-natural disasters are those that result from one or more non-natural events; examples include disasters brought on by failed technology endeavors and disease outbreaks, such as the rise in casualties brought on by the DBD and COVID-19 outbreaks in Bojonegoro Regency (Nurdsiansyah & Wafa, 2021)(Nisa, 2022). A sequence of artificial events, including social conflicts within communities or organizations or acts of terrorism, can lead to social disasters (Xu et al., 2016).

Due to its strategically located location at the meeting point of two continents and oceans, as well as the mountain paths that cut through it, Indonesia is frequently hit by natural disasters like earthquakes and volcanic eruptions that cause fatalities and extensive damage to the surrounding area, including infrastructure destruction and property losses (Murdiaty et al., 2020).

By analyzing disaster events and patterns discovered from disaster data, a process known as data mining, the impact of disasters might be lessened or avoided. The process of gathering and analyzing historical data to identify patterns, norms, or connections in large amounts of data is known as data mining. The output of this data mining can be used to help make decisions in the future (Hajian et al., 2016). Data mining can be used in processing disaster data, such as clustering and association rules.

Another data mining method often used is clustering, which is grouping data points into two or more groups so that the data points belong to groups that have similarities rather than different groups based on the information available with the data points (Aggarwal, 2015). The application of clustering methods is easier with the help of RapidMiner software (Sudirman et al., 2018). Many disaster studies use clustering methods, such as data mining, to analyze natural disaster data using the K-means algorithm (Riasetiawan et al., 2022). Another study also used K-means to analyze the distribution of disaster-prone points in disaster management (Akgün et al., 2015). K-means is commonly used in health studies such as clustering infectious diseases (Furuse et al., 2020). The K-Mean method is also superior to other clustering methods in extensive data studies, such as in elementary school data, especially data on learning capacity and facilities for elementary schools in Bojonegoro Regency (Nurdiansyah et al., 2023). The K-Mean method is also superior to other clustering methods on small data studies such as on Population data in Bojonegoro Regency (Sholikhah, 2022).

Another data mining method rarely used is the association rule, which looks for relationships between one item and another item from a market basket analysis (Kaur et al., 2016). The algorithm commonly used in association rule methods is the Apriori method. The Apriori method is one of the methods in data mining to find relationships between data based on their characteristics so that rules are formed based on clusters. The Apriori algorithm is a data mining algorithm with association rules to determine the association relationship of a combination of elements whose application meets the minimum support requirements specified (Das et al., 2021). The research with association rules with disaster data has been done with another algorithm, namely FP-Growth (Wu & Zhang, 2023).

The objective of this study is to ascertain how sub-districts in Bojonegoro Regency are grouped according to the occurrence of disasters and to comprehend the implications of the Association Rule using the Apriori algorithm on disasters in Bojonegoro Regency. In order for the community to learn about disasters in Bojonegoro Regency and be able to prepare for future disasters and take part in environmental protection to reduce tragedies, the Bojonegoro Regency Regional Disaster Management Office can take into consideration the benefits of this research when deciding on the next step in creating policies related to disaster management in Bojonegoro Regency.

In this research, descriptive statistics using frequency distribution tables and mapping are carried out as an update, and two data mining methods are applied, namely the clustering method (K-Means) and the associative method (Apriori) in extracting disaster data in Bojonegoro Regency. Although it is impossible to predict when a disaster will strike, it is possible to determine when a disaster is likely to occur by examining the relationships between different disasters. When people, like in Bojonegoro Regency, need more information and awareness of disasters, it might be difficult to foresee when disasters will occur. Thus, proposing research entitled "Implementation of Data Mining Through Clustering and Association for Early Warning of Disasters in Bojonegoro Regency" is necessary to calculate disasters more easily.

II. METHODS

2.1 Data Source

A quantitative approach is used in this research. The proposed statistical methods are frequency distribution, distribution mapping, K-Means algorithm clustering, and association rule with apriori algorithm. The ways in data analysis are applied with the help of Rapidminer and QGIS software. This study used secondary data as disaster data with 8 types of disasters originating from the National Disaster Management Agency and the Bojonegoro Regency Regional Disaster Management Agency office. There are 8 types of disasters in Bojonegoro Regency in the range of January 5, 2019, to January 18, 2023, with a total of 2078 events occurring in 589 days, which include House Fires, Extreme Weather, Overflowing Floods, Landslides, Flash Floods, Forest and Land Fires, Drought, and Other Events.

2.2 Research Variables

This study used variables with different measurement scales for each analysis. The variables used are presented in Table 1 and Table 2 as follows.

Table 1 Definition of Research Variables for the Apriori Algorithm.

Variable	Scale Measurement	Description
Sub-districts	Nominal	The sub-districts in Bojonegoro Regency include Ngraho, Tambakrejo, Ngambon, Ngasem, Bubulan, Dander, Sugihwaras, Kedungadem, Kepohbaru, Baureno, Kanor, Sumberrejo, Balen, Kapas, Bojonegoro, Kalitidu, Malo, Purwosari, Padangan, Kasiman, Temayang, Margomulyo, and Trucuk.
Disaster_1	Ratio	Number of House Fires
Disaster_2	Ratio	Number of Extreme Weather Events
Disaster_3	Ratio	Number of Overflow Flood events
Disaster_4	Ratio	Number of Landslide events
Disaster_5	Ratio	Number of flash flood events
Disaster_6	Ratio	Number of Forest and Land Fire events
Disaster_7	Ratio	Number of Drought events
Disaster_8	Ratio	Number of other events

Table 2. Definition of Research Variables for K-Means Algorithm and Mapping.

Variable	Scale Measurement	Description
Date	Nominal	Date of disaster
Disaster_1	Ratio/Binary	0 = no house fire 1 = house fire occurred
Disaster_2	Ratio/Binary	0 = no extreme weather 1 = Extreme weather occurred
Disaster_3	Ratio/Binary	0 = No overflow flooding occurred 1 = Overflow flooding occurs
Disaster_4	Ratio/Binary	0 = No landslides occur 1 = landslide occurs
Disaster_5	Ratio/Binary	0 = no flash flooding 1 = Flash flood occurs
Disaster_6	Ratio/Binary	0 = no forest and land fires 1 = forest and land fires occur
Disaster_7	Ratio/Binary	0 = no drought 1 = Drought occurs
Disaster_8	Ratio/Binary	0 = no miscellaneous events occurred 1 = Various events occurred

2.3 Data Analysis

This research uses three different analysis methods to obtain complete results. First, at the beginning of the analysis, a frequency distribution table will be provided to simplify the data, followed by a visualization of the disasters that occurred in Bojonegoro Regency.

The clustering method used in this research is the K-Means method, which is commonly used to generate information in determining the best number of clusters based on the Elbow method approach. The analysis steps for data clustering are as follows:

1. Perform data transformation.
2. Determining the number of groups or clusters to be formed by entering it in the k value and initializing the k value of the cluster centre by taking a random value from the data.
3. Apply the Euclidean distance formula to find the closest distance to each centroid by using the distance calculation every time the data is input at each centroid.
4. Classifying the centroid with each data according to the level of closeness of the data (smallest distance).
5. Update the centroid value by using the average value of the cluster according to the formula:

$$\mu_k = \frac{1}{N_k}\sum_{q=1}^{N_k} x_q$$

The value μ_k is the centroid point of the K-th cluster, N_k represents the number of data in the K-th group, and x_q is the q-th data in the K-th cluster.
6. Repeat steps 2 through 5 until there is no change in the members of each cluster. If the repetition has stopped, the determination of data classification can use the value formed in the last iteration.

The association rule method used in this research uses the Apriori algorithm with the following procedure:

1. Transforming the data into binary.
2. Cleaning observation data that only has one event in one observation.
3. Determine the minimum support value and minimum confidence value.
4. Calculate the support value of itemsets (with size k = 1) in the database. This process will produce a candidate rule. The formula used to calculate the Support value is

$$Support\ (\text{A}) = (Number\ of\ observations\ containing\ \text{A})/(Total\ observations)\ \text{X}\ 100\%$$

5. Pruning the candidate set by removing items with support smaller than the given threshold.
6. Combine the most frequently occurring itemsets to form a size k + 1 set, and iterate through the group until no more itemsets are formed.
7. Calculate the confidence value of the itemset formed with the formula

$$Confidence\ (\text{AB}) = (Support\ (\text{AB}))/(Support\ (\text{A}))$$

8. Pruning the candidate set by eliminating items with Confidence smaller than the given threshold.
9. Define condition and result (conditional association rule).

III. RESULTS AND DISCUSSION

3.1. Frequency Distribution

The highest number of house fire disasters occurred in the Ngasem sub-district, with 156 incidents, and the lowest number of house fire disasters happened in the Kedewan sub-district, with 13 incidents. The highest number of extreme weather events occurred in the Ngasem sub-district, with 146 events and the lowest occurred in the Kedewan sub-district, with 12 events. The highest flash floods occurred in the Ngasem sub-district, with 161 events and the lowest in the Kedewan sub-district, with 14 events. The highest number of landslides occurred in the Ngasem sub-district, with 148, and the lowest number in the Kedewan sub-district, with 10. The highest flash floods occurred in the Ngasem sub-district, with 162 incidents and the lowest flash floods occurred in the Kedewan sub-district, with 14 incidents. The highest incidence of forest and land fires happened in the Ngasem sub-district, with 155 incidents and the lowest incidence of forest and land fires occurred in the Kedewan sub-district, with 13 incidents. The highest incidence of drought happened in the Bojonegoro sub-district with 142 events, and the lowest incidence occurred in the Kedewan sub-district with 8 events. The highest incidence of other disasters occurred in the Ngasem sub-district, with 159 events. The lowest incidence of other tragedies occurred in the Kedewan and Margomulyo sub-district, with 13 events.

3.2. Clustering

Clustering to group all disasters that occur in each sub-district in Bojoengoro Regency. The Elbow technique, which looks at the proportion of results between the number of groups that will form an elbow at a point (first sloping), is used to identify the number of clusters. The comparison of each cluster to get the best group used the Average Within Cluster size. The number of sets to be tested is from 2 classes to 10 classes. The results of determining the number of clusters with the Elbow method are presented in Table 3 below.

Table 3. Results of Average Within Cluster

Number of Cluster	Average Within Cluster
2	-29.016
3	-25.806
4	-12.158
5	-9.187
6	-8.395
7	-4.016
8	-2.88
9	-2.422
10	-1.708

From the Average Within Cluster calculation process results, the best number of clusters used according to Elbow is shown on the first sloping line as in the 5th cluster. Thus, until this study, the number of groups chosen is 5 classes as the best number of sets. Furthermore, the operation is carried out with the help of rapidminer, which gets the results in Table 4 as follows.

Table 4. Output Model Cluster K-Means

Cluster Model	
Cluster 0	13 items
Cluster 1	6 items
Cluster 2	1 items
Cluster 3	4 items
Cluster 4	4 items
Total number of items: 28	

The data in Bojonegoro Regency is divided into five groups of 28 sub-districts using the K-Means model. Cluster 0 has the most group members, namely 13 sub-districts, namely Balen District, Baureno District, Bubulan District, Kalitidu District, Kanor District, Kasiman District, Kedungadem District, Kepohbaru District, Padangan District, Purwosari District, Sekar District, Sukosewu District, and Trucuk District. Cluster 1 has 6 sub-district members, namely Gayam, Gondang, Kedewan, Malo, Margomulyo, and Ngambon sub-district. Cluster 2 only has 1 member, namely Bojonegoro sub-district. Cluster 3 has 4 members: Ngasem, Ngraho, Sumberrejo, and Tambakrejo sub-district. Cluster 4 has 4 members: Dander, Kapas, Sugihwaras, and Temayang sub-district, given the thematic map of the cluster results in Figure 1 below.

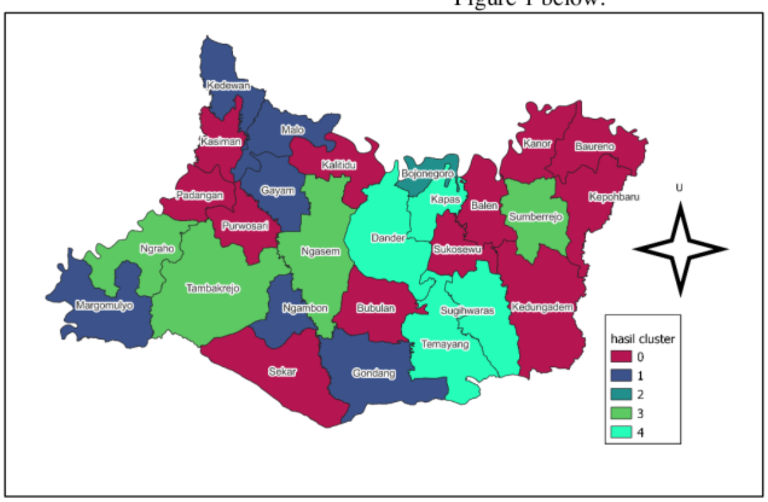

Figure 2. Mapping of Clustering Results

3.3 Association Rule with Apriori Algorithm

The formation of 1 Item set of disaster data that has been cleaned with a total of 118 observations will be calculated with a minimum support of 10%.

Table 5. Support Value of 1 Item Set

Type of disaster	Number of Events	Support
Disaster_1	29	24.58%
Disaster_2	47	39.83%
Disaster_3	26	22.03%
Disaster_4	34	28.81%
Disaster_6	49	41.53%
Disaster_7	33	27.97%
Disaster_8	28	23.73%
Total of Events	118	

Of the eight types of disasters in Table 5, there is 1 type of disaster that does not meet the minimum support, namely Disaster_5, with a minimum clearance of 0.85%.

The formation of 2 item sets is done by cross-item process on one itemset that has been calculated as the support value. Eight pairs of item sets meet the minimum support as in Table 6 below.

Table 6. Support Value of 2 Item Set

Names of Item set	Support item	Support item set
Disaster_2, Disaster_3	34.75%	11.02%
Disaster_2, Disaster_4	34.75%	11.86%
Disaster_4, Disaster_2	26.27%	11.86%
Disaster_4, Disaster_3	26.27%	11.02%
Disaster_3, Disaster_4	19.49%	11.02%
Disaster_3, Disaster_2	19.49%	11.02%
Disaster_6, Disaster_7	38.98%	22.03%
Disaster_7, Disaster_6	27.97%	22.03%

The potential of association rules forming is then ascertained by searching each item set's confidence value for sets of items that have fulfilled the support. 50% is the minimal level of confidence that has been established. As shown in Table 7 below, four association rules have been developed.

Tabel 7. Results of Confidence Calculation

Association Rule	Support	Confidence
If Disaster_3 occurs, then Disaster_4 occurs	11.02%	56.52%
If Disaster_3 occurs, then Disaster_2 occurs	11.02%	56.52%
If Disaster_6 occurs, then Disaster_7 occurs	22.03%	56.52%
If Disaster_7 occurs, then Disaster_6 occurs	22.03%	78.79%

The association rules that were developed are as follows: first, in the event that Disaster_3 (Flash Flood) occurs, there will be Disaster_4 (Landslide) with a probability level of 56.52%; second, in the event that Disaster_3 (Flash Flood) occurs, there will be a probability level of 56. Disaster_2 (extreme weather) will occur 52% of the time. Disaster_7 (drought) will occur 56.52% of the time if Disaster_6 (forest and land fires) occurs. Disaster_7 (drought) will occur 78.79% of the time if Disaster_6 (forest and land fires) occurs. It is the fourth association rule. Drought and forest and land fires are two disasters that frequently occur jointly. They have a support value of 22.03% and a confidence level of 78.79%, indicating a 22.03% dominance rate for both itemsets. The odds of two itemsets happening are 78.79%.

IV. CONCLUSION

Bojonegoro subdistrict had the highest frequency of drought disasters, while Kedewan subdistrict had the lowest frequency; Ngasem subdistrict had the highest frequency of other tragedies, while Kedewan subdistrict and Margomulo subdistrict had the lowest frequency of six other disaster events. The Kedewan sub-district had the lowest occurrence, and the Ngasem sub-district had the highest. The data in the Bojonegoro Regency is 7 divided into five groups of 28 sub-districts based on the results of the K-Means model. There are 13 sub-district members in Cluster 0, 6 sub-district members in Cluster 1, 1 sub-district member in Cluster 2, 1 sub-district member in Cluster 3, and 4 sub-district members in Cluster 4. The association a6lysis produces four association rules results with a minimum support of 10% and a minimum confidence of 50%. From the data of the results of the rules that have been obtained, it can be seen that disasters often occur simultaneously.

Suggestions for this research for future research can be used observation data with the latest year so that it can provide more up-to-date information related to disaster events that occur in Bojonegoro Regency, for future research can be used village-scale data so that it can provide more accurate information related to disaster events that occur in Bojonegoro Regency, for the Bojonegoro District Regional Disaster Management Agency to pay special attention to the group of sub-districts that have a high enough disaster level so that it can be anticipated, for the Bojonegoro District Regional Disaster Management Agency to provide handling when a disaster occurs can be handled immediately so as not to cause another disaster to occur.

V. ACKNOWLEDGEMENT

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We express our gratitude to Universitas Nahdlatul Ulama Sunan Giri (UNUGIRI) for granting us access to the computer lab necessary to conduct this study. We would also like to thank the Regional Disaster Management Agency of Bojonegoro Regency for providing disaster data in Bojonegoro Regency so that researchers can access it through the One Data Bojonegoro Website.

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