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Analyzing the Distribution of Health Workers in Semarang City Using K-Means Clustering Method

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Abstract

This research employed the K-Means Clustering method to examine the distribution of health workers in Semarang City, emphasizing their pivotal role in the public health infrastructure. Leveraging current data encompassing health worker locations and quantities, the clustering analysis discerned areas exhibiting similar distribution characteristics through the application of the K-Means technique. Quantitative analysis revealed distinct clusters, shedding light on the spatial patterns of health workforce dispersion within Semarang City. The study's quantitative findings furnish valuable insights crucial for formulating more efficacious health policies. By delineating the utility of the K-Means Clustering method in public health planning and providing quantitative evidence of health worker distribution, this research substantially augments geographical comprehension in the examined region.

Keywords: K-Means Clustering, Health, Community, Distribution, Health Workers, Spatial Analysis, Semarang City.

1. INTRODUCTION

Health workers have a very important role in providing services at the Community Health Center. Puskesmas as the main door for health services to the community must be able to provide optimal basic health services and in accordance with competency standards. Health workers according to Health Law no. 36 of 2009 is someone who has the knowledge, skills and permission to carry out health actions or efforts and is willing to dedicate himself to society in the health sector [1]. Meanwhile, based on Minister of Health Regulation Number 75 of 2014, it is stated that health workers who work based on staff standards at community health centers have at least 9 different types of health workers [2].

The ratio of health workers in the distribution of health workers is still significantly large, leading to frequent instances where Community Health Centers in Semarang City fail to meet standards. Thus, there is a pressing need for policy interventions regarding the planning and procurement of health workers to ensure that their distribution aligns with competency standards, particularly in Semarang City. One of the classic challenges encountered by Semarang City is the unequal availability and distribution of health workers at the basic service level, particularly within Community Health Centers, hindering efforts to achieve fair and equitable health services for the community.

The occupancy of Semarang City health centers with 9 (nine) types of complete health personnel according to the Minister of Health Regulation is apparently still below 50%. There are 1,513 Community Health Centers that do not have doctors at all (15%). SISDMK data also shows that there are community health centers lacking dentists (45.53%), community health centers lacking nurses (2.4%), community health centers lacking midwives (3.4%), community health centers lacking public health personnel (29.47%), Community Health Centers lack environmental health personnel (26.9%), Community Health Centers lack medical laboratory experts - ATLM (35.01%), Community Health Centers lack nutrition personnel (24%) and Community Health Centers lack pharmaceutical personnel (22.88%).

Data analysis can be done in various ways, one of which is by using Data Mining. Data mining is a data processing method to find important patterns hidden in data. The results of data processing can become useful information for the future. Data mining has various methods or even models that can be used. For this research we used clustering techniques. Clustering is a method of grouping data, where each data will be combined into groups that have similar data characteristics to each other [3].

One of the well-known algorithms in the clustering method is K-Means. K-Means is a method for analyzing data. This algorithm determines the number and value of clusters (k) randomly. This value is the initial center of the cluster or can be called the centroid [4]. In clustering methods, the K-Means algorithm is popular because the algorithm is relatively simple and efficient to use. This algorithm is included in the unsupervised learning category where we do not need to carry out a training process or in other words there is no learning stage so it can be applied in various fields. K-Means divides data into k separate regions where k is a positive integer. The K-Means algorithm is very famous because of its simplicity and ability to classify large data and outliers very quickly [5].

Research using the K-Means algorithm with clustering techniques has often been used, one of which is for the problem of the distribution of districts and cities based on data on the number of health workers in Banten Province [6]. analyze and classify data using the K-Means algorithm to be able to group the number of health workers in Karawang Regency. So this research aims to use the K-Mens Clustering method to determine the distribution of health workers in Semarang City as a novelty in research.

2. METHODS

The research method used in this research is a quantitative method. Quantitative data is research that aims to examine a certain population or sample and random sampling through the use of tools to collect data, and statistical data analysis [17]. The research method explains the stages used in the research, namely by using the K-Means clustering algorithm and the Davies Bouldin Index (DBI) cluster evaluation.

2.1 Research Strategy and Design

This research adopts the waterfall system development method, renowned for its structured and sequential approach to analyzing systems. In this method, each step must be completed before proceeding to the next; hence, if any preceding step remains unfinished, subsequent processes cannot commence. Consequently, Process 4 cannot initiate unless Processes 1, 2, and 3 have been executed. The waterfall method encompasses distinct phases: Analysis, Design, Code, Testing, Implementation, and Maintenance. Pressman describes the Waterfall Method as a classic, systematic, and linear sequential model for software development, also known as the "Linear Sequential Model". The author's choice of the waterfall method stems from its structured nature, which ensures software quality and facilitates easy maintenance. This model is advantageous for users as it allows comprehensive planning and preparation of necessary data and process requirements from the outset, enabling smooth and problem-free execution.

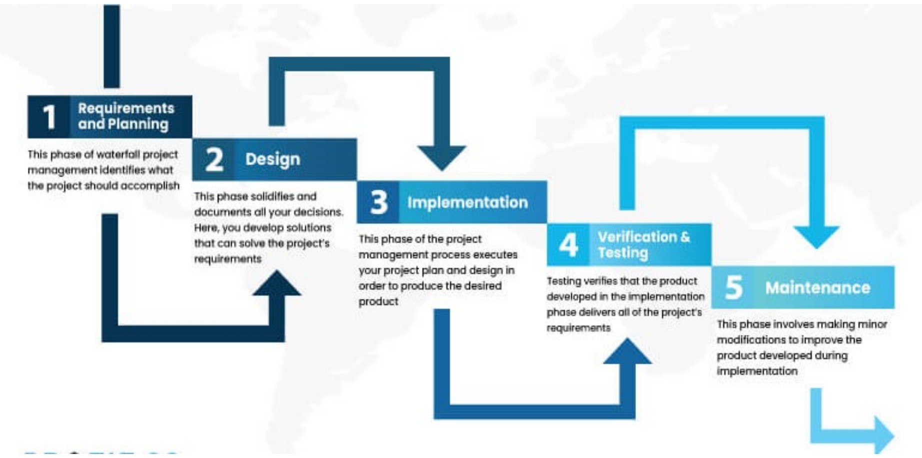

1 Requirements and Planning
This phase of waterfall project management identifies what the project should accomplish
2 Design
This phase solidifies and documents all your decisions. Here, you develop solutions that can solve the project's requirements
3 Implementation
This phase of the project management process executes your project plan and design in order to produce the desired product
4 Verification & Testing
Testing verifies that the product developed in the implementation phase delivers all of the project's requirements
5 Maintenance
This phase involves making minor modifications to improve the product developed during implementation

Figure 1. Waterfall Model

The following are the stages of the Waterfall Model as in Figure 1 according to Roger S Pressman [18]:

1) Requirements, this stage starts from collecting requirements to be applied to the device system to be developed. This stage collects the required requirements with incentives to be understood by the user, these needs are intended for the user as a future user of the system.
2) Design, this stage designs the interface design requirements for the system to be developed. Interface design needs to be done when you want to develop the system.
3) Implementation, this program creation stage must be implemented using software.
4) Verification, this system testing stage is carried out logically and functionally which is used to find out the parts of the system that have been tested previously. This testing is to minimize errors that occur in the program.
5) Maintenance, the system maintenance or maintenance phase needs to be carried out because system requirements can continue to be improved after use.

2.2 Data CollectionT

According to [19] the subject is one part or member of the sample. Research subjects are parties who are used as sources of information or data sources in a study. This research took data in the city of Semarang. This stage is carried out by direct observation of the object being studied. This will observe how health worker data is managed, so that a soft copy of the 2023 Integrated Data is obtained. The 2023 Health Worker data is given to Semarang City Health Workers.

2.3 K-Means Clustering

After the data is collected, the next stage is the analysis stage. At this stage what is done is to process the data collected from the previous stages. The K-Means Clustering stages are divided into several processes, namely:

1) Data Preprocessing
   The stage before data processing in data mining is better known as the data preprocessing stage, while the benefit of this process is to improve the quality of data grouping results using the K-means algorithm. An explanation of the data preprocessing stages is as follows:
   a) Attribute Selection
      In collecting data from bpskotasemarang.com, there were 10 health worker variables in the data. Next, the selection of attributes is carried out by sorting the attributes according to research needs with the aim of reducing the scope of the research. There are 3 attributes used, namely Doctor, Nurse and Midwife.
   b) Data Cleaning
      Cleaning is carried out to remove data that is not suitable for entering the data mining process, such as noise data and missing values. In this

research, data that was not appropriate to the research was also deleted, such as data filled in by respondents who were outside the research case study.

c) Data Transformation
At this stage, data is changed from data types that initially cannot be processed mathematically into data that can be processed. Data transformation aims to avoid damaged and invalid data. In the K-Means process, alpha numeric (text) data is transformed into numeric.

2) K-Means Clustering Calculation Process
At this stage the completion of the K-Means Clustering algorithm is carried out using a predetermined formula. As explained in the Introduction Chapter, this research aims to determine the distribution of Semarang City Health Workers using K-Means Clustering. The way it works is by dividing the data into clusters through a systematic process. After obtaining the clusters, an analysis of the cluster formation patterns is carried out which can produce useful information. The entire data calculation process uses manual calculations and then continues with testing with Rapid Miner 8.1 software to reduce the impact of human error that occurs during manual calculations.

3) System Testing
This testing stage focuses on functional and non-functional testing and will later carry out User Acceptance Testing with end users to verify whether the designed system meets their needs.

3. RESULTS AND DISCUSSION

3.1 Data Preprocessing

The data sourced from bpskotasemarang.com comprised 16 datasets detailing the total count of healthcare workers in each sub-district within Semarang City. Within these 16 sub-district datasets, emphasis was placed on three key variables: Doctors, Nurses, and Midwives. These variables were identified as crucial for the community in accessing essential healthcare services.

Next, the data goes through the Data Processing stage to produce a dataset as in Table 1.

Table 1. Semarang City Health Worker Dataset

Subdistrict	Doctor	Nurse	Midwife
Mijen	9	29	18
Gunung Pati	7	14	10
Banyumanik	166	155	29
Gajah Mungkur	248	419	69
Semarang Selatan	436	2123	165
Candisari	8	9	7
Tembalang	165	405	91

Subdistrict	Doctor	Nurse	Midwife
Pedurungan	72	25	22
Genuk	142	547	45
Gayamsari	61	117	7
Semarang Timur	160	219	80
Semarang Utara	9	10	4
Semarang Tengah	221	663	51
Semarang Barat	30	48	17
Tugu	9	14	10
Ngaliyan	123	244	47

3.2 K-Means Clustering Calculation

This stage, calculations are carried out using the K-Means algorithm based on the dataset that has been obtained. In calculating the data, the data will be grouped into 3 clusters based on the small number of health workers (C1), medium cluster (C2), and large cluster (C3). In the calculation results, 3 iterations or repetitions are carried out until a value of 0 is obtained or the same value as the previous iteration. Meanwhile, the determination of the cluster center is as follows.

1) Centroid 1, taken from Candisari District data with Doctor, Nurse, and Midwife variables (8, 9, 7).
2) Centroid 2, taken from Genuk District data with Doctor, Nurse, and Midwife variables (142, 547, 45).
3) Centroid 3, taken from South Semarang District data with Doctor, Nurse, and Midwife variables (436, 2123, 165).

The distance between each data and the initial cluster center that has been determined is calculated. Then clusters 1, 2, and 3 are grouped based on the minimum distance of each cluster.

Table 2. First Iteration Cluster Center

Cluster center	Doctor	Nurse	Midwife
C1	8	9	7
C2	142	547	45
C3	436	2123	165

Table 3. First Iteration Results

Subdistrict	Doctor	Nurse	Midwife	C1	C2	C3	MIN
Mijen	9	29	18	22.84732	535,483	2142,142	22.84732
Gunung Pati	7	14	10	5.91608	550.9437	2157,764	5.91608
Banyumanik	166	155	29	216.2499	393.0598	1991,085	216.2499
Gajah Mungkur	248	419	69	479.1075	167.9166	1717,025	167.9166
Semarang Selatan	436	2123	165	2162,671	1607,673	0	0
Candisari	8	9	7	0	555.7373	2162,671	0
Tembalang	165	405	91	434.1901	151.0265	1740,816	151.0265
Pedurungan	72	25	22	67.65353	527.1745	2134,139	67.65353

Subdistrict	Doctor	Nurse	Midwife	C1	C2	C3	MIN
Genuk	142	547	45	555.7373	0	1607,673	0
Gayamsari	61	117	7	120.3038	439.2095	2046,857	120.3038
Semarang Timur	160	219	80	269.3195	330.3528	1925,777	269.3195
Semarang Utara	9	10	4	3.316625	554.7423	2161,717	3.316625
Semarang Tengah	221	663	51	689.2177	140.4742	1480,142	140.4742
Semarang Barat	30	48	17	45.88028	512.1806	2119.52	45.88028
Tugu	9	14	10	5.91608	550.4571	2157,368	5.91608
Ngaliyan	123	244	47	264.6696	303.6017	1908,542	264.6696

The data is grouped into a cluster based on the data that has the smallest value from the cluster center. This aims to group clusters based on the smallest value, so that these results will later be used to determine new clusters. The results of cluster grouping can be seen in Table 4.

Table 3. First Iteration Smallest Value Grouping

Subdistrict	C1	C2	C3
Mijen	X		
Gunung Pati	X		
Banyumanik	X		
Gajah Mungkur		X	
Semarang Selatan			X
Candisari	X		
Tembalang		X	
Pedurungan	X		
Genuk		X	
Gayamsari	X		
Semarang Timur	X		
Semarang Utara	X		
Semarang Tengah		X	
Semarang Barat	X		
Tugu	X		
Ngaliyan	X		

Calculating a new cluster based on the smallest grouping value of the cluster in the first iteration, which can be seen in Table 5.

Table 4. Second Iteration Cluster Center

	Doctor	Nurse	Midwife
C1	59.45455	80.36364	22.81818
C2	194	508.5	64
C3	436	2123	165

The distance between each data and the cluster center that has been determined is calculated. Then clusters 1, 2, and 3 were grouped in the second iteration based on the minimum distance of each cluster. The calculation results can be seen in Table 6.

Table 5. Second Iteration Results

Subdistrict	Doctor	Nurse	Midwife	C1	C2	C3	MIN
Mijen	9	29	18	72.16023	516.0051	2142,142	72.16023
Gunung Pati	7	14	10	85.55652	531.4276	2157,764	85.55652
Banyumanik	166	155	29	130.2334	356.3303	1991,085	130.2334
Gajah Mungkur	248	419	69	390,329	104.6482	1717,025	104.6482
Semarang Selatan	436	2123	165	2081,914	1635,657	0	0
Candisari	8	9	7	89.3899	536.0459	2162,671	89.3899
Tembalang	165	405	91	348.1054	110.8253	1740,816	110.8253
Pedurungan	72	25	22	56.77315	500.4201	2134,139	56.77315
Genuk	142	547	45	474.3999	67.4333	1607,673	67.4333
Gayamsari	61	117	7	39.93528	417,385	2046,857	39.93528
Semarang Timur	160	219	80	180.5525	291.9285	1925,777	180.5525
Semarang Utara	9	10	4	88.60489	535.0956	2161,717	88.60489
Semarang Tengah	221	663	51	605.2737	157.3793	1480,142	157.3793
Semarang Barat	30	48	17	44.14551	491.0858	2119.52	44.14551
Tugu	9	14	10	84.34512	530.7271	2157,368	84.34512
Ngaliyan	123	244	47	177,1994	274.3907	1908,542	177,1994

The data is grouped into a cluster based on the data that has the smallest value from the cluster center according to the previous explanation. The grouping results can be seen in Table 7.

Table 6. Second Iteration Smallest Value Grouping

Subdistrict	C1	C2	C3
Mijen	X		
Gunung Pati	X		
Banyumanik	X		
Gajah Mungkur		X	
Semarang Selatan			X
Candisari	X		
Tembalang		X	
Pedurungan	X		
Genuk		X	
Gayamsari	X		
Semarang Timur	X		
Semarang Utara	X		
Semarang Tengah		X	
Semarang Barat	X		
Tugu	X		
Ngaliyan	X		

This stage will continue to be carried out until we get an iteration that matches the previous iteration. In the second iteration of the calculation, if seen based on the grouping of data that has the smallest value, it has the same results as the previous iteration. Therefore, the dataset processing was stopped until the second iteration.

3.3 System Testing

Figure 2 and Figure 3 show the testing process using Rapidminer by looking for the cluster (k) valuebest, by using PerformanceVector to find the smallest DBI value. Meanwhile, Figure 5 and Figure 6 show the test results dataset which shows the numbers according to the results of manual testing that was carried out in the previous stage.

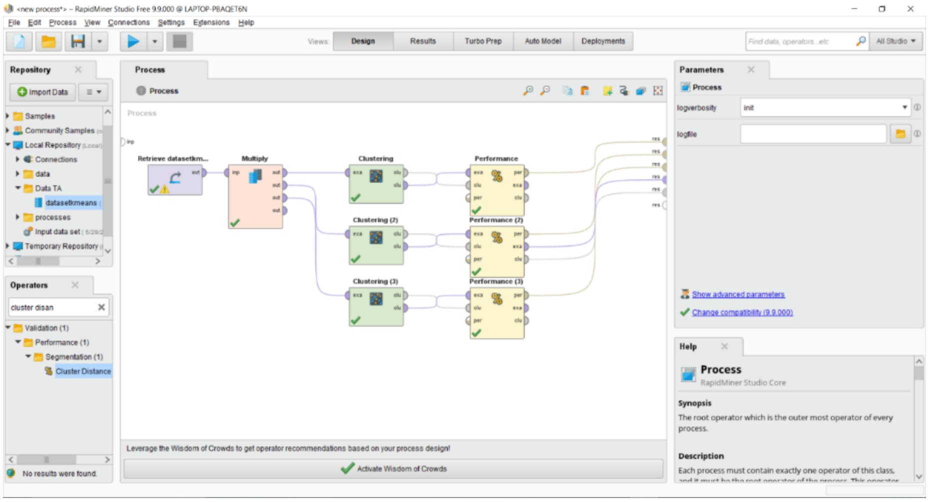
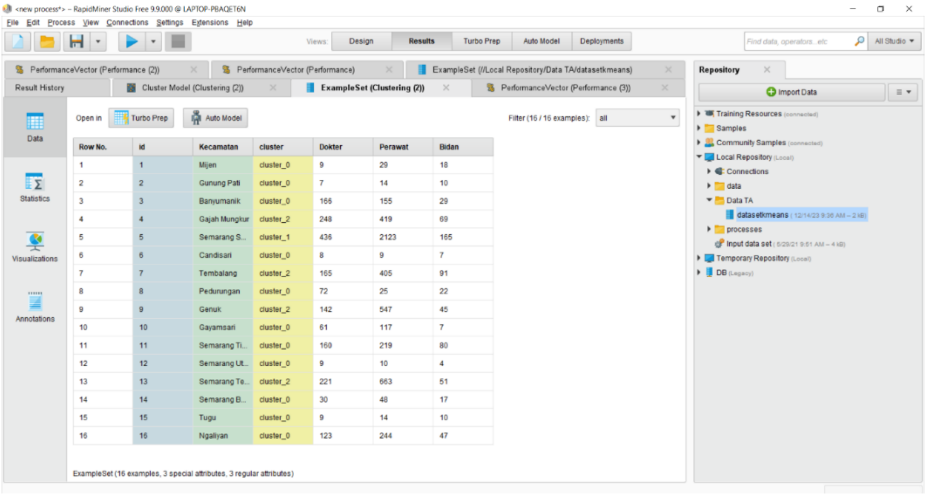


Figure 2. Testing with RapidMiner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ExampleSet (Clustering (2))
PerformanceVector (Performance (3))
Data
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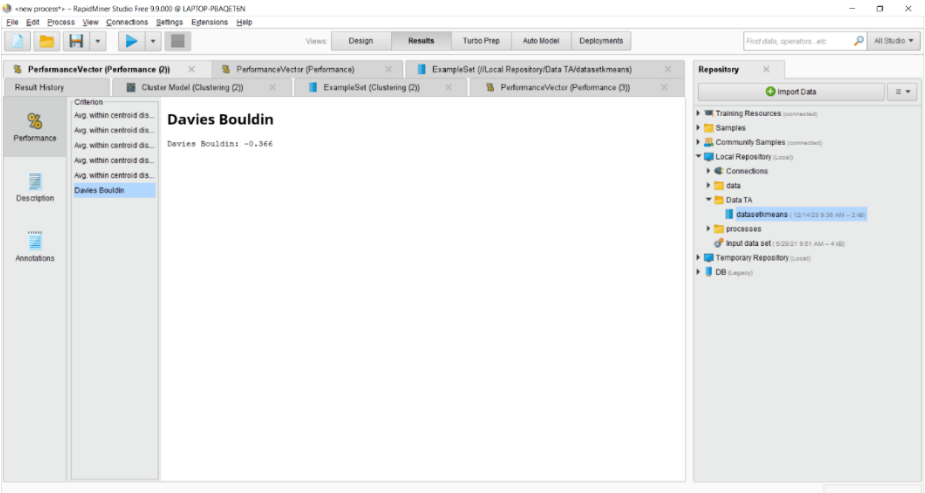
Repository

Row No.	id	Kecamatan	cluster	Dokter	Perawat	Bidan
1	1	Mijen	cluster_0	9	29	18
2	2	Gunung Pati	cluster_0	7	14	10
3	3	Banyumanik	cluster_0	166	155	29
4	4	Gajah Mungkur	cluster_2	248	419	69
5	5	Semarang S...	cluster_1	436	2123	165
6	6	Candisari	cluster_0	8	9	7
7	7	Tembalang	cluster_2	165	405	91
8	8	Pedurungan	cluster_0	72	25	22
9	9	Genuk	cluster_2	142	547	45
10	10	Gayamsari	cluster_0	61	117	7
11	11	Semarang Ti...	cluster_0	160	219	80
12	12	Semarang Ut...	cluster_0	9	10	4
13	13	Semarang Te...	cluster_2	221	663	51
14	14	Semarang B...	cluster_0	30	48	17
15	15	Tugu	cluster_0	9	14	10
16	16	Ngaliyan	cluster_0	123	244	47

ExampleSet (16 examples, 3 special attributes, 3 regular attributes)

Figure 3. RapidMiner Dataset Result

Then from the PerformaceVector test results in Figure 4 and Figure 5, the DBI values for clusters (k=3): -0.326; cluster (k=4): -0.366; and for cluster (k=5): -0.398. From the test results, it can be concluded that the cluster (k=3) is the best cluster used in this research because the resulting DBI value is the smallest among the other clusters, so it is considered good.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Cluster Model (Clustering (2))
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Annotations
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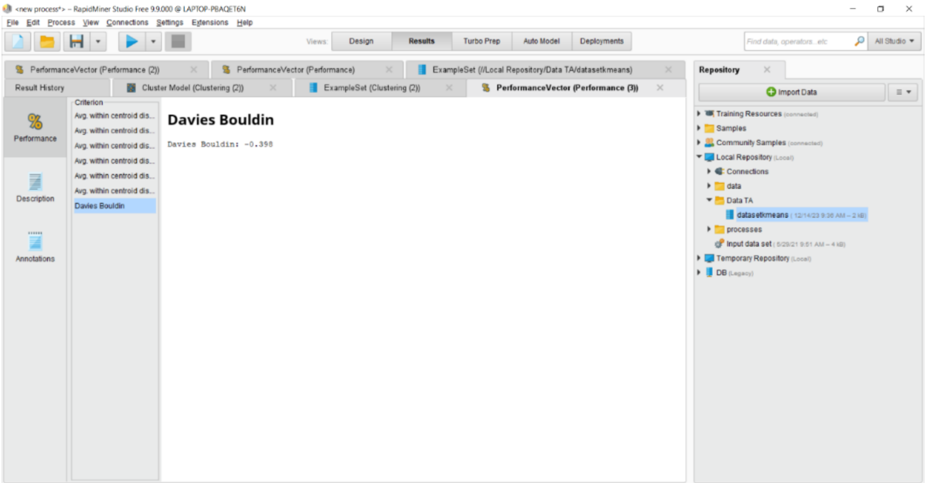
Figure 4. DBI Cluster Value Results (K=3)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PerformanceVector (Performance (2))
PerformanceVector (Performance)
ExampleSet (//Local Repository/Data TA/datasetkmeans)
Result History
Cluster Model (Clustering (2))
ExampleSet (Clustering (2))
PerformanceVector (Performance (3))
Performance
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Figure 5. DBI Cluster Value Results (K=4)

Based on the results of testing with RapidMiner that has been carried out, it can be concluded that the amount of Health Workers in Semarang City has a large distribution in only 1 sub-district, namely South Semarang, the medium category in 4 sub-districts, namely, Gajah Mungkur, Tembalang, Genuk, and Central

Semarang. and with a small category in 11 sub-districts, namely Mijen, Gunung Pati, Banyumanik, Candisari, Pedurungan, Gayamsari, East Semarang, North Semarang, West Semarang, Tugu, and Ngaliyan.

4. CONCLUSION

Based on the results of the research and trials that have been carried out, it can be concluded that the application of the K-Means Clustering algorithm in determining the distribution of the number of health workers in each sub-district in Semarang City resulted in cluster 1 with 11 sub-districts still having a shortage of health workers, including Mijen, Gunung Pati, Banyumanik, Candisari, Pedurungan, Gayamsari, East Semarang, North Semarang, West Semarang, Tugu, and Ngaliyan with a DBI value of -0.326. Then there are 4 sub-districts with a medium number of health workers, namely Gajah Mungkur, Tembalang, Genuk, and Central Semarang. Meanwhile, the number of health workers is only found in 1 sub-district, namely South Semarang. In conclusion, this research underscores the importance for the Semarang City Government and relevant agencies to prioritize the evaluation of healthcare staffing levels in accordance with standards. With the population steadily increasing and unpredictable weather conditions compromising immune systems, there is a heightened susceptibility to infectious diseases.

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