P-ISSN: 2655-3724 E-ISSN: 2720-9881
STATMAT (Jurnal Statistika dan Matematika)
Vol. 7, No. 1, April 2025
Artikel ke-5, Halaman: 41-53
https://doi.org/10.32493/sm.v7i1.46533

MULTIDIMENSIONAL SCALING ANALYSIS BASED ON FACTORS AFFECTING UNDER-FIVE MALNUTRITION CASES IN WEST JAVA

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ABSTRACT

Malnutrition is a condition where the body's nutrition is below the average standard. Nutritional issues, particularly among toddlers, remain a serious problem in various provinces in Indonesia, including West Java. In 2022, 3.3% of toddlers in West Java experienced undernutrition, and 0.4% suffered from severe malnutrition. This study aimed to map 27 regencies/cities in West Java Province based on factors influencing toddler malnutrition in 2022, highlighting similarities among these areas. A statistical method, Multidimensional Scaling (MDS), was used to classify objects based on similar characteristics. This method illustrated the dispersion of observational units based on measured variables, creating a two-dimensional map. Nearby regencies/cities indicated similar malnutrition conditions among toddlers, suggesting that the same mitigation efforts could be applied in those areas. The analysis resulted in four quadrants. Red circles were used on the map to mark points that were very close. To test the validity, STRESS and R-Square values were calculated. The STRESS value of 0.012% indicates that the generated map is in the perfect category, demonstrating that this analysis has precise reliability and validity. The R-Square value of 99.76% shows that the variance of the data is well explained by the model. This indicates that the Multidimensional Scaling (MDS) model is acceptable for mapping purposes. The findings of this study serve as valuable information and a reference for the West Java provincial government to make more effective and targeted efforts in combating malnutrition.

Keywords: Toddlers, Malnutrition, West Java, Health, Multidimensional Scaling (MDS)

ABSTRAK

Gizi buruk merupakan suatu kondisi dimana nutrisi tubuh berada di bawah standar rata-rata. Masalah gizi, khususnya pada kelompok balita, masih menjadi masalah serius di berbagai provinsi di Indonesia, salah satunya Provinsi Jawa Barat. Pada tahun 2022, kasus di Jawa Barat menunjukkan bahwa 3.3% balita mengalami gizi kurang dan 0.4% balita menderita gizi buruk. Penelitian ini bertujuan untuk memetakan 27 kabupaten/kota di Provinsi Jawa Barat berdasarkan faktor-faktor yang mempengaruhi gizi buruk pada balita tahun 2022, sehingga terlihat kemiripan kabupaten/kota dari faktor-faktor tersebut. Terdapat metode statistik untuk mengklasifikasi beberapa objek berdasarkan karakteristik yang sama, yaitu Multidimensional Scaling (MDS). Metode ini menggambarkan persebaran unit observasi berdasarkan karakteristik atau variabel yang diukur untuk membuat peta berdimensi dua. Kabupaten/kota yang berdekatan menunjukkan bahwa kondisi gizi buruk pada balita di wilayah tersebut hampir sama, sehingga upaya penanggulangan yang diterapkan di wilayah tersebut bisa sama. Berdasarkan hasil analisis, terdapat empat kuadran yang terbentuk. Pada peta, lingkaran merah diberikan untuk titik-titik yang jaraknya sangat dekat. Untuk menguji validitasnya, dihitung nilai STRESS dan R-Square. Nilai STRESS sebesar 0.012% menunjukkan bahwa peta yang dihasilkan termasuk dalam kategori sempurna, yang menandakan bahwa analisis ini memiliki reliabilitas dan validitas yang tepat. Nilai R-Square sebesar 99.76% menunjukkan bahwa varians data dapat dijelaskan oleh model. Artinya, model Multidimensional Scaling (MDS) dapat diterima untuk menggambarkan pemetaan. Hasil penelitian ini dapat dijadikan informasi dan acuan dalam pengambilan keputusan oleh pemerintah Provinsi Jawa Barat, agar upaya penanggulangan gizi buruk

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lebih efektif dan tepat sasaran.

Kata kunci: Balita, Gizi Buruk, Jawa Barat, Kesehatan, Multidimensional Scaling (MDS)

1. INTRODUCTION

One of the problems of nutritional status is malnutrition. Malnutrition is a significant and prevalent health problem in the hospital setting, affecting a large proportion of hospitalised patients worldwide (Wong *et al*., 2024). Malnutrition is a condition where a person experiences nutritional deficiencies due to a lack of sufficient energy and protein intake from the daily diet. This is usually characterised by weight and height that are not age-appropriate (Septiawati *et al*., 2021). There are three types of malnutrition status, namely due to carbohydrate deficiency (*marasmus*), protein deficiency (*kwashiorkor*), and due to lack of both (*marasmic-kwashiorkor*) (Fitriyanto & Mahfudz, 2020).

Malnutrition can affect all age groups in society, but infants and toddlers require special attention. Toddlers are a group of people who require adequate nutritional intake because this age is considered a period of optimal growth and development (*golden age*). So that nutritional imbalances that occur during this period, if not handled properly, can have a negative impact on the quality of the next generation (Pratami *et al*., 2021). Child malnutrition exists in various forms, including undernutrition (*wasting*, *stunting*, and *underweight*), micronutrient deficiencies, and overweight and obesity, constituting a triple burden of disease, especially in low and middle income countries, and is one of the main causes of poor health and a major barrier to self-development and achievement of full human potential worldwide (Vassilakou, 2021).

The characteristics of malnutrition are bulging bellies, dry skin, brittle hair, reduced fat under the skin, and muscle wasting (Rahma & Suhartini, 2023). As a result of malnutrition, children are vulnerable to various dangerous diseases, such as suboptimal brain development. If nutritional conditions are not immediately corrected, brain cells cannot develop properly and recovery will be difficult (Wahyuni *et al*., 2019). Therefore, nutritional problems in children under five are a serious concern in Indonesia. In more severe cases, when poor care is combined with the onset of other diseases, malnutrition can lead to death (UNICEF, 2023). Disease-related malnutrition arises due to reduced food intake, malabsorption, increased nutrient losses or altered metabolic requirements. Extensive changes in physiological function occur in malnourished patients leading to increased morbidity and mortality rates (Dipasquale *et al*., 2020).

According to the West Java Provincial Health Office, nutrition cases in 2022 were 3.3% of under-fives still experiencing malnutrition and 0.4% of under-fives suffering from malnutrition. This figure has decreased by 0.3% compared to the previous case in 2021. Malnutrition in children under five can be caused by various internal and external factors. Internal factors include malnutrition in infants, low birth weight, and poor parenting of under-fives. Meanwhile, external factors include the economic condition of the community and the number of poor people (Frumence *et al*., 2024). Poverty exacerbates the risk of malnutrition. Poor people are more susceptible to various forms of malnutrition. In addition, malnutrition increases healthcare costs, lowers productivity, and inhibits economic growth, which can perpetuate the cycle of poverty and health problems (WHO, 2020).

Therefore, this study will discuss the Multidimensional Scaling (MDS) analysis of 27 regencies/cities in West Java Province based on factors affecting under-five malnutrition cases in 2022. Through this analysis, a mapping of each regencies/cities can be obtained which is expected to be used as information for the West Java Provincial Government, so that efforts to overcome malnutrition are more effective and targeted.

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2. RESEARCH METHODS

2.1. Type of Research

This research uses a quantitative approach by applying Multidimensional Scaling (MDS) analysis. The MDS method describes the distribution of observation units based on measured characteristics or variables to create a two-dimensional map. Regencies/cities in West Java Province that are close to each other indicate that the malnutrition conditions of children under five are similar, so that the countermeasures applied in these areas can be the same.

2.2. Data Source

The data used in this study are secondary data obtained from Badan Pusat Statistik (BPS) (https://jabar.bps.go.id/indicator/23/51/1/persentase-penduduk-miskin.html) and the West Java Province Health Profile Year 2022 (https://diskes.jabarprov.go.id/informasipublik/profil). The observation units used were 27 regencies/cities in West Java Province.

2.3. Research Variables

There are four variables used, namely factors that affect malnutrition in children under five years of age in 2022, including the percentage of infants with Low Birth Weight (LBW), the percentage of households that have a clean and healthy lifestyle, the percentage of the poor population, and the percentage of infants who receive exclusive breastfeeding (Pratami *et al*., 2021).

Table 1. Research Variables

Variable	Description	Measurement Scale
X_1	Percentage of infants with Low Birth Weight (LBW)	Ratio
X_2	Percentage of households that have a clean and healthy lifestyle	Ratio
X_3	Percentage of poor population	Ratio
X_4	Percentage of infants who are exclusively breastfed	Ratio

2.4. Multidimensional Scaling

Multidimensional Scaling (MDS) is one of the multivariate analysis techniques that can be used to determine the relative position of objects based on their similarity assessment, as well as to identify interdependence relationships between variables or data (Hatsuda *et al*., 2022). This relationship is not known through the reduction or grouping of variables, but through the comparison of variables contained in each object in question using a perception map. MDS is a method that reproduces the original location of objects based on distance data between objects (Ishibashi & Taguchi, 2021).

Basically, the concept of MDS is mapping. MDS is used to create a map that describes the position of an object with other objects based on the similarity between these objects, so the purpose of MDS is to map observation units onto a two-dimensional map based on the

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characteristics measured on objects or observation units, then the output is a map that describes the distribution of observation units based on the characteristics or variables measured (Joviandi & Kesumawati, 2024).

Dual-dimensional scaling refers to a method that helps identify the underlying measures of respondent's judgements of an object. Dual-dimensional scaling is also known as a perceptual map. Perceptual map is a form of visual representation of the respondent's perception of several objects consisting of two or more dimensions (Pradita *et al*., 2019). To perform data analysis with Multidimensional Scaling (MDS), values are used that describe the level of similarity or the level of dissimilarity between objects called proximity which is divided into similarity and dissimilarity (Syaifudin & Rifa, 2022). Based on the data type, MDS is divided into two, namely metric Multidimensional Scaling and non-metric Multidimensional Scaling.

2.5. Metric Multidimensional Scaling

The distance data used in this scaling is quantitative data with an interval/ratio scale. This scaling is used to find the set of points in n-dimensional space where each point represents one object so that the distance between points becomes $d_{rt} \approx f(d_{rt})$ (Pura *et al*., 2019). In metric Multidimensional Scaling, it does not matter whether this input data is the actual distance or not, this procedure only composes the geometric shape of the object points that are attempted to be as close as possible to the given input distance (Syaifudin & Rifa, 2022).

2.6. Non-Metric Multidimensional Scaling

The distance data used in this scaling is ordinal-scale qualitative data. In this analysis, the transformation function only has the limitation $\delta_{rt} < \delta_{r't'} \rightarrow f(\delta_{rt}) \leq f(\delta_{r't'})$ for all $1 \leq r, t, r', t', \leq n$ (Safitri & Arnellis, 2021). The distance data used in the transformation is monotone (equal) to the actual data so that arithmetic operations can be performed on the unequal values, to adjust the distance to the unequal order values. The monotonic transformation will maintain the order of the dissimilarity values so that the distances between objects that do not conform to the order of the dissimilarity values are transformed in such a way that they will still fulfil the order of the dissimilarity values and approach the original distances (Siena *et al*., 2020).

2.7. Analysis Procedure

Multidimensional Scaling is an analysis to visually map perceptions in a multidimensional map. The following are the stages of conducting Multidimensional Scaling analysis (Pura Nurmayanti *et al*., 2023).

1. **Calculating the Euclidean distance matrix**

   The proximity between objects on the perceptual map can be calculated using the Euclidean distance between the first object and the j-th object with the following formula:

$$d_{ij} = \left[\sum_{k=1}^{p} \left(X_{ih} - X_{jh} \right)^2 \right]^{\frac{1}{2}} \quad (1)$$

   where,

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d_{ij} = distance between i-th object and j-th object
X_{ih} = measurement result of the i-th object on variable h
X_{jh} = measurement result of the jth object on variable h

2. Multidimensional Scaling Analysis

After finding the Euclidean distance, we need to calculate the eigenvalues and eigenvectors to get the coordinate points. Eigenvalues are useful for determining the number of dimensions required to accurately represent the inequality matrix. Here are the formulas to find eigenvalues and eigenvectors:

$$\det(B - \lambda I) \text{ and } \det(B - \lambda I)X \tag{2}$$

where calculates the matrix B with elements:

$$b_{ij} = -\frac{1}{2}(d_{ij}^2 - d_{i.}^2 - d_{.j}^2 + d_{..}^2) \tag{3}$$

with,

$$d_{i.}^2 = \frac{1}{n}\sum_{i} d_{ij}^2 \tag{4}$$

$$d_{.j}^2 = \frac{1}{n}\sum_{i} d_{ij}^2 \tag{5}$$

$$d_{..}^2 = \frac{1}{n^2}\sum_{ii} d_{ij}^2 \tag{6}$$

Then, form the object coordinates based on the eigenvectors $X = [x_1, x_2]$, then further calculate the value of $\hat{D}$ which is the Euclidean distance of the formed coordinates.

3. Multidimensional Scaling Plot

Next, a Multidimensional Scaling plot will be formed on the data with dimensions for the coordinates formed are two dimensions. The interpretation of this plot is that for each adjacent point represents the similarity or closeness between objects (Simatupang *et al*., 2020). MDS interpretation is based on groups and patterns in the dimensional locus and not on the individual coordinates of the points (Mochado & Lopes, 2020). From this interpretation, it will produce a mapping based on quadrants but these results cannot be used as a reference for assigning objects because there are certain objects that are in different quadrants but have a close distance or have high similarity.

4. Calculating the STRESS and R-Square values

Testing the results of the analysis is done by calculating the STRESS and R-Square values. The level of model fit (goodness of fit) can be evaluated using a measure of error criteria (lack of fit or error). A configuration of objects that includes coordinates for each point in a specified number of dimensions and an estimate of model misfit between the dissimilarity matrix and the MDS configuration, called STRESS (Meyer & Reynolds, 2022). STRESS values are obtained from the monotonic relationship between similarity and final distance. A STRESS (Standardised Residual Sum of Square) function is as follows:

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$$STRESS = \sqrt{\frac{\Sigma_{r,t}\left(d_{rt} - \widehat{d_{rt}}\right)^2}{\Sigma_{r,t} d_{rt}^2}} \quad (7)$$

With the value provisions as in the following table (Toruan *et al*., 2021).

Table 2. STRESS Value Provisions

STRESS (%)	Criteria
> 20	Poor
10 < STRESS ≤ 20	Fair
5 < STRESS ≤ 10	Good
2,5 < STRESS ≤ 5	Excellent
< 2,5	Perfect

The smaller the STRESS value indicates that the monotonic relationship between dissimilarity and distance between pairs of objects into a new measure is getting better (obtained suitability) and the perception map formed is more perfect (Ammar Taqiyyuddin & Irfan Rizki, 2021). Conversely, the greater the R-Square value formed, the greater the proportion of data variance that can be explained by Multidimensional Scaling. With the criteria if the $R^2 > 0.6$, the MDS results are declared acceptable (Nafisah & Setiawan, 2019).

The following is a flow diagram in the stages of Multidimensional Scaling analysis (Ramadhani *et al*., 2022).

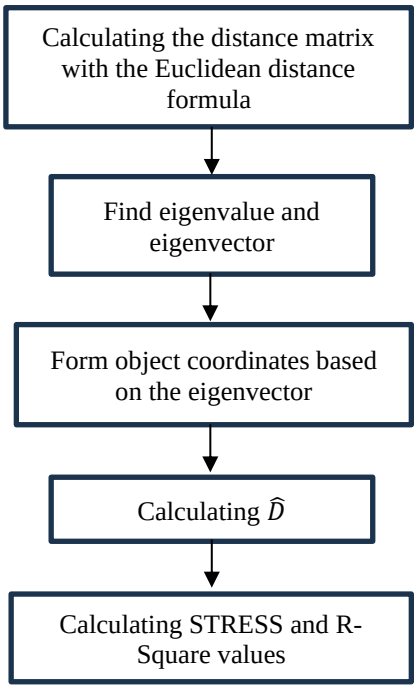

Figure 1. Multidimensional Scaling Analysis Stages

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3. RESULTS AND DISCUSSION

The above analysis procedures were carried out one by one in sequence. The analysis was conducted using R Studio software, starting from data input to testing the analysis results.

3.1. Multivariat Normal Assumption Testing

Table 3 Mardia Test Results

Mardia Test	P-Value
Mardia Skewness	0.915
Mardia Kurtosis	0.076

Based on the results of the Normality Test calculation above, the p-value of Mardia Skewness (0.915) and Mardia Kurtosis (0.076) > α(0.05) means that H_0 is accepted. So, it can be concluded that the data fulfils the assumption of multivariate data normality.

3.2. Calculating the Euclidean Distance Matrix

The Euclidean distance matrix in MDS analysis is calculated using the formula previously described, so that the Euclidean Distance matrix is obtained as follows:

Table 4. Euclidean Distance Matrix

	1	**2**	⋯	**26**	**27**
1	0				
2	10.61	0			
⋮	⋮	⋮	⋮		
26	10.67	⋮	⋮	0	
27	33.90	⋮	⋮	42.51	0

The output shows the value of the Euclidean distance. Empty columns and rows show the results of the distance between objects and themselves or the results of the same distance that has been written before.

3.3. Multidimensional Scaling Analysis

Table 5. Fit Points

Regency/City	Fit Points [,1]	Fit Points [,2]
Bogor Regency	-10.39	2.08
Sukabumi Regency	-0.51	4.86
Cianjur Regency	11.26	2.49
.	.	.
.	.	.
Cimahi City	-5.67	10.74
Tasikmalaya City	-19.46	5.84
Banjar City	22.99	6.86

P-ISSN: 2655-3724 E-ISSN: 2720-9881
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The fit points results above are the coordinates of each object needed to depict the 27 regencies/cities into a two-dimensional plot. In addition, eigenvalues and eigenvectors are also obtained to obtain coordinate points with column 1 being the coordinate for the x-axis while column 2 is the coordinate for the y-axis.

3.4. Multidimensional Scaling Plot

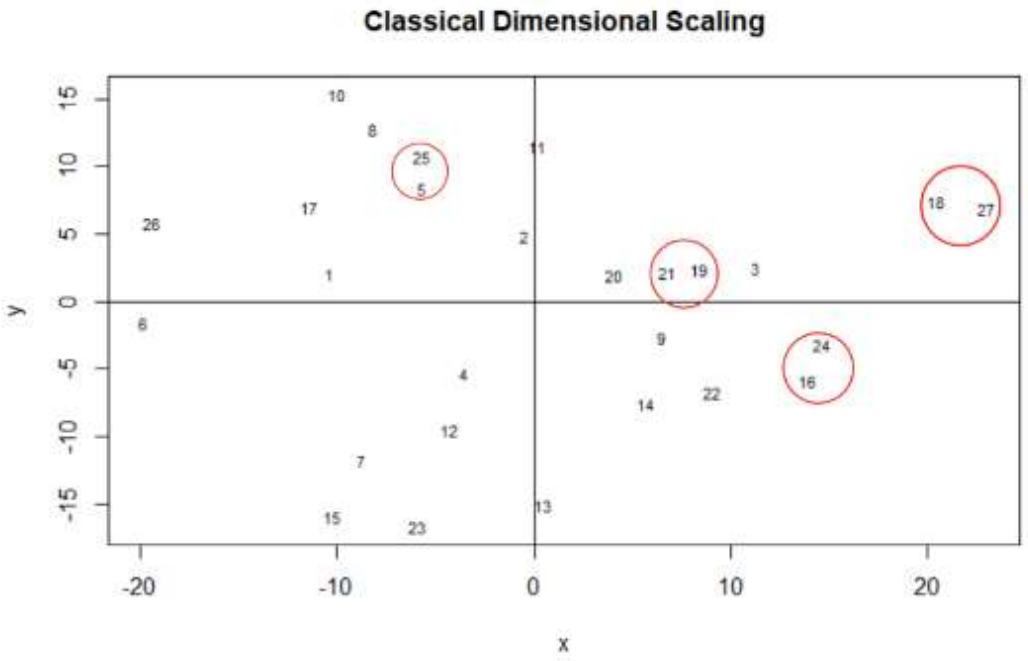

Figure 2. Multidimensional Scaling Analysis Mapping

The figure above shows that each adjacent point represents the similarity or closeness between objects. The similarity is measured based on the distance between the four malnutrition variables in each regencies/cities. Based on the quadrants in the figure, regencies/cities are grouped according to characteristics based on the value of the variables owned by each regencies/cities.

Quadrant I: Banjar City, Sumedang Regency, Pangandaran Regency, Cianjur Regency, Bogor City, Sukabumi City, Bandung City

Quadrant II: Bogor Regency, Garut Regency, Majalengka Regency, Sukabumi Regency, West Bandung Regency, Cimahi City, Kuningan Regency, Tasikmalaya City

Quadrant III: Bandung Regency, Tasikmalaya Regency, Ciamis Regency, Indramayu Regency, Karawang Regency, Bekasi City

Quadrant IV: Cirebon Regency, Subang Regency, Purwakarta Regency, Bekasi Regency, Cirebon City, Depok City.

In quadrant I, the value of variable X_1 quite high, with a range of 1.8% to 5.3%. The value of variable X_2 is also quite high, ranging from 59.12% to 81.59% which is the highest value among all quadrants. The value of variable X_3 is quite low, with the highest value of only 10.55% and the lowest of 4.25%. The value of variable X_4 ranges quite high, from 73.9% to 86.3%, which is also the highest compared to other quadrants.

In quadrant II, the value of variable X_1 is quite high, from 1.8% to 6.1%, which is also the highest compared to other quadrants. The value of variable X_2 is quite low, with the

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highest value being only 55.09% and the lowest being 43.88%. The value of variable X_3 is quite high, with a range of 5.11% to 12.76%. The value of variable X_4 also ranges quite high, from 67.6% to 80.2%.

In quadrant III, the value of variable X_1 is quite low, with a range of 0.3% to 4.8%. The value of variable X_2 is in the middle position, with the highest value of 64.59% and the lowest of 46.37%. The value of variable X_3 from 4.43% to 12.77%, the highest among the other quadrants. The value of variable X_4 is low, from 51.7% to 64.2%.

In quadrant IV, the value of variable X_1 is quite low, from 0.6% to 4.3%. The value of variable X_2 is quite high, from 70.54% to 78.28%. The value of variable X_3 is quite low, from 2.53% to 12.01%. The value of variable X_4 is in the middle position, with the highest value of 71.02% and the lowest of 57%.

In addition to grouping by quadrant, grouping can also be done based on the proximity of coordinate points. The figure above shows four groups of red circles representing regencies/cities that are grouped based on the proximity of their coordinates. The characteristics of each regencies/cities based on their variable values influence the grouping.
Group 1: Pangandaran Regency and Banjar City
Group 2: Bogor City and Bandung City
Group 3: Garut Regency and Cimahi City
Group 4: Bekasi Regency and Depok City.

In group 1, Pangandaran Regency and Banjar City are in quadrant I with the characteristics of high values in variables X_1 and X_2, quite low values in variable X_3, and very high values in variable X_4. In group 2, Bogor City and Bandung City are also in quadrant I with low values in variables X_1, quite high values in variable X_2 and X_4, and quite low values in variable X_3. In group 3, Garut Regency and Cimahi City are in quadrant II with low values in variables X_1, quite low values in variable X_2 and X_3, and quite high values in variable X_4. In group 4, Bekasi Regency and Depok City are in quadrant IV with a very low values in variable X_1, quite high values in variable X_2 and X_4, and low values in variable X_3.

3.5. Calculating STRESS and R-Square Values

Table 6. STRESS and R-Square Values

Goodness of Fit	Value (%)
STRESS	0.012515
R-Square	99.76329

The STRESS value obtained is 0.012%, meaning that the resulting map is in the perfect category, indicating that the analysis has the right level of reliability and validity. Furthermore, the R-Square value obtained is 99.76% of the data variance can be explained by the model used, meaning that the Multidimensional Scaling (MDS) model is acceptable for describing the mapping performed.

4. CONCLUSIONS

Based on the results of the analysis using the Multidimensional Scaling (MDS) method on data on factors affecting under-five malnutrition cases in 27 regencies/cities in West Java Province in 2022, four groups of regencies/cities were obtained that were most similar based on the distance between objects. This grouping is influenced by the characteristics of each regencies/cities based on its variable values. The variables X_1 and X_3 with the variables X_2

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https://doi.org/10.32493/sm.v7i1.46533

and X_4 have opposite meanings. If there is a high percentage value in variables X_1 and X_3, then the regencies/cities has many LBW cases and poor people, which has a negative impact on the regencies/cities. As for variables X_2 and X_4, if the regencies/cities has a high percentage value on these variables, then clean and healthy lifestyle in the regencies/cities environment has been implemented by the majority of the population. This also has an impact on variable X_4 so that the percentage of infants who get exclusive breastfeeding also increases as the percentage value of clean and healthy lifestyle increases. If the values of variables X_2 and X_4 are high, then the values of variables X_1 and X_3 will decrease as seen in quadrants I and IV. On the other hand, quadrants II and III show that the values of variables X_2 and X_4 are not high enough, so that the values of variables X_1 and X_3. This also applies to groups created based on proximity.

Then, the STRESS value of 0.012% is obtained, which indicates that the resulting map is in the perfect category. This value indicates that this analysis has the right reliability and validity. In addition, the R-Square value of 99.76% indicates that the variance of the data can be explained by the model. This means that the MDS model is acceptable for describing mapping. Therefore, these results can be used as a guide in decision-making by the government. If the West Java Provincial government wants to improve clean and healthy lifestyle, then the method used can be adjusted to the existing quadrants or groups. For quadrants III and IV that have a low clean and healthy lifestyle percentage value, then efforts to improve clean and healthy lifestyle are needed. As for quadrants I and II, what must be improved is Low Birth Weight (LBW). The method used in each quadrant is different due to different characteristics and needs, so that the results achieved are more optimal. Likewise, for regencies/cities that are grouped based on coordinate proximity, for example in group 3 which has a low clean and healthy lifestyle values, efforts need to be made to improve clean and healthy lifestyle in Garut Regency and Cimahi City, and likewise with other groups.

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Hatsuda, Y., Maki, S., Ishizaka, T., Omotani, S., Koizumi, N., Yasui, Y., Saito, T., Myotoku,

P-ISSN: 2655-3724 E-ISSN: 2720-9881
STATMAT (Jurnal Statistika dan Matematika)
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