

Biplot Analysis of Life Satisfaction Dimensions in the Happiness Index

Bimo Okta Syahputra¹, Rachma Hikmaya², Nabila Angel Nafisha³, Immanuel Alexander Sirait⁴, M. Fariz Fadillah Mardianto⁵, Dita Amelia⁶, Elly Anna⁷

^{1,2,3,4,5,6,7}Statistics Study Program, Department of Mathematics, Faculty of Science and Technology, Universitas Airlangga, Indonesia

⁵Corresponding author Email: m.fariz.fadillah.m@fst.unair.ac.id

Abstract. The main goal of every individual in life is to achieve happiness, a subjective concept. To measure happiness, one approach used is the life satisfaction dimension. In multivariate analysis, the biplot method emerges as a useful tool to map variables and objects of observation simultaneously in a two-dimensional graph. This study was conducted with the aim of analyzing biplots on the happiness index, with the dimension of life satisfaction as the main variable. The data used comes from the Central Bureau of Statistics (BPS), specifically related to the Life Satisfaction Dimension of the Happiness Index in 2021. By conducting careful biplot analysis, the pattern of relationships between provinces in the context of happiness can be revealed. The results of the biplot analysis show that provinces in the same quadrant have closer similarities in happiness characteristics than provinces in different quadrants.

Keywords: *biplot analysis; happiness index; indonesia provinces; life satisfaction; similarities.*

1 Introduction

The happiness index in the life satisfaction dimension is a measure used to evaluate the level of happiness and life satisfaction of a person or group in a country or region. According to Dewi [1], measuring welfare is one of the problems that continues to be studied in the economy. According to Atasoge [2], inflation and other things are not enough to describe the prosperity of a society, not only in material measures but in others. The happiness index is usually based on several factors, including but not limited to economic conditions, health, education, environment, and the quality of social relationships. Different countries often have different methodologies for measuring happiness indices. Such methods may involve surveys asking about life satisfaction, stress levels, psychological well-being, social support, and other factors thought to influence human happiness. Among the factors that often influence the happiness index are education, work, the economy, and others [3].

The results of this happiness index can provide valuable insights for policymakers and the general public to identify areas that need improvement to improve the quality of life [4]. The latest news regarding the happiness index is usually published by relevant institutions or the

government in the country after conducting surveys and analysis. This journal can help in understanding changes in happiness trends from year to year. By recording and analyzing data from this period, we can see how certain factors have contributed to these changes [5]. We can identify patterns or correlations between certain factors and levels of happiness. This can help in formulating more effective recommendations or policies to increase people's happiness.

Well-documented data can be a valuable resource for further research. Further research can be conducted to deepen understanding of the factors influencing happiness and ways to increase it [6]. Keeping a journal of the dimensions of life satisfaction or happiness index during the 2021 period will help in building a better understanding of the aspects that influence happiness in various communities, and can be a strong foundation for the development of better policies in the future. According to Rahayu [7], happiness studies in Indonesia still have potential research.

2 Biplot Analysis

Biplot was first introduced by Gabriel in 1971 [8]. Biplot is a method in multivariate analysis that is used to map a group of variables and objects of observation simultaneously in a two-dimensional graph. Thus, the characteristics of variables and observation objects as well as the relative position between observation objects and variables can be analyzed [9]. The information contained in a two-dimensional biplot graph includes [10]:

1. Proximity between object observations that describe the relative similarity between objects of observation.
2. The cosine of the angle formed between two variable vectors describes the relationship or correlation between variables, as well as the length of the vector which describes the diversity of each variable.
3. By combining information 1 and 2, the relative position between the object of observation and the variable will be known.

2.1 Singular Value Decomposition

According to Jolliffe [11], biplot analysis is based on singular value decomposition (SVD). SVD aims to decompose the matrix X which is $n \times p$, where n is the number of observation objects and p is the number of variables, into three matrices, namely matrices U , L , and A' . The SVD equation can be written as follows:

$$X = U L A' \quad (1)$$

with:

X : Matrix of size $n \times p$

U : Matrix of size $n \times r$ whose columns are singular vectors column

L : Diagonal matrix of size $r \times r$ with the main diagonal element being the square root of the eigenvalues of the *matrix* X'

A : Matrix of size $p \times r$ whose columns are eigenvectors of the matrix $X'X$

From the decomposition results using the *Singular Value Decomposition* (SVD) technique, the matrix L can then be factored into $L^\alpha L^{1-\alpha}$, where L^α is a diagonal matrix of size $r \times r$ with the main diagonal elements in the form of $\lambda_1^{\alpha/2}, \lambda_2^{\alpha/2}, \dots, \lambda_r^{\alpha/2}$ and $L^{1-\alpha}$ is a diagonal matrix of size $r \times r$ with the main diagonal element being $\lambda_1^{1-\alpha/2}, \lambda_2^{1-\alpha/2}, \dots, \lambda_r^{1-\alpha/2}$. By defining $G = U L^\alpha$ and $H' = L^{1-\alpha} A'$, the equation can be written:

$$X = U L^\alpha L^{1-\alpha} A' = G H' \quad (2)$$

Matrix G contains the main component scores which are the coordinate points of n observation objects. Meanwhile, the H matrix contains eigenvectors which are the coordinate points of the p variables. The mapping of variables and observation objects in two-dimensional biplot graphs is based on the first two columns of the G and H matrices [12].

2.2 Biplot Fit Measures

The suitability of the data information presented in the biplot is measured based on the value ρ^2 . The closer the value ρ^2 is to 1, the higher the suitability of the information presented in the biplot to the information contained in the actual data [13]. Gabriel [14] formulated the biplot suitability measure as follows:

$$\rho^2 = \frac{\lambda_1 + \lambda_2}{\sum_{k=1}^r \lambda_k} \quad (3)$$

With λ_1 as the first largest eigenvalue, λ_2 as the second largest eigenvalue, and λ_k as the k^{th} largest eigenvalue with $k = 1, 2, \dots, r$.

3 Data and Analysis Methods

The data used in this research is happiness index data in the dimension of life satisfaction for Indonesian people in 2021 on a scale of 0-100 [15] which is secondary data obtained from the official website of the Central Bureau of Statistics (BPS). This data is the result of a survey regarding the happiness index in 10 dimensions of people's life satisfaction in 34 provinces in Indonesia in 2021. The objects of observation in this research are 34 provinces in Indonesia, and the variables used are the 10 dimensions of life satisfaction of Indonesian people. These variables can be detailed and presented in Table 1 as follows:

Table 1 Research Variables

Research variable	Dimensions
x_1	Education
x_2	Work
x_3	Household Income
x_4	Health
x_5	Home Condition and Assets
x_6	Social Relations
x_7	Environmental Conditions
x_8	Security Conditions

x_9	Family harmony
x_{10}	Availability of Free Time

Biplot analysis was carried out using Statistics *software*. The steps in biplot analysis are as follows:

1. Carry out calculations and descriptive statistical analysis
2. Calculate the correlation value between variables
3. Do singular value decomposition
4. Display a two-dimensional biplot graph
5. Interpret two-dimensional biplot graph

4 Results and Discussion

4.1 Descriptive Statistics

A descriptive statistical analysis of the dimensional variables of people's life satisfaction is presented in Table 2 as follows:

Table 2 Statistics Descriptive

Variable	Minimum		Maximum max		Mean
	Mark	Province	Mark	Province	
x_1	56.81	West Sulawesi	71.25	Maluku	63.9535
x_2	69.06	Bengkulu	79.32	North Kalimantan	73.7509
x_3	62.97	Bali	74.14	North Maluku	67.7718
x_4	73.38	Banten	80.99	Kep. Riau	77.0844
x_5	69.59	East Nusa Tenggara	80.05	North Kalimantan	74.4444
x_6	74.59	Banten	85.22	North Maluku	80.2576
x_7	78.39	East Kalimantan	85.71	Maluku	81.9291
x_8	76.89	Papua	86.39	North Maluku	82.0618
x_9	79.04	Banten	89.02	North Maluku	84.2526
x_{10}	72.26	Bengkulu	82.16	North Maluku	76.8026

Based on Table 2, it can be seen that the average community happiness index in 34 provinces in Indonesia for the education dimension is 63.9535 with a minimum index of 56.81 produced by West Sulawesi Province and a maximum index of 71.25 produced by Maluku Province; The average index for the job dimension is 73.7509 with a minimum index of 69.06 produced by Bengkulu Province and a maximum index of 79.32 produced by North Kalimantan Province; The average index for the household income dimension is 67.7718 with a minimum index of 62.97 produced by Bali Province and a maximum index of 74.14 produced by North Maluku Province; The average index for the health dimension is 77.0844 with a minimum index of 73.38 produced by Banten Province and a maximum index of 80.99 produced by Kep Province. Riau; The average index for the dimensions of house condition and assets is 74.4444 with a minimum index of 69.59 produced by East Nusa Tenggara Province and a maximum index of

80.05 produced by North Kalimantan Province; The average index for the social relations dimension is 80.2576 with a minimum index of 74.59 produced by Banten Province and a maximum index of 85.22 produced by North Maluku Province; The average index for the environmental condition dimension is 81.9291 with a minimum index of 78.39 produced by East Kalimantan Province and a maximum index of 85.71 produced by Maluku Province; The average index for the security condition dimension is 82.0618 with a minimum index of 76.89 produced by Papua Province and a maximum index of 86.39 produced by North Maluku Province; The average index for the family harmony dimension is 84.2526 with a minimum index of 79.04 produced by Banten Province and a maximum index of 89.02 produced by North Maluku Province; and the average index for the dimension of free time availability is 76.8026 with a minimum index of 72.26 produced by Bengkulu Province and a maximum index of 82.16 produced by North Maluku Province. The dimension that has the highest average happiness index is the dimension of family harmony. Meanwhile, the dimension that has the lowest average happiness index is the education dimension.

4.2 Biplot Analysis

To determine the magnitude of data diversity that can be explained by a two-dimensional biplot graph, factor analysis was carried out and the results obtained are presented in Table 3 below:

Table 3 Total Explained Diversity

Component	Eigenvalues		
	Total	Diversity Percentage (%)	Cumulative (%)
1	6,954	69,541	69,541
2	1,672	16,716	86,256
3	0.356	3,563	89,819
4	0.290	2,896	92,715
5	0.261	2,608	95,323
6	0.224	2,239	97,563
7	0.112	1,118	98,681
8	0.066	0.661	99,341
9	0.037	0.372	99,713
10	0.029	0.287	100,000

The results of factor analysis in Table 3 show that 86.256% of the 10 different dimensions of life satisfaction can be depicted on a two-dimensional eigenspace biplot. Thus, the use of these two main components is considered capable of explaining the diversity of data on different dimensions of life satisfaction.

This can also be shown by the *scree plot graphic* in Figure 1. *The screen plot* of the dimensions of life satisfaction in Figure 1 shows that the eigenvalues from component 1 to component 2 experienced a fairly sharp depreciation, after that from component 2 to component 10 there was no significant depreciation or the line was almost horizontal, this figure illustrates that The 10 dimensions of life satisfaction with a happiness index can be described in a two-dimensional eigenspace with component 1 as the abscissa and component 2 as the ordinate.

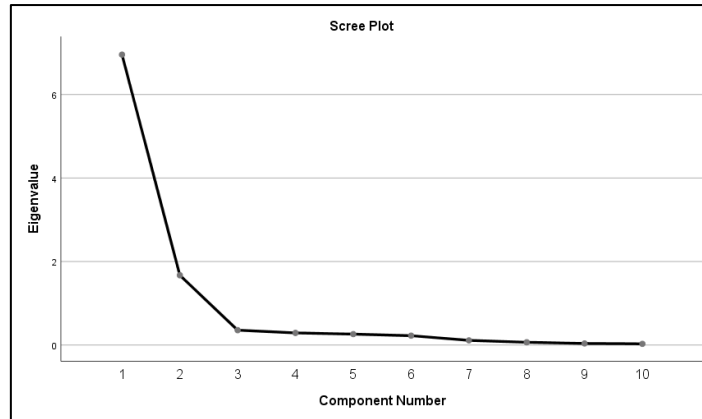


Figure 1 *Scree Plot* of Life Satisfaction Dimensions

The mapping of each variable and observation object into a two-dimensional biplot graph is based on the component matrix and factor matrix as presented in Table 4 and Table 5 as follows:

Table 4 Component Matrix

Variable	Component	
	1	2
x_1	0.718	-0.540
x_2	0.946	-0.202
x_3	0.861	-0.302
x_4	0.916	-0.235
x_5	0.815	-0.410
x_6	0.779	0.580
x_7	0.725	0.531
x_8	0.719	0.582
x_9	0.891	0.243
x_{10}	0.925	-0.090

Table 5 Factor Matrix

Province	Factor	
	1	2
Aceh	-0.34354	0.44709
North Sumatra	-0.88210	-0.08319
West Sumatra	-0.80904	-0.09554
Riau	-0.22457	0.20383
Jambi	0.23814	-0.13388
South Sumatra	-0.33979	0.12974
Bengkulu	-1.59321	0.46085
Lampung	-0.49898	0.00039
Kep. Bangka Belitung	0.12329	0.49661
Kep. Riau	0.70458	-0.91874
DKI Jakarta	-0.52883	-2.35747

West Java	-0.94069	-0.21875
Central Java	-0.66433	0.46570
DI Yogyakarta	-0.83297	0.32609
East Java	-0.06315	0.06054
Banten	-1.74336	-1.15254
Bali	-0.62702	0.10538
West Nusa Tenggara	-0.96806	1.41231
East Nusa Tenggara	-0.75192	1.63662
West Kalimantan	-0.26982	0.41250
Central Kalimantan	0.02129	-0.62329
South Kalimantan	-0.02531	-0.83501
East Kalimantan	0.40965	-2.33571
North Kalimantan	1.66274	-1.03922
North Sulawesi	1.65482	-0.38773
Central Sulawesi	1.10966	-0.07881
South Sulawesi	0.12871	0.54708
Southeast Sulawesi	0.63612	1.35274
Gorontalo	1.11255	1.01505
West Sulawesi	0.41212	2.58007
Maluku	2.00728	-0.10802
North Maluku	2.22996	0.35881
West Papua	1.01595	-0.50203
Papua	-1.36016	-1.14148

Table 4 contains eigenvectors which are the coordinate points of each variable. Component 1 is the abscissa which maps each variable on the x -axis and component 2 is the ordinate which maps each variable on the y -axis. Meanwhile, Table 5 contains the main component scores which are the coordinate points of each observation object. Factor 1 is the abscissa which maps each observation object on the x -axis and factor 2 is the ordinate which maps each observation object on the y -axis.

Based on Table 4 and Table 5, it is possible to map variables and objects of observation simultaneously in a two-dimensional graph as presented in Figure 2 below:

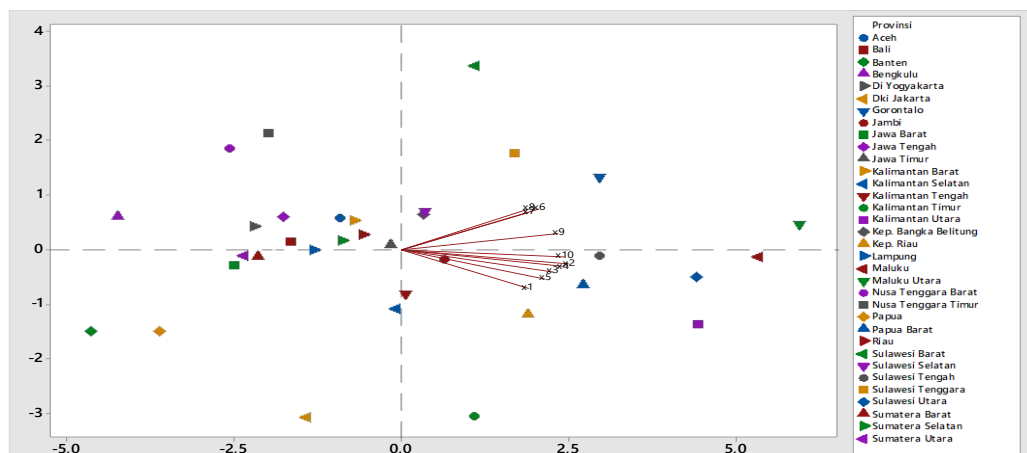


Figure 2 Biplot Graph of Dimensions of Life Satisfaction

a. Proximity between objects

Based on the biplot display in Figure 2, information about provinces with similar characteristics can be seen. Provinces in the same quadrant are said to have fairly close similarities in happiness characteristics if analogous to provinces in different quadrants. In Figure 2 you can see the provinces that are in the same quadrant, namely:

1. Quadrant I, including the provinces of West Sulawesi, Southeast Sulawesi, Gorontalo, West Kalimantan, and North Maluku, have similar characteristics of happiness in indicators of social relations, security conditions, environmental conditions, and family harmony.
2. Quadrant II, including the Provinces of East Nusa Tenggara, West Nusa Tenggara, Central Java, South Sulawesi, Bengkulu, Kep. Bangka Belitung, DI. Yogyakarta, Aceh, West Kalimantan, West Sumatra, Bali, Riau, and East Java have similar happiness indicators in social relations, security conditions, environmental conditions, and family harmony.
3. Quadrant III, including the provinces of North Sumatra, Lampung, West Java, Central Kalimantan, Banten, Papua, South Kalimantan, and DKI Jakarta, have similar happiness characteristics in terms of indicators of health, employment, condition of housing and assets, education, availability of free time, and household income.
4. Quadrant IV, including the Provinces of Central Sulawesi, Maluku, North Sulawesi, West Papua, North Kalimantan, and Kep. Riau and East Kalimantan have similar happiness characteristics in indicators of health, employment, condition of house and assets, education, availability of free time, and household income.

b. Interpretation of variable values in an object

Information regarding the results of value interpretation is used to define the characteristics of happiness in each region (province). A region that is located in the same direction as the happiness characteristic vector shows a high value of the happiness characteristic for that region, which has a value above the average for the entire province. On the other hand, if a region is located in the opposite direction to the happiness characteristic vector, the happiness characteristic value is low or below the average for the entire province. Meanwhile, an area that is almost in the middle means that the area has happiness characteristic values that are close to the average. Based on Figure 2 shows that:

1. Jambi Province is in the same direction as the variable vector (x_1). Following the original data, the Education indicator in the province is 64.29 above the overall average of 63.96.
2. Aceh Province is in the opposite direction to the variable (x_2) which means the literacy rate and employment indicator rates are below the average for the entire province.

c. Diversity of variables

The biplot output display in Figure 2 contains information used to see the diversity of happiness characteristics for each province. With this, we can estimate the characteristics of happiness that need to be improved to increase the happiness index with certain strategies. In a biplot, components with large variability are depicted as interconnected vectors. Based on Figure 2, it is found that the happiness indicators are located in quadrants I and IV and are dominantly adjacent to the position.

d. Correlation between variables

Table 6 Correlation Between Variables

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
x_1	1,000									
x_2	0.798	1,000								
x_3	0.664	0.884	1,000							
x_4	0.764	0.875	0.837	1,000						
x_5	0.770	0.797	0.803	0.847	1,000					
x_6	0.250	0.626	0.475	0.591	0.377	1,000				
x_7	0.295	0.539	0.438	0.553	0.387	0.811	1,000			
x_8	0.233	0.575	0.463	0.485	0.401	0.870	0.795	1,000		
x_9	0.482	0.795	0.655	0.773	0.617	0.870	0.693	0.712	1,000	
x_{10}	0.667	0.917	0.851	0.830	0.722	0.669	0.621	0.553	0.797	1,000

The relationship between variables can be seen based on the magnitude of the correlation value between variables, where the magnitude of the correlation value between variables is the magnitude of the cosine of the angle formed between two variable vectors. The more closely two variable vectors coincide, the greater the correlation value. The largest correlation between variables is owned by the variable pair x_2 (work) and x_{10} (availability of free time) with a correlation value of 0.917. This shows that people who have a high level of satisfaction with the work dimension tend to have a high level of satisfaction with the dimension of free time availability. Vice versa. Meanwhile, the lowest correlation value is 0.377, namely between the variables x_5 (house condition and assets) and x_6 (social relationships).

5 Conclusion

Based on the research results, it can be concluded that provinces in one quadrant show significant similarities in happiness characteristics when compared to provinces in other quadrants. Analysis of the variable values for certain objects reveals that Jambi Province has a variable vector direction (x_1) in line with the original data, where the Education indicator in the province exceeds the overall average, namely 64.29 compared to the average of 63.96. In contrast, Aceh Province has the opposite direction of the variable vector (x_2), indicating that the literacy rate and employment indicators in the province are below the national average. When looking at the diversity of variables, there is a tendency for happiness indicators to be in quadrants I and IV with close positions. The highest correlation occurs between the variables x_2 (work) and x_{10} (availability of free time) with a correlation value of 0.917. This shows that the level of satisfaction with the work dimension tends to be positively correlated with the level of satisfaction with the dimension of free time availability, and vice versa. Meanwhile, the lowest correlation value is 0.377. It is between the variables x_5 (house condition and assets) and x_6 (social relationships). Thus, this research emphasizes the importance of understanding the characteristics of happiness based on the variables described previously in each province to formulate more effective policies.

7 References

- [1] Dewi, S.Y., 2020, *Determinan Indeks Kebahagiaan di Indonesia*, Jurnal Ilmiah Mahasiswa FEB, **8**(2). Atasoge, I.A.B., 2021, *Determinan Indeks Kebahagiaan di Indonesia*, Jurnal Ekonomi Pembangunan, **7**(2), 127-141.
- [2] Ekasari, M.F., Riasmini, N.M. & Hartini, T., 2019, *Meningkatkan Kualitas Hidup Lansia: Konsep dan Berbagai Strategi Intervensi*, Wineka Media.
- [3] Gunawan, G., 2016, *Peran Subjective Well Being Dalam Membentuk Perilaku Positif di Era Transformasi Digital*, Penelitian yang Berperspektif Multidisiplin Ilmu, 86.
- [4] Halawa, N., 2023, *Dampak Stres pada Kesejahteraan Mental: Penelitian Meta-Analisi*, Literacy Notes, **1**(2).
- [5] Setiadi, I., 2016, *Psikologi positif: Pendekatan saintifik menuju kebahagiaan*, Gramedia Pustaka Utama.
- [6] Rahayu, T.P., 2016, *Determinan kebahagiaan di Indonesia*, Jurnal Ekonomi dan Bisnis, **19**(1), 149-170.
- [7] Anuraga, G., 2015, *Analisis Biplot untuk Pemetaan Karakteristik Kemiskinan pada Kabupaten/Kota di Jawa Timur*, J Statistika: Jurnal Ilmiah Teori Dan Aplikasi Statistika, **7**(1), 26-34.
- [8] Kroonenberg, P.M., 2007, *Biplot and their interpretation*, Applied Multiway Data Analysis, pp. 491-500.
- [9] Fitriana, A.R., Rusyana, A. & Wisreini, 2011, *Analisis Biplot untuk Mengetahui Kebutuhan terhadap Lulusan Program Studi Statistika*, Jurnal Matematika, Statistika & Komputasi, **8**(1), 39-51.
- [10] Jolliffe, I.T., 2002, *Principal Component Analysis*, Springer-Verlag, pp. 78-110.
- [11] Leleury, Z.A. & Wokanubun, A.E., 2015, *Analisis Biplot Pada Pemetaan Karakteristik Kemiskinan di Provinsi Maluku*, Barekeng, **9**(1), 21-31.
- [12] Raden, A.L.N. & Pramaputri, D.D., 2021, *Analisis Biplot atas Kinerja Pemerintah dalam Penanganan Stunting di Indonesia*, Jurnal Anggaran dan Keuangan Negara Indonesia, **3**(1), 117-135.
- [13] Gabriel, K.R., 1971, *The biplot graphic display of matrices with application to principal component analysis*, Biometrika, **58**(3), 453-467.
- [14] BPS, 2021, *Dimensi Kepuasan Hidup Indeks Kebahagaiaan 2017-2021*, Badan Pusat Statistik, Jakarta.