IOSR Journal Of Humanities And Social Science (IOSR-JHSS)
Volume 28, Issue 7, Series 4 (July, 2023) 50-60
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

Multidimensional Sustainable Development Index: An Approach In The Coastal Municipalities Of The State Of Paraná – Brazil

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Abstract:
Background*: The Application Of The Sustainable Development Goals Of The 2030 Agenda Gained Strong Support In Various Parts Of The World And Are Currently Representative By Virtue Of The Collective Effort In The Search For Progress Towards A Fairer World. However, The Lack Of Evaluation Processes That Reveal Whether The Progress Of The Sdgs Is Effective Leaves Doubts Among Volunteers, Especially When Socially Vulnerable Communities Are Involved, As Is The Case On The Coast Of Paraná. Thus, Given The Lack Of Indicators And The Complexity Involved In Implementing The Sdgs In Vulnerable Regions, This Study Aimed To Promote An Estimate Of The Multidimensional Sustainable Development Index (MSDI) Of The Municipalities On The Coast Of The State Of Paraná Based On The Sdgs.*
Materials And Methods*: For Data Analysis, A Performance Scale Was Established, Which Allows Standardizing Social, Environmental And Economic Indicators Through A Dimensionless Metric, Verifying The Influence Of Indicators On Each Other And Their Contributions To The Composition Of The Multidimensional Development Index Sustainability In The Municipalities Of The State Of Paraná.*
Results*: The Study Confirms That The 17 Sdgs Must Be Developed In A Systemic Way, As A Set Of Parts That Are Interrelated And Integrated With A Common Objective, Since The Data Suggest That Due To The Association Between The Indicators, Verified Through The Factorial Analysis And By Artificial Intelligence Techniques As The Quality And Quantity Of Data Of An Indicator Improves Its Index, The Results Resulting From The Analyzes Of Other Sdgs Tend To Also Show Greater Robustness, Performance Improvements And Greater Significance*
Conclusion: *It Is Concluded That In This Format Of Action, Public Policies Related To The Implementation Of The Sdgs Will Be More Effective In Their Implementation.*
Key Word*: Social Indicators; Poor Communities; Agenda 2030; Sdgs*

Date of Submission: 06-07-2023 Date of Acceptance: 16-07-2023

I. Introduction

Planet earth experiences a period of extreme difficulty, whether people in the most varied places on the planet, whether due to hunger, lack of water, minimum sanitary conditions, heat or even excess cold weather conditions due to the imbalance of climate conditions, this situation has worsened even more after the period of the industrial revolution, and in the present time and urgent measures are needed to minimize all these adversities, GUIMARÃES (2009) questions how it is possible that man immersed in his planet causes the harmful changes that affect himself and his fellows?

However, the harmful times experienced on the planet are not only restricted to environmental issues, but they overcome the barrier of the "human being" when women are still enslaved, children living in subhuman conditions and outside schools, elderly whose should be in a phase of stability but who suffer multiple pains in the soul due to the difficulty of survival, according to UNDP (2022) the issues that permeate the impossibility of living in a fairer, more supportive and egalitarian world are so many and diverse, that it was urgent and necessary to create mechanisms that could be a source of hope and that would promote an inspiration in the search for a

better future in the world, in an unprecedented period aggravated by the crisis of the New SARS-COV-2 coronavirus, thus the great challenge in the history of humanity is to eradicate poverty and significantly reduce the inequalities and social exclusion that haunt billions of people in the world.

The SDGs through the 2030 Agenda have gained strong adherence in more than 190 countries, Moura et al (2020) points out that in several parts of the world governments, civil society, universities, the private sector and in particular a large number of citizens have embarked on a collective journey with a view to establishing a more just, economically viable and environmentally sustainable society, but to this end the implementation of the global agenda must be considered, considering the specificities of their cities and population.

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Brazil had a strong participation in the search to achieve the SDGs, but there were difficulties in implementing the SDGs, especially in some Brazilian regions reaching the proposed goals has represented an even greater challenge. The coast of Paraná is one of the regions that presented difficulties in the implementation of the SDGs in several aspects, Anacleto et al. (2020) describes that the coast of Paraná presents itself as a region of paradoxes, while presenting numerous economic alternatives and income generation, there are also dozens of communities with low HDI, with hundreds of families living in conditions and social vulnerability, many living below the poverty line.

This intricate relationship and the set of problems arising from the development systems installed in the region, therefore, requires that the development of SDG actions be rethought, so that there are changes in the paradigms currently installed and changes in the models of socially unfair development.

Impoverished communities that have low HDI, need effective actions related to the SDGs, however they also need propositions that are appropriate to the reality experienced by them, and in this context, it is noteworthy that the coast of Paraná despite its relevance, presents little information about families in socially vulnerable conditions, and the elaboration of accurate diagnoses about these situations and effectiveness is apparently a powerful direction in order to succeed in this endeavor.

The absence or scarcity of information that refers to a diagnosis or overview of the situation does not occur only on the coast of Paraná, but in most regions where poverty is accentuated, and I need to consider that the SDGs are representative and by virtue of the collective have managed to achieve advances, this is undeniable, however Gil (2018) states that in other objectives the proposal is so extensive and complex that achieving the results is almost impossible, and can be considered as a mixture of rhetoric, political cynicism and technical inconsistency. Also, according to Gil (2018), it is necessary to consider one of the critical points of the implementation is the confirmation of the effectiveness of the SDGs through reports, and emphasizes the urgency of improving the knowledge and information of the implementation actions. The problems related to lack of data inhibit the significant progress of the SDGs that need clear and precise political decisions and commitments that transform empty rhetoric and empty words into effective measures of transformation, for this the elaboration of diagnoses becomes essential.

Gomes and Ferreira (2018) corroborate the assumption described by Gil (2018) emphasize that it is necessary to evaluate whether all efforts for implementation have in fact turned into concrete results that are benefiting present and future societies, and if in fact they create conditions to provide sustainable development based on intergenerational sustainability, committed to guaranteeing collective ownership rights and all dimensions of sustainability in their entirety, for this it is necessary to evaluate actions, since without evaluation the effectiveness of the SDGs can be a rhetorical and non-effective sustainability only.

Thus, in view of the presented and the complexity involved in the implementation of the SDGs in vulnerable regions, this study aimed to promote an estimate of the Multidimensional Sustainable Development Index (MSDI) of the municipalities on the coast of the state of Paraná based on the SDGs.

II. Material And Methods

The first step to be taken was to obtain minimally viable data to assist in the structuring of the demand and, when worked, become practical information for the decision making of the governments. However, due to the analysis of the SDGs and the various mechanisms considered, there is no identification of methodology for the integrated analysis of the different metrics of each indicator of the three dimensions of sustainability. Thus, the performance scale was established, which allows the standardization of social indicators with environmental and economic indicators through a dimensionless metric, verifying the influences of the indicators on each other and their contributions to the composition of the multidimensional sustainable development index of the municipalities of the state of Paraná.

Once the performance of each indicator was established for each municipality and the composition of the variables of the statistical models of integration was elaborated, the models of integration of the dimensions of sustainable development were developed. This was possible through methods of analysis and transformation of this information to generate differentiated levels of knowledge on the subject matter, which can be referred to as the "synergy of information". It is the analysis of horizontal and vertical coherence of information in the various places where it is generated until it reaches the highest levels of the organizational hierarchical system, whether public or private. Through this mechanism, managers or decision makers will have more subsidies in the decision-making process, providing a greater and more assertive speed to the opportunities and/or limits of public governance.

The resulting models will allow the integration and the possibility of analyzing each component factor of the sustainable development objectives, allowing to understand how the indicators interact with each other and what are the possible consequences of future actions to improve the individual performances of each factor and the overall total performance for the state. Attention is drawn to the unique and innovative condition of these methods, by establishing an objective and free analysis of the influence of value judgments to define the priorities and contribution weights of each indicator for each municipality. The overall objective of the study was to estimate the Multidimensional Sustainable Development Index (MSDI) of the coastal municipalities of the state of Paraná.

The methodology used in the study consists of the exploratory technique, observing data available and in the public domain on government platforms at the state and federal levels, especially that of the Paranaense Institute for Economic and Social Development (IPARDES) and the Brazilian Institute of Geography and Statistics (IBGE).

Indicators were used that had observations in at least 90% of the municipalities and at least two observations over the 5-year monitoring period (2014 to 2019). Indicators that did not meet this criterion were disregarded in the modeling. The missing values, when present, corresponded to less than 10% of the municipalities and were replaced by the average of the differences in the 399 municipalities of each variable. The absence of SDGs and indicators in this study was due to their non-availability in the databases of the government instruments consulted.

156 valid variables harmonized to the SDGs for 2030 were collected, according to the resolution of the Organization for Economic Cooperation and Development (OECD), the United Nations (UN) and the Institute for Applied Economic Research (IPEA). The samples collected from the variables represent a sample of 288,123 (Table 1).

Table 1: Characterization indicators of municipalities

Estimated Total Population (Number of inhabitants) in the years 2014, 2015, 2016, 2017 and 2018;
Total Urban Population (Number of Inhabitants) in 1996, 2000, 2007 and 2010;
Total Rural Population (Number of Inhabitants) in 1996, 2000, 2007 and 2010;
Total Female Population (Number of Inhabitants) in 1996, 2000, 2007 and 2010;
Total Male Population (Number of Inhabitants) in the years 1996, 2000, 2007 and 2010;
Proportion of Population Living Below the Poverty Line in 1991, 2000 and 2010;
Economically Active Population (Number of Inhabitants) in 1991, 2000 and 2010;
Economically Active Male Population (Number of Inhabitants) in the years 1991, 2000 and 2010;
Economically Active Female Population (Number of Inhabitants) in 1991, 2000 and 2010;
Proportion of Population Over 65 in the years 1996, 2000, 2007 and 2010;
Population aged 10 to 14 years (Number of Inhabitants) in 1996, 2000, 2007 and 2010;
Demographic Density (Number of Inhabitants/km²) in the years 2014, 2015, 2016, 2017 and 2018;
Rural Demographic Density (Number of Inhabitants/km²) in the years 1991, 2000, 2007 and 2010;
Urban Demographic Density (Number of Inhabitants/km²) in the years 1991, 2000, 2007 and 2010;
Territorial Area km² in the years 2014, 2015, 2016, 2017 and 2018.

The indicators defined for each of the SDGs, based on the data available so far and that met the cutoff criteria are presented in table 1.

The descriptive statistics used in the set of indicators listed were the mean, mode, median, minimum value, maximum value, amplitude of the values, variance, standard deviation, standard error of the mean, coefficient of variation (%), lower limit and upper limit of the confidence interval, with a confidence level of 95%. The descriptive statistics of the indicators were obtained through the Julia program (julialang.org).

In the modeling, for each indicator, the average value of the annual differences was obtained, in order to assimilate the dynamics of each variable. This allows modeling the indicators with different numbers of observations in the sampling space of periods. These mean difference values Δ were rescheduled for the performance scale Δ^* such that the higher value (5) can be assigned as the best characteristic for the indicator and zero values as the undesirable characteristic for the indicator (Table 2).

Table 2: Sustainable Development Indicators

SUSTAINABLE GOAL	NUMBER OF INDICATORS	Number of Valid Indicators *
Characterization	13	13
SDG 1	05	05
SDG 2	12	08
SDG 3	38	19
SDG 4	45	25
SDG 5	09	08
SDG 6	17	08
SDG 7	14	13
SDG 8	33	30
SDG 9	13	12
SDG 10	00	00
SDG 11	03	02
SDG 12	00	00
SDG 13	01	01
SDG 14	00	00
SDG 15	12	04
SDG 16	06	04
SDG 17	08	04
Total	216	156

Source: Developed by the authors

For indicators where positive values of Δ are required, the values of Δ^* were obtained through quartiles with their respective positions for the I=399 municipalities, in such a way. Obtaining the values Δ^* allows to equalize large values as positive characteristics for the indicators, while small values as undesirable characteristics for the variables.

Multivariate factor analysis was used to generate the multidimensional sustainable development index (MSDI). This technique was used for two reasons: i) there are 156 variables and some of these are strongly correlated, which makes it difficult to establish inferences for the municipalities; ii) to obtain latent variables (variates) in order to observe the multidimensionality of the observations, to understand the relationship of the variables and the municipalities.

The basic idea of factor analysis is to describe a set of p original X_1, X_2, …, X_p variables in terms of a smaller number of factors, in order to obtain a better understanding of the relationship of these variables. Thus, find a way to condense (summarize) the information contained in several original variables into a smaller set of new dimensions (factors), with minimal loss of information.

The random variables were grouped according to their correlations, so that within the factors (latent variables) the original variables are highly correlated and among the factors that the original variables have low correlations. For this purpose, the orthogonal factorial model was used:

$$\begin{aligned} X_1 - \mu_1 &= l_{11}F_1 + l_{12}F_2 + \cdots + l_{1m}F_m + \varepsilon_1 \\ X_2 - \mu_2 &= l_{21}F_1 + l_{22}F_2 + \cdots + l_{2m}F_m + \varepsilon_2 \\ &\vdots \\ X_p - \mu_p &= l_{p1}F_1 + l_{p2}F_2 + \cdots + l_{pm}F_m + \varepsilon_p \end{aligned}$$

Where:

μ_i= = mean of the i-th variable. Mean of the -th variable.

F_j= j-th common factor.

ε_i= i-th error or specific factor.

l_{ij}= weight or loading on the i -th variable X_i of the j -th factor F_j, $i = 1,2, \dots, p,$ and $j = 1,2, \dots, m.$

The total variance of the multidimensional observations is calculated as follows:

$$V(X_i) = l_{i1}^2 + l_{i2}^2 + \cdots + l_{im}^2 + \Psi_i$$

or

$$V(X_i) = h_i^2 + \Psi_i, i = 1,2, \dots, p.$$

In Which:

$h_i^2 = l_{i1}^2 + l_{i2}^2 + \cdots + l_{im}^2$, commonality (portion of the variance of the Variable X_i that is distributed by the common m factors).
Ψ_i= portion of the variance $V(X_i)$ due to the specific factor, also called specificity or specific variance.
l_{ij} is the covariance of the $i-$ th variable X_i with the $j-$ th common factor F_j.

As in the research the variables have different units of measurement and in the modeling it was denoted to consider the standardization of the variables, the correlation matrix was used, then the l_{ij} corresponds to the correlation coefficient between the th variable $i-$th variable X_i with the $j-$ th common factor.

$$l_{ij} = cov(X_i, F_j)$$
$$l_{ij} = cor(X_i, F_j)$$

To estimate the factorial loads (l_{ij}) and the specific variances (Ψ_i) the method of the main components was used, as described in the sequence.

Let be the pairs of eigenvalues and eigenvectors of $\hat{\sum}$ (sample variance-covariance matrix): $(\hat{\lambda}_1, \hat{e}_1), (\hat{\lambda}_2, \hat{e}_2)$,..., $(\hat{\lambda}_p, \hat{e}_p)$, in which $\hat{\lambda}_1 \geq \hat{\lambda}_2 \geq \cdots \geq \hat{\lambda}_p$. Let be $m < p$ the number of common factors.

The estimator of the matrix of the weights or loads of the factors $\hat{l}_{ij}$ is given by:

$$\hat{L} = \hat{C}\hat{D}_{\lambda}^{1/2}$$

Where:

$$\hat{C} = \begin{bmatrix} \hat{e}_{11} & \hat{e}_{12} & \cdots & \hat{e}_{1p} \\ \hat{e}_{21} & \hat{e}_{22} & \cdots & \hat{e}_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{e}_{p1} & \hat{e}_{p2} & \cdots & \hat{e}_{pp} \end{bmatrix}$$

$$\hat{D}_{\lambda}^{1/2} = \begin{bmatrix} \sqrt{\hat{\lambda}_1} & & & \\ & \sqrt{\hat{\lambda}_2} & & \\ & & & \sqrt{\hat{\lambda}_p} \end{bmatrix}$$

The observations of the data set $\underline{x}_1, \underline{x}_2, \ldots, \underline{x}_p$ were standardized (to eliminate the effect of the units of measurement of the variables), in such a way:

$$\underline{z}_j = \begin{bmatrix} \frac{x_{1j} - \overline{x}_1}{s_1} \\ \frac{x_{2j} - \overline{x}_2}{s_2} \\ \vdots \\ \frac{x_{pj} - \overline{x}_p}{s_p} \end{bmatrix}$$

In this case, the sample covariance matrix $\hat{\sum}$ (S) corresponds to the correlation matrix $\hat{\rho}$.

The estimated specific variances are provided by the diagonal elements of the matrix $\hat{\Psi} = S - \hat{L}\hat{L}'$. Like this:

$$\hat{\Psi} = \begin{bmatrix} \hat{\Psi}_1 & & & \\ & \hat{\Psi}_2 & & \\ & & \ddots & \\ & & & \hat{\Psi}_p \end{bmatrix} \text{com } \hat{\Psi}_i = s_i^2 - \sum_{j=1}^{m} l_{ij}^2$$

Communalities are estimated as:

$$h_i^2 = l_{i1}^2 + l_{i2}^2 + \cdots + l_{im}^2$$

The choice of the number of factors was performed according to the Kaiser criterion, in which as many factors as the number of eigenvalues greater than 1 were selected.

The latent values for each original observation $\underline{x} = [x_1, x_2, \ldots, x_p]'$ were estimated (factorial scores) using the expression:

$$\hat{\underline{F}} = (\hat{L}'\hat{L})^{-1} L'\underline{z}$$

The resulting values determined the creation of synthetic indicators for each factor obtained (latent variable). The final indicator ($\underline{I}_j$), for each municipality, refers to an indicator weighted by the amount of information explained by each of the factors, that is:

$$\underline{I_j} = \frac{\underline{\hat{F}_{i1}}\hat{\lambda}_1 + \underline{\hat{F}_{i2}}\hat{\lambda}_2 + \cdots + \underline{\hat{F}_{iJ}}\hat{\lambda}_J}{\hat{\lambda}_1 + \hat{\lambda}_2 + \hat{\lambda}_J}$$

The discriminant index of municipalities refers to the weighted scores of each discriminant function as a function of its eigenvalue. The values resulting from this multidimensional index were rescheduled to the domain between 0 and 1.

III. Result and discussion

In the statistical treatment, it was identified which factor loadings carried the most in the four distinct canonical discriminant functions and the scaled multidimensional index was generated for each canonical discriminant function, that is, a linear combination of variables that presents the correlations between groups in the set between discriminant variables and standardized canonical discriminant functions, generating a latent variable. The variables are ordered by absolute size of correlation in the function presenting the highest absolute correlation between each variable in any discriminant function, thus occurring a loading of the variables in each canonical function.

The grouping of variables by means of canonical functions generated an assertiveness of 99.7%, with the first canonical function representing 50% of the explanation of the variables, the second canonical function 25%, adding 75% of the two canonical functions together. The third and fourth canonical functions represent 12.25 each (Table 3).

Table 3: Factorial loads for the first canonical function in relation to the most important variables

Variable	l_{i1}
Total Estimated Population	0,422
Total Male Population	0,398
Total Female Population	0,394
Number of Occupied Male	0,377
Economically Active Male Population	0,348
Number of Occupied Persons	0,342
Demographic Density (Number of Inhabitants/km²)	0,340
Occupied People in the Urban Zone	0,335
Number of Establishments Served with Electricity	0,330
Economically Active Population	0,326
Residential Electricity - Number of Consumer Residences	0,323
Total Urban Population	0,314
Number of Occupied Female	0,309
Economically Active Female Population	0,306
Number of Establishments Supplied with Water	0,298
Water Supply - Residential Serviced Units	0,274
Waste Water Volume (m³)	0,251
Gross Domestic Product of Local Trade and Services (R$1,000.00)	0,231
Gross Domestic Product (GDP) at Current Prices (R$1,000.00)	0,222
Billed Water Volume (m³)	0,221
Enrollment in Basic Education	0,215
Value Added Tax on Activities Characteristics of Tourism (R$1.00)	0,206
Proportion of Population Living Below the Poverty Line	-0,187
Proportion of Population Over 65	-0,183
Enrollment of Women in On-site Higher Education	-0,174
Number of Enrollments in Public Schools (Basic and Elementary)	0,166
Ageing Index (%)	-0,164
Water Consumption Per Capita (m³/inhab)	0,148
Vaccine Coverage - Pregnant Triple Acellular (Tdap) (%)	-0,120
Number of people employed in rural areas	0,120
Average Nominal Income per Hour in Commerce - Female (R$1.00)	0,115
Ratio between Public Beds (SUS) and Total Beds	-0,113
Illiteracy rate – 25 years or older (%)	-0,107
Municipal Human Development Index (MHDI)	-0,105
Proportion of Schools with Access to Computers for Pedagogical Purposes (%)	-0,105
Average Nominal Income per Hour in the Industry - Female (R$1.00)	0,093
Vaccine Coverage - Viral Tetra (SCR+VZ) (%)	-0,092
Number of Misleading Homicides	0,091

Total Rural Population	0,090
Vaccine Coverage - Hepatitis B in Children Under 1 Month (HB < 1m) (%)	-0,086
Average Household Income Per Capita.	0,085
Number of Bodily Injury Followed by Death	0,078
Number of larceny	0,078
Average Nominal Yield per Hour in Civil Construction - Male (R$1.00)	0,069
Ratio between Residential Consumption (MWh) and Total Consumption (MWh)	0,064
Average Nominal Yield per Hour in the Industry - Male (R$1.00)	0,059
Adolescent Pregnancy Rate - 15 to 19 years of age (1,000 live births)	0,056
Average Nominal Yield per Hour in Commerce - Male (R$1.00)	0,054
Ratio of Public Schools to Private Schools	-0,054
Ratio between Commercial Consumption (MWh) and Total Consumption (MWh)	-0,054
Male Employability Rate	-0,043
Gini index	-0,032

Source: Developed by the authors

It was observed that the variables that carried the most in canonical function 1 were variables that contemplate variables of characterization of municipalities, carrying variables that can be considered multidimensional, as they present information of various dimensions of the SDGs, being composed of economic variables (SDG 8), electricity (SDG 7), water (SDG 6), education (SDG 4), violence (SDG 16), health (SDG 3), among others (TABLE 2).

When observing the municipalities of the coast of Paraná, the municipality of Paranaguá stands out because it is considered the regional pole of the coast where the largest population of the coast is located and the port of Paranaguá, source of numerous formal and informal jobs, providing the highest regional per capita income (R$62,839.97/2019) and the second highest demographic density (169.92 inhab/Km2), as in several other variables providing the municipality with a better performance in the Multidimensional Index of Sustainable Development.

The municipality of Guaraqueçaba, was the one that performed lower than the other municipalities of the coast of Paraná due to low population density (3.90 inhabitants/km2) and with an incipient industry generate a low degree of occupation of the economically active population. It is observed that the municipality is composed of several traditional Caiçaras communities that have the habit of using artisanal economic practices (artisanal fishing, handicrafts with products from the Atlantic Forest region, among other activities) generating low levels of income per capita (R$13,830.62/2019).

The municipalities of Pontal do Paraná, Matinhos and Guaratuba have tourism as their main economic activity, being the same seasonal, that is, its peak is in the summer season and incipient in winter generating a lower performance than the municipality of Paranaguá, but superior to the municipalities of Guaraqueçaba, Antonina and Morretes (Table 4).

Table 4: Factorial loads for the second canonical function in relation to the most important variables

Variable	l_{i1}
Vaccine Coverage - Penta Bacterial (Pentavalent) (DTP+Hib+HB) (PENTA) (%)	0,604
Vaccine Coverage - Pneumococcal 10V (Pncc10V) (%)	0,598
Vaccine Coverage - Conjugated Meningococcal (Men C) (%)	0,510
Vaccine Coverage - Polio (VOP) (%)	0,490
Vaccine Coverage - Hepatitis B (HB) (%)	0,475
Vaccine Coverage - Human Rotavirus (vorh) (%)	0,454
Vaccination Coverage - BCG (Tuberculosis) (%)	0,299
Vaccine Coverage - Viral Triple (SCR) (%)	0,282
Vaccine Coverage - Hepatitis A (HA) (%)	0,127
Number of Health Professionals - Doctors (thousand inhabitants)	0,093
Ratio between Industrial Consumption (MWh) and Total Consumption (MWh)	-0,067
Average Nominal Income per Hour in Agriculture - Female (R$1.00)	0,056
Proportion of Children Vulnerable to Poverty (%)	0,046
Ratio between Rural Power Units and Total Units Serviced	-0,012
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach Elementary School - Final Years - State Network (%)	0,006

Source: Developed by the authors

In canonical function 2, the variables that carried the most were related to health (SDG 3), with vaccines from the mandatory cycle of the Ministry of Health, electricity (SDG 7), children vulnerable to poverty, education (SDG 4) (TABLE 3). When observing the factorial loads of the 2nd canonical function, the municipalities of Guaraqueçaba, Antonina perform better than the other municipalities on the coast, that is, they were closer to the vaccination target proposed by the Ministry. But without exception, all municipalities fall short of the coverage rates indicated by the Ministry of Health, that is, to be more sustainable and achieve the Sustainable Development Goals by 2030. Thus, municipalities should pay greater attention to health variables and achieve pre-established goals, and consequently may improve other indices that are linked to health, such as education. Observing the Human Development Index (HDI/2010), the municipality of Paranaguá (0.750) is better listed on the coast of Paraná, followed by Matinhos (0.743), Pontal do Paraná (0.738), Guaratuba (0.717), Antonina (0.687), Morretes (0.686) and Guaraqueçaba (0.587) (Table 5).

Table 5: Factorial loads for the third canonical function in relation to the most important variables

Variable	l_{i1}
Jobs (RAIS)	0,332
Number of jobs	0,332
Female Employability	0,294
Number of Industrial Jobs	0,215
Population aged 10 to 14 years (Number of Inhabitants)	-0,209
Number of Industries	0,174
Electricity consumption (MWh)	0,157
Ratio of Occupied Population to Economically Active Population	-0,144
Reason between Occupied Women and Economically Active Women	-0,141
Ratio between Busy Men and Economically Active Men	-0,140
Measured Water Volume (m³)	0,139
Gross Domestic Product (GDP) Per Capita (R$1.00)	0,139
Rural Electricity Consumption (MWh)	0,126
Gross Value of Livestock Production (R$)	0,126
Ratio between Occupied People in the Urban Area and Economically Active Population in the Urban Area	-0,124
Home Power Consumption (MWh)	-0,124
Home Power Consumption	0,123
Average Nominal Yield per Hour - Female (R$1.00)	-0,121
Ratio of Industry Gross Value Added to Total Gross Value Added	0,114
Rural Electricity Consumers	0,114
Gross Value of Agricultural Production (R$)	0,112
Fixed Network Broadband Internet Accesses per 100 Inhabitants, per Connection Speed - 12 Mpbs at 34 Mbps (%)	-0,111
Fixed Network Broadband Internet Accesses per 100 Inhabitants, per Connection Speed - 2 Mbps to 12 Mbps (%)	0,105
Number of Public Beds (SUS)	-0,105
Ratio between Occupied Rural Population and Economically Active Rural Population	-0,102
Employment in the Industry Sector as a Percentage of Total Employment (%)	0,101
Number of Electronic Service Stations (PAE) (100 thousand adults)	0,100
Number of Emergency Health Care Unit – UPAS	0,076
Percentage of Industry Value Added over GDP (%)	0,076
Proportion of Live Births with 7 or more Prenatal Visits (%)	-0,074
Federal Conservation Units Area (ha)	-0,069
Federal Conservation Units	-0,069
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach - High School - State Network (%)	-0,068
Ratio between Enrollments in Public Schools (Basic and Elementary) and Private Schools (Basic and Elementary)	-0,062
High School Dropout Rate	0,052
Proportion of Schools with Internet Access (%)	-0,050
Household Water Consumption (m³/residence)	-0,050
Ratio between Occupation of Livestock Areas and Total Area	-0,050
Livestock Area (ha)	-0,047
Average Nominal Yield per Hour in Services - Male (R$1.00)	-0,043
IDEB – Elementary School Final Years Federal Network	-0,039
Number of RPPNMS	0,030
Female Employability Rate	0,026
Life Expectancy at Birth	-0,026

Source: Developed by the authors

In canonical function 3, the variables that carried the most were variables from the various dimensions of the SDGs, which demonstrate the workforce in the municipalities, that is, the economic variables (SDG 8), infrastructure variables (SDG 9), electricity variables (SDG 7), environmental variables (SDG 15), food security variables (SDG 2), health variables (SDG 3), education variables (SDG 4), among others (TABLE 6).

The municipality of Paranaguá had the best performance of the economic variables that demonstrate that the workforce resulting from the economic activities developed in the municipality that generate a higher level of jobs as a result of higher levels of income for the population providing greater sustainability of the municipality when compared to its peers on the coast of Paraná. On the other hand, the municipalities of Guaraqueçaba, Antonina and Morretes, being smaller municipalities demographically has as a consequence less economic activity generating less levels of employment and income for the general population. The municipalities of Pontal do Paraná, Matinhos and Guaratuba with great strength in tourism, in the high season generates a lot of temporary jobs, which provide temporary income for the population of these municipalities, as they are dependent on tourism for their sustainable development.

Table 6: Factorial loads for the fourth canonical function in relation to the most important variables

Variable	l_{i1}
Enrollment of Men in On-site Higher Education	0,227
Enrollments in On-site Higher Education	0,226
Commercial Energy Consumption (MWh)	0,161
Enrollment in Youth and Adult Education	0,147
Remaining Area Native Forests (hectares)	-0,144
Proportion of Total Municipal Public Expenditure on Education and Social Security (%)	-0,133
Victims of Guilty Homicide in Traffic	-0,130
Number of Traffic Victims	-0,130
Number of General Hospitals	0,117
Average Nominal Yield per Hour - Male (R$1.00)	-0,116
Fixed Network Broadband Internet Accesses per 100 Inhabitants, by Connection Speed - 0 kbps to 512 kbps (%)	-0,115
Ratio between Gross Value of Livestock Production and Gross Value of Total Production	0,114
Average Nominal Income per Hour in Agriculture - Male (R$1.00)	-0,112
Proportion of Jobs (Rais) in Tourism Characteristic Activities (%)	0,110
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach - Elementary School - Early Years - Municipal Network (%)	-0,104
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach - Elementary School - Early Years - Total (%)	-0,103
Proportion of Women in Management Positions (Rais) (%)	0,102
Agricultural Planting Area Temporary Crops (ha)	-0,098
Territorial area km²	0,089
Ratio of Billed Volume to Waste Volume	0,088
Ratio between Gross Value of Agricultural Production and Gross Value of Total Production	-0,081
Number of Health Professionals (thousand inhabitants)	0,075
Number of Health Professionals - Nurses (thousand inhabitants)	0,074
IDEB – Elementary School Initial Years Public Network	0,072
IDEB – Elementary School Initial Years Municipal Network	0,071
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach - Early Childhood Education - Municipal Network (%)	-0,065
Ratio between Rural Consumption (MWh) and Total Consumption (MWh)	-0,063
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach - High School - Total (%)	-0,061
Average Nominal Income per Hour in Services - Female (R$1.00)	-0,060
Ratio between Gross Domestic Product Local Trade and Total Local Gross Domestic Product	0,058
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach - Early Childhood Education - Total (%)	-0,057
Number of Cultural Spaces	-0,053
School Evasion Rate Elementary School	0,051
Number of Public Schools of Basic Education, Elementary Education and High School	0,048
IDEB – Elementary School Final Years Public Network	0,044
Fixed Network Broadband Internet Accesses per 100 Inhabitants, per Connection Speed - 512 kbps to 2 Mbps (%)	0,043
IDEB – Elementary School Final Years State Network	0,040
Ratio between Occupation of Temporary Agricultural Plantations and Total Area	0,036
Proportion of 4-5 year olds enrolled in preschool (%)	-0,034
Proportion of Schools with Adapted Infrastructure for Students with Disabilities (%)	0,032

Number of Health Professionals - Dentists (thousand inhabitants)	0,030
Proportion of Schools with Access to Electricity (%)	0,027
Proportion of Teaching with Teachers whose Higher Education is Suitable for the Area of Knowledge They Teach - Elementary School - Final Years - Total (%)	-0,027

Source: Developed by the authors

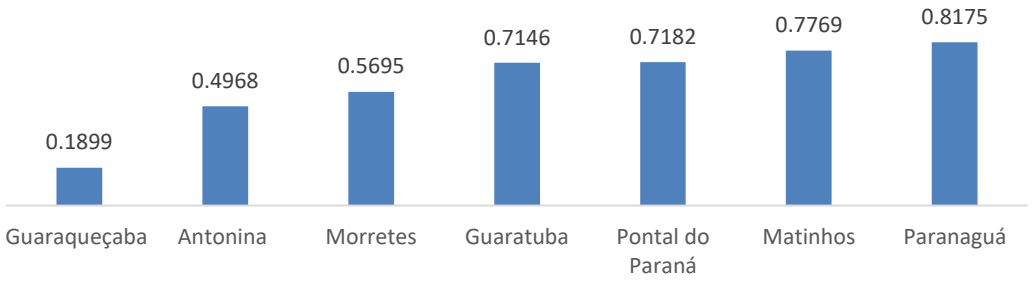
In canonical function 4 the variables that carried the most were the variables related to education, some social aspects and aspects of social violence (TABLE 5). It is observed that the variables related to education generate sustainability in the medium and long term, that is, the municipalities invest today to enjoy their results in the future. Consequently, with better levels of education in the general population, it provides in the long term a decrease in social violence and other social aspects.

The scaling of the Multidimensional Sustainable Development Index (MSDI) of the municipalities of the coast of Paraná generated through the performance of the municipalities and through the stepped discriminant functions can be considered as the one that presents the best economic, social and environmental performances. It is observed that the composition of the MSDI composes the most diverse dimensions of the SDGs, and was scaled from 0 to 1.

Among the 7 municipalities on the coast of Paraná, the municipality of Paranaguá stands out with the Multidimensional Sustainable Development Index of 0.8175, followed by the municipality of Matinhos with 0.7769, Pontal do Paraná with 0.7182 and Guaratuba with 0.7146. The municipalities with lower performance are Morretes with 0.5695, Antonina with 0.4968 and Guaraqueçaba with 0.1899, according to graph 1.

It is worth mentioning that the municipality of Paranaguá when observing the performance of the variables listed, it obtains the best performance of the set of variables observed in the first canonical function, and when compared with its peers on the coast of Paraná providing the best Multidimensional Sustainable Development Index (MSDI) (Figure 1).

Figure 1: Multidimensional Sustainable Development Index (MSDI).



Source: Prepared by the authors

When observing the performance of the population of the municipalities of the coast of Paraná, the municipalities of Guaraqueçaba and Antonina were the ones that lost population in the period between 2014 and 2019, and in the same period, the other municipalities obtained an increase in population.

Another factor that explains the Multidimensional Sustainable Development Index (MSDI) of these municipalities are the economic aspects such as economically active population, employed population, gross domestic product of the municipality, per capita income, population living below the poverty line, employability rate, among others. Thus, with the decrease in the supply of jobs for the population of smaller municipalities demographically, it caused a greater migration to larger cities where employment levels are higher, and with this inter-municipal exodus generated a mitigation of economic activity providing a lower index in the municipalities of Guaraqueçaba, Antonina and Morretes.

When observing the environmental variables, all municipalities on the coast of Paraná have shown satisfactory performance and environmental tourism has been growing on the coast of Paraná due to the environmental aspects located there, such as the Atlantic Forest in the municipalities of Guaraqueçaba, Antonina and Morretes, and the beaches in the municipalities of Pontal do Paraná, Matinhos and Guaratuba. It is noteworthy that there is much to be done as the development of coastal development policies to make the region more attractive for tourism.

Another aspect to be observed is the low vaccination rate of the population, thus, they present themselves with lower performance and falling, that is, the population is not getting vaccinated and providing a significant drop in these rates and increasing the incidence of diseases that were considered as eradicated, such as measles.

The objectives of Sustainable Development are goals to be followed and, in order for us to achieve them, all social actors involved in these objectives must commit to make their own changes, being in the economic

aspects, that is, to use resources in a rational way so that everyone in the future can enjoy the same quantities and with their same quality. In the social aspect, constantly seek social equity, so everyone develops in a way where social differences something over time tend to be shortened. In the environmental aspect, seek more sustainable ways where the environment has the capacity to regenerate, making our planet more conducive to the perpetuation of the human race in all corners of the Earth, seeking cleaner technologies that generate the greatest possible economic development without destroying the environment.

IV. Conclusion

The 17 Sustainable Development Goals (SDGs) should be thought of and worked on in a systemic way, that is, as a set of parts that interrelate and integrate with a common objective, since the data suggest that the evaluation of municipalities is multidimensional, due to the association between the indicators, verified through factor analysis and artificial intelligence techniques. Thus, as the quality and quantity of data of each indicator considered are improved, the results resulting from the analyzes will also have robustness, better performances and greater significance and public policies will have greater effectiveness in their implementations.

Regardless of the technique used in the analysis of sustainable development indicators, there will always be correlation or association between them, through their multidimensionalities. The corrections revealed the completeness of the sustainability of economic, social, environmental indicators and their interrelationships, through the Multidimensional Sustainable Development Index.

The Sustainable Development Goals and their targets are set to be achieved by the year 2030 to make cities and states more sustainable in the full sense of the word. Given this context, the development of an index that can measure the sustainability of a site is of great importance because its result can indicate the most significant economic, social and environmental variables in the composition of the Multidimensional Sustainable Development Index (MSDI).

In the composition of the MSDI, attention is drawn to the unique and innovative condition of this method, by establishing the objective and free analysis of the influence of value judgments to define the priorities and contribution weights of each indicator for each municipality generated by statistical means without human interference, generating an index where the subjectivity of the authors were not employed, with their impartiality occurring.

Another relevant factor identified in the composition of the MSDI is that, when observing the performance of the SDG variables, it identifies which are vulnerable points and which populations are more prone to economic, social and environmental vulnerabilities faced a worsening of the living conditions of this population. Thus, this tool comes to give decision-making subsidies applied to the SDGs for 2030, aiming at a more egalitarian, socially more balanced and economically fairer world for our generation and future generations.

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