

## Forum: Practical Perspectives

# Sanitation indicators: analysis of variables to construct municipality indicators

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After nine years of the Sanitation Law that defines the national guidelines in this area, it is still necessary to clarify the elements characterizing basic sanitation, and seek tools that enable monitoring sanitation in municipalities. Increasing international initiatives employ composite indicators to measure the performance of cities, compare them and use them to influence national and international political discussions. In this direction, the objective of this study is to analyze variables for the elaboration of sanitation indicators for the municipalities of São Paulo in order to generate information for the public administration. The method is based on thematic content analysis to understand the sanitation's components and attributes, and factorial exploratory analysis to elaborate indicators. The results show three indicators that compose a municipal index and indicate the need for data to fully evaluate sanitation.

**Keywords:** sanitation; Sanitation Law; indicators; counties.

### Indicadores de saneamento: uma análise de variáveis para elaboração de indicadores municipais

Passados nove anos da Lei do Saneamento, que define as diretrizes nacionais, verifica-se a necessidade de integrar os componentes do conceito de saneamento básico e buscar meios para monitorar os municípios. Crescentes iniciativas internacionais utilizam indicadores compostos para mensurar o desempenho das cidades, compará-las e para influenciar discussões de políticas nacionais e internacionais. Nesse sentido, o objetivo foi analisar variáveis para elaboração de indicadores de saneamento básico para os municípios paulistas a fim de gerar informações para a administração pública. O método fundamenta-se na análise de conteúdo temática de documentos para compreender os componentes e atributos do saneamento; e na análise fatorial exploratória para elaboração dos indicadores. O resultado da análise originou três indicadores que compõem um índice municipal e indica a necessidade de dados para avaliar de forma completa o saneamento.

**Palavras-chave:** saneamento básico; Lei do Saneamento; indicadores; municípios.

### Indicadores de saneamiento: análisis de variables para construir indicadores municipales

Después de nueve años de Ley de Saneamiento, que establece las directrices nacionales, aun existe la necesidad de integrar el concepto de los componentes de saneamiento y buscar formas de controlar el saneamiento en los condados. Crecientes iniciativas internacionales utilizan indicadores compuestos para medir el desempeño de las ciudades, para compararlas y para influir en los debates de políticas nacionales e internacionales. En este sentido, el objetivo es analizar variables para la elaboración de indicadores de saneamiento para los municipios de São Paulo a fin de generar información para la administración pública. El método se basa en el análisis de contenido temático para entender los componentes y atributos del saneamiento; y análisis exploratorio factorial para elaborar indicadores. El análisis resultante arrojó tres indicadores que componen un índice municipal e indican la necesidad de datos para evaluar completamente el saneamiento.

**Palabras clave:** saneamiento; Ley de Saneamiento; indicadores; condados.

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## 1. INTRODUCTION

In Brazil there are roughly 3.3 million households without running water, which represents 6% of permanent households, according to the 2010 Census (IBGE, 2012). Only 55.5% of households have permanent sewage facilities and 11.6% have a septic tank. In relation to solid waste, roughly 80% is collected directly by sanitation services in permanent households. This data demonstrates the need for improvements in basic sanitation.

Internationally, Agenda 2030 reinforces the concern about sanitation by establishing “Objective 6 — Assuring the availability and sustainable management of water and sanitation for all,” of the United Nations.

Brazil, in turn, has the goal of universalizing access to sanitation services as a human right by 2030, according to the National Plan for Basic Sanitation (PlanSab) based on Law N<sup>o</sup> 11,445/2007 — the Sanitation Law (Brazil, 2007). To do this, it will be necessary to monitor the sanitation situation in municipalities to determine the dimensions of the effort and resources necessary.

By monitoring sanitation in the municipalities, public administration can plan specific actions, establish performance and quality metrics, and orient public policies. That’s why our objective is to analyze variables to elaborate basic sanitation indicators for the municipalities of the State of São Paulo based on the principles of the Sanitation Law. Since this is an explanatory study, our application focuses on a group of municipalities to evaluate the possibility of this type of usage.

## 2. METHODOLOGY

Our analysis of variables for the elaboration of composite basic sanitation indicators for the municipalities of the State of São Paulo uses a mixed approach. Qualitative research provides more profound research about a given situation (Cooper and Schindler, 2011), and this is why we have applied it in order to understand the components and attributes of sanitation. We’ve employed quantitative research on the other hand, to analyze variables for the elaboration of indicators that reflect the sanitary conditions of the municipalities in São Paulo. This is an applied study that uses data from the National Sanitation Information System (SNIS), which in the future will incorporate the National Basic Sanitation Information System (Sinisa) as envisioned by Law N<sup>o</sup> 11,445/2007, and the Municipal Basic Information Survey (Munic) of 2013.

The analysis of the variables used to elaborate the composite indicators for basic sanitation is based on the *Handbook on constructing composite indicators* (Giovannini et al., 2008) and the methodological issues concerning the construction of rankings discussed in the work of Meijering, Kern and Tobi (2014), according to box 1.

Our qualitative data was analyzed based on thematic content analysis according to Bardin (2011), applied to the document of Law N<sup>o</sup> 11,445/2007 to define the breadth of the basic sanitation concept and the concept of adequate basic sanitation, which support the formulation of the selection criteria for the variables (Step 2).

Step 3 is based on exploratory factor analysis (FA) to determine the structure of the relationships between the variables (Corrar, Paulo and Dias Filho, 2012).

**BOX 1**      **STEPS IN THE ELABORATION OF SANITATION INDICATORS**

Steps	Description
1. Definition of theoretical framework	<ul style="list-style-type: none"> <li>• Definition of the concept</li> <li>• Breaking it down into attributes</li> </ul>
2. Data selection	<ul style="list-style-type: none"> <li>• Database and variable selection criteria</li> <li>• Variable characteristics</li> <li>• Treatment of missing data</li> </ul>
3. Multivariate analysis	<ul style="list-style-type: none"> <li>• Exploratory factor analysis</li> <li>• Multiple linear regression</li> </ul>
4. Normalization, weighting and aggregation	<ul style="list-style-type: none"> <li>• Normalization of factor scores</li> <li>• Weighting of factor scores</li> <li>• Aggregation of factor scores in an index</li> </ul>
5. Grouping of municipalities	<ul style="list-style-type: none"> <li>• Classification of municipalities, according to defined groupings of cities</li> </ul>
6. Visualization of results	<ul style="list-style-type: none"> <li>• Graphic representation of the sanitation classification results and the results report</li> </ul>

**Source:** Adapted from Giovannini and collaborators (2008) and Meijering, Kern and Tobi (2014).

Even though FA is generally just for metric variables, Hair and collaborators (2009) consider it acceptable to include a small number of dichotomic variables among the metric variables analyzed by factors. To accomplish this, we used 83 metric variables, and 9 dichotomic variables related to urban drainage which has a scarcity of data. In terms of the sample size, according to Hair and collaborators (2009), there need to be more observations than variables, with the minimum acceptable ratio being 5:1 and the ideal being 10:1. The sample consisted of 490 observations (the quantity of municipalities) and 92 variables, equivalent to a ratio of 5:1, the minimum acceptable as a general rule.

The municipalities selected for the analysis were those which possessed a majority of the information related to the four components of basic sanitation, this being a sample that conveniently represents 76.0% of the municipalities in the State of São Paulo.

For the FA, we used the IBM SPSS software version 23 for Bartlett's test of sphericity, the Measure of Sampling Adequacy (MSA) and the Kaiser-Meyer-Olkin (KMO) test. After these tests, we used an octagonal rotation using the Varimax method to interpret the solution. Finally we tested for internal consistency by using Cronbach's Alpha to verify if the individual items or indicators were measuring the same construct.

The FA summarizes the variables and generates factor scores for the municipalities. According to Hair and collaborators (2009), the factor score represents the degree to which each municipality has a an elevated score within the group of items that have elevated weights for a given factor; that is, higher values with elevated weights for a factor result in a larger factor score. The justification for this factor score is that it is computed based on the factor weights of all of the variables that make up a factor, avoiding a repetition of information.

For the municipality groupings, we have adopted the city typology as suggested by Meijering, Kern and Tobi (2014), avoiding the comparison of municipalities that have different characteristics. The groupings realized by the municipality typology proposed by the National Habitation Plan synthesize 11 typologies of the 19 in the original study (realized by the Observatório Metr opolis), to emphasize the aspects relevant to habitation issues such as: metropolitan regions, income ranges, number of inhabitants, degree of urbanization, and GDP (Minist rio das Cidades, 2009).

### 3. SANITATION INDICATORS

Within the international context, there is a growing utilization of performance indicators in the sanitation sector to monitor the providing of, regulation of, and planning of these services (Sperling and Sperling, 2013). From the point of view of public administration, the monitoring of data is important and necessary in order to accompany the progress of activities, improve the transparency of the accounting, and demonstrate results (Schwemlein, Cronk and Bartram, 2016).

According to Kern (2008 apud Meijering, Kern and Tobi, 2014), one tool that has often been used to influence national and international political discussions is the European green city rankings.

In Brazil, there are two relevant initiatives, the basic sanitation ranking of the 100 largest cities by the Instituto Trata Brasil (2016) and the Blue Green Municipal Program within the Environmental Secretariat of the State of S o Paulo (S o Paulo, 2016). There is also a sanitation ranking initiative that has been undertaken by the government of India. What these three rankings have in common is that they are based on indicators or indices that are applied to cities and that range in number from 12 to 70. However, there are no rankings or structured initiatives to elaborate Brazilian indicators that contemplate the components of basic sanitation according to Law N  11,445/2007 in order to measure and monitor adequate sanitation.

## 4. RESULTS AND DISCUSSION: THE ELABORATION OF SANITATION INDICATORS

### 4.1 DEFINITION OF THE THEORETICAL FRAMEWORK

Thematic content analysis of the Sanitation Law confirmed four components: 1. the supply of water, 2. sewage networks, 3. urban solid waste and urban cleaning, 4. drainage and the management of rainwater. Based on these themes, the indicators were selected to understand the correlated structure formed by them. The concept of adequate sanitation was also defined through a thematic content analysis of the principles of the Sanitation Law, which have been grouped by these themes, forming the attributes of box 2.

Of the 16 attributes, the data selection managed to include only eight of them, and some of them only partially. This signifies that roughly 50% of the concept of adequate sanitation is represented. This is an estimate, because an attribute cannot always be measured by just one indicator.

Attributes such as “completeness” require close analysis, given that the studies of Patil and collaborators (2014) and Kumar and Taunk (2010) show the need for the completeness of sanitation programs to ensure effective results. Furthermore, the study of Schwemlein, Cronk and Bartram (2016) points to the need to evaluate inter-relationships between indicators. In terms of universalization,

the SNIS is still not able to furnish information about sanitation in the rural and peripheral areas discussed in the study conducted by Schneider and collaborators (2010).

**BOX 2**      **ATTRIBUTES OF ADEQUATE SANITATION**

Attributes of Adequate Sanitation	Attributes Contemplated in the Ranking
1. Universalization of basic sanitation services	Partially, does not include the rural population
2. Completeness	-
3. Adequate public health services	-
4. Adequate environmental protection services	-
5. Methods, techniques and processes that consider regional and local characteristics	-
6. Articulation with policies that handle urban and regional development, habitation, the fight against poverty, environmental protection, and the promotion of health and social interests	-
7. Efficiency	Partially, with the exception of urban drainage
8. Economic sustainability	Partially, with the exception of urban drainage
9. Appropriate technologies	-
10. Transparency	Partially, not all municipalities provide information to the SNIS
11. Social control	Yes
12. Security	Partially for urban drainage and it just reports the occurrence of flooding
13. Quality	Partially, for the urban supply of water, sewage and drainage
14. Regularity	Yes
15. Integration of infrastructure and services with efficient management of water resources	-
16. Measures to encourage moderation in water consumption	-

Source: Elaborated by the authors.

## 4.2 MULTIVARIATE ANALYSIS

The objectives of the FA were: to understand whether the sanitation indicators can be “grouped” according to the components cited by the Sanitation Law and summarized by the characteristics of sanitation. To summarize these characteristics, we applied factor analysis using R, which analyzes a group of variables to identify its latent dimensions.

The verification of the conceptual and statistical fit of the sample variables was performed using Bartlett’s test for sphericity which examines the entire correlation matrix for the presence of correlations between variables, and the result for a significance of  $< 0.001$ ,  $X^2(45) = 15141.823$ , indicates that there is a sufficient correlation between the variables. The Measure of Sampling Adequacy (MSA) had values for general and individual MSA over 0.5. The Kaiser-Meyer-Olkin (KMO) test indicated the adequacy of the sample size, and with a value of 0.857, it was considered good. The correlation matrix analysis considered only values above 0.5 times the diagonal of the anti-image correlation matrix.

The criteria for the extraction of the number of factors was the latent root, with only eigenvalues greater than 1 being considered significant, which resulted in three factors or latent dimensions: the coverage of water supply, sewage and solid waste services (WSW Coverage) which explains 60.6% of the variance; efficiency in the distribution of water (W Efficiency) which explains 21.1%; and urban drainage efficiency (D Efficiency) which explains 11.6%. In total, the factors explain 93.4% of the variance.

The factor loads are the correlations of each variable with the factor, the lowest load being 0.869 and the largest being 0.997. The rotated solution presented in Table 3 resulted in three factors which are denominated as Factor 1 — WSW Coverage; Factor 2 — W Efficiency; and Factor 3 — D Efficiency.

The degree to which the results can be generalized was tested by dividing the sample randomly into two sub-samples and the results of the Varimax rotation loads, the communalities, and the factor structure proved to be stable, because there was no representative load of the variable in other factors.

Table 1 shows the Cronbach’s Alpha values for each factor as well as the factor loads and communality for each variable.

**TABLE 1** SANITATION FACTOR ANALYSIS

Factor	Variables	Load	Commonality	Cronbach’s Alpha
1	A1 — Total population that receives water (inhabitants)	0.997	0.999	0.894
	A2 — Macro-measurement of water volume (1,000 m <sup>3</sup> /year)	0.996	0.997	
	E1 — Total population served by the sewage system (inhabitants)	0.997	0.999	
	E2 — Volume of collected sewage (1,000 m <sup>3</sup> /year)	0.995	0.996	
	R1 — Total quantity of solid household and urban waste collected by all of the agents (Metric tons/year)	0.995	0.995	
	R2 — Urban population served by the household collection service (inhabitants)	0.997	0.999	

*Continue*

Factor	Variables	Load	Commonality	Cronbach's Alpha
2	EF1 — Water revenue index (%)	0.945	0.902	0.866
	EF2 — Distribution efficiency index	0.923	0.893	
3	D1 — There has been no ponding in the municipality's urban areas during the past five years	0.872	0.780	0.715
	D2 — There has been no flooding in the municipality's urban areas during the past five years	0.869	0.778	

**Source:** Elaborated by the authors.

To create the Municipal Basic Sanitation Index (MBSI) we used the factor scores resulting from FA, which were measurements composed of each factor computed for each municipality.

#### 4.3 NORMALIZATION, WEIGHTING AND AGGREGATION

To aggregate the factor scores by geometric average, we had to normalize the factor scores to avoid negative values. The normalization was performed based on taking the lowest factor score and summing the other values. In addition, it was necessary to differentiate the value of zero, to not arrive at a geometric value of zero, by considering the value closest to zero.

In terms of the weighting, in FA the weighting intervenes to correct the overlapping of information between two or more correlated indicators and does not measure the theoretical importance associated with the indicator (Giovannini et al., 2008). In this sense, different weights were not attributed due to theoretical importance; equal weights were considered for all of the factors.

In terms of the aggregation of the factors, we opted for the geometric average due to facility of applying it and to reduce, at least partially, the problem of it being a compensatory technique.

#### 4.4 GROUPING OF MUNICIPALITIES

The typologies of the municipalities of the State of São Paulo were composed of nine different typologies subdivided into subgroups: municipalities of metropolitan regions and those above 100 thousand inhabitants (A, B, D); those between 20 and 100 thousand inhabitants (E, G, H); and those with less than 20 thousand inhabitants (I, J, K) (Ministério das Cidades, 2009).

Table 2 shows the quantities of the state municipalities and their respective typologies as well as those of the sample.

It may be noted that the municipalities not included in the analysis due to a lack of data did not significantly affect the representativeness of the sample, given that the proportions were maintained. Only Profile I had a large reduction in representativeness.

In relation to the classification of the municipalities according to the MBSI, it is necessary to discuss the case of the City of São Paulo which demonstrates a large value for WSW Coverage, in comparison with the other municipalities which are also classified under Typology A. In terms of the WSW Coverage indicator, the value of 25 is much larger than the second largest value. This was due to the population's characteristics.

**TABLE 2** TYPOLOGIES OF THE POPULATION AND THE SAMPLE

PROFILE	Population			Sample	
	No data	Municipalities	% TOTAL	Municipalities	% SAMPLE
I	94	356	55%	262	41%
F	27	127	20%	100	16%
A	14	39	6%	25	4%
K	7	33	5%	26	4%
B	1	29	4%	28	4%
D	2	28	4%	26	4%
J	5	16	2%	11	2%
G	3	15	2%	12	2%
H	2	2	0%	0	0%
<b>Total</b>	<b>155</b>	<b>645</b>	<b>100%</b>	<b>490</b>	<b>100%</b>

Source: Elaborated by the authors.

**TABLE 3** SANITATION VARIABLE ANALYSIS — TYPOLOGY A

Municipality — Typology A	WSW Coverage	W Efficiency	D Efficiency	MBSI
São Paulo	25.03992	3.7686	3.67135	7.0234
Biritiba-Mirim	3.4322	4.00165	4.25234	3.8798
Guarulhos	5.80004	2.66982	3.52089	3.7919
Salesópolis	3.41195	3.69961	4.29265	3.7841
Arujá	3.50234	3.15612	4.38728	3.6467
Embú das Artes	3.68063	3.26898	3.22705	3.3862
Santo André	4.52851	3.67631	2.01079	3.2229
Cotia	3.62082	2.73634	3.30375	3.1989
Osasco	4.47495	1.79765	3.50826	3.0446
Barueri	3.74729	2.11395	3.4041	2.9987
São Caetano do Sul	3.58362	3.8682	1.91157	2.9813

Continue

Municipality — Typology A	WSW Coverage	W Efficiency	D Efficiency	MBSI
São Bernardo do Campo	4.65714	2.63461	2.15013	2.9769
Taboão da Serra	3.69111	3.16375	1.99171	2.8545
Franco da Rocha	3.42172	3.33423	1.94842	2.8117
Ferraz de Vasconcelos	3.49125	3.19735	1.96725	2.8003
Santana de Parnaíba	3.39886	3.27991	1.95534	2.7934
Guararema	3.26434	3.39107	1.91769	2.7689
Poá	3.43911	3.11817	1.977	2.7677
Ribeirão Pires	3.3945	2.92626	2.00142	2.7090
Diadema	3.90873	2.30357	2.14602	2.6834
Cajamar	3.32411	2.78553	2.00996	2.6501
Mauá	3.7572	2.29761	2.11166	2.6318
Itapevi	3.51941	2.23532	2.10189	2.5477
Itapecerica da Serra	3.36446	2.28933	2.08015	2.5210
Mogi das Cruzes	3.87615	1.59118	2.23031	2.3960

**Source:** Elaborated by the authors.

In general, the MBSI values for municipalities are very close to each other. This can be attributed to the fact that municipalities in the State of São Paulo have very similar levels of service, especially in terms of WSW Coverage which for most municipalities has a value close to 3. However, in terms of the indicators W Efficiency and D Efficiency, more differences emerge among these municipalities.

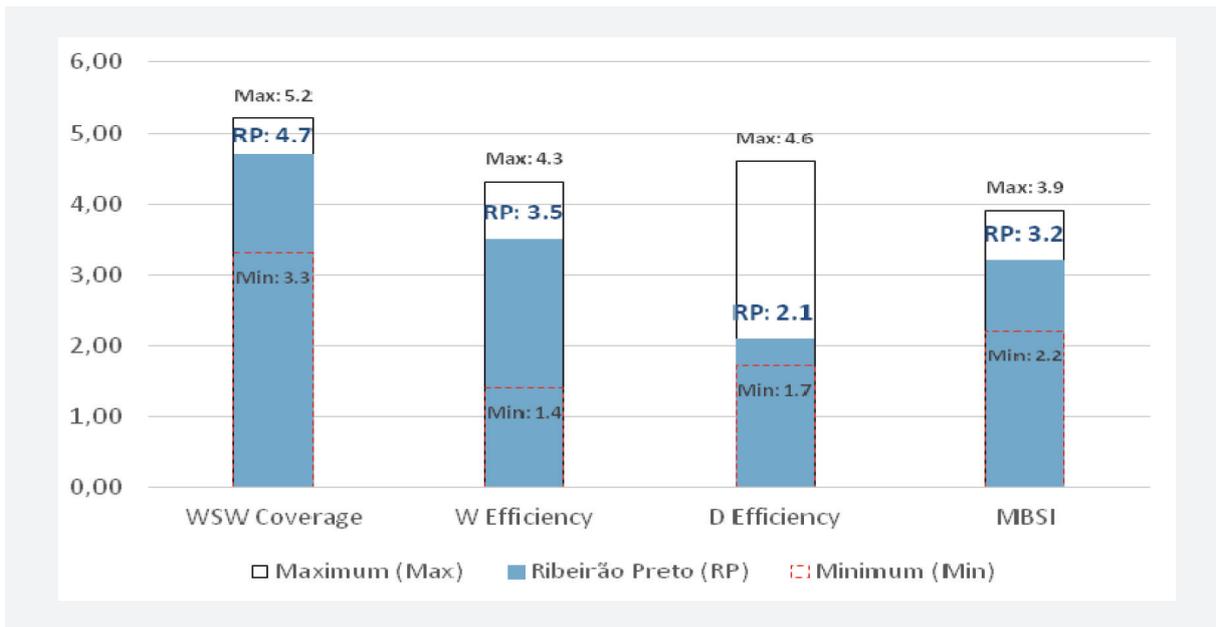
The strong points of the elaborated sanitation indicators are: their capacity to classify municipalities in a quantitative manner, making it possible to make comparisons based on typologies considering characteristics in common, that they make it possible to visualize their values by dimension (WSW Coverage, W Efficiency, D Efficiency), and that they provide a measure that unites various aspects of adequate sanitation. The points that need to be improved have to do with the typology of the City of São Paulo which could be compared to other metropolises in other states, and the need to perform FA to obtain the factor scores with all of the data.

#### 4.5 VISUALIZATION OF THE RESULTS

The visualization of the classification results facilitates the interpretation of information in a clear and objective manner. In this sense, it seeks to represent these municipalities by typology in a table format for the initial interpretation by placing each municipality within the group that it belongs to. The second form of analysis is the value of each of the factors. Overall it follows a standard structure: the presentation, executive summary, methodology, results, and final considerations.

In Graph 1 we have an example of the representation of the results for each municipality, with references such as the point total, the lowest and highest point totals for each of the municipalities in the profile, and the points for each of the dimensions/factors.

**GRAPH 1** MUNICIPAL BASIC SANITATION INDEX — RIBEIRÃO PRETO (SP)



Source: Elaborated by the authors.

## 5. FINAL CONSIDERATIONS

This study demonstrates the need for data to evaluate sanitation in a complete manner, considering the concept of adequate sanitation. Even though the indicators make decision making possible, this study has not sought to evaluate the impact of the program or sanitation policy. In terms of its contributions, this study offers: the understanding of this database with sanitation information, the understanding of the relevance of sanitation indicators, the structure of sanitation information through exploratory factor analysis which has yielded factors (new sanitation dimensions), the selection of variables with a great weight of information, and the classification of municipalities in the State of São Paulo in terms of adequate sanitation.

In terms of limitations, we can cite the lack of available data for all of the municipalities, the reliability of the collected data, the difficulty of integrating information from various databases, the manner of comparing municipalities based on profiles, and the aggregation of data which has the limitation of using a compensatory method, even though this was only used to a partial extent.

As far as opportunities are concerned, this methodology can be applied to other states in future studies, and there is a need for greater breadth in terms of indicators to monitor adequate sanitation services in these municipalities.

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