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FERRAMENTA PARA AVALIAÇÃO DA GESTÃO DE RESÍDUOS SÓLIDOS URBANOS A TOOL FOR THE EVALUATION OF MUNICIPAL SOLID WASTE MANAGEMENT

ANA BEATRIZ SUQUISAQUI, KATIA VENTURA

Ana Beatriz Suquisaqui has a degree in Environmental Management and Analysis, a Master in Urban Engineering, and is a researcher in the Postgraduate Program in Science and Materials Engineering at the Federal University of Sao Carlos, Brazil. She studies indicators, urban sustainability and solid waste management, public consortia, and management tools. biasuqui@hotmail.com

Katia Sakihama Ventura is a Civil Engineer and Doctor in Hydraulics and Sanitation. She is an Associate Professor at the Civil Engineering Department and the Postgraduate Program in Urban Engineering, both at the Federal University of Sao Carlos, Brazil. She studies solid waste management, public consortia, water safety planning, indicators and evaluation methods, and urban environmental systems. katiasv@ufscar.br

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Abstract

The Municipal Solid Waste Management (MSWM) is a great challenge for public managers especially because they need to comply with the initiatives recommended by the National Solid Waste Policy (NSWP) – Federal Law 12,305/2010, which is considered the regulatory framework for the sector in Brazil. The use of instruments to evaluate the MSWM is extremely helpful to identify its gaps and define actions to improve the system. This paper aims to structure a conceptual model for MSWM evaluation, which involves five initiatives (sanitary landfill, composting, selective collection, public consortium, and reverse logistics) and has a total of fifty qualitative indicators. The study followed four methodological stages: the selection of indicators, evaluation by experts, data consistency analysis, and elaboration of the tool. The use of several research methods has led, among other results, to the conceptual model of the SAGReS tool, which structures a dashboard with the relevant indicators for public managers. This study allows us to control the actions that may subsequently assist the decision-making of public administration regarding urban cleaning services and solid waste management.

Keyword: Indicator, Evaluation tools, Public service, Environmental management

1 Introduction

Recently, the concern with sustainability issues has grown in national and international spheres, especially because of the growing diversity of worldwide events and actions about this discussion (Bonjardim, Pereira, and Guardabassio, 2018). Regarding the Municipal Solid Waste Management (MSWM), Brazil seeks to develop best-case scenarios despite the challenges faced particularly by developing countries Ghesla *et al.* (2018).

The Brazilian Law 12,305 of August 2, 2010, which is also known as the National Solid Waste Policy (NSWP), enacted by Decree No. 7,404 of December 23, 2010, represents the regulatory framework for the Brazilian solid waste management. According to Baptista (2015), the lack of urban planning in many Brazilian cities resulted in the establishment of dumps over the country, which do not have any kind of sanitary structure.

Fratta, Toneli, and Antonio (2019) point out that MSWM needs to be monitored and rigorously evaluated to efficiently impact on the procedures and bring effective results in short, medium, and long terms. Consequently, it is also necessary to diagnose the situation of MSWM and define strategies according to the weaknesses of each situation.

Management tools can minimize some of the weaknesses of the procedures. Besides, the use of indicators is an option to analyze the MSWM models and enable, above all, the adequacy of the management to sustainability precepts (Pereira, Curi, and Curi, 2018).

According to section 19 of the NSWP, the municipal administration is responsible to implement measures for the analysis of the operational and environmental performance of public urban cleaning services and the MSWM (BRAZIL, 2010). The indicators and management tools are useful examples of this practice. As Menikpura, Gheewala, and Bonnet (2012) states, environmental issues, legal and human health aspects, are inherent to MSWM and have a close relation to the urban infrastructure and public management. The lack of some stages of urban services, such as MSWM, causes environmental pollution and economic losses to society, which sometimes cannot be recovered (POLETTO *et al.*, 2016).

This paper becomes relevant for ensuring the urban life quality once it enables the study of these activities and their performance analysis, whose concept relies on the procedures adopted in the solid waste management through indicators (Ventura, Reis, and Takayanagui, 2010). The greatest scientific contribution of the work is the conception of the tool, which contains fifty qualitative indicators and whose application is available to any Brazilian municipality, to monitor the waste management. Besides, this study has generated a range of sequential procedures for the implemented method to support new research in correlated areas.

The research aims to propose an evaluation model for the MSWM through several methods based on the initiatives recommended by the NSWP. The idea of measuring the condition of the initiatives, which we can comprehend as the implementation of public policies to the economic development along with the exploitation of natural resources, concerns the search for sustainability in municipal scale to ensure these same resources to future generations (World Health Organization, 2015).

The tool Municipal Solid Waste Management Evaluation System (SAGReS in Portuguese) was organized on an Excel spreadsheet through the VBA (Visual Basic for Applications) programming. The dashboard and its indicators suggest the points to be better managed. The tool runs on computers with Microsoft Office 2016 or above.

The SAGReS application occurred in two municipalities of the São Paulo state, in southeast Brazil, whose details are in Suquisaqui (2020). The SAGReS application analysis includes other methods that are not the focus of this paper.

2 Methods, techniques, and instruments of research

The research followed four main stages, whose details are in Table 1.

Stage	Activity
1	Bibliographic survey: systematic bibliographic review and documentary survey
2	Selection of indicators
3	Indicator evaluation by experts: AHP matrix and data consistency analysis
4	Elaboration of the SAGReS Tool

Table 1: Research methodological stages. Source: Authors, 2020.

2.1 Bibliographic research

The selection of indicators for SAGReS consisted of bibliographic and documentary researches. The search for information relied on two different methods regarding the selection of scientific-based works for the conception of the tool: Documentary Research and Systematic Literature Review (SLR).

The documentary research involved the search for reports, inventories, laws, theses, and dissertations, among other documents, in public agencies, companies, and government departments. This stage was essential for us to discover the aspects related to the research themes, as well as to identify and define the new indicators for each initiative.

Bereton *et al.* (2007) say the SLR has a narrative character and focuses on the application of scientific methods. It allows the researcher/manager to achieve a strict and reliable evaluation of the issue while enabling the synthesis of the relevant information (Biolchini et al., 2005). This process implies a set of stages, techniques, and specific tools (Conforto, Amaral, and Silva, 2011).

The SLR protocol relied on Ospina's research (2018). The selected databases were *Scopus, Web of Science*, and *Compendex*, which are available in the CAPES system (an institution of the Brazilian Education Ministry) and it is classified as the main bases of the civil engineering area.

The next stage was the definition of the research *strings*, whose choice consisted of several attempts since they depend on the definition, testing, and adaptation of the terms (Conforto, Amaral, and Silva, 2011). This occurs due to the need of testing the combination of the terms with the Boolean search operators. Besides, the *strings* were defined in English to find the largest number of papers could, as shown in Table 2.

THEME	SCOPUS	WEB OF SCIENCE	COMPENDEX
Sanitary Landfill	"sanitary landfill" AND indicator*	"sanitary landfill" AND indicator*	"sanitary landfill" AND indicator*
	"sanitary landfill" AND "urban solid waste management"	"sanitary landfill" AND "urban solid waste management"	"sanitary landfill" AND "solid waste management"
Selective Collection	"Selective collection" AND indicator*	"Selective collection" AND indicator*	"Selective collection" AND indicator*
	"Selective collection" AND "urban solid waste management"	"Selective collection" AND "urban solid waste management"	"Selective collection" AND "solid waste management"
Composting	"waste composting" AND indicator*	"waste composting" AND indicator*	"waste composting" AND indicator*
	"waste composting" AND "urban solid waste management"	"waste composting" AND "solid waste management"	"waste composting" AND "solid waste management"
Public Consortia	"public consorti*" AND indicator*	"public consorti*" AND indicator*	"public consortia" AND indicator*
	public consorti*" AND "solid waste"	public consorti*" AND "solid waste"	"public consortia" AND "waste"
	"intermunicipal consortia" AND "solid waste"	"Intermunicipal consorti*" AND "solid waste"	"Intermunicipal consorti*" AND "solid waste"
	"intermunicipal cooperation" AND "solid waste"	intermunicipal cooperation" AND "solid waste"	intermunicipal cooperation" AND "solid waste"
Reverse Logistics	"reverse logistic*" AND Waste AND indicator*	"reverse logistic*" AND Waste AND indicator*	"reverse logistic*" AND waste AND indicator
	"reverse logistic*" AND "solid waste management"	"reverse logistic*" AND "waste management"	"reverse logistic*" AND "waste management"

*: The Boolean operator "asterisk" allows the database to search the term in the singular and in the plural.

Table 2: The *Strings* used for SLR in the 2018-2019 period. Source: Authors, 2020.

The research timeframe was the first SLR filter established for obtaining papers from the year 2000 and forward. Subsequently, the abstracts of the selected papers were read to investigate the relevance to the current research, which considered: i) the discussions on the researched themes; ii) the indicators of the themes or; iii) both.

2.2 Indicators Selection

This stage consisted of reading the papers to find specific indicators for each theme. The selection better led to qualitative parameters, whose information was more available by initiative than by quantitative data.

The researchers considered the following criteria to ensure the reliability of the indicators' selection method: i) according to Suquisaqui and Hanai (2017), the indicators must be easy to understand, useful, measurable, as well as ii) it should enable the deployment and monitoring as well as facilitate the data updating, according to Ventura, Reis, and Takayanagui (2010).

Table 3 illustrates the definition of the criteria for the selection of indicators.

CRITERIA	DEFINITION	REFERENCE
Be easy to understand	It must be simple and clear, its meaning must be easy to understand, also by non-specialists.	Zhang and Guindon (2006); Ventura (2009); Suquisaqui and Hanai (2017)
Be useful	It must be useful and relevant from the point of view of the research and the purpose for which it will be used.	Ventura (2009); Suquisaqui and Hanai (2017)
Be measurable	It must be possible to be compared in different situations and to be applied.	Keirstead and Leach (2007); Ventura (2009); Suquisaqui and Hanai (2017)
Be viable	Availability of relevant data sets needed to quantify them.	Zhang and Guindon (2006); Ventura (2009)

Table 3: Indicator's Selection Criteria Established in the 2018-2019 period. Source: Authors, 2020.

Despite all the procedures for this stage, the number of published papers regarding indicators was very low or non-existent for some initiatives. In this way, it was necessary to include a new research stage to define new indicators.

2.3 Definition of new indicators

We carried out the new stage to obtain relevant information for each initiative. We also developed other procedures to identify the inherent aspects of the new indicators. Consequently, we met with other researchers, focusing on the exchange of knowledge. Besides, we conducted a literature review to identify such aspects and, subsequently, proposed new indicators considering the criteria defined in Table 2. Finally, we consulted with experts to verify the relevance of the indicators to the tool.

2.4 Evaluation of indicators by experts

We selected twelve experts from the solid waste study field to evaluate the proposed indicators. The experts' profiles included consultants, professors, self-employed people, service providers, and public service managers. The evaluations took place individually for each expert.

The adopted method for evaluating the indicators followed two steps: i) the evaluation of the indicators by experts through the Analytic Hierarchy Process (AHP) method; ii) the analysis of the consistency of their responses according to the Saaty method. The AHP method compares the answers in pairs and proposes to answer two questions (Leite and Freitas, 2012): (1) the most relevant criteria; (2) the proportion of their relevance?

This methodology consists of splitting a problem into several elements by structuring a hierarchy in which decision-makers can define priorities according to the alternatives, comparing them in pairs based on the numerical scale of Saaty (Ventura, 2009). The Fundamental Scale of Saaty (1977) defines and explains the values from 1 to 9, which assigns the decisions in comparison to the elements in pairs. However, we adapted the scale and applied the scale from 1 to 7 to facilitate the judgments of experts, as Table 4 shows.

VALUE	DEFINITION	EXPLANATION
1	Equal importance	Two indicators contribute equally to the objective.
3	Moderate importance	Experience and judgment slightly in favor of one indicator over the other.
5	Strong importance	Experience and judgment strongly in favor of one indicator over the other.
7	Demonstrated importance	An indicator is strongly favored and its dominance is demonstrated in practice.

Table 4: Judgment Scale, adapted to the present study, for evaluation of indicators by experts. Source: Adapted from Saaty (1977); Ventura (2009); Zatta *et al.* (2019).

For the AHP method, the number 1 composes, obligatorily, the main matrix diagonal since the comparison of a factor with itself has equal importance. The diagonal represents the line that separates the assigned values to the indicator and its inverse. For example, the value of indicator A according to indicator B is X, so the value of B for A is 1/X.

The filling of the AHP judgment matrix is defined by Saaty (1977) as in Figure 1:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ 1/a_{n1} & 1/a_{n2} & \cdots & 1 \end{bmatrix}$$

Figure 1: Judgment Matrix for the AHP Method. Source: Saaty (1977)

After filling the matrix, we normalized its values by summing each column element from the judgment matrices. Later, we divided each column element by the summed value. With the normalized matrix, we calculated the averages of each matrix line and, finally, put these values in ascending order to define the global priority of the comparisons (Zatta *et al.*, 2019).

We put each initiative result in a single table. Each cell resulted in an arithmetic average of the attributed weights by each participant. Then, we calculated the arithmetic average, per line, whose final result meant the indicator position and, consequently, its final classification. However, this stage occurred only for assessments we considered as consistent, as the following topic will show.

2.5 Analysis of data consistency

The application of the AHP method has as a disadvantage the possible inconsistency of the attributed weights by the evaluators (Ventura, 2009). Therefore, we should verify the results to ensure consistent responses. According to Saaty (1977), the improvement of consistency does not mean getting an answer closer to reality. Instead, it means that the estimated ratio in the matrix is closer to being logically related than randomly selected.

Saaty (1977) states that when the consistency index points out that there are major distortions in this test, it is very likely that the obtained result is unreliable and the aforementioned information cannot be used in the model. To verify the consistency of the experts' answers, we followed the steps below (Saaty, 1977). Table 5 exemplifies the described calculations.

a. Using the experts' normalized AHP matrix, as explained in point 2.4;

b. Calculation of the average of the lines from this matrix, resulting in the average vector of the lines;

c. Calculation of the sum of products of the average vector by the element, per line, of the original matrix (other than the normalized one), generating the column vector;

d. Calculation of the vector λ by dividing each element of the column vector by the respective average vector.

e. Calculation of the average of the values of each element of the vector λ for obtaining the λmax vector value;

f. Identification of the Random Index (RI) of the matrix for finishing the calculations. This value was standardized by Saaty (1991) and depends on the number of elements (n) of the matrix as shown in Table 6;

g. Calculation of the Matrix Consistency Index (CI), defined by Equation 1:

$$CI = \frac{[\lambda max - n]}{[(n-1)]}$$

h. Calculation of the Consistency Ratio (CR) following Equation 2. According to Saaty (1991), the CR must be less or equal to 0.10 for considering the experts' responses. The closer this ratio is to zero, the more consistent the matrix will be.

$$CR = \frac{CI}{RI}$$

Variable	Weights of specialists			Standardized matrix			Averag of lines	Vetor Coluna	Vetor λ	n = 3, therefore RI = 0,58
	V1	V2	V3	V1	V2	V3				
V1	1	0,33	3	0,23*	0,076	0,69	0,33	1,42**	4,30	$CI = \frac{[4,30 - 3]}{[(3-1)]}$
V2	3	1	0,33	0,69	0,23	0,076	0,33	1,42	4,3	
V3	0,33	3	1	0,076	0,69	0,23	0,33	1,42	4,3	CI = 0,65
Sum	4,33	4,33	4,33				Vetor $\lambda_{max} = 4,3$			$CR = \frac{0,65}{0,58} = 1,12$

Table 5: Example of calculating the consistency index for this research. Source: Adapted from Ventura (2009).

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
IR	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

Table 6: Value of Random Index (RI) according to the matrix order. Source: Saaty (1991).

For this research, we defined that we should exclude the inconsistency matrices of experts should from the evaluation. It allowed us to evaluate only the consistent responses and rank the importance of the indicators. Therefore, the low weights obtained by the judgment of the experts meant that a certain indicator is less important than another, which does not justify its exclusion from the tool.

There was no problem in disregarding inconsistent evaluations. For initiatives with more than one consistent result, we performed the average of the evaluations, generating a single matrix for this initiative. Based on this matrix, we obtained the normalization calculations were and, then, organized the results hierarchically to finish the importance list of the indicators. For initiatives that obtained only one consistent evaluation, we used the prioritization list we obtained directly from the expert.

2.6 Elaboration of the tool

The five initiatives inserted in the tool were based on the NSWP recommendations: sanitary landfill, selective collection, public consortium, composting, and reverse logistics. We structured each initiative with ten specific indicators for each theme. The purpose of the tool was to identify the main gaps of each initiative so that the public manager could enable actions and solve problems.

We elaborated the tool in a spreadsheet after the evaluation of the experts and the selection of the indicators. The evaluation of the indicators for each initiative followed three criteria, according to Table 7: the existence, quality, and importance level of the information.

CRITERIA	DEFINITION
Existence of information	Refers to the information that the indicator represents. Reference question: does the information regarding the analyzed indicator exist (yes, under construction or not)?
Quality of information	It refers to the quality of the information given the level of detail it presents. Reference question: what is the quality of the information (low, medium or high)?
Importance of information	It refers to the importance of information in relation to the analyzed indicator. Reference question: what is the level of importance of the information that the indicator presents (low, medium or high)?

Table 7: Defined criteria for the elaboration of the Municipal Solid Waste Management Tool. Source: Authors, 2020.

The evaluation of the indicators used scores based on the Likert scale. This scale is applied to measure attitudes and provide answers to a question or statement (Jamieson, 2004). For this reason, a scale with odd variation is usually applied to assign the value to each agreement or disagreement criterion of the analyzed indicator, according to Pereira (1999). In this research, the scale adopted was:

a Value 3 - High: the analyzed indicator has a low possibility to fulfill the criterion. It implies that it is unlikely that the activity or service will be performed.

b Value 2 - Medium: the indicator has a medium possibility of fulfilling the criterion. It implies a moderate probability of implementation of the activity or service.

c Value 1 - Low: the indicator has a high possibility to fulfill the criterion. It implies a high probability of implementation of the activity or service.

From each of the three established criteria, we multiplied the scores of a certain indicator, which resulted in a wide numerical set ranging from 1 (1x1x1) to 27 (3x3x3). Figure 2 illustrates the indicator final raking scale after the multiplication of the three criteria scores. The higher the value of the multiplication of scores for a certain indicator, the worse is the analyzed situation, requiring the strict attention from the manager to establish priority actions that integrate the indicator into MSWM.

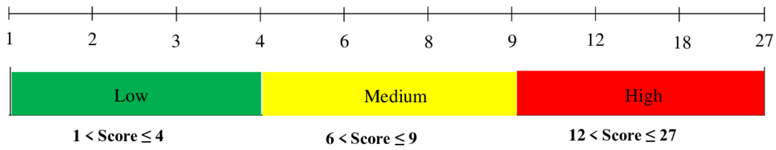


Figure 2: Adopted scale for the compliance degree of the indicator with the established criteria. Source: Authors, 2020.

3 Results

The results were elaborated according to the methodological steps, detailed above.

3.1 SLR Results

To illustrate this information, Table 8 shows the number of papers we found in each database.

Strings	*Scopus*		*Web of Science*		*Compendex*	
	Total	Fom 2000	Total	From 2000	Total	From 2000
Sanitary landfill + indicator	46*	35	28	22	22	12
Sanitary landfill + urban solid waste management	5	4	2	2	70	42
Selective collection + indicator	19	18	18	18	11	11
Selective collection + urban solid waste management	6	6	4	4	23	22
Waste composting + indicator	40	35	33	30	23	20
Waste composting + solid waste management	79	51	21	17	23	15
Intermunicipal consortia + solid waste	2	2	0	0	0	0
Intermunicipal cooperation + solid waste	6	6	13	13	3	3
Public consortia + indicator	0	0	0	0	0	0
Public consortia + solid waste management	4	4	3	3	2	2
Reverse logistic + indicator	29	29	5	4	3	2
Reverse logistic + solid waste management	42	42	24	21	17	17

Table 8: Number of Papers Found in SLR until December 2018. Source: Authors, 2020.

As we can see, the component "public consortia" did not return any document related to the research. This situation required the search through other terms, such as "inter-municipal cooperation" and "inter-municipal consortium".

International consortia operation has a similar legal structure to private organizations, which is different from Brazilian public consortia. Such fact may have interfered in the search, once it was restricted to public cases (Ventura and Suquisaqui, 2020).

3.2 Experts' evaluation results

Table 9 illustrates the summary of the results from the experts' assessment through the AHP method and the subsequent consistency analysis according to the Saaty method. Based on the proposed methods, the tool was called Municipal Solid Waste Management Evaluation System (SAGReS in Portuguese).

Initiatives	Number of evaluations performed	Quantity of consistent results
Sanitary Landfill	6	2
Selective Collection	6	2
Composting	6	1
Public Consortia	7	2
Reverse Logistics	7	1

Table 9: Number of evaluations performed and consistent results. Source: Authors, 2020.

3.3 Result of the SAGReS tool design

The SAGReS model was designed in VBA programming in Excel and has the following structure: Cover, Home Page; How to use the tool?; Start Evaluation; Evaluation by initiatives; Definition of indicators; Final report in PDF. Figure 3 illustrates the interface for evaluating the "Sanitary Landfill" initiative.

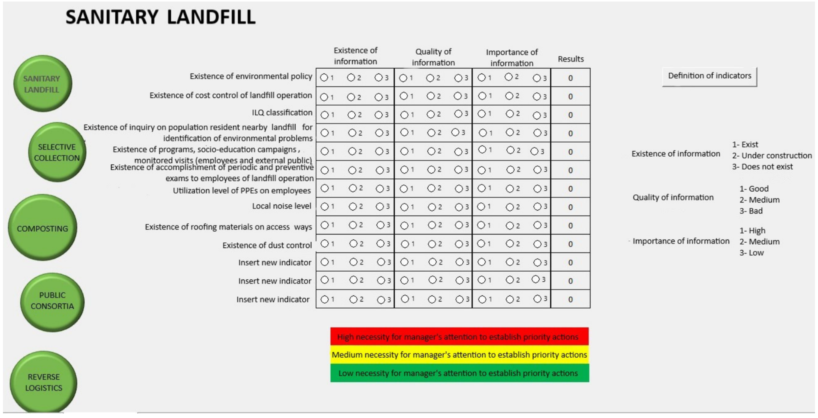
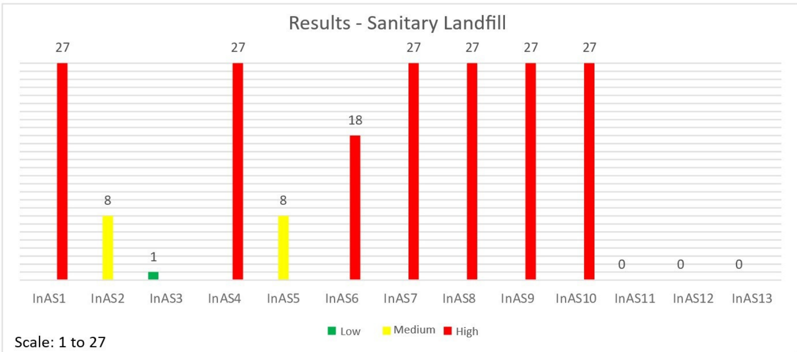


Figure 3: Visualization of the "Sanitary Landfill" Initiative applicable to Brazilian municipalities. Source: Authors, 2020.

The results for each initiative were saved into a single PDF document that provides an overview of the information considered by the SAGReS evaluator. The results of each initiative have a graphical representation, as shown in Figure 4.



Code	Indicator
InAS1	Existence of environmental policy
InAS2	Existence of cost control of landfill operation
InAS3	ILQ Classification
InAS4	Existence of inquiry on population resident nearby landfill for identification of environmental problems
InAS5	Existence of programs, socio-educational campaigns, monitored visits (employees and external public)
InAS6	Existence of accomplishment of periodic and preventive exams to employees of landfill operation
InAS7	Utilization level of PPEs on employees
InAS8	Local noise level
InAS9	Existence of roofing materials on access ways
InAS10	Existence of dust control

High necessity for manager's attention to establish priority actions

Medium necessity for manager's attention to establish priority actions

Low necessity for manager's attention to establish priority actions

Figure 4: Example of a result, obtained by the SAGReS application, for the "Selective Collection" Initiative. Source: Authors, 2020.

4 Conclusions

The conceptual model for SAGReS intends to assist public managers in the decision-making process to intensify the performance of the initiatives. Through the indicators, MSWM professionals can obtain a stricter view of specific actions to the improvement of the initiative's management.

A detailed description of the applied methods to achieve the purpose was necessary to clarify the methodological steps. The procedures generated a range of useful steps for future researches, operating as a working guide. The greatest challenges were, inevitably, the scarce amount of scientific and technical works regarding qualitative indicators, and, above all, the absence of instruments specifically developed to evaluate MSWM in Brazil.

New qualitative indicators can be inserted in SAGReS, differently from the quantitative methods, once they were not used in the conceptual model. Future researches may associate these indicators with the improvement of the tool and expand the MSWM evaluation. For the quantitative indicators, it is recommended that they are available on a digital platform and useful to all Brazilian municipalities. As an example, the indicators of the National System of Sanitation Information (SNIS in Portuguese) may be useful to the tool in its updated version.

The Integrated Management of Solid Waste (GIRS in Portuguese) encompasses a set of actions involving political, economic, environmental, cultural, and social dimensions, according to section 3 of the Brazilian NSWP. The suggested indicators complied with the concept of Solid Waste Management, which does not necessarily encompass the aforementioned dimensions.

The authors recommend the validation of SAGReS by other researchers before its application into the object of study. In this case, it is essential to provide the access of the manager to the tool, so this validation keeps in line with the municipal reality and can support the absence of data in the digital platform. Finally, we also suggest the proposition of an action plan to these managers at the end of the initiative's evaluations, so that decisions are guided by the results obtained in the tool.

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References

Baptista, V. F., 2015. 'As políticas públicas de coleta seletiva no município do Rio de Janeiro: onde e como estão as cooperativas de catadores de materiais recicláveis?', *Revista de Administração Pública***,** 46(1), pp.141-164.

Bereton, P., Kitchenham, B. A., Budgen, D., Turner, M., Khalil and M., 2007. 'Lessons from Applying the Systematic Literature Review Process within the Software Engineering Domain.', *The Journal of System and Software*, 80, pp.571-583.

Biolchini, J., Mian, P. G., Natali, A. C. C. and Travassos, G. H., 2005. 'Systematic review in software engineering', *System Engineering and Computer Science Department COPPE/UFRJ, Technical Report ES*, 679(5), pp. 45.

Bonjardim, E. C., Pereira, R. S. and Guardabassio, E. V., 2018. 'Análise bibliométrica das publicações em quatro eventos científicos sobre gestão de resíduos sólidos urbanos a partir da Política Nacional de Resíduos Sólidos – Lei nº 12.305/2010.', *Desenvolvimento e Meio Ambiente,* 46, pp. 313-333.

Conforto, C. E., Amaral, D. C. and Silva, S. L., 2011. '*Roteiro para revisão bibliográfica sistemática:* aplicação no desenvolvimento de produtos e gerenciamento de projetos.', Congresso Brasileiro de Gestão de Desenvolvimento de Produtos.

Fratta, K. D. S. A., Toneli, J. T. C. L. and Antonio, G. C. 2019. 'Diagnosis of the management of solid urban waste of the municipalities of ABC Paulista of Brazil through the application of sustainability indicators', *Waste Management***,** 85, pp. 11-17.

Ghesla, P. L., Gomes, L. P., Caetano, M. O., Miranda, L. A. S. and Dai-Prá, L. B., 2018. 'Municipal Solid Waste Management from the experience of São Leopoldo/Brazil and Zurich/Switzerland.', *Sustainability***,** 10, pp.14.

Jamieson, S. 2004. 'Likert scales: how to (ab)use them.', *Medical Education*, 38, pp. 1217-1218.

Keirstead, J. and Leach, M., 2007. 'Bridging the Gaps Between Theory and Practice: A Service niche Approach to Urban Sustainability Indicators.', *Sustainable* Development, 16, pp. 320-340.

Leite, I. M. S. and Freitas, F. F. T., 2012. 'Análise comparativa dos métodos de apoio multicritério a decisão: AHP, ELECTRE e PROMETHEE.'. In: *XXXIII Encontro Nacional de Engenharia de Produção*, Bento Gonçalves, Brazil.

Menikpura, S. N. M., Gheewala, S. H. and Bonnet, S., 2012. 'Sustainability assessment of municipal solid waste management in Sri Lanka: problems and prospects.', *Journal of Material Cycles and Waste Management.,* 14, pp. 181-192.

World Health Organization – WHO, 2015. 'Transformando Nosso Mundo: A Agenda 2030 para o Desenvolvimento Sustentável.' *Objetivos de Desenvolvimento Sustentável***.** Available at: https://nacoesunidas.org/wp-content/uploads/2015/10/agenda2030-pt-br.pdf. Accessed: 3 Mar. 2019.

Ospina, D. A. C., 2018. 'Indicadores para a integração da gestão das águas subterrâneas e no planejamento do uso e ocupação do solo', Master's dissertation, Federal University of São Carlos.

Pereira, J. C. R., 1999. *Análise de dados qualitativos*: estratégias metodológicas para ciências da saúde, humanas e sociais., EDUSP FAPESP, São Paulo.

Pereira, S. S., Curi, R. C. and Curi, W. F., 2018. 'Uso de indicadores na gestão dos resíduos sólidos urbanos: parte II – uma proposta metodológica de construção e análise para municípios e regiões: aplicação do modelo.', *Engenharia Sanitária e Ambiental,* 23(3), pp. 485-498.

Poletto, M., De Mori, P. R., Schneider, V. E. and Zattera, A.J. 2016. 'Urban solid waste management in Caxias do Sul/Brazil: Practices and challenges', *Journal of Urban and Environmental Engineering,* 10(1), pp. 50-56.

Presidência da República 2010, Federal Decree no. 7,404, Brazil. Available at http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/Decreto/D7404.htm. Accessed: 20 Feb. 2019.

Presidência da República 2010, Federal Law no. 12,305, Brazil. Available at http://www.planalto.gov.br/ccivil_03/_ato2007–2010/2010/lei/l12305.htm. Accessed: 20 Feb. 2019.

Saaty, T. L., 1991. *Método de análise hierárquica*. McGraw-Hill, Makron Books, São Paulo.

Saaty, T. L., 1977. 'A scaling method for priorities in hierarchical structures.', *Journal of Mathematical Psychology,* 15, pp. 234-281.

Suquisaqui, A. B. V., 2020. 'Elaboração e aplicação de ferramenta para avaliação da gestão e gerenciamento de resíduos sólidos urbanos para municípios brasileiros. Estudo de Caso: Municípios de Araraquara (SP) e São Carlos (SP). MSc Thesis, Federal University of São Carlos.

Suquisaqui, A. B. V. and Hanai, F. Y., 2017. 'Indicadores de Sustentabilidade Aplicados ao contexto de gestão e planejamento ambiental de cidades na concepção de metabolismo urbano.' Scientific Initiation (FAPESP), Federal University of São Carlos.

Ventura, K. S., 2009. 'Modelo de avaliação do gerenciamento de resíduos de serviço de saúde (RSS) com uso de indicadores de desempenho. Estudo de caso: Santa Casa de São Carlos – SP.' PhD thesis, University of São Paulo.

Ventura, K. S. and Suquisaqui, A. B. V. 2020., 'Aplicação de ferramentas SWOT e 5W2H para análise de consórcios intermunicipais de resíduos sólidos urbanos.' A*mbiente Construído,* 20 (1), pp. 333-349.

Ventura. K. S., Reis, L. F. R. and Takayanagui, A. M. M., 2010. 'Avaliação do gerenciamento de resíduos de serviços de saúde por meio de indicadores de desempenho.', *Engenharia Sanitária e Ambiental,* 15(2), pp. 167-176.

Zatta, F. N., Mattos, A. L., Oliveira, R. R., Freitas, R. R. and Gonçalves, W., 2019. 'Aplicação do *Analytic Hierarchy Process* na escolha de planos de saúde.', *Research, Society and Development,* 8(1), pp. 1-25.

Zhang, Y. and Guindon, B., 2006. 'Using satellite remote sensing to survey transport-related urban sustainability part 1: methodologies to indicator quantification.', *International Journal of Applied Earth Observation and Geoinformation,* 8, pp. 146-164.