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Urban Solid Waste Management Indicator Applied to a Case Study of Campinas, SP, Brazil

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***Abstract*— Solid waste management is a challenge for the municipalities in developing countries mainly due to the increasing generation of waste, without planning. This paper introduces the application of an alternative indicator methodology to urban solid waste management, as an integrated management tool – the Urban Solid Waste Management Indicator - in a case study of Campinas - São Paulo State, Brazil. Therefore, this paper deals with an extension of the range of sub indicators combined, in order to express with larger property the municipal conditions related to the topic, by the Indicator of Urban Solid Waste Management (I_{USWM}). Thus, the Campinas' I_{USWM} calculation with a base year as 2014 resulted on 5,42 – which are classified on regular condition by Batista & Silva (2006). Generally, the establishment of urban solid waste management tools contributes effectively as a measure instrument of sanitation provision, because it evidences the evolution or possible failures on management system.**

***Keywords*— urban solid wastes; indicators; sanitation; management tools**

1. Introduction

Indicators are necessary to organize data. Firstly, they can be used to assist in planning the future changes in solid waste systems and the environment, as well as to understanding and predicting local, regional, or global situations. Besides, indicators can be used to compare systems, either for a single area at different points in time, or between different areas. For this use, they can measure progress or provide benchmarks such as comparisons of quality of life [10].

Garn (1976) [8] affirmed that indicators can be used as tools for reducing the level of uncertainly about a decision. Furthermore, the value judgments are an inherent part of indicator development and the selection of what to measure depends of the study focus [11]

According to Ristic (2005) [13], from a policy perspective, there are two main orientations that can be identified in line with the priorities of waste management indicators: the minimization of environmental impacts of waste generation, with the overall objective of reducing and the reduction of resource use. Besides, basic indicators of integrated solid waste management applied to Europe can be: generation and treatment of sewage sludge; landfilling of biodegradable municipal waste; total waste generation and waste generation from household and commercial activities.

Another sustainable indicator suggested by Zabaleta (2008) [16] in a case study of Stockholm, that can be adapted to waste management are: poverty, governance, health, education, demographics, natural hazards, atmosphere, land, ocean, seas and costs, freshwater; economic development; biodiversity; global economic partnership; consumption and production patterns. Furthermore, the author affirms that it would be interesting to use more specific indicators designed for other steps or parts of the broad Waste Management Program (WMP) process: deciding the location of the plants, the transport routes, collection methods, etc.

Armijo *et al.* (2011) [1] listed a number of variables to the Waste Management Program in Mexico based on the model Driving Force-Pressure-State-Impact-Response (DPSIR), in terms of percentage, as persons that are not satisfied with the waste management system, recoverable material collected, total waste collected compared to the waste generated, coverage of collection service, homes that separate waste, population eager to participate in the separation of waste, comments in favor of recycling, recyclable waste recovered, total tones recovered compared to the total generated, persons that know the Waste Management program and composition of the waste collected.

When talking about urban solid waste management in Brazil, we have to attend to a diversity of aspects that involve them, well as the existence of a range of solid waste types, classified by the Federal Law nº 12.305/2010 [3] – that establishes the Solid Waste National Policy's (SWNP).

The Sanitation Municipal Plans (SMP) – required by Sanitation National Policy's (SNP) – were created considering a temporal horizon of twenty years and

they've to be updated periodically every four years. Thus, becomes crucial establish tools that allow the assessment of effectiveness in the sanitation services provision; in this case, applied to solid wastes.

This paper introduces the application of an alternative indicator methodology to urban solid waste management, as an integrated management tool – the Urban Solid Waste Management Indicator - in a case study of Campinas - São Paulo State, Brazil.

2. MATERIAL AND METHODS

The **Indicator of Urban Solid Waste Management** (I_{USWM}) was adapted of an overpast methodology, the Solid Waste Indicator – component of Environmental Sanitation Indicator (ESI) – concept introduced by CONESAN (1999) [6]. Despite the contribution of these applications, this work becomes significant because each locality shows own characteristics and different needs of priorization.

This paper deals with an extension of the range of sub indicators combined, in order to express with larger property the municipal conditions related to the topic. Furthermore, in this methodology opted to work with weighted average, instead of arithmetic average adopted by (ESI) - through the establishment of assigned weights according to community's needs, related to public health and environment.

Therefore, the assigned weights to each component selected to the Indicator of Urban Solid Waste Management (I_{USWM}) are showed at Table 01.

Table 01- Weights and Sub Indicators of I_{USWM}

Sub Indicators of (I_{USWM})	Weights
Indicator of Regular Collection (I_{RC})	0,25
Indicator of Urban Solid Waste's Final Disposal (I_{SWD})	0,15
Indicator of Final Disposal's Saturation (I_{DS})	0,15
Indicator of Selective Collection (I_{SC})	0,15
Indicator of Voluntary Delivery Points (I_{VDP})	0,05
Indicator of Reuse Domestic Solid Waste (I_{RDSW})	0,10
Indicator of Urban Cleaning (I_{UC})	0,10
Indicator of Reuse Solid Wastes of Urban Cleaning (I_{RUC})	0,05

Thus, the ponderations of the Indicator of Urban Solid Waste Management can be calculated by the following equations.

$$\mathbf{IUSWM = [(0,25 \times I_{RC}) + (0,15 \times I_{SWD}) + (0,15 \times I_{DS}) + (0,15 \times I_{SC}) + (0,05 \times I_{VDP}) + (0,10 \times I_{RDSW}) + (0,10 \times I_{UC}) + (0,05 \times I_{RUC}) / 100} \quad (1)$$

The methodology to estimate each component of IUSWM that varies on a scale of 0 (inadequate) to 10 (adequate) can be viewed below.

2.1 Components of Indicator of Urban Solid Waste Management - I_{USWM}

Indicator of Regular Collection (I_{RC})

This indicator quantifies households served by regular waste collection, in other words, the coverage of the collection service. It can be calculated by the equation:

$$I_{RC} = \frac{10\ x[(0{,}98\ x\ UHRC) + (0{,}02\ x\ RHRC)]}{TH} \quad (2)$$

Where,

- I_{RC} –Indicator of Regular Collection;
- UHRC – urban households served by regular waste collection (%);
- RHRC - rural households served by regular waste collection (%);
- TH – total of households served by regular waste collection (%).

Indicator of Urban Solid Waste's Final Disposal (I_{SWD})

This indicator was developed by CETESB – Company of Environmental Sanitation Technology – to qualify the final disposal of urban solid wastes, based on supervisions in each installation from the application of standardized questionnaires. The board bellow shows the classification established:

Board 01: Indicator of Urban Solid Waste's Final Disposal [5]

I_{SWD}	Classification	Values
0,00 a 7,00	Unsuitable Conditions (UC)	0,00
7,01 a 10,00	Suitable Conditions (SC)	10,00

Indicator of Final Disposal's Saturation (I_{DS})

This indicator demonstrates the life cycle of the final disposal sites and the needs of the new sites' construction. It can be calculated based on this criteria:

$$I_{DS} = \frac{10\ x\ t}{tmax} \quad (3)$$

Where,

- I_{DS} – Indicator of Final Disposal's Saturation;
- t - years to saturation of final disposal (years);
- t_{max} - life cycle of final disposal, (years).

Indicator of Selective Collection (I_{SC})

This indicator quantifies amplitude of households served by selective collection of recyclable wastes. It can be calculated based on the following criteria:

$$I_{SC} = 10x[0,98x\left(\frac{USCc}{USCm}\right) + 0,02x\ (\frac{RSCc}{RSCm})] \quad (4)$$

Where,

- I_{SC} – Indicator of Selective Collection;
- USCc - current urban selective collection (%);
- USCm - maximum of urban selective collection (%);
- RSCc - current rural selective collection (%);
- RSCm - maximum of rural selective collection (%).

Indicator of Voluntary Delivery Points (I_{VDP})

This indicator represents the population served by Voluntary Delivery Points (VDP) of Solid Wastes in Campinas, calculated by the following criteria:

$$I_{VDP} = 10\ x\ \frac{PVDP}{TP} \quad (5)$$

Where,

- I_{VDP}– Indicator of Voluntary Delivery Points;
- PVDP – Population served by VDP (%);
- TP – Total Population (%).

Indicator of Reuse Domestic Solid Waste (I_{RDSW})

This indicator shows the degree of solid wastes reuse collected on selective collection, whose importance is based on the requirement of Federal Law nº 12.305/2010 and it can be calculated by the equation:

$$I_{RDSW} = 10\ x\ \frac{RDSWc}{RDSWm} \quad (6)$$

Where,

- I_{RDSW} – Indicator of Reuse Domestic Solid Waste;
- RDSWc – current reuse of domestic solid wastes (%);
- RSDWm – maximum of reuse domestic solid wastes (%) – until 35%.

Indicator of Urban Cleaning (I_{UC})

This indicator quantifies areas served by cleaning of urban roads, both manual and mechanized and it can be calculated by:

$$I_{UC} = 10\ x\ \frac{UCc}{UCm} \quad (7)$$

Where,

- I_{UC} – Indicator of Urban Cleaning;
- UCc – current Urban Cleaning Solid Wastes (%);
- UCm – maximum of Urban Cleaning Solid Wastes (%).

Indicator of Reuse Solid Wastes of Urban Cleaning (I_{RUC})

This indicator quantifies the reuse solid wastes of urban cleaning by composting, after regular collect system, instead of final disposal.

$$I_{RUC} = 10\ x\ \frac{RUCc}{RUCm} \quad (8)$$

Where,

- I_{RUC} – Indicator of Reuse Solid Wastes of Urban Cleaning;
- RUCc – current reuse of urban cleaning (%);
- RUCm –maximum of reuse urban cleaning (%).

2.2 Analysis of Effectiveness of Urban Solid Wastes Management (I_{USWM})

To analyze the effectiveness of sanitation services provision related to solid wastes management by the Indicator of Urban Solid Wastes Management (I_{USWM}), it was applied an adaptation of the methodology established by Batista & Silva (2006) [2], showed on Board 02:

Board 02 – Analysis of Sanitation Conditions

SANITATION CONDITIONS	CLASSIFICATION
Unhealthy	0,00 – 2,50
Low Healthy	2,51 – 5,00
Average Healthy	5,01 – 7,50
Healthy	7,51 - 10,00

Adapted from BATISTA E SILVA, 2006 [2]

Therefore, to each update of Campinas sanitation diagnostics – fixed by Brazilian Law nº 11.445/2007 to be compiled in a period of four years – can be recalculated the I_{USWM}, to establish a sanitation services provision overview in the municipality, in compare with value of the reference year (2014).

3 RESULTS

The Table 02 and the Figure 01 show the values attributed to the Indicator of Solid Wastes Urban Management (I_{USWM}) variables to 2014 analysis.

Table 02 – Values atributted to variables of I_{USWM}

I_{USWM} Variables (units)	Values Measured	Values Attributed
Urban households served by regular waste collection (%)	100	-
Total of households served by regular waste collection (%)	100	-
Rural households served by regular waste collection (%)	50	
I_{RC}	-	**9,90**
Indicator of Urban Solid Waste's Final Disposal (I_{SWD})	9,8	**10,00**
years to saturation of final disposal (years)	1	
I_{DS}	-	**0,5**
current urban selective collection (%)	75,00	-
current rural selective collection (%)	0	
I_{SC}	-	**7,35**
Population served by VDP (%)	21,82	

Total Population (%)	100	
I_{VDP}	-	**2,18**
Current reuse of domestic solid wastes (%)	2,09	-
Maximum of reuse domestic solid wastes (%)	35	-
I_{RDSW}	-	**0,59**
Current Urban Cleaning Solid Wastes (%);	10,05	
I_{UC}	-	**1,00**
Current reuse of urban cleaning (%)	0	
I_{RUC}		**0**

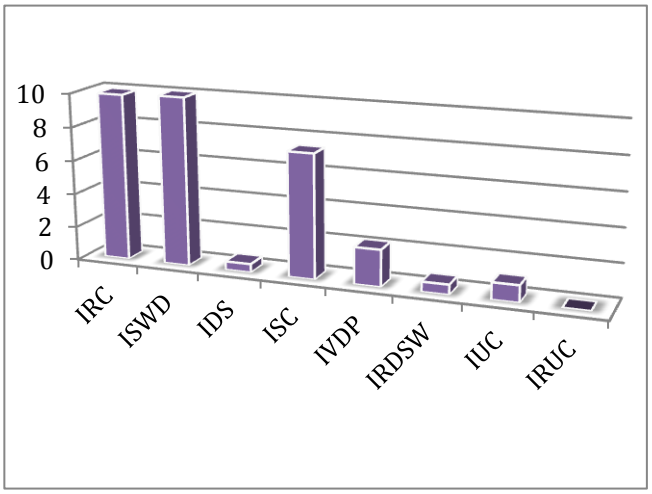

Figure 01 – Values Attributed to Variables of I_{USWM}

4 DISCUSSION

Through data collected in the diagnostic stage about the situation of Solid Wastes Management at Campinas, São Paulo State, it is possible to calculate the current Indicator of Solid Wastes Urban Management (I_{USWM}), in order to analyses the effectiveness of services provision, throughout the duration of the Sanitation Municipal Plan, with their calculation and comparison in each update of four years.

It is noteworthy that the others solid wastes contemplated on Solid Wastes National Policy (Law nº 12.305/2010), that are not public service responsibility and are borne by the generator, were not incorporated on Indicator calculations, due to the blank of quantitative management data. However, the inclusion of these future data on the indicator are fundamental to the construction of urban solid waste management diagnostics and consequently, action planning.

Thus, the I_{USWM} can be used as a useful tool on Municipal Sanitation Plans, once presents a panorama of sanitation services provision and evidences optimization needs, well as hierarchizes population sectors that should be priorized. Furthermore, the indicator can be used on each update of four years to guide the stakeholders.

Thus, the Campinas' I_{USWM} calculation with a base year as 2014 resulted on 5,42 – which are classified on regular condition by Batista & Silva (2006) [2]. This value is approximated to the Solid Waste Indicator (I_{SW}) of Campinas' Municipal Sanitation Plan, that was calculated on 5,93, well as the Environmental Performance Indicator (I_{EP}), regulated by Municipal Law nº 12.585/2006, which resulted on 5,8 on 2008.

On the other hand, quite different the "Indicator of Urban Solid Waste's Final Disposal – New Proposal" developed by CETESB (2013) [5], that recorded 9,8 and was framed as adequate conditions to urban solid wastes' final disposal. Well as the Solid Waste Management Indicator (I_{SWM}) adopted by "Coordenadoria de Planejamento Ambiental do Estado de São Paulo" (CPLA), that established 7,3 to Campinas, in 2012 – considered as average conditions.

A summary board and a graphic to the Solid Wastes Indicators of Campinas can be seen below (Board 03 and Figure 02).

Board 03 – Values of Solid Wastes Indicators of Campinas

Indicators	Values	Classifications	Criteria
I_{USWM} (2014)	5,42	Regular Conditions	5,1< v <7,5 [1]
I_{SW} (2013)	5,93	Regular Conditions	50,1< v <75,0 [2]
I_{EP} (2008)	5,80	Approved	v > 5,0 [3]
I_{SWM} (2012)	7,30	Average Conditions	6< v < 8,0 [4]
I_{SWD} (2011)	9,80	Adequate	v > 7,0 [5]

Criteria: Adopted by Batista & Silva (2006) [1] [2]; Municipal Law nº 12.585/2006 [3]; Municipal Sanitation Plan of Campinas (SVDS, 2013) [4]; CPLA (2012); CETESB (2013) [5]

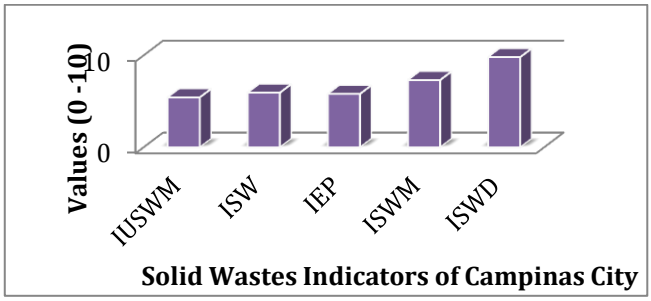

Figure 02 - Solid Wastes Indicators of Campinas City

In Taiwan, [9] developed an aggregated indicator to asses municipal solid waste collection efficiency based on multiple factors, since it is the major and more expensive task for local waste management authorities. The authors applied their indicators on 307 local governments and concluded that the model can be aggregated by other indexes and it can be adjusted to another countries based on the local operational environment.

Rogge & Jaegger (2012) [14] applied a similar model, based on technique Data Envelopment Analysis (DEA), to evaluate municipality waste

collection on 293 locations of Belgium. The authors concluded that the impact of both controllable variables - such as outsourcing decisions or characteristics of the collection and processing service - as non-controllable variables - the median income of the citizens, the demography of the citizens, the typology of the municipality or the population density - on cost efficiency needs additional research.

Furthermore, the indicator suggested in this paper compared to other countries - as local governments in United States, for example - is more robust, since they commonly use management cost per ton or cubic yard of waste and waste composition, according to [10].

5 CONCLUSIONS

The I_{USWM} allow describing an overview of sanitation provision and to promote a comparison between "future scenario", whether established actions on Sanitation Municipal Plans be adopted until 2033. Thus, the indicator works as a thermometer to effectiveness analyses of Plans, once the I_{USWM} is related to its ability to reflect reality and it assigns weights to achieve its goals.

Furthermore, through the study case of Campinas, it is possible to prioritize actions and programs to urban solid waste management that were forecasted by previous steps (diagnosis and prognosis).

Generally, the establishment of urban solid waste management tools contributes effectively as a measure instrument of sanitation provision, because it evidences the evolution or possible failures on management system.

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