A set of indicators for waste management programs

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Abstract. Proponents of initiatives for solid waste management require tools to assess the efficiency of their programs both environmentally and from the economic and social perspectives, and thus take the appropriate decisions to improve the performance. The objective of this study was to develop an assessment tool through a set of indicators integrated into a model that measures the effectiveness in which programs operate with solid waste management. The methodology consisted in adjusting performance indicators for waste management programs into a Driving Force-Pressure-State-Impact-Response (DPSIR) model. The most relevant indicators were chosen through a selection process that included opinions from experts, literature review based on relevance and applicability to different waste program settings. Eighteen indicators were selected and fitted into the DPSIR model. The model has indicators for causes, pressure, state, impact and response, where the status of each criterion is evaluated. This model will help decision makers optimize the performance of their waste management programs.

Keywords: indicators, waste management, program performance.

1. Introduction

The waste generation in Mexico is constantly increasing due to several factors such as growing population and industrial development, as well as changes in the consumer habits of the Mexican population with a culture that favours consumerism. To address the problems derived from solid waste generation, the Mexican government issued the General Law for the Prevention and Comprehensive Management of Waste (LGPGIR). This Law embraces a preventive approach to achieve its objectives which are based on the application of the principle of common but differentiated responsibility, of all social sectors that generate and manage waste.

At present the LGPGIR has two instruments to achieve proper waste management (WM): 1) WM plans, which are an ordered series of activities and operations necessary to achieve the objectives of the Law, and 2) WM plans, which are defined as instruments whose objective is to minimize the generation of waste and maximize the recovery of valuable waste [1].

In face of this challenge, diverse organizations have implemented WM programs in settings such as schools, NGO’s, and public institutions, among others, but the net results of these programs have not been measured. Thus in spite of these efforts the quantity of residues that end-up in the landfill have not decreased. This leads to questioning: Are the waste management programs in place successful? How do their promoters measure the performance of a WM program? Is it possible to integrate the performance indicators into a model? In an attempt to give response to the previous questions the objective of this work was to develop an instrument of evaluation for WM programs using a set of indicators integrated into a model.

2. Method
The construction of the evaluation model for Waste Management Programs (WMP) consisted of two main phases:

1) Construction and definition of indicators and,

2) Integration of the indicators into the Driving Force-Pressure-State-Impact-Response (DPSIR) model.

Next, these are phases are described.

2.1. Construction of indicators

The construction of indicators was carried out considering three sources of information:

a) Identification of criteria and variables described in specialized literature: More than 90 publications specialized on how to handle solid residues were studied; 21 publications were selected in which factors, criteria and variables for handling solid waste were clearly identified

b) Variables or elements proposed by experts: For the detection of the relevant elements of a waste management system, Briones [2] proposed the use of experts’ judgment, since they know details about the evolution and functioning of the system. Experts were chosen among academicians who have specialized on WM issues, authorities of the municipality that deal with WM, and members of NGO’s. The consultation with seven experts was done through a semi structured interview [3] that consisted of seven open questions aimed to detect the criteria and variables that could help to construct indicators for the evaluation of WMP.

c) Opinion of WM programs’ users: A questionnaire was developed [4, 5], validated and applied to a representative sample (n=95) [5, 6] of the community of El Sauzal de Rodriguez, located North of the city of Ensenada. This community was chosen for being the target for a WM Pilot Program of the Municipality. The instrument consisted of 22 questions focused on three themes; perception, knowledge, and attitude towards waste.

d) Construction of Indicators: a list of criteria was obtained derived from the three previous phases. This list was applied to construct the WM indicators, which seek to meet the established international standards. For the construction of each indicator evaluation ranges were defined (based on relevant information related to each variable). A scale of 3 values was used, where 3 is the ideal state or maximum value and 1 the minimum or worst case.

2.2. Integration of indicators into the DPSIR model

Based on the DPSIR model (Figure 1), a scheme was constructed in which the indicators for WM were integrated into each of the parts that compose the model.

![DPSIR Model](image)

Fig. 1: Driving Force-Pressure-State-Impact-Response (DPSIR).

The model has indicators for causes (driving forces), pressure, state, impact and response, where the state of each criterion is evaluated using equation (1).

\[
\text{State} = F(x) = [(-\text{cause}) + (-\text{pressure})] = \text{response}
\]

(1)

3. Results and Discussion

As result of the analysis, 18 indicators were obtained (Table 1), 16 are applicable to any WM system and two are flexible so they can be adapted to a particular WM program.

Table I. Indicators for WM Programs
### Criteria | Key | Variable
--- | --- | ---
Operation cost | CP | Average cost per ton ($/Ton)
Social perception | CS | % of persons that are not satisfied with the waste management system
Handling | ERS | % of recoverable material collected
 | ER | Total waste collected compared to the waste generated (%)
Quality | CDS | Average qualification to the WM system and collection service
Final disposal | DF | Comply with Mexican regulation NOM083ECOL
Resources | CA | Coverage of the collection service
Social participation | PC | % Homes that separate waste (of the total number of homes)
 | pp | % of the population eager to participate in the separation of waste
 | CR | % of comments in favor of recycling
Financial | AE | Financial autonomy
Recovery and treatment | ERS | % of recyclable waste recovered
 | ER | Total tones recovered compared to the total generated (%)
Communication | D | % of persons that know the WM program
Composition | CPR | Composition of the Waste collected (% each category)

For every indicator a descriptive card was elaborated, that included name, key, target, interpretation, variable components, measurement of the variables, sources, evaluation range and formula.

Using the indicators we developed seven schemes of the DPSIR model, one for each of the following parts of the waste system: Coverage, Generation, Cost, Diffusion, Resources, Efficiency and Composition. Each scheme integrated the relevant indicators that evaluate each part. An example for the part of coverage is shown in Figure 2 where five coverage indicators are integrated.

![Fig.2 Indicators of coverage integrated into the DPSIR model](image)

The indicators selected emerged from one or more of the sources used. For example, the criteria for coverage, generation and costs were suggested in the literature [8-12], by the experts and were also proposed by users according to the results of the questionnaires applied in this work. While the criteria of efficiency, composition and resources were recommended mainly by the experts. Several authors [4, 5, 8, 13-15] suggest the use of criteria for perception and social participation, even though only two of them actually use them [4-5]. From the literature reviewed only the OCDE [9] and Rodrigues [7] integrate the two approaches for the follow-up of waste programs, emphasizing the need to integrate social aspects into the WM systems.
assessment in order to have a more complete panorama of the problems generated by waste and of the variables that compose the system.

Each proposal for WM stresses different aspects. On one hand the proposal of the OECD [10] is focused on indicators for national, international and global use, which does not allow representing the real conditions at a municipality level; while Rodrigues [7] analyzes the elements that must be in place for municipalities’ WM good practices. This author also emphasizes the relevance to comply with coherent legal instruments and the importance to have trained personnel, financial resources and citizen participation. On the other hand the Mexican Office of Ecology in cooperation with the German Agency GTZ, propose a list of more than 100 indicators for the follow-up of WM Programs [1], nevertheless such amount of indicators is not practical in a real context. The enormous difference between one method and other, show the need to have an effective and simple tool that manages a general vision of the problem and faces the real waste problems at a local level.

In the present study the WM programs’ assessment indicators were formulated and are incumbent to the municipal governments. These indicators were based on the DPSIR model, on the literature and on the opinion of experts and users. It is important to note that this is not a simulation model; the DPSIR model and its set of indicators are useful to measure the actual performance of each of the components of an integrated waste management program. Thus it does not intend to simulate future scenarios but to bring detailed information to understand how a real WM program is actually performing. The method proposed in this work represents a grounded and a simpler way to measure the advance of a WM program by a smaller number of indicators that it uses in comparison to the other described models. The construction of indicators reported in this work considered both social and technical aspects of WM, which creates a more realistic model that is more grounded on the context where the WM program is to be implanted.

4. References

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