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A multicriteria DM framework in the eco-management of operations: a case of organic waste reuse

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Abstract

This article presents a case study for decision-making regarding the reuse of organic waste. It introduces a framework for eco-management operations using a multi-criteria approach based on the perspective of organizational stakeholders. Applying the Analytical Hierarchical Process (AHP) it was possible to prioritize options in an environmentally sustainable and economically viable way. The framework integrates several criteria, such as environmental impact, economic viability, social acceptability and regulatory compliance, to provide a comprehensive and robust assessment of alternatives. A decision model is developed to identify the main concern attributes for determining the most suitable process for organic waste treatment. Empirical data has been collected from a central supplier located in the metropolitan region, in Chile. This supplier site contributes as an externality approximately 50% of the waste of the neighborhood where it is located and approximately 10% of the operational costs for the organization. The procedure is followed according to the methodological approach of the study including the experience and perspectives of the actors of the organization. The case study results indicate the efficacy and practicality of the multi-criteria framework in supporting eco-management decision-making processes.

Keywords: Multicriteria decision support; AHP; Organic waste reuse; Eco-management operations.

1. Introduction

The proper management of organic waste has become a critical issue globally due to its environmental and economic impact. [1]**.** At the international level, two primary instruments have been used to regulate environmental management systems: ISO 14000 standards and European regulation EMAS 761/2001, that stands for Eco-Management and Audit Scheme. These instruments invite organizations to implement environmental management systems, using the PDCA methodology (plan, do, check, and act). While not mandatory, they allow organizations to demonstrate their environmental responsibility and can lead to operational cost savings [2], [3] and [4]. At a national

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level, Chile has a Policy of Integral Management of Solid Waste". (PIMSW) that aims to build and implement solid waste information systems, from years ago. All the same, it has been identified a municipal solid waste annual growth, along with the National Commission for the Environment [5] and less than 1% of municipal solid waste in Chile undergoes a transformation process. Thus, it is perceived the need for eco-environmental responsibility from solid waste generators to minimize externalities generated in their manufacturing or service processes [6] and [7].

Hence, an effective eco-management framework is essential for organizations to ensure sustainable waste management practices that prioritize environmental protection while being economically feasible [8]. This is where the multicriteria decision-making framework, comes in, which integrates various criteria to provide a comprehensive and robust assessment of different alternatives for organic waste reuse. It considers criteria such as environmental impact, economic feasibility, social acceptance, and regulatory compliance, making it a comprehensive tool for eco-management decision-making. To demonstrate the applicability of the framework, a case study was conducted on organic waste reuse in a municipal setting. The case study of organic waste reuse (transformation process) is territorially framed in the metropolitan region in Chile, where 43% of the country's municipal solid waste production is concentrated, selecting the main horticultural trade center where the composition of solid waste is predominantly organic matter (95%), making it a natural source for carrying out valorization operations. An AHP [9] decision model was designed to facilitate the selection of the most appropriate alternative for transforming organic waste for a horticultural trade center. The methodology also considers the perspectives and experiences of stakeholders within the organization, making it a more holistic approach to eco-management decision-making. By considering multiple criteria, the framework provides a more comprehensive assessment of different options for organic.

2. The problem situation and the case study

The concern about the reuse of organic waste (transformation process) is territorially concentrated in the metropolitan region of Chile and refers to the principal fruit and vegetable trade business, where the cost of transportation would not be a relevant variable for implementing the transformation process.

The establishment in study sells about 5,500 tons/day of fruit and vegetable products corresponding to 60% of these transactions in the country and 90% in the local city. The production activities are developed in an area of 310,000 m^2, with 4,100 jobs sales and employment for 5,000 people.

The operational annual costs amounted about $ 2 million, 60% are at the disposal of solid waste and cleaning. Empirical data have been compiled from the central supplier located at the Metropolitan Region in Chile. This supplier, contributes as an externality with approximately 50% of the waste of the locality and for the organization approximately 10% of operational costs. Figures 1 and 2 detail the production process and the discrimination of the operational costs of the fruit and vegetable trading Centre under study.

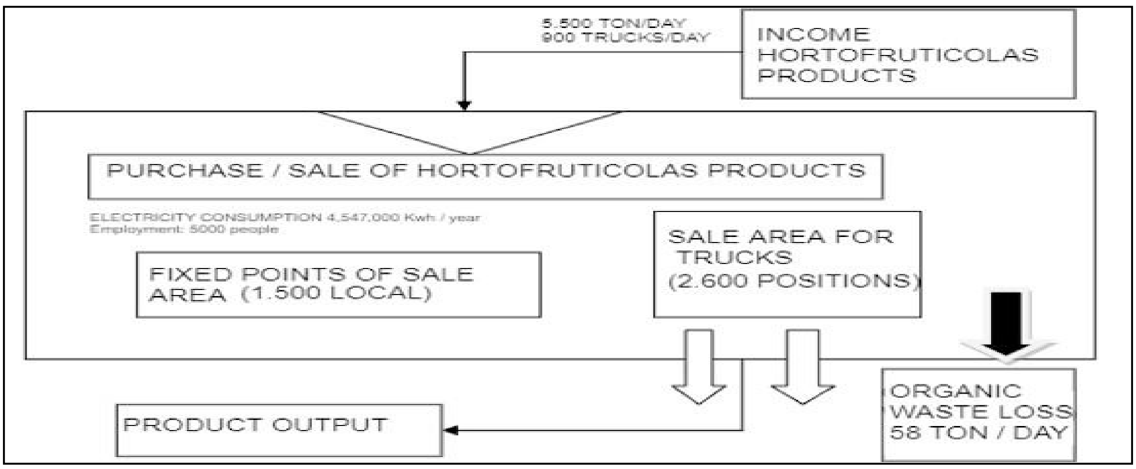


Fig.1.Production process scheme for fruit and vegetables trade centre

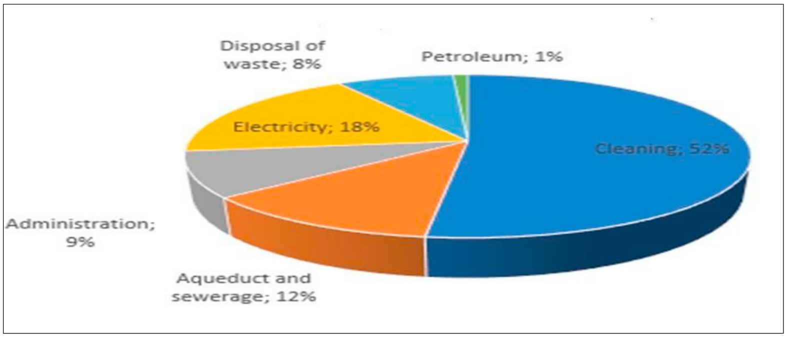


Fig.2 Operational costs for fruit and vegetable trade center

At present, the center is considering the investment in new technologies and processes for the transformation of organic waste and there is confidence that this is a way for improvement.

Organic waste recovery operations

The transformation of organic waste is currently a cutting-edge process in developed countries and is being promoted in less developed countries. According to CONAMA in Chile, the amount of organic matter managed is 32,000 tons per year (90% composting, 2% co-incineration and 8% vermicomposting and others). Table 1 explains succinctly the recovery techniques applied nationally and internationally, listing advantages, disadvantages and products of the transformation process, which in turn form the alternatives analyzed in the case study. There are 5 main process clusters to be considered in the process.

Table 1. Operations of valorization applied to organic material

Transformation Process	Advantages	Disadvantages	Products
Pellets: the organic material is triturated, mixed dried compacted and packed	Continuous system of loading of raw material Reduced space required	Medium sized investments Requirements of technical skills	Concentrated food
Worm composting: raising worms in captivity using organic material	Low level of investments High demand of worms (Europe) Experience in the Country No qualified workers Reduced implementation time	Large areas required Large maturation time Emission of disagreeable smell Source of viral vectors	Soil recovery Fertilizer (agriculture, ornamental plants) Liquid fertilizer Worms, worm meals & earthworm
Compost: Aerobic process of humidifying organic material	Experience in the Country implementation time Low level of investments	Large areas required Emission of disagreeable smell Source of viral vectors	Fertilizer for parks & urban gardens Soil recovery Fertilizer for agriculture
Biogas: produced by the decomposition of organic material	Reduced space required Low contamination Variety of sub-products	Large level of investment Low local experience Professional people required High construction time Specific care in the production required	Methane gas Electricity Heating Liquid fuel Fertilizer for agriculture and ornamental

Plasma: biochemical transformation process	Reduced space required Low contamination	Large level of investment Low local experience Radioactive waste produced Professional people required	Liquid fuel Fertilizer for agriculture Gas composed of monoxide of carbon and hydrogen

3. The Case Study Approach

The problem to be addressed is associated with decision making for the selection of the most favorable alternative for the transformation of organic waste for the fruit and vegetable trading center, which, in accordance with the methodological approach of the study, includes the experience and perspectives of the actors of the organization (qualitative analysis). For this purpose, the analytical hierarchy process (AHP) developed by Saaty [10], [11] & [12] was chosen as the method of analysis, which allows the design of models based on the definition of criteria and preferences, and which in an environment of certainty allows the inclusion of quantitative data relating to the decision alternatives.

For the case study, through surveys, interviews and training workshops on organic waste processing techniques with the administrative and operational managers of the fruit and vegetable trading center, a hierarchy model was built, defined in five levels (see Figure 3). The analysis includes the experience and perspectives of stakeholders in the organization.

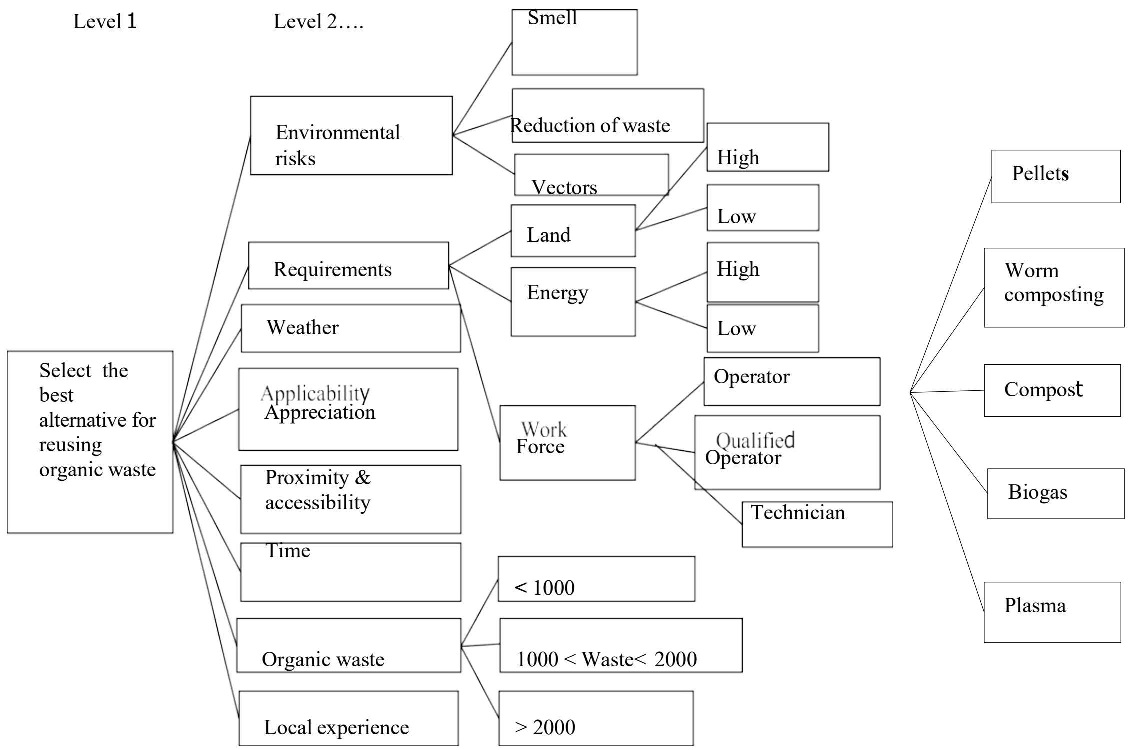


Fig.3 Proposed hierarchy model for reusing organic waste

The first level relates the desired overall objective, the next level relates the comparison criteria to the contributing and interesting aspects of the processing technique. The third and fourth levels defined the sub-criteria that influence the progress of each of the criteria on the top level. The last level was the alternatives for the reuse of organic waste. The criteria and sub-criteria were defined as follows :

Environmental risks: refers to the assessment of the proliferation of odors, vectors and efficiency of the technique in reducing organic waste.
Requirements: analysis of the land, energy and manpower available for the implementation of the different alternatives.
*Weathe*r: evaluation of processing techniques in cold-rainy, cold, temperate and hot climates.
Applicability appreciation: evaluates the appropriateness of one alternative over the other, from the perspective of resource availability, space required, and cost-benefit.
*Organic waste***:** associated with the capacity of the process.
Proximity and accessibility: in terms of the space required for the development of the alternative, the relevance of the proximity and accessibility factors is evaluated.
Time: duration in terms of time for the implementation and start-up of the alternative.
Local Experience: it assesses the country's experience in the recovery operation

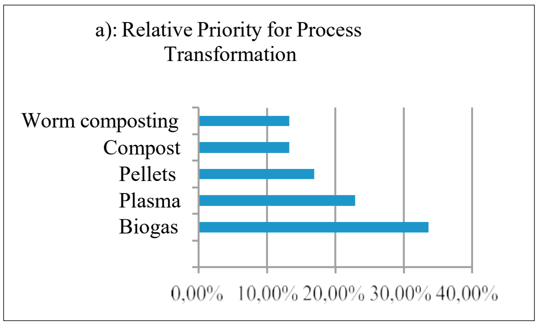
The evaluation process

The aim is to determine the most suitable process to transform organic waste and endow it with new technology. The initial part of the study is to identify the significant attributes that would influence the transformation process. A team of experts composed of plant managers, project engineers, members of senior management and operators (12 people) was formed, who will be able to give their judgement on what are the most relevant aspects to consider in the selection of a process and how appropriate the available alternatives are. The group of experts underwent the hierarchy structure. A paired comparison was made using judgements of each of the participants and weighted together to obtain a single overall model consisting of a priority matrix at each level of the hierarchy structure, representative of the group's opinion.

Once the judgements of each expert were obtained on the comparisons set out in the AHP model [8], a single overall model was formed using all the information provided by the panel. The final values were derived using the geometric mean of the judgements.

Results

A numerical score is obtained from the expert panel (with reference to Saaty´s scale) according to the accomplishment of the objective requirement. This can be summarized and graphically represented in figure 4 a) related to process transformation and b) to the aspects priority.



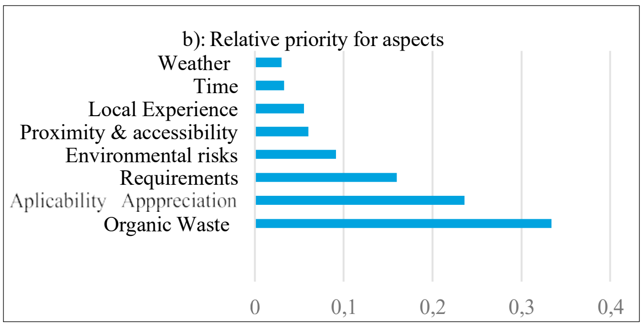


Fig.4. (a): Relative priority for process transformation, (b) Relative priority for aspects

With the above information, the managers of the fruit and vegetable trading center have parameters to select the most suitable organic waste processing alternatives to be applied for the case study.

Result analysis

The application of AHP suggests the use of Biogas and Plasma as the best 2 alternatives. Though, in order to have a more confident selection. a financial analysis was carried out. The equivalent annual cost (EAC) was used as shown in formulas 1&2.

$$EAC = CVC\ [(r\ (1+r)\ \hat{}\, n) / ((1+r)\ \hat{}\, n - 1)] \tag{1}$$

&

$$CVC = \\ = \sum_{i=0}^{n} \frac{C_i}{(1+r)^i} \tag{2}$$

Where,
CVC = the current value of the cost flow (CVC)
C_i = cost in year i (includes investment costs, maintenance and operation)
r = discount rate (15% in this case)
n = evaluation horizon (15 years, in this case)

Table 2 shows the results of the annual cost for the two main concern alternatives. It reveals that the best alternative for this case is the use of Biogas

Table 2. Annual cost for alternatives

Alternatives	**Investment Costs**		**Maintenance and Operation Costs**	
	CH$/kW	USD/kW	CH$/kW	USD/kW
Biogas	1.746.400	3.700	141.600	300
Plasma	5.280.736	11.188	244.024	517

The graph depicted in figure 5 shows the equivalent annual cost for these two alternatives.

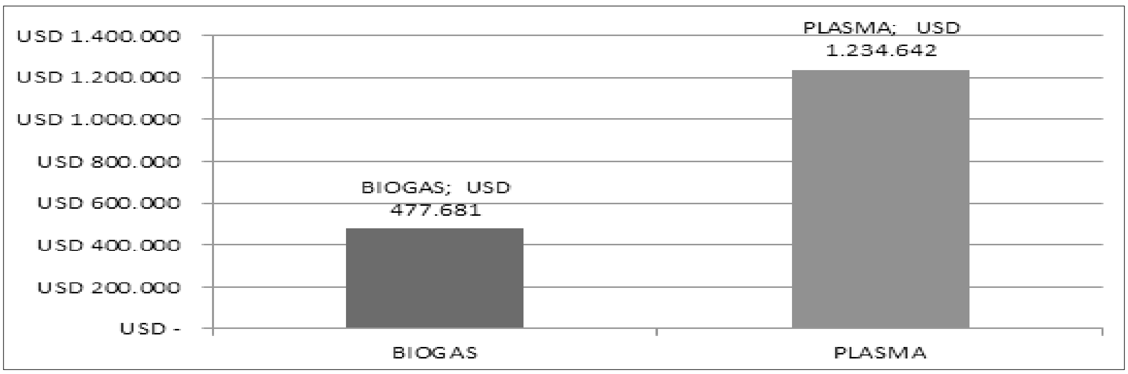


Fig.5. Equivalent annual cost for alternatives

The quantitative analysis recognizes that, with the reduction of 23% of the operational costs of the Centre of horticulture, would be potentially viable the implementation of the recovery process through the technique of Biogas, which also would be possible to provide an income associated with the transformation of organic waste.

Therefore, the authors recommend developing a next stage of a feasibility study in order to promote and encourage this community with environmental responsibility.

4. Conclusions

A Multicriteria model allows to examine in detail the elements of a problem, which makes it possible to find the solution that best meets a goal in a rigorous manner. The research described in the paper it can also be viewed as a contribution to waste management domain supported be movement called “green informatics” or green IT” [13].

AHP turned out to be a useful tool to structure and order the decision problem, identifying the aspects that influence directly in the selection of alternatives for the reuse of organic waste, thus strengthening the relevance of the theory of decision-making with incentive to the "eco-management".

In the case study, the transformation capacity (33%) and the perspective of the applicability appreciation (23%) were identified as relevant for the development of recovery operations applied to waste organic.

This level of disaggregation obtained in the hierarchy analysis helps decision makers in defining the prioritization of actions, policies, and resources

The results of the case study indicate that the MCDM framework can offer a practical tool to support ecological management decision-making processes. By taking into account multiple criteria, the framework provides a more comprehensive assessment of different organic waste reuse options.

Acknowledgements

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