Micro Location of a Recycling Plant for Multilayered Packaging in The State of Tlaxcala, Through the Delphi and AHP Techniques

Ivonne Maldonado Hernández • Héctor Domínguez Martínez • Jorge Luis Castañeda Gutiérrez • Kathy Laura Vargas Matamoros

Postgraduate Studies and Research Division, Technological Institute of Apizaco, Technologic National of Mexico, Tlaxcala, Mexico
maldonadohernandez.ivonne@gmail.com

Abstract. The recycling of multilayer containers has enormous potential in Mexico, due to the fact that, on the one hand, there is currently a high percentage of waste from it and, on the other hand, the product obtained as a result of this process is cellulose, which has an attractive level of demand for the practice of recycling in general. Another singular fact is the fact that the State of Tlaxcala has a privileged location for the establishment of production plants of different types and the recycling of multilayer containers is no exception, for which reason it has been proposed to establish a plant in the state of Tlaxcala, having the task of defining where in the State to establish the plant. This article deals with a proposal for the micro location of a multilayer packaging recycling plant in the State of Tlaxcala. This proposal is based on two techniques used to establish the micro location. These techniques are the Delphi technique, accompanied by the methodology for decision-making called the analytic hierarchy and analytic network processes for the measurement of intangible criteria and for decision-making (AHP), which are combined to achieve the stated objective.

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1. Introduction:

The State of Tlaxcala is located within the coordinates 19.318164, -98.236752 Being a place located in the center of Mexico, which potentializes it as a very good area for logistics strategies, that is why it has been proposed as a location area for a multilayer packaging recycling plant, having as a point to treat the micro location within this place. There are different methods to perform a micro-localization of the plant, however, some turn out to be very subjective, in this work a method is proposed where the Delphi technique and the analytical hierarchical AHP technique are combined.

The Delphi technique is a tool developed at the Rand Corporation by Norman Dalkey and Olaf Helmer, which consists of surveying a group of experts iteratively and anonymously to obtain their criteria and proposals for a given topic, seeking to agree on the opinions and reaching a point of convergence, the technique has been used for various purposes, to name a few. Climent *et al.* (2014) Whose work aims to carry out a strategic diagnosis of insertion companies in Spain by using the Delphi method or questionnaire to experts, supported by analysis DAFO to obtain the qualitative technique already mentioned, To which he concluded that companies with low levels of training, both in general and in management, and that depend financially on public administrations, have positive expectations derived from the economic viability of the projects on which they are based and the growth possibilities. Sierra *et al.* (2012) He used the Delphi method of a quantitative-descriptive type to characterize the situation of the tourist development of the city of Maracaibo where they concluded that the recognition of tourism is a complementary and not a main economic activity, elaborating a plan of tourist development in which the value of its resources, quality of equipment and infrastructure are contemplated.

Silva *et al.* (2002) in his research to assess the level of satisfaction of users of the paved road network in the State of Guanajuato, considered as an additional criterion to those already existing to make the decision on the investment strategy in road maintenance using the Delphi technique, selecting and ordering the significant variables and defining their importance weights, concluding that the user's opinion is an input of great importance for decision-making on conservation strategies and even agreement with the highway administration to apply the methodology used.

On the other hand, the Analytical Hierarchy Method, was developed in by Dr. Thomas L. Saaty, this method is an instrument that evaluates alternative solutions to problems, using solid mathematical foundations, which makes it very useful in terms of decision-making and has been used for plant location purposes, such as:

Bacalla *et al*. (2014) says that the location of a plant is the process of choosing a geographic location to carry out the operations of a company, in which two groups of factors are considered: Quantitative, which are easy to quantify and qualitative, which are less tangible, difficult to quantify, the evaluation of the latter depends on the analyst's appreciation, maintaining a tinge of subjectivity, which means that no model used guarantees that the chosen place is the optimum. In his study he exposes and demonstrates the contribution of the Analytical Hierarchical Process (AHP) in the task of optimizing the location of an industrial plant, compared to other methods. Of which its result is that the Analytical Hierarchical Process (AHP), in comparison with the other plant location models, is a multi-criteria model that allows an adequate evaluation of qualitative factors, optimizing the location process of an industrial plant, It has a rating scale that allows a decrease in the degree of subjectivity, in the evaluation of qualitative factors, and also allows an adequate weighting of locational factors among themselves, improving the location criteria of an industrial plant. Cock & Rendon, (2009) In his project of a manufacturing plant, he aims to address the problem of locating this plant, involving qualitative and quantitative techniques through the AHP technique, complemented with a mathematical model using Solver for Excel, which concluded that the approximation of the result served to understand the complexity of the problem and was also a motivational element in the search for solutions and served as a good approximation in the search for optimal locations.

Medina *et al*. (2009) mentions that the selection of a new plant is very important in the first stages of an investment project or feasibility study, since it has a great impact on future production costs, organization and profitability. of the company. In his project to locate a petrochemical and chemical plant, whose objective is the analysis of the different characteristics according to the process and its products, with which parameters I use the Analytical Hierarchy Process (AHP) technique for its micro level, the results obtained are promising enough to continue advancing in quantitative aspects derived from this project and that allowed it to make a decision with a reasonable basis for its final location.

2. Methodology:

2.1. The Delphi technique

The Delphi technique has as a methodological basis, the anonymous application of a questionnaire which may consist of one or several questions, depending on the object of study, there is no rule to determine the number of questions, to subsequently carry out the analysis, the methodology of this technique is summarized in Figure 1.

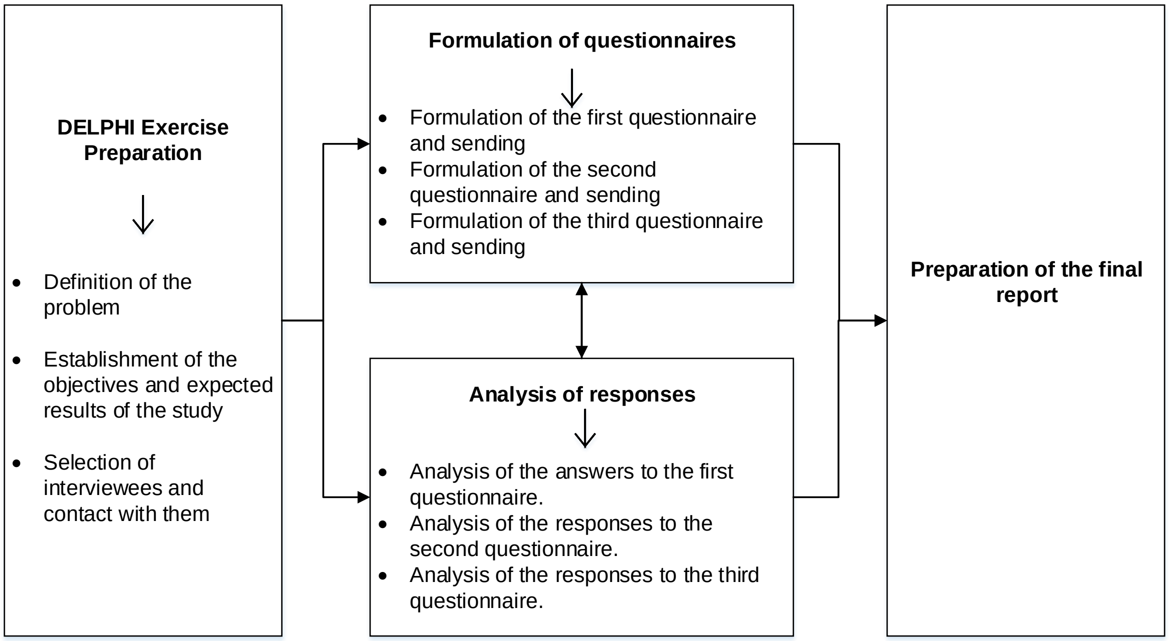

Figure 1. Delphi method methodology.
Taken for: Sánchez, G. Participatory Techniques for Planning (2003). chap. 13. Page 127.

2.2.The AHP Technique:

The AHP method has the methodology of taking the alternatives for solving problems and evaluating them through a series of evaluation criteria, these criteria are evaluated from a series of mathematical steps, the methodology is summarized in figure 2.

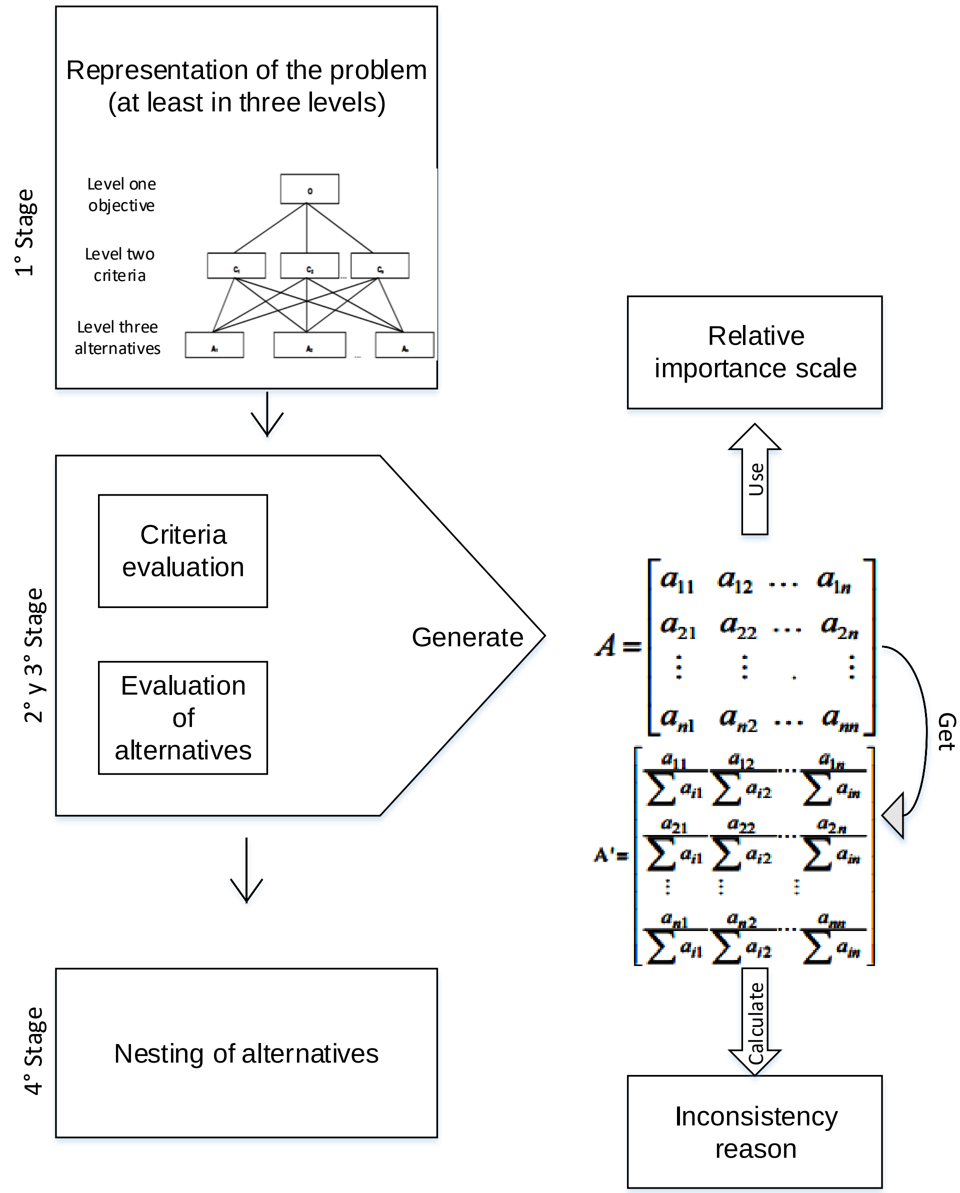

Figure 2. AHP method methodology.
Taken for: Sánchez, G. (2003). Participatory Planning Techniques. chap. 16. Page. 167.

than 10%, it can be said that the matrix is consistent, then make the final evaluation with all the weights w obtained.

Regarding mathematical evaluation, it consists of establishing a Matrix A, first with the evaluation criteria and then with the evaluation of each solution alternative, with respect to each evaluation criterion, to obtain the evaluation weights w, for this, it is necessary to determine the congruence of the matrix arrangement by obtaining an IR inconsistency index, if this index is less

The corresponding steps are shown below:

1. Prepare matrix arrangements A where:

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdot & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad \textbf{(1)}$$

It presents the property that $a_{ji} = \frac{1}{a_{ij}}\ y\ a_{ii} = 1$

2. Normalize matrix A, where:

$$A' = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \cdots & \frac{a_{1n}}{\sum a_{in}} \\ \frac{a_{21}}{\sum a_{i1}} & \frac{a_{22}}{\sum a_{i2}} & \cdots & \frac{a_{2n}}{\sum a_{in}} \\ \vdots & \vdots & . & \vdots \\ \frac{a_{n1}}{\sum a_{i1}} & \frac{a_{n2}}{\sum a_{i2}} & \cdots & \frac{a_{nn}}{\sum a_{in}} \end{bmatrix} \quad \textbf{(2)}$$

3. Obtaining the weights w of the criteria and alternatives evaluated in matrix A, which is calculated by obtaining the average of each row of the normalized matrix A':

$$w = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \cdots & \frac{a_{1n}}{\sum a_{in}} \\ \frac{a_{21}}{\sum a_{i1}} & \frac{a_{22}}{\sum a_{i2}} & \cdots & \frac{a_{2n}}{\sum a_{in}} \\ \vdots & \vdots & . & \vdots \\ \frac{a_{n1}}{\sum a_{i1}} & \frac{a_{n2}}{\sum a_{i2}} & \cdots & \frac{a_{nn}}{\sum a_{in}} \end{bmatrix} = \begin{bmatrix} w_1 \\ \\ w_2 \\ \\ w_n \end{bmatrix} \quad \textbf{(3)}$$

4. Obtain the IR inconsistency index to validate the weights w.

The RI inconsistency ratio is calculated using the following expression:

$$RI = \frac{IC}{CA} \quad \textbf{(4)}$$

Where:
IC = is the consistency index.
CA = is the random consistency.
The calculation of the IC consistency index is obtained as follows:

$$IC = \frac{\lambda_{max} - n}{n-1} \quad \textbf{(5)}$$

λ_{max} : is the average characteristic value.
n: is the size of the array.

To calculate λ_{max} AW is multiplied, obtaining an estimate of λ_max W that is:

$$AW = \lambda_{max} W \quad \textbf{(6)}$$

Finally, the final evaluation is performed, multiplying the criteria weights by the evaluation weights obtained from each alternative under each evaluation criterion.

3. Results

In principle, the criteria for evaluating alternatives have been established using the Delphi technique, under the following parameters:

1. The Delphi technique has been applied to eight experts in logistics and who know the existing panorama in the State of Tlaxcala.
2. The question applied to the experts for the analysis is:

Taking into consideration land options to build (locate) a multilayer packaging recycling plant in the State of Tlaxcala, considering as main assumption that the lands have similar dimensions that meet the needs of space and also that the options in question have equal conditions in terms of services such as electricity, water, drainage, telephone, among other basic services. What would be the main criteria that you would take to make the decision to locate the plant? List the options you consider in order of importance, with 1 the most important option and 4 the least important.

From the Delphi analysis, the following evaluation criteria were obtained in order of importance:

a. Land cost.
b. Communications infrastructure.
c. Government facilities to locate.
d. Close to urban areas.

As a next point, the location alternatives are shown, obtained through the investigation of land available in the municipalities of Tlaxcala with better conditions based on the established criteria, having four alternatives with location in the municipalities of Tlaxcala, Ixtacuixtla, Calpulalpan and Chiahutempan. The locations within the State of Tlaxcala are shown in figure 3., and the location coordinates of each alternative are shown in Table 1.

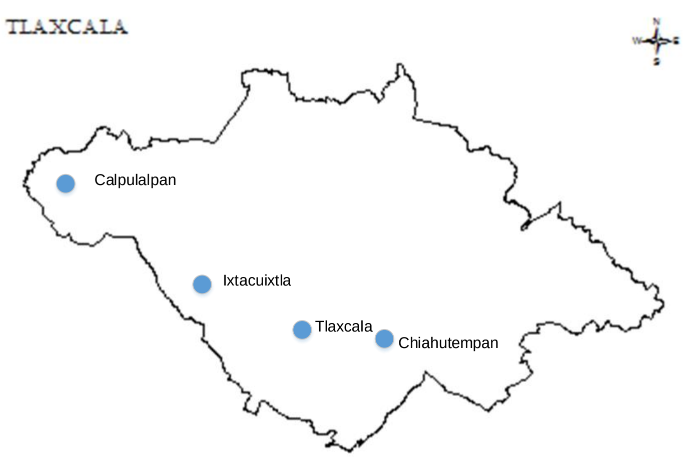

Figure 3. Locations of the municipalities of alternative locations in the State of Tlaxcala.
Taken for: Own elaboration with data from INEGI, 2018.

Table 1. Location coordinates and cost in Mexican currency of the location alternatives.

Micro location alternatives	Latitude	Length	Costs
Tlaxcala	19.297249	98.256051	$1,200,000
Chiahutempan	19.317117	98.20948	$1,900,000
Ixtacuixtla	19.311162	98.389543	$1,300,000
Calpulalpan	19.580674	98.547761	$1,548,000

Taken for: Google Maps, 2020.

Once the evaluation criteria have been established, as well as the corresponding alternatives, the representation of the problem is established, which is shown in Figure 4.

After representing the problem, the corresponding calculations are carried out to determine the best alternative, the summary of these calculations is shown in table 2.

Discussions:

After having put in place the proposed methodologies, it is concluded that the best option is to locate the plant in the micro-location alternative corresponding to that of the municipality of Tlaxcala.

On the other hand, it can also be concluded that the methodological proposal in this work can be successfully replicated in other contexts and micro locations of plants of different types, this is due to the fact that the Delphi technique frames the evaluation criteria in a more effective way by adjusting to the panorama and the current environment of the place where the micro-location is made, , in addition to being accompanied by a proven method of localization such as AHP, which leads to more efficient results compared to other methods.

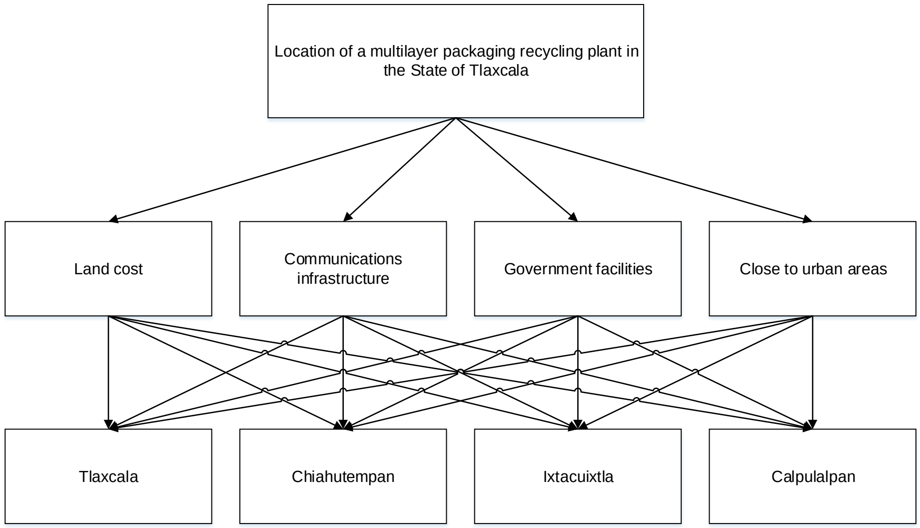

Figure 4. Graphic representation of the micro localization problem.
Taken for: Own elaboration, 2020.

Table 2. Concentration of the calculations of the PHP technique.

	Option ratings					
Micro location alternatives	**Criteria weights**	**Cost**	**Infrastructure**	**Government facilities**	**Close to population**	**Final score**
Tlaxcala	0.5847441	0.57429006	0.413182832	0.111874237	0.30046041	0.45918269
Chiahutempan	0.19747224	0.22206728	0.413182832	0.111874237	0.34434078	0.25727427
Ixtacuixtla	0.12544684	0.12635227	0.101867336	0.424908425	0.27584657	0.17277393
Calpulalpan	0.09233681	0.0772904	0.071767001	0.351343101	0.07935224	0.11076911

Taken for: Own elaboration, 2020.

Corresponding Author:
Ivonne Maldonado Hernández, Eng.
Postgraduate Studies and Research Division,
Technological Institute of Apizaco, Technologic
National of Mexico, Tlaxcala, Mexico.
E-mail: maldonadohernandez.ivonne@gmail.com

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