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Multi-attribute evaluation and selection of sites for agricultural product warehouses based on an Analytic Hierarchy Process

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ABSTRACT

Site selection for companies is a complex and unstructured problem that must be analyzed carefully and properly, since a localization error could drive to bankrupt. This problem has been discussed widely and effectively using multi-attribute methods in a manufacturing context, but it has been little studied in agribusiness. The goal of this work is a methodological approach oriented to evaluate optimal locations of new agri-food warehouses. Furthermore, a literature review is developed, analyzing the location problem and the attributes and techniques most widely used applied to agribusiness, and a case-study is presented in order to exemplify the methodological proposal. The multi-attribute technique called Analytic Hierarchy Process has been selected as the basis for the research, and it is applied to the real case study analyzed: the selection of a site for a new banana distribution warehouse. Six generic criteria have been analyzed: accessibility to the area, distance, cost, security of the region, local acceptance of the company, and its needs. The process includes the assignment of attributes to each one of the generic criteria, as well as the assessment of their importance levels. Three different areas of Guadalajara, Jalisco, and Mexico DF have been evaluated for the case-study, and the methodological proposal has been utilized to determine the best option.

1. Introduction

1.1. Research context

One of the most important and difficult decisions posed to an investor who wants to promote a new company building is the identification of the location. The same problem is faced when an investor already well established in the market wishes to expand the business and seeks for a location for a new plant or branch. In both cases, the investor faces the same problem; however, those getting involved in this process for the first time are the ones who perceive a higher sense of risk and uncertainty when making this kind of decisions.

Since this kind of decision-making is not too common and always presenting special features, it can be asserted that it is a complex and unstructured problem, because there is no consensus among the experts regarding the multiple aspects that must be taken into account, the techniques to be used, and who are the responsible people to make the decision.

Due to the complexity of this selection problem, an investor should follow the course lead by several questions that assure the proper placement of the new company building or branch. Some of these questions are associated to: Which are the features or variables that should be taken into account when assessing a new placement as an alternative to establish a new company building or branch? Which are the most widely used techniques in the process of assessment and selection of a new placement location? Which are the main problems that an investor faces when selecting a new placement location? Which are the main mistakes that can be made when selecting a new placement location? (Osanloo and Ataei, 2003).

Uncu et al. (2002) assert that the location of a company building should take into account the current market in global terms, the changing conditions of the market, and a long list of environmental macro-factors linked to technological, economical, socio-political and legal changes, etc. In the same way, there is a long list of micro-factors, mainly composed of environmental and ecological aspects. Furthermore, it should be taken into account which kind of

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client will receive the service or product, as well as if the production is focused on a local or foreign environment. Besides, it is necessary to consider aspects such as the quality of the commodities, availability of qualified work force, competitors and suppliers.

Finally, the selection problem of a location of the new building involves the simultaneous assessment of several alternatives. There is also the possibility of buildings located in several distant places, since in the current globalized system there are many trade agreements between countries, such as the Free Trade Agreement between Mexico, the United States and Canada, the European Union, Mercosur, the GATT, and the like. It is quite common to see companies sponsored with foreign funds which are located in another country, according to certain commercial strategies that seek closeness to the clients, specialized work force, lower costs, and higher availability of resources and commodities for the production processes.

The objective of this paper is to generate a multi-criteria and multi-attribute assessment model that allows selecting the ideal location for warehouses for perishable agricultural products. In the implementation of the case study selected for application of the methodology, all the above stated circumstances are present; but the criteria and attributes presented in this research can be applied, in general, to any land field selection process.

In the coastal zone of Michoacán, Mexico, there is a wide group of farmers devoted to the plantation of banana. The local market is exhausted. The association of farmers has decided to establish a new distribution warehouse with different locations, with distances higher than 300 kilometers from the production site and with elevated options of exportation. And finally, the product (bananas), being perishable, requires special facilities for its preservation.

1.2. Site selection methods

Nowadays, there are different techniques for the decision making in the optimization of the selection process of the ideal location of production plants. The techniques more commonly used are (Au et al., 2006): Expanding the classification or scoring methods (Hoffman and Schniederjans, 1996); Analytic Hierarchy Process – AHP (Yurimoto and Masui, 1995; Liu et al., 2008; Dey and Ramcharan, 2008); Linear programming – LP (Brimberg and Revelle, 1999; Schmidt and Wilhelm, 2000); Heuristic (Rönnqvist et al., 1999) and Simulation (Chakravarty, 1999). Similarly, the multi-criteria mapping is also used, within which stands out the Technique for Order of Preference by Similarity to Ideal Solution – TOPSIS (Liang and Wang, 1991; Mahamid and Thawaba, 2010; Onut et al., 2010; Semih and Seyhan, 2011) and Analytic Network Process – ANP (Felice et al., 2012).

However, the techniques used in the process of assessing and selecting new sites, require experience and knowledge from the evaluators about the several alternatives considered. Taking advantage of the accumulated knowledge and expertise, artificial intelligence and expert systems are being used in the decision-making for searching the appropriate solutions (Banar et al., 2007). In the same way, since a few years ago Decision Support Systems (DSS) are being brought supported by the On-Line Analytical Processing (OLAP) System and Data Mining (DM) System, as a basic element of consultation where a quick response is always needed. Finally, it is worth noting the use of the Simple Additive Weighting (SAW) method.

Table 1 presents a literature review including authors, dates, methodology used and journal that publishes on the subject area. It is observed that AHP is one of the most used methodologies in the studies that have been conducted to assess new sites (see Fig. 1).

2. Materials and methods

The study adopts AHP methodology, developed by Thomas Saaty in 1980. According to Saaty (1992, 1993), it is considered ideal and consistent with the objective of creating a methodology for selecting the ideal location of warehouses for perishable agricultural products, since it belongs to the family of multi-criteria and multi-attribute techniques, and also due to the wide options for creating attributes, sub-attributes, and decision alternatives. Likewise, in this technique, the attributes involved in the assessment process have a subjective and appreciative character according to the perception of the evaluator who causes its wide acceptance in terms of conducting an assessment when the subjectivity values are elevated.

2.1. STEP 1: Attributes that an ideal location must meet

A detailed study has been made (shown in Table 2) to make a list of the main attributes suggested by 18 authors, who have researched the problem of site location for agricultural and industrial processing plants. The attributes are sorted descending from more to less cited. It can be seen that 16 of the 18 cites make reference to the road accesses of the location under assessment. Likewise, it is observed that the closeness and purchase capacity of the customers is a very important factor and requires further analysis. Moreover, the local labor force available is of great importance, as well as its training and expertise and the cost that it may imply. Finally, it is necessary to review the concept of *tax facilities* offered by the different administrations of a country.

2.2. STEP 2: Identification of problems and errors

During the selection process of new work locations, every company usually faces the following problems (Coretz, 2008), these problems present a temporal sequencing, due to the decision making by the management team of the company:

1st. There are numerous potential sites or rather excessive alternatives for the same issue.
2nd. There are also differences in risk perception by the people involved in the decision-making process.
3rd. The management board wants to meet a number of multiple objectives, quite often conflicting.
4th. These shared objectives are intangible or difficult to quantify.
5th. There is a wide variety of interests in the people responsible for the decision-making.
6th. There is a need to analyze and assess the environmental, economic and technological impacts.
7th. There are possible delays and problems in building permits and licenses.
8th. There are different perception values when assessing the compensations granted by local, state, and federal governments.
9th. When the alternatives are too distant from the place of origin of the investment funds, cultural aspects of the new location should be taken into account (gender and equity issues, customs and traditions, etc.).

On the other hand, it is also necessary to control and minimize the number of errors that are frequently made during the selection process of a new work location, based on previous experiences and generated knowledge. Below, they are shown in a categorized way the mistakes more commonly made, which the AHP model should minimize.

Table 1
Main techniques used in site selection.

Author	Journal	Methodology	Field
Akinci et al. (2013)	Computers and Electronics in Agriculture	AHP, GIS	Determination of suitable lands for agriculture
Carbajal-Hernández et al. (2013)	Ecological Indicators	AHP	Monitoring of shrimp farms
Uyan et al. (2013)	Computers and Electronics in Agriculture	DSS, GIS	Land reallocation
Chavez et al. (2012)	Agricultural Systems	AHP	Diversification strategies for tobacco farmers
Eastwood et al. (2012)	Agricultural Systems	DSS	Learning and adaptation challenges for farmers
Mendas and Delali (2012)	Computers and Electronics in Agriculture	GIS	Development of land suitability maps for agriculture
Aragonés-Beltrán et al. (2010)	Journal of Environmental Management	AHP, ANP	Location of solid waste plant
Ekmekçioĝlu et al. (2010)	Waste Management	AHP, TOPSIS	Location of solid waste plant
Onut et al. (2010)	Expert Systems with Applications	AHP, TOPSIS	Industrial site selection
Nekhay et al. (2009)	Computers and Electronics in Agriculture	AHP, GIS	Wildlife habitat restoration
Lee et al. (2009)	Quality and Quantity	SWOT, AHP	Environmental analysis for locations
Wan et al. (2009)	Ecological Economics	AHP	Evaluate alternatives for pest-control strategies
Dey and Ramcharan (2008)	Journal of Environmental Management	AHP	Industrial site selection
Liu et al. (2008)	Supply Chain Management: An International Journal	AHP	Location for warehouses and suppliers
Carrión et al. (2008)	Renewable and Sustainable Energy Reviews	AHP, GIS	Location of photovoltaic power plants
Kauko (2007)	International Journal of Strategic Property Management	AHP	Industrial site selection
Padmaja et al. (2007)	Proceedings of 22nd International Conference on Solid Waste Technology and Management	AHP	Location of solid waste plant
Banar et al. (2007)	Environmental Geology	ANP, AHP	Location of solid waste plant
Srdjevic et al. (2007)	Business Strategy and the Environment	AHP	Industrial site selection
Kauko (2006)	Journal of Housing and Built Environment	AHP	Industrial site selection
Partovi (2006)	Omega	QFD, AHP, ANP	Multi-criteria site selection
Cheng et al. (2005)	Construction Innovation	AHP, ANP	Multi-criteria site selection
Ma et al. (2005)	Biomass and Bioenergy	AHP, GIS	
Timor and Sipahi (2005)	The Business Review, Cambridge	AHP	Location of animal waste plant
Kontos et al. (2005)	Waste Management	GIS, AHP, SAW	Location of solid waste plant
Takamura and Tone (2003)	Socio-Economic Planning Sciences	AHP	Site selection
Dey (2002)	Environmental Impact Assessment Review	AHP	Location of petroleum pipelines

- Critical errors:
- – Lack of thorough research and consideration of the factors involved.
- – Use of inappropriate variables for the model.
- – Selection of a very remote place.
- – Not identifying properly the customer profile.
- – Use of inadequate experts in the modeling process.
- – Inadequate assessment of the workforce.
- – Selection of a new location based on short-term criteria and policies and not on long term needs.
- – Decision-making based on verbal promises of local or regional governments.
- – Making decisions based on inadequate and insufficient samples.
- – Over adjusting the model.
- – Inadequate assessment of the competition.
- Non-critical errors:
- – Imposition of prejudices of executives regarding a certain issue.
- – Choosing a location where team members are afraid or uncertain.
- – Not verifying physically the location of the alternatives.
- – Lack of consensus among executives.
- – Ignoring the personal likes and habits of residents of the town where the new warehouse or factory placed.
- – Election of an existing facility that does not meet the needs, trying to find a bargain.
- – Attempting to adjust the model to all the problems of work site selection.
- – Not understanding the limitations of commonly used models.
- – Excessive secrecy in the process.

It is observed that the lack of reliable information about the locations analyzed and considered as alternatives is one of the issues most cited by the authors. It causes the improper integration of the variables in the assessment model; when variables are ignored, they simply do not integrate.

Site selection is a complex problem that involves many qualitative attributes that make its assessment difficult. Likewise, there are several alternatives to be assessed, and the decision-making board is often multidisciplinary, what attempts greatly against reaching a consensus. These features, along with others, cause that this type of problems are considered complex or unstructured; therefore, there is no current agreement on the proper methodology to be followed to solve them.

2.3. STEP 3: Determining the alternatives and attributes

In this stage, the information associated to each of the alternative sites identified and a description of the attributes that characterize them are collected. It is necessary to create a decision-making board comprising people that are familiar with the company objectives and the eligible areas to establish the

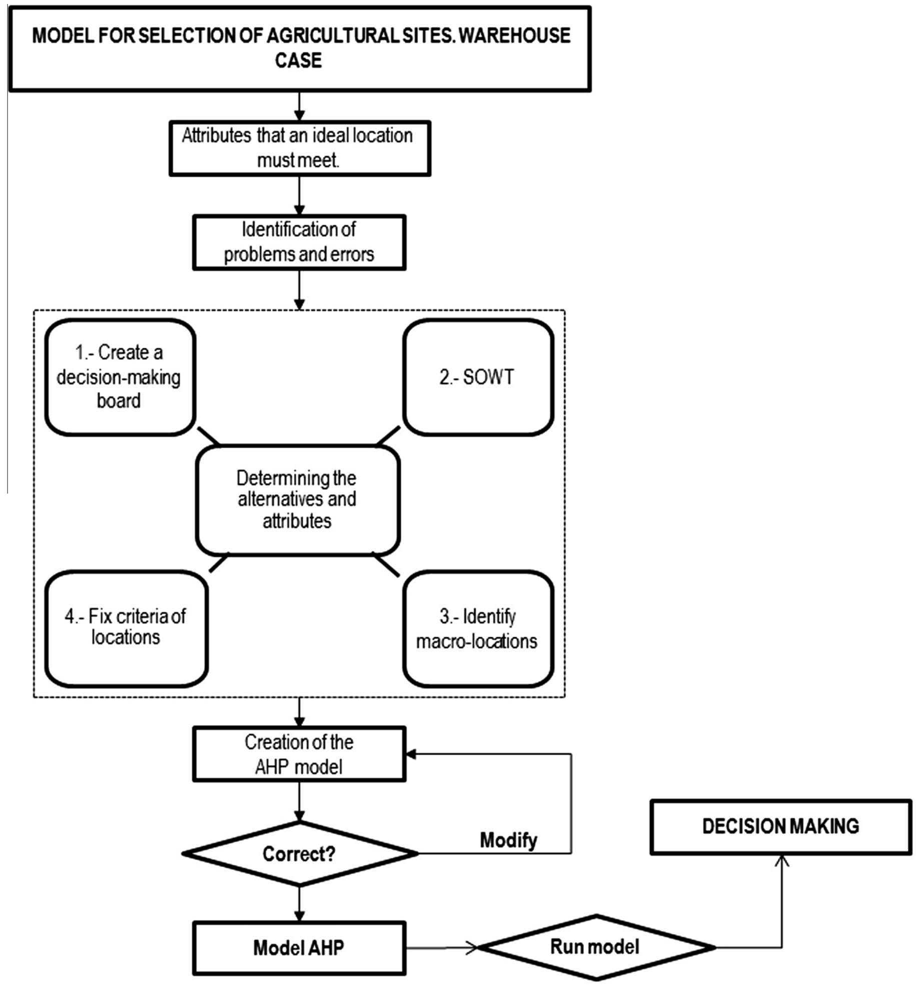

Fig. 1. Research model.

warehouse. This board is composed of administrators of Agricultural Cooperatives (AC) and some of the shareholders of the agribusinesses (Xu, 2008), given the strategic aspect of this type of decision (Zeleny, 1982; Chen and Yang, 2012).

Similarly, an analysis of the strengths and weaknesses of the AC is made, in order to determine the size of the warehouse to be built, and the production capacities of the members of the AC are assessed, as well as the different banana varieties that those members can offer and the current and estimated demand for each variety. In Table 3, some of the strengths and weaknesses that the AC had at the time of the site selection are briefly illustrated.

Once the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis is performed, it is considered as an important strategic tool, since the benefit obtained from its application consists in knowing the real situation of the implementation proposal, as well as the risk and opportunities provided by the new market.

The SWOT analysis shows the strengths and weaknesses that are within the company's internal, enabling the analysis of resources and capabilities. It is a fundamental in this proposed methodology, since it allows considering a wide range of factors relating to production, resources, funding, organization, etc.

Furthermore, it permits determining the threats and opportunities that belong to the external environment of the company and must be taken into account in the attributes to be considered in the model. This analysis enhances the flexibility and entrepreneur dynamism of the business.

Secondly, it is necessary to identify macro-locations in urban areas. The macro-location should be narrowed down even further, since there are influencing factors that should not be included in the criteria and attributes. In this case, some aspects are considered, such as building regulations and licenses established by the federal, state and local/municipal governments, forbidding or hindering constructions like the one required. Thus, the pre-criteria determine that only three potential locations should be assessed; they are identified as $\mathbf{Z}_1$, $\mathbf{Z}_2$ and $\mathbf{Z}_3$. In the case-study provided as example three possible locations are selected: $\mathbf{Z}_1$ Downtown Guadalajara, $\mathbf{Z}_2$ Industrial Zone of Jalisco, and $\mathbf{Z}_3$ México DF.

To make a pre-assessment of the selected sites, the first step is to generate a list of the criteria and attributes that are to be assessed at each of the locations. Each of the integrant of the decision-making board evaluates the presence or absence of each of the attributes of each criterion, based on a Likert Scale containing values from one to five (wherein, number one indicates the absence of the attribute, and number five the absolute presence). The assessments of each of the attributes are arithmetically averaged, as shown in Table 4 for only some selected attributes. A full list of the attributes assessed is presented below:

2.3.1. Accessibility (ACC)

It refers to the ease with which the warehouse can be reached with the product from the growing areas.

Table 2
Attributes analyzed in the assessment of new locations.

Attributes	Authors: Hermone (1970)	Cook and Green (2003)	Keller (2011)	Friedman et al. (1992)	Moravec (2011)	Shapiro (2011)	Goldsmith and Mitchell (2007)	Karadeniz (2009)	Constantine (2009)	Olson (2010)	Weyrich et al. (2011)	Gambale (2008)	Thompson et al. (2011)	Augustin (1999)	Blair and Premus (1987)	Pittman (2006)	De Cesare (2010)	Total cites
Road accesses	×	×		×	×	×	×	×	×	×	×		×	×	×	×	×	15
Purchase capacity and closeness of the customer	×	×	×	×	×	×		×		×	×				×	×	×	12
Labor force	×		×			×	×	×	×	×	×	×				×	×	11
Local government facilities			×			×			×		×	×	×	×		×	×	9
Production costs			×			×	×	×	×		×		×	×	×			9
Services					×	×	×		×	×					×	×	×	8
Terrain	×		×	×	×	×						×						6
Taxation				×	×				×			×			×	×		6
Education and quality						×			×	×	×	×					×	6
Quality of life		×				×				×				×		×		5
Raw material									×				×	×	×			4
Risks			×				×					×	×			×		5
Competition		×	×					×								×		4
Productivity				×				×					×		×			4
Customs									×			×	×					3
Climate				×			×			×								3
Union activity				×											×			2

- Land routes (LAR).
- Maritime routes (MAR).
- Railways (RAW).
- Distance (DIS).

It refers to the distance between two given points over which the transportation of the bananas or the warehouse staff has to be done.

- Distance from the house of the staff members to the warehouse (DIM).
- Distance from the growing area to the warehouse (DIG).
- Distance from the warehouse to customers (DIC).

2.3.2. Security (SEC)

It refers to the perception that the members of the decision-making board have about the security issues in the three assessed areas.

- Rate of loss by robbery (RAL).
- Presence of organized crime (POC).
- Security personnel (SEP).
- Security systems (SES).

2.3.3. Needs of the agricultural product warehouse (NEA)

This attribute refers to the ease with which services are available for the proper functioning of the company.

- Qualified labor force (QLF).
- Machinery and equipment (MAE).
- Energy (ENG).
- Terrain (TER).
- Services (SER).

2.3.4. Acceptance (ACE)

It refers to the social acceptance that the warehouse may have on the environment where it is supposed to be built.

- Community acceptance (COA).
- Government Acceptance (GOA).

2.3.5. Costs (COS)

In this criterion, the attributes analyzed are related to the costs of product transportation, wages and salaries of workers and managers, etc.

- Supplies (SUP).
- Distribution (DIT).
- Wages and salaries (WAS).
- Energy (ENE).
- Insurances (INS).

Including the above information associated with the criteria to be evaluated, Fig. 2 shows the initial AHP model with the six generic criteria: accessibility to the production plant, distance, security, needs, social acceptance, and costs. The model is extended with the attributes that belong to each of the criteria previously selected.

2.4. STEP 4. Creation of the AHP model for assessing new warehouse locations

As discussed previously, the AHP is the methodology used to select the most suitable location to establish a warehouse for agricultural products. For Gass and Rapcsak (2004), AHP is used to solve complex problems that can be decomposed in a hierarchical

Table 3
SWOT analysis of the AC.

	Strengths	Weaknesses
Internal analysis	• Production capacity to supply the market • Short distance in kilometers in comparison with the competitors • Economic resources to make the purchase of the terrain and the construction of the warehouse	• Little experience of the investors in business expansion processes • Reluctance of the investors to investment risk • The source of information associated to the sites comes from third persons
	Opportunities	Threats
External analysis	• Entry to the market of Guadalajara • Generation of work sources • Weaknesses of the competitors	• Possible price changes • Rise of fuel costs • Possible presence of climatic phenomena (hurricanes, storms)

Table 4
Summary of the subjective assessment of the locations by means of five attributes.

Attribute	Z_1	Z_2	Z_3
Land routes (LAR)	8	2	2
Maritime routes (MAR)	7	1	2
Railways (RAW)	3	8	2
Distance from the house of the staff members to the warehouse (DIM))	4	3	6
Distance from the growing area to the warehouse (DIG)	5	6	7

structure, where each of the levels is sectioned into specific elements. The main objective has been given top priority; the criteria, attributes, sub-attributes and the decision alternatives are listed in descending levels of the hierarchy.

One of the advantages of the AHP is that it analyses the attributes and criteria without the requirement of being based on a common scale for all of them. Table 5 shows the scale used to make the paired comparisons with the AHP.

Paired comparatives are made with the objective of determining the levels of importance of the criteria and attributes. For instance, the paired comparison of element i with element j is placed in the position of a_{ij} of the matrix A of paired comparisons, as shown in (1). The inverse values of these comparisons are placed in positions a_{ji} of A, in order to preserve the consistency of the judgment. The decision-maker involved should compare the relative importance of one element to the other, using the nine points scale shown in Table 5. For example, if the first element is classified as element with strong dominance over element two, then in position a_{12} the value 5 is placed, and reciprocally, 1/5 is placed in position a_{21}.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \cdot & \cdot & \cdots & \cdot \\ \frac{1}{an} & \frac{1}{a_2} & \cdots & 1 \end{bmatrix}$$

One of the advantages of this methodological proposal is that it allows identifying and taking into account the inconsistencies of the decision-makers, since they are rarely consistent in their judgments about qualitative factors. According to the AHP efficiency criteria that Saaty (1992) established (and further used by Condon et al. (2002)), a Consistency Index (CI) and a Consistency Relationship (CR) are incorporated into the analysis; they are estimated according to Eqs. (2) and (3); the RC is used to measure the quality of the judgments made by a decision-maker. An RC lower than 0.10 is considered acceptable; if it is higher, it will be necessary to ask the decision-maker to make the assessments or judgments once again.

$$\mathrm{CI} = \frac{\lambda_{\mathrm{MAX}} - n}{n - 1} \tag{2}$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{3}$$

The CR index depends on the CI and RI, given that the latter represents a Random Index. Thus, CR represents a measure of the error made by the decision-maker and it should be lower than 10% of the RI. Table 6 shows the RI for values of 3 to 10 attributes.

Since in the trouble shooting of the issue hereby presented more than one decision-maker is involved, it is necessary to add up and average the judgments of the various decision-makers. Mikhailov (2004) and Escobar et al. (2004) suggest the use the geometric median as average when the personal assessments of the decision-makers are added up in a matrix of final decision, as shown in Eq. (4) for n decision-makers.

$$a_{ijT} = \left(a_{ij1} * a_{ij2} * a_{ij3} * \cdots * a_{ijn}\right)^{1/n} \tag{4}$$

For the modeling of the final structure of the decision-making problem, as well as for the calculations or estimations of the levels of importance that each of the problems had, the software package *ExpertChoice*® has been used in our case-study as a tool to make it easy. Fig. 3 shows the final model generated to determine each of the weightings of the three alternatives analyzed.

3. Results and discussion

As mentioned above, the AHP is used to estimate the levels of importance of each of the attributes and criteria analyzed through the creation of matrixes of paired comparisons, as illustrated in Table 7 for the case of the six main criteria. Every a_{ij} position corresponds to the geometric mean of the opinions of the experts involved in the decision-making processes (using Eq. (4)); in the final column there is the level of importance or weighting of the criteria. In this case, to generate assessments of the judgments of the decision-makers involved, each one of them is asked about how important a criterion is over the other. For instance, for the element a_{12} there is a six, which, according to the scale used, shown in Table 5, means that the *Accessibility* (ACC) has a slight dominance in importance over the *Distance* (DIS); and in the same way, in the position a_{21} appears 1/6, the inverse.

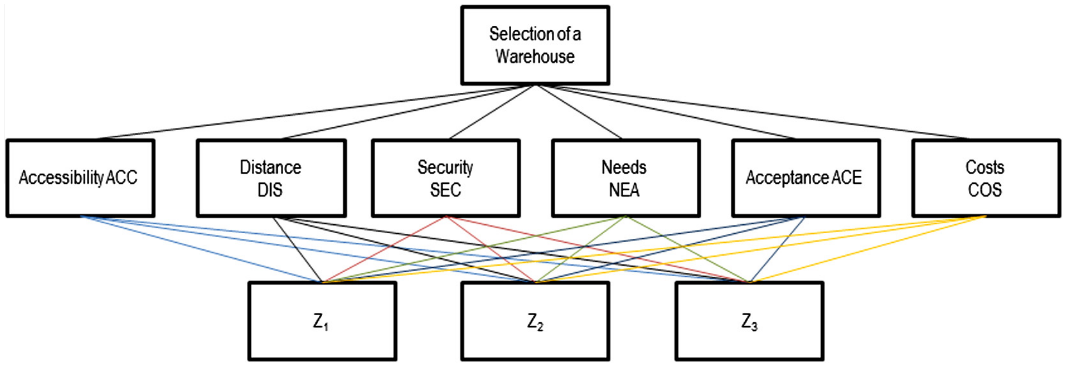

Fig. 2. Initial model of generic criteria and alternatives.

Table 5
AHP scale of 9 points used in the paired comparatives.

Importance	Definition	Explanation
1	Equal importance	Two elements contribute identically to the objective
3	Weak dominance	According to experience, there is a weak dominance of one element over the other
5	Strong dominance	According to experience, there is a strong dominance of one element over the other
7	Proven dominance	The dominance of one element over the other is completely proved
9	Absolute dominance	The evidences show that one element is absolutely dominated by the other
2, 4, 6, 8	Intermediate values	These are intermediate values of decision
1/9, 1/8…1/2	Reciprocal values (inverses)	They are placed in the transposed positions of an assignment

Table 6
Consistency random index.

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 7
Matrix of paired comparisons for criteria.

	ACC	DIS	SEC	NEA	ACE	COS	W_i
ACC	1	6	2	4	2	4	0.397
DIS	1/6	1	1	3	3	6	0.190
SEC	½	1	1	4	2	5	0.200
NEA	¼	1/3	¼	1	1	2	0.073
ACE	½	1/3	½	1	1	1	0.087
COS	1/4	1/6	1/5	1/2	1	1	0.053
Inconsistency = 0.09							

For this specific case, the consistency ratio is 0.09, which is lower than the bound 0.1, which has been set as maximum value. As it can be seen, for the integrants of the decision-making board, in this case, the *Accessibility* to the sites represents a 39.7% of the importance, followed by a 20% of the *Security* and a 19% of the *Distance*, which is consistent with the literature reviewed.

To understand the importance that the lower levels of the structure of the decision-making model have, the methodology followed is similar to the one previously selected. For example, to determine the importance of the attributes that compose the criterion of *Accessibility*, all the integrants of the decision-making

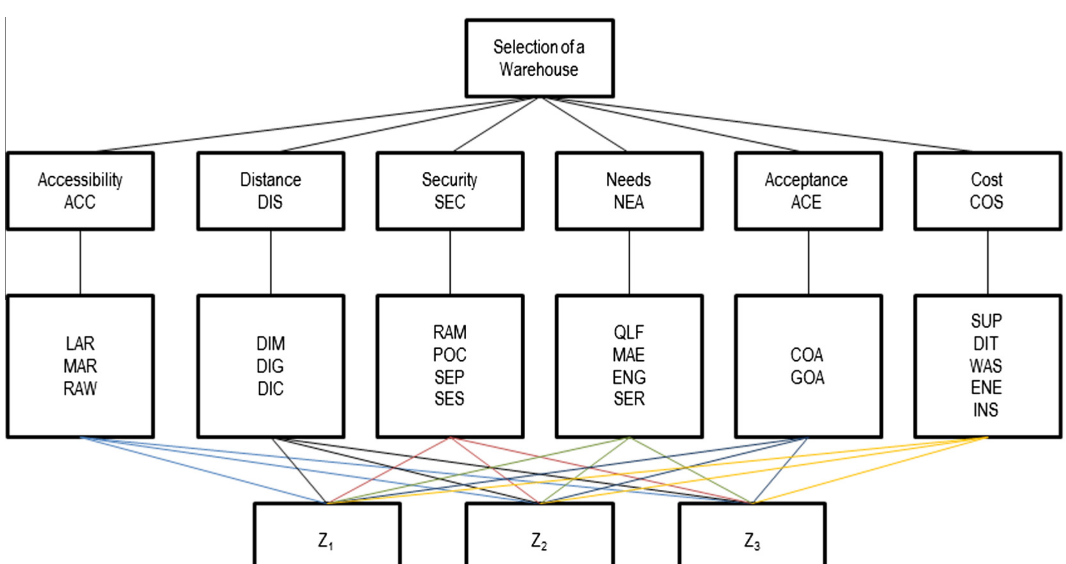

Fig. 3. Final model of hierarchy of attributes and alternatives.

Table 8
Matrix of paired comparisons for the criterion *Accessibility*.

	LAR	MAR	RAW
LAR	1	6	2
MAR	1/6	1	1/5
RAW	½	5	1
Inconsistency = 0.03			

Table 9
Matrix of paired comparisons for the attribute *Land routes*.

	Z_1	Z_2	Z_3	W_i
Z_1	1	6	3	0.678
Z_1	1/6	1	1	0.142
Z_1	1/3	1	1	0.179
Inconsistency = 0.05				

board are asked about how important is for them each of the attributes. In this case, *Land routes* (LAR), *Maritime routes* (MAR) and *railways* (RAW). Table 8 illustrates this process.

Likewise, paired comparisons are made for each of the attributes in relation to the three alternatives analyzed. Table 9 shows the calculations made to determine the importance of each of the building locations in relation to LAR or *Land routes*. The part of the analysis made in this article is shown underlined in Table 10.

Table 10 shows the calculations and results obtained in three significant figures and sorted according to the way in which they are shown in Fig. 3 of the final model (Column: Criterion-Name).

Column W_c shows the level of importance or weighting that the analyzed criterion has. However, following the AHP method, the levels of importance of each of the attributes are estimated regarding the decision criteria analyzed in the previous level, as shown in the Column: *Attribute – Name* and *Attribute –* W_a. It should be taken into account that the sum of all attributes with respect to the

Table 10
Summary of the assessment.

Criterion (Level 1)		Attribute (Level 2)		Weighting by Zone (Level 3)			Contribution by Zone		
Name	W_c	Name	W_a	Z_1	Z_2	Z_3	Z_1	Z_2	Z_3
ACC	0.397	LAR	0.577	0.678	0.143	0.179	0.155	0.033	0.041
		MAR	0.081	0.54	0.297	0.163	0.017	0.010	0.005
		RAW	0.342	0.172	0.726	0.102	0.023	0.099	0.014
DIS	0.19	DIM	0.195	0.333	0.14	0.528	0.012	0.005	0.020
		DIG	0.406	0.192	0.634	0.174	0.015	0.049	0.013
		DIC	0.399	0.276	0.129	0.595	0.021	0.010	0.045
SEC	0.2	RAM	0.339	0.416	0.458	0.126	0.028	0.031	0.009
		POC	0.348	0.169	0.388	0.443	0.012	0.027	0.031
		SEP	0.196	0.55	0.21	0.24	0.022	0.008	0.009
		SES	0.117	0.14	0.528	0.332	0.003	0.012	0.008
NEA	0.073	QLF	0.076	0.278	0.664	0.058	0.002	0.004	0.000
		MAE	0.355	0.594	0.249	0.157	0.015	0.006	0.004
		ENG	0.355	0.143	0.678	0.179	0.004	0.018	0.005
		TER	0.214	0.673	0.101	0.226	0.011	0.002	0.004
ACE	0.087	COA	0.833	0.709	0.06	0.231	0.051	0.004	0.017
		GOA	0.167	0.163	0.297	0.54	0.002	0.004	0.008
COS	0.053	SUP	0.267	0.584	0.184	0.232	0.008	0.003	0.003
		DIT	0.290	0.25	0.655	0.095	0.004	0.010	0.001
		WAS	0.316	0.21	0.694	0.096	0.004	0.012	0.002
		ENE	0.055	0.443	0.388	0.169	0.001	0.001	0.000
		INS	0.072	0.416	0.458	0.126	0.002	0.002	0.000
Total							0.412	0.349	0.239

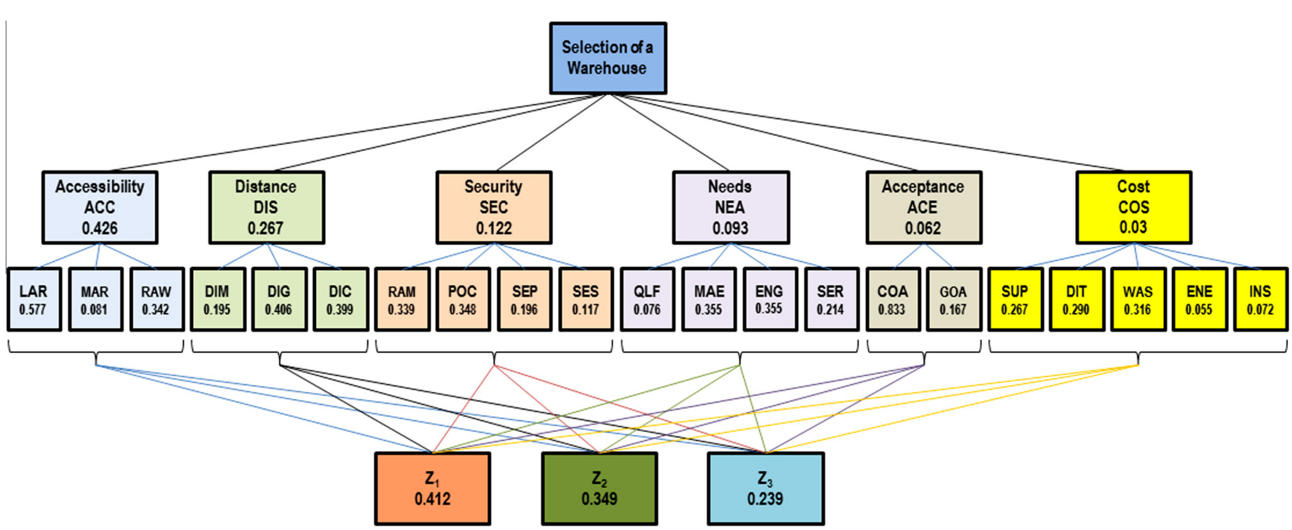

Fig. 4. Results obtained with the final model of hierarchy of attributes and alternatives.

criterion by which they are estimated gives a result equal to a unit. For example, in the case of *Accessibility* (ACC), it can be seen that the attributes that constitute it are LAR, MAR and RAW, with weights or importance levels of 0.577, 0.081 and 0.342 respectively, which sum one. The same process is repeated for each of the five criteria analyzed.

In the same way, an analysis is made of the level of importance that each of the areas (elements of the third hierarchy level) has with respect to the attributes (elements of the second level of the hierarchy), and the values obtained are shown in the column labeled as *Weight of the Areas*. In this case, the sum of the weightings obtained from the three zones analyzed should result again in a unit; for example, in the case of the analysis of the contribution of the zones with respect to the attribute LAR, the results are 0.678, 0.143 and 0.179 for $\mathbf{Z}_1$, $\mathbf{Z}_2$ and $\mathbf{Z}_3$, respectively.

In the case of the column named *Contribution per Zone*, the values are obtained multiplying in a recursive way the existing values in each of the previous levels. For example, to obtain the contribution of $\mathbf{Z}_1$ regarding ACC–LAR, the value of 0.155 (contribution of $\mathbf{Z}_1$) is obtained by multiplying 0.397 of ACC (first level) by 0.577 of LAR (second level) and $\mathbf{Z}_1$ of 0.678 (third level). A similar operation is made for each one of the other values.

Fig. 4 shows the final results of the proposed model and allows estimating the contribution of each of the zones analyzed. It is observed in both, Fig. 4 and Table 10, the contribution per zone; thus, $\mathbf{Z}_1$ obtains a total of 0.412, $\mathbf{Z}_1$ obtains 0.349, and $\mathbf{Z}_3$ obtains 0.239. According to the arguments presented in this paper, option $\mathbf{Z}_1$, which corresponds with Guadalajara, should be selected for the establishment of the new warehouse for banana by the society of farmers of the state of Michoacan in Mexico.

4. Conclusions

After a revision of the methodologies, attributes, and frequent errors found during the process of selecting a placement location, it can be asserted that despite its wide variety, AHP is one of the most reliable methodologies according to the scientific literature consulted. Its main advantage is that it allows the integration of very diverse quantitative and qualitative attributes that depend on each specific case.

The study shows that there is not a set of attributes that must necessarily be analyzed, as each agricultural company requires integrating its own attributes according to its needs and features. In this study, the methodology proves to be very effective and the analysis made provides valuable information for the people responsible of the decision-making in this type of problems. It is also worth noting that there exist specialized software applications that can constitute a great support, as it facilitates the application of the methodology and provides a user-friendly interface for the final user.

The methodology presented, in both temporal sequencing and with the attributes and sub attributes evaluated by the AHP model, is assumable by any company wishing to locate a new agricultural storage facility. It is noteworthy that the methodology presented requires the companies to develop in-depth studies of SWOT and the creation of multidiciplinares teams. The obtained results have application not only in choosing a new location, but also in finding out the real situation of the company as well as the risk and opportunities offered by the new market.

Regarding the mistakes made during the assessment process, the conclusion is that the companies often make decisions in haste, and the executives impose their prejudices due to the lack of more accurate information or due to time and resource constraints, as well as because of cultural differences between countries. Furthermore, the alternatives are not verified personally; it is thus strongly recommended that before making a decision, up-to-date information should be obtained and consulted as a basis support.

In the case study presented in this paper about the selection of a location for establishing a new warehouse, the model generated by AHP methodology facilitates the decision-making process. Likewise, it has been proved that the accessibility to the storage place and the accessibility of the customers is the most important factor, which is consistent with recent works by Thompson et al. (2011), Pittman (2006), De Cesare, (2010) and others authors reported in Table 1.

Finally, it is worth mentioning that in the practical case implemented with the proposed model, the Cooperative Society of Banana Producers has acquired the land and is currently in the process of management of construction permits and licenses from local government authorities. Furthermore, the technique is being used in other assessment processes related to this warehouse building, such as the selection of the building company and the design proposals presented, as well as the purchase of equipment and services.

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