AN APPLICATION OF THE ANALYTIC HIERARCHY PROCESS (AHP) FOR LOCATING A DISTRIBUTION CENTER

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Summary: *This article describes an application of the AHP to a logistics problem of site selection. The site selection problem is considered one of the most important strategic decisions taken by organizations. It involves a great number of aspects related to investments and operational costs, directly or indirectly related to the company's operation, not to mention social related aspects. The proposed methodology was applied for locating a distribution center of non-durable consumer goods in the São Paulo Metropolitan Region, Brazil, counting on about 18 million inhabitants. It was developed considering all the challenges involving the site selection problem, based on a proposed checklist that contemplates nearly 100 parameters.*

1. Introduction

Facility location is one of the main topics concerning logistics and strategic planning. Its conceptualization encompasses all aspects in supply chain management. It may be said, corroborating with the arguments by Fuller *et al* (1993) *apud* Korpela and Tuominen (1996), that logistics is the next potential element to add value to consumers, as well as one of the main sources for reducing costs, and an important discipline to activate the commercialization processes.

The decision on where to locate facilities involves evaluating several criteria with different influence levels in the final product, including the need to contemplate quantitative and qualitative issues in the analysis, increasing the complexity of the problem.

Site selection for new manufacturing or commercial facilities, distribution centers, railway, truck or port terminals, bank agencies, sanitary landfills, that is, for the most different purposes, has been widely discussed in different forms, but generally restricted to tangible aspects. In many situations, the large number of feasible candidate alternatives requires the use of mathematical models seeking to maximize or minimize an objective function, generally associated to total profit or cost.

The use of the *Analytic Hierarchy Process* – AHP was considerated appropriate for this purpose, since it can deal with quantitative and qualitative attributes, either simultaneously or separately. According to Hedge *et al* (1990) apud Lin and Tu (2000) the AHP method allows condensing decision scenarios, besides providing clarity in the choice process.

A relevant contribution of this research consists in the proposition and application of a typical check list, generic in nature, that can be useful in a wide range of site selection problems utilizing multicriterial methodologies to support decisions, such as the AHP.

A case study involving a site selection for a distribution center of a company in the non-durable consumer goods sector is considered. It was solved using the Expert Choice software, which encompasses the AHP concepts.

The organization of this paper is as follows: section 2 describes the premises to a facility location problem. In section 3, the method proposed is described, while the case study is in section 4. Finally, the conclusions and final considerations are outlined in section 5.

2. Modeling the facility location problem

Optimization models have been widely used for solving real world complex location problems, though its difficulties to adequately represent the complexity of such problems. Mathematical models tend to reflect and represent partial aspects of real cases, as pointed out by Pidd (1999), otherwise becoming extremely complex to solving. Thus, along the past few years, and with greater emphasis as from the 1970s, new tools for solving complex problems have been discussed and proposed as alternatives to traditional optimization models.

Rosenhead (1989) *apud* Correa (1996) states that optimization models usually follows the solution methodology of the type models / techniques / solutions, widely applied and well suited to problems of operational and tactic nature, but facing difficulties in solving problems of strategic order, due to the lack of data and the underlying uncertainties.

The rigid structuring imposed by optimization models for solving strategic problems has stimulated new approaches which, according to Checkland (1985) *apud* Correa (1996), are characterized by:

- non-optimization, that is, the search for alternative solutions which are acceptable in different dimensions, without the necessity of analyzing trade-offs or compensations;
- reduced data needs, attained by great integration between quantitative and qualitative data, the latter relying on subjective judgments;
- simplicity and transparency, aiming to clarify conflicting situations;
- consideration of people as active subjects in the decision process;
- providing conditions that foster a bottom-up planning;
- acceptance of uncertainties, seeking to leave options open to ensure flexibility related to future events.

Lin and Tu (2000) state that the facility location problem is complex and that the AHP can, effectively and appropriately, deal with both qualitative and quantitative factors in a multiple criteria decision environment, thus being an important tool to synthesize scenarios and to produce a diagnosis that allows the decision maker to understand the inter-relational behavior of the systems that form decision.

Decision making problems usually involve evaluating and considering a wide number of elements, which, apparently, are not always directly compatible among themselves. Nevertheless, when a procedure is established in such a way that it aggregates the relevant elements according to common properties, the comparison of alternatives becomes possible.

The combination of linear programming and goal programming models with the AHP for a site selection problem in natural reserves was discussed by Mau-Crimming and Liberti (2002). The study contemplated the stakeholders' ponderations, that is, of the different parts involved in order to structure the problem in a suitable format for applying the AHP. The resulting rates were used as factors applied to the decision variables of a mathematical model in both the objective function and the constraints.

In the present case study, the problem refers to a company's strategic decision to build a new distribution center. The decision making process imposed constraints of time order and lack of resources for more detailed studies to support the decision. In other words, the decision had to be made by the company board in a situation that did not allow for a detailed collection of information.

The environment for selecting the location of the distribution center for this company configures a complex problem with different qualitative and quantitative attributes, both tangible and intangible, which systemically interact and had to be dealt with concomitantly. The lack of knowledge on certain attributes which would normally be tangible led to the need of considering them as intangible, increasing the complexity of the decision making process.

The scenario described above coincides with several strategic decision making situations in which little is known about what is to be decided upon, little can possibly be spent to support the decision process, and the decision must be reached in a short period of time.

3. The use of a checklist and AHP for site selection

Gualda (1995) discusses aspects of the location theory, stressing its multidisciplinary character and calling attention to different factors to be considered and weighted in treating real world location problems. These range from factors contemplated in the company strategic planning, in its master planning, in its production planning, as well as in its socio-economic environment.

Environmental constraints, technological capacitation and union relationship have recently exerted greater influence on strategic decision. These aspects have proven to be difficult to be considered in the traditional site selection approaches, due to the need to convert them into monetary values.

The above aspects supported and stimulated the application of AHP for the formulation and solution of the site selection problem under consideration.

The versatility of the AHP has stimulated its application for site selection based on a checklist encompassing items usually considered as relevant ones for site selection.

A proposed checklist was derived and is presented in Table 1. It has a generic nature and should be adapted to the type of premise to be evaluated and implemented, with the necessary adjustments to the respective intrinsic characteristics of the treated problem. The list aims to encompass different attributes related to the effectiveness of the facility location.

The proposed checklist is comprehensive in nature. However, for specific characteristics of the facility to be located, it may be either excessive or even impose the consideration of additional attributes.

4. Application of AHP to a logistic problem of site selection for a distribution center

The AHP method was applied to select the most adequate location to build a distribution center for a given company in the non-durable consumer goods sector whose products require special packaging and handling due to their fragility.

The candidate sites for implementing the distribution center are located in the outskirts of the São Paulo metropolitan region, in Brazil: Site A - Raposo Tavares road km 20, Site B – Anhanguera road km 30 and Site C - Marginal Tietê (ring road).

The distribution center shall receive products that will undergo a small industrialization process, including packaging, and then stored for later distribution to wholesalers and retailers.

Customers located within a range of 200-km radius shall be served by the distribution center.

Table 1 - Typical checklist for site selection.

Typical check list for site selection	
1. Area for implementation a) cost of the area b) availability of the necessary amount of area for the project 2. Inputs a) Water and Effluents i) availability of supplying sources ii) availability of effluent disposal iii) supplying costs (1) large availability of industrial and drinking water (2) distance from sources (3) availability of reservoir for effluent disposal (4) water collection /delivery/ treatment and storing systems (5) water treatment (6) effluent treatment b) Natural Gas i) availability of natural gas ii) contract for natural gas supply and its reliability iii) supply cost (1) distance to gas duct (2) costs for accessing the gas networks (3) gas cost c) Electric Power i) electric power availability and sources ii) contract for energy supply and its reliability iii) supply cost (1) distance to power networks (2) costs for accessing the power networks (3) integration to the network (4) necessary reinforcements for the energy output generated d) Transport i) Labor (1) Availability (2) Cost ii) Product (1) Availability (2) Cost iii) Raw Material (1) Availability (2) Cost iv) Acess Routes (1) Road (2) Railway (3) River (4) Air e) Raw Material i) raw material availability ii) cost	3. Market a) domestic b) export to other consumer centers c) identification of investments foreseen in the region d) competition 4. Environmental Aspects a) state and municipal environmental legislation b) phases and deadlines for environmental license c) environmental hindrances d) cost of abiding by the legislation 5. Vegetation, Fauna and Climate a) vegetation and its legal protection provisions b) endangered animal species and legal protection provisions in the municipality c) climate and temperature d) rain standard, overflow and floods e) winds 6. Urban Occupation and Housing a) nearby cities b) population c) development projects d) social impact 7. Human resources a) work legislation b) unions and their action in the region c) engineering and construction firms d) availability of services and of qualified professionals e) availability of educational and vocational training programs f) availability of medical and odontological care services g) costs i) direct labor ii) auxiliar services iii) indirect and support labor 8. Life Quality a) other industries in the region, labor quality and its general behavior b) labor housing conditions in the region c) housing, safety and social infrastructure d) availability for leisure e) cost of life in the region i) housing ii) transport iii) infrastructure 9. Taxes and Fees a) area b) inputs c) labor d) profit remittance e) others 10. Fiscal and Tributary Incentives a) State b) Municipal c) General for granting land, execution of necessary infrastructure etc.

The Expert Choice software, which encompasses the AHP concepts, was used. The available software version imposed some adaptations to problem modeling.

The considered attributes and their abbreviations are shown in Table 2.

Table 2 - Attributes and abbreviations.

Abbreviation	Definition	Abbreviation	Definition
$ Input	Inputs Cost	Inc	Tax Incentives and Reductions
$ MO	Labor Cost	Legisla	Legislations: Environmental, State and Municipal
$ ServAux	Level of cost for auxiliary services	MeioAmbi	Environmental Aspects
$ de Vida	Cost of Living – housing, schools, transportation etc.	Mercado	Market evaluation
A – RT 20	Site A – Raposo Tavares km 20	Ocupa	Urban Occupation and Housing
Adeq MO	Availability of adequate MO	Padrão	Level of quality of life concerning housing, safety, transportation, etc.
B – Anh 30	Site B – Anhanguera km 30	PrazoAmb	Phases and Deadlines for environmental licensing
C – M.Tiet	Site C – Marginal Tiete	Products	Tax burden on the product or service
CustoAmb	Cost of Abiding by the Environmental Legislation	QualVida	Quality of Life
CustoTer	Cost for acquiring the area	Quantid	Expanse of area for implementing the project
Desenvol	Regional Development Plans	RH	Human Resources
Disp Ins	Availability of input concerning quantity and availability	Serv.Aux	Availability of Auxiliary Services
Disp MO	Availability of labors in quantity	Sindic	Union Action
Edifica	Tax burden on buildings and lots – IPTU	Trans MO	$ of MO Transportation
Energia	Energy Cost	Trans PR	Price of Products Transportation
Imp-Inc	Taxes, duties and Incentives	Água	Price of Water
Impacto	Social and Urban Impact	Area	Availability of area for implementation

The hierarchic structure, based on the *checklist* presented in Table 1, was built in the Expert Choice software and is shown in Figure 1. It should be noticed that some attributes, such as Cost of Living, Cost of Abiding by the Environmental Legislation and Urban Occupation and Housing, despite being notedly tangible, had to be considered as intangible due to the lack of appropriate related data.

The results of the application are shown in Figure 2. They indicate that alternative A-RT 20, i.e. A – Raposo Tavares km 20, is best ranked.

Figure 2 also presents the inconsistency index of the judgments of 0.01, which can be considered as good enough, giving the large amount of variables evaluated. The maximum acceptable value would be 0.1 according to Saaty (1990), Forman and Selly (2001), and to the Expert Choice user's manual.

Figure 3 presents the sensitivity analysis concerning the first level of the hierarchy, that is, the main goal, which allows for simulating some variations on chosen attributes. This graph is one of the most elucidative among those available in the Expert Choice software.

The attribute Imp-Inc, which represents taxes, duties and incentives, has shown to be important for alternative A-RT20 to attain the highest rank among the evaluated alternatives.

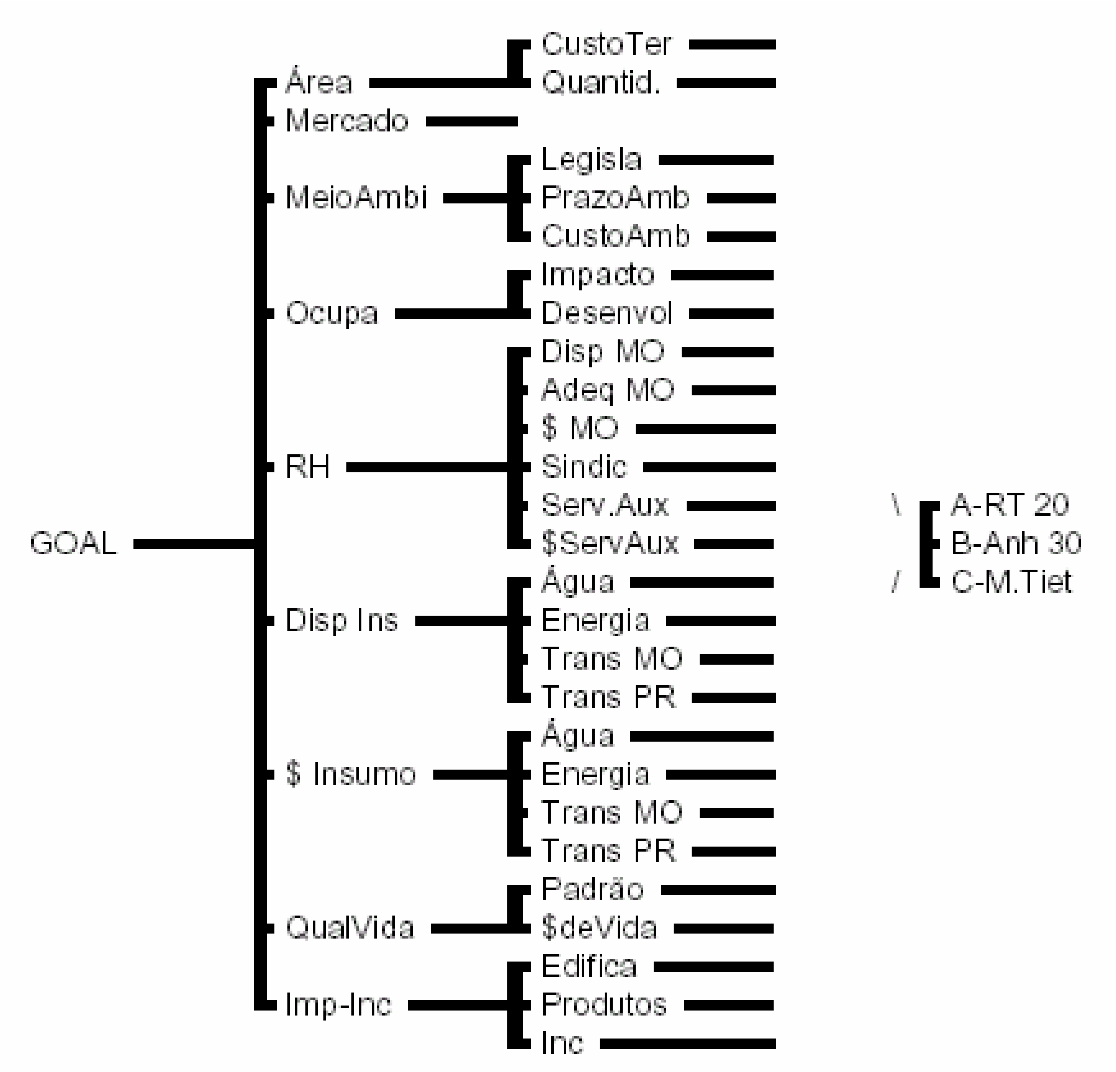

Figure 1 - Hierarchic structure as implemented in the Expert Choice Software (3 levels).

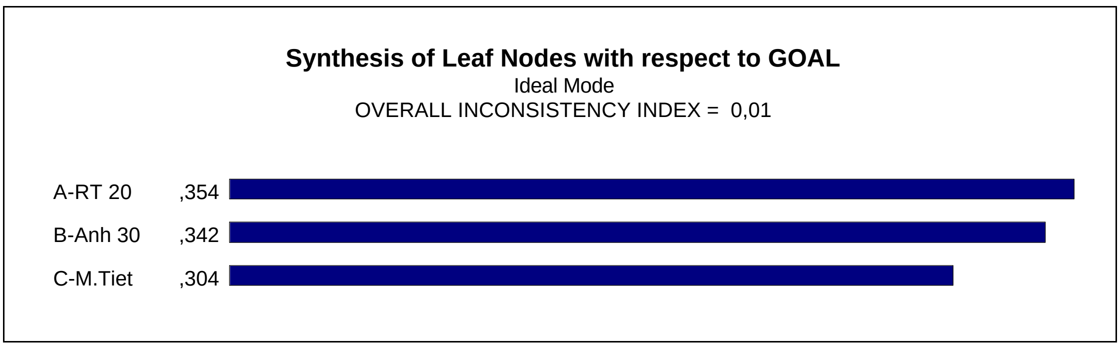

Figure 2 - Synthesis with priority scale among the alternatives for selection.

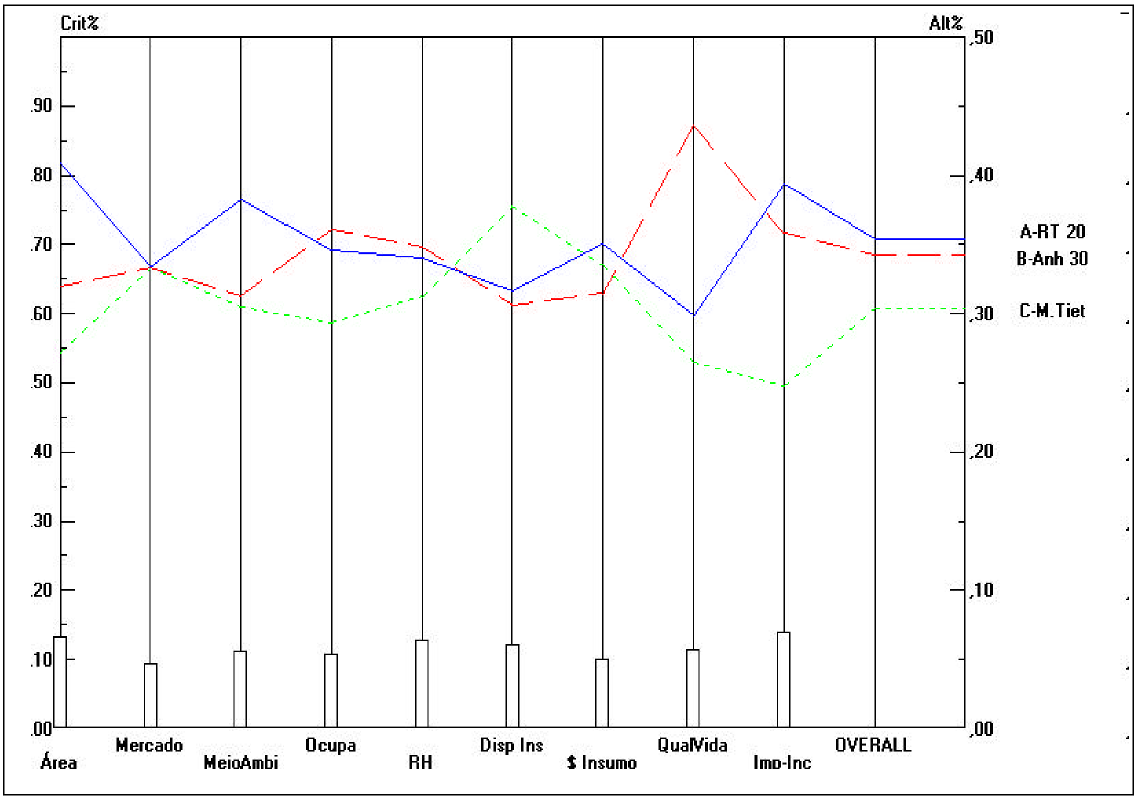

Figure 3 - Sensitivity Analysis.

5. Conclusions and final remarks

AHP has shown to be a suitable tool to support location decision making, mainly in the initial phase of the evaluation process, in which there is a lack of some data required by a more sophisticated modeling approach. It allowed the identification of the most adequate location for implementing the Distribution Center in the studied case.

The proposition of a comprehensive checklist can be seen as a relevant contribution of the present research. It can be useful in a wide range of site selection problems, mainly those related to multicriterial methodologies to support decision. In particular, for application of AHP to location problems.

The proposed checklist is somehow extensive and may not be fully required in some cases since its evaluation may be time and effort consuming. However the large number of items in the checklist provides guidance for selecting relevant attributes influencing site selection in specific cases.

The lack of data for some attributes did not actually bias the evaluation procedure, since the methodology allows for taking into consideration the experience of the decision-makers,. In addition, the proposed hierarchic structure contributed to dissect the inter-relationships existing among the components of the problem.

The available version of the software imposed some difficulties to formulate the problem, due to the restrictions on the number of levels to be considered, but this limitation was overcome.

It should be noticed that a single hierarchic structure was organized to take into consideration both costs and benefits. Separate structures could be considered for costs and benefits. However, this split approach would not add to the quality of the solution, given the quality of the available data.

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