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USAGE OF AHP METHODOLOGY IN SELECTING COMMERCIAL BUILDING SITES IN THE CITY OF RIO DE JANEIRO

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ABSTRACT

The aim of this article is the selection of commercial building sites in the city of Rio de Janeiro by using techniques of multiple criteria decision-making processes. The technique chosen was based on the Analytic Hierarchy Process (AHP) methodology, due to its features, flexibility, and large applicability in engineering problems involving multiple criteria decision-making processes. Its application was done on an opinion survey among construction specialists, in which six criteria were selected to evaluate ten alternatives for commercial building sites. To operate the analytics of the method, researchers used the software *Super Decisions*, presenting the factors according to their priority in selecting the sites. And in the end, the results were demonstrated according to the hierarchical selection order.

Keywords: Decision-Making, Multi-criteria Analysis, Analytic Hierarchy Process, Real Estate Market, Site Selection.

1. INTRODUCTION

The increased demand for housing in large urban centers generated a considerable appreciation of the square meter in these locations. Yet, the search for available proprieties and land for building is frequent. The effect of appreciation brought up the investigation regarding land availability for construction companies and construction investors to know the best purchasing option available to finance the erection of buildings (Diário do Nordeste, 2012).

Therefore, the intense and accelerated urbanization generates problems, such as the lack of adequate areas for building in large urban centers. The search for available and appropriate lands for construction is already a common issue among construction companies.

Studies of land searching encompasses a set of proceedings that deal with elements seen in the regional and urban scale, getting to the conditions that will determine the selection of a certain terrain, involving complex physical and legal issues (Carvalho, 2005). Besides the observation of values involved, dimensions, and location, it is necessary to see if the soil and the water in the location will cause any impact due to previous activity (Arend et al., 2011). The countless attributes are a challenge to an effective and quick selection process for construction companies. With the use of decision-making models makes possible to analyze the present large number of attributes required to solve the problem, and to facilitate the same process, thus making the selection of an available land a more objective and conscious process.

A research, published on the Civil Construction Survey Journal, part of the Brazilian National Industry Confederation (CNI, in Portuguese), in 2010, listed the main issues found by companies of civil construction, indicating that the lack of availability of vacant land was one of the listed problems, most mentioned by small companies in the field.

According to the Federation of Industries of Rio de Janeiro State (FIRJAN, in Portuguese), in 2013, the civil construction sector was the direct responsible for more than 100 thousand new legal job positions, generating R$ 222 billion in Brazilian gross domestic product (GDP). Besides demonstrating a considerable expansion, these numbers show new challenges for the next years in many areas: innovation, technology, professional education, and favorable environment to productivity, to business competition, and to the country's development.

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More recently, it was observed a progressive deterioration of the economic and environmental conditions for business, in special in 2014, when the government clearly lost control of the fiscal budget. The recent past represents a legacy that should not get lost, an important contribution to income and job creation, and to the increase in quality of life of Brazilians. The expectations in 2015 showed the exhaustion of a historical cycle of investments in construction businesses, and the leaders in the field foresee the necessity to focus on measures that will support a sustainable recovery of the activities, improving the business environment (Revista Conjuntura da Construção, 2015a, p.3-4).

The selection of land for building is extremely important for the market of constructions, with great possibilities for financial feedback. There will always be a viable project, indifferently if the it is in a commercial or residential area. Therefore, the topic arose from a challenge faced by the researcher, when studying other researches and the theory itself (Prodanov et Freitas, 2013, p.120).

To define the selection of land using decision-making methods positively influences investors of this field. The article aims to propose the use of methods that support the decision-making process to select new building sites in the city of Rio de Janeiro, demonstrating through confrontation of specific methods the best investment possibilities in the field. The applied method was the Analytic Hierarchy Process (AHP), which is flexible, functional, and has a large application in engineering problems that involve multiple criteria, permitting a previous selection of lands according to the necessities of investors. Besides that, it permits to compare the types of soil using the same decision-making process, thus presenting a ranking of alternatives based on a defined scenario.

Hence, taking into consideration the measurable factors, the researchers desire to answer the following research question: are the results from the AHP methodology satisfactory in supporting the decision-making process to select building sites in the city of Rio de Janeiro? The general objective is to analyze the effectiveness of the decision-making process being evaluated, in order to select the best building sites in the city.

According to the president of the FIRJAN Systems, Mr. Eduardo Eugenio Gouvêa Vieira, and the president of the Civil Construction Industry Union of Rio de Janeiro State (Sinduscon-Rio, in Portuguese), Mr. Roberto Kauffmann, the construction civil industry is in the spotlight. The field, with is strategic for the development of the country, both by the use of large workforce and by the boost in the whole productive chain, is now the key to a successful arrival of voluminous investment, somewhere around R$ 235.6 billion between 2014 and 2016, as forecasted in the paper *Decisão Rio* (Sistema FIRJAN, 2014a, p.9).

Considering the large investments in the state of Rio de Janeiro, the concentration of the largest construction companies in the city of Rio de Janeiro, and mainly because civil construction is one of the most important sectors of Brazilian economy, as Brenner (2015) mentions, it is necessary an analysis process that enables a structured and simplified view to help in the decision-making processes in the field.

The article is structured in sections. The initial part mentions, in a broader view, the characteristics of the civil construction segment, and the importance of a decision-making method – the goals and the objectives are demonstrated in structured information. The second part is constituted by a logical and didactical presentation of the information acquired from bibliographical references, contextualizing civil construction concepts, as well as building sites, decision-making processes, the characteristics of the city of Rio de Janeiro and its real estate market, and in the end, the AHP method. Later, the methodology is portrayed in the development of the research method. The following section presents the databank survey and the description of the factors to apply the method. Next, there is a detailed analysis of data, using the method selected. Finally, the conclusion, with the limitations and challenges found, recommendations, and suggestions for future studies, and bibliographical references used.

2. 2. MATERIAL AND METHOD

2.1 Civil Construction

According to the Brazilian Ministry of Education, in the publication of national curricula standards for professional education (MEC, 2000, p.9), the field of civil construction englobes all the activities related to building. This area includes activities destined to planning and project, execution, maintenance, and rebuilding in different segments – buildings, roads, ports, airports, navigation channels, tunnels, building installations, sanitation works, and foundation and landing in general. Yet, according to the document, civil construction has interfaces with many other professional areas, such as management, clearly present in the managerial activities of execution and maintenance.

Civil construction was a strong propeller to the recent economic boom in Brazil, being its GDP accumulating a 47% growth in the period 2003-2013, against 46% from the rest of the economy as a whole during the same period. If the present investment rate in Brazil is relatively low, around 18% of the national GDP in the studied period, it is impor-

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tant to note that constructions were responsible for 40% of this investment (Revista Conjuntura da Construção, 2014, p.5).

Comparing in the global spectrum, between 2007 and 2013, the field of constructions generated 1.5 million job positions. In relative terms, the growth was 12% per year, in average. Both in the USA and in Europe, the picture was completely different. In the same period, US civil construction companies terminated 1.8 million positions, an average decrease of 3.1% per year. Considering the 27 countries of the European Union, the fall in job positions in the field between 2007 and 2013 achieved the level of three million professionals, thus resulting in an average decrease of 3.6% per year (Revista Conjuntura da Construção, 2015a, p. 14).

However, during the present moment, the area of constructions sees a reduction of job opportunities due to the Brazilian national economic momentum. In the state of Rio de Janeiro, the civil construction job market registered a negative result of 1,908 positions in 2014, while in 2013 there were 14,628 new positions. This scenario of job retraction persisted during the first semester of 2015, when only civil construction in the Baixada Fluminense region registered the drop of 2,070 job positions, according to the Bulleting of Job Markets, from the FIRJAN System (FIRJAN, 2015).

The industry of constructions is one of the most important segments of the economy in every country. In the past years, this field had had a significant process of expansion, and besides the effects of the international economic crisis, this dynamic state has found support, thus leading to new challenges. According to the data produced by the Getúlio Vargas Foundation, to cover the housing debt until 2022, investments must reach the level of R$ 3 trillion. Rio de Janeiro state, on its side, is in the center of all attentions as the largest holder of public and private investments (Sistema FIRJAN, 2013, p. 5).

The field of civil constructions depends directly from the management of information and flux of resources (people, materials, and equipment), which are characteristics that differ from other areas of industry, where production is determined by the speed of their machinery. The companies in the field of civil construction, as they belong to a very complex environment, demand from their managers a more specific approach. This field requires an extreme capacity for change to adapt to a new era, through the improvement of its processes and administrative standards, searching to have more competitiveness in the market (Xavier et al., 2014, p. 19 and 34).

2.2 Construction sites

Building projects are fundamental in the production process in the field of construction, as seen in Image 1. Building is a task that involves a detailed stud of the structure, calculus analysis, decision making processes, and other factors to achieve a satisfactory conclusion of the project design. According to the Brazilian National Classification of Economic Activities (CNAE), from the Brazilian Institute for Geography and Statistics (IBGE, 2007), the activity of building construction (class 4521-7) includes:

a) construction of residential buildings;

b) construction of commercial and services buildings;

c) construction of industrial buildings;

d) the activity also includes the construction, repair, or restoration of buildings of all types or their parts.

Image 1. Simplified representation of building processes of a project

Source: Designed from CLETO, F. R., (2006, p.43)

The Building and civil engineering works are performed both by the responsible units for the whole construction plan, by companies themselves, or by subcontractors, such as specialized units to perform part of the building plan (excavation teams, embankment, drainage, scaffolding, concreting, etc.), which are normally subcontracted.

There are many aspects to be characterized when evaluating a future building site. Camposinhos (2006, p. 2-3) mentions, among the main items, the legal framework, accessibility, topography, and elements for appreciation or depreciation.

In the definition of building capacity of a certain land, it is necessary to clearly know its legal-administrative status. It is a competence that the evaluator must have, looking for any possible charges registered in real estate registration offices, such as liens, mortgages, and their value. This information cannot be omitted, and when this data is not accurate, the investor must be informed of such imprecision. There are many documents that need to be observed: they must be all legal papers; the evaluator needs to observe the municipal director plans, the detailed plans, and the municipal services to verify eventual restrictions that can condition the constructive capacity of a site (Camposinhos, 2006, p.2).

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Yet, according to Camposinhos (2006, p. 3), it is fundamental to confirm it the land has direct access through a confronting track or road, or if the access is conditioned by a passage through another site. The available width and the inclination of the access route can determine the circulation of priority vehicles, firefighting trucks, and ambulances. Irregular lands are less used, therefore are less expensive. The position related to the level of the streets (if the land is located above or below street level) is a relevant fact; a terrain with higher inclination can force an increase of investment costs. The proximity to the sea or to a green zone in a central area of a city is an appreciation factor; the proximity to polluting industrial zones, illegal agglomerates, or the surroundings of hospitals, cemeteries, bars/nightclubs are considered (or can be considered) depreciative elements.

There are many criteria to be considered to build a certain project. The selection of a building site must take into consideration from essential aspect, such as sizing and location, to more specific ones, such as physical and legal limitations, which influence directly into the project, thus being able to undermine a whole building project.

2.3 Characteristics of the city of Rio de Janeiro

According to Rio Guia Oficial (2013), the city of Rio de Janeiro is located 22º54'23" South and 43º10'21" West. It is the capital of the state of Rio de Janeiro, one of the components of the Southeast region of Brazil. In the North, the city has many other municipalities as neighbors. Rio de Janeiro is bathed by the Atlantic Ocean in the South, by the Guanabara Bay in the East, and by Sepetiba Bay in the West. Its maritime frontier is larger than its terrestrial frontier.

The Metropolitan Area of Rio de Janeiro is composed by other 17 municipalities - Duque de Caxias, Itaguaí, Mangaratiba, Nilópolis, Nova Iguaçu, São Gonçalo, Itaboraí, Magé, Maricá, Niterói, Paracambi, Petrópolis, São João de Meriti, Japeri, Queimados, Belford Roxo, Guapimirim – which are denominated the Greater Rio, with a total area of 5,384km^2.

The total area of the municipality of Rio de Janeiro is 1,255.3km^2, including islands and continental waters. From East to West, it is 70 km long, and from North to South, 44 km long. The municipality is divided in 32 administrative regions, with a total of 159 districts, and 6,453,682 inhabitants (IBGE, 2014a).

According to Rio Guia Oficial (2013), the city's landscape belongs to the system of Serra do Mar (Sea Mountains), covered by the Mata Atlântica (Atlantic Forest). It is characterized by striking contrasts, mountains and the sea, forests and beaches, rocky escarpments near to extensive lowlands, making a landscaping view of rare beauty, which made Rio worldwide known as the Marvelous City. Rio de Janeiro presents three important mountain groups, some lower mountains, and isolated hills in plains surrounded by these main massifs.

Rio de Janeiro is the city with second highest GDP in Brazil, just behind São Paulo. It also has the 30th highest GDP per city in the world, which, according to IBGE, in 2007, was equivalent to 5.4% of the total national GDP. The services provide the largest part of this GDP (65.52%), followed by tax revenue (23.38%), industrial activity (11.06%), and by the agribusiness (0.04%).

2.4 Real Estate market in the city of Rio de Janeiro

Regarding the real estate market, according to data from the real estate website VivaReal, in 2014, the average price per m^2 in the city has grown 2% between the fourth quarter of 2013 and the same period of 2014. Chart 1 presents the evolution of the prices per quarter between 2013 and 2014.

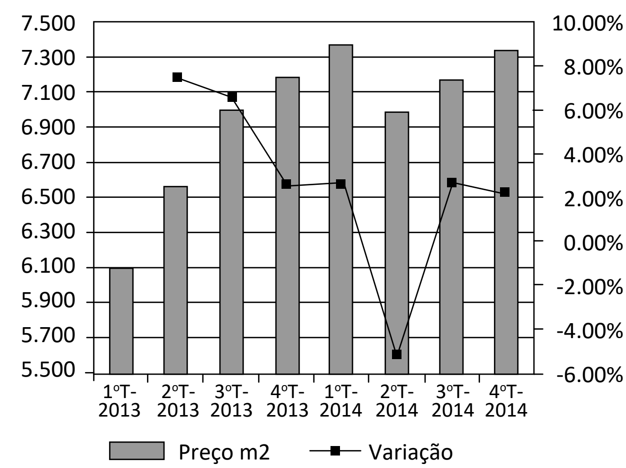

Chart 1. Evolution of average prices per m² in the city of Rio de Janeiro

Source: VIVAREAL (2014)

Legend: Preço m^2 = Price m^2; Variação = variation

The ten most expensive districts of Rio de Janeiro are represented in Chart 2. The gap between the most expensive district of the city and the tenth place is considerably large, once the district with the highest average price is Leblon, with values around R$23,631/m², and the tenth district is Botafogo, with price average of R$12,821/m².

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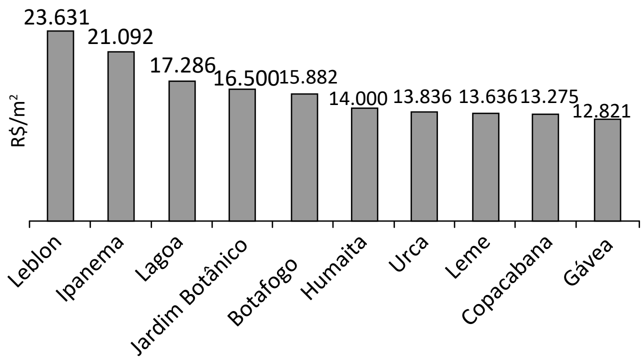

Chart 2. The ten most expensive districts of Rio de Janeiro
Source: VIVAREAL (2014)

However, according to the same real estate market source, none of these districts is between those that had largest appreciation in the price per square foot. Chart 3 shows the ten districts with highest appreciation between the first and the fourth quarter of 2014.

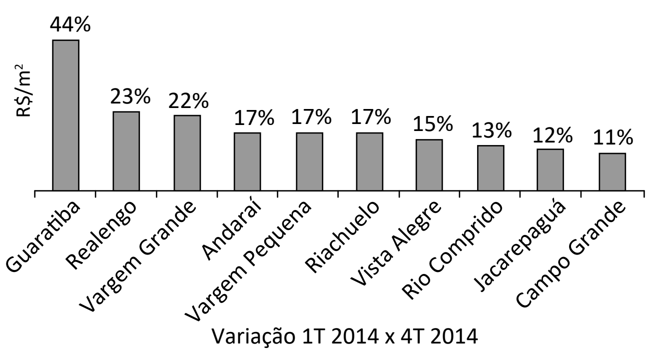

Chart 3. Districts of Rio de Janeiro with higher appreciation, between the first to the fourth quarter of 2014
Source: Designed from VIVAREAL (2014)

2.5 Decision-making process

This is the process to identify a problem or an opportunity, and to choose a line of action to solve it. A problem occurs when the present state of a situation is different from the desired one. An opportunity occurs when the circumstances offer a chance to an individual or to an organization to overcome his/its goals and/or targets (Lachtermacher, 2007, p.3).

In the 1960s, some researches started with the objective to find optimal solutions to support decisions, a motivation that became the main cause of development of new decision methods (Roy, 1968 in Barin, 2012, p. 43).

According to Gomes (2007), when recognizing that the decision-making process occurs in a dynamic scenario, which means, it develops through time, it is possible to state that the good decision is the one that solves a problem, based on a multiple criteria analysis. Once the scenario changes, better decisions, supported by the same support can arise. The multi-criteria support to the decision-making process has a crucial role, with an eminent technical nature, for processes under complex structures. It illuminates the trial procedure to find a satisfactory solution to the problem, by a wide observation of the structure of the problem, using analytical approach, and the usage of methods. Once there are multiple – and conflicting – decision criteria, it is possible to imagine that the satisfactory solution will answer, in different levels, to the many goals that characterize the decision problem.

As Lachtermacher (2007, p.3) mentions, there are many advantages that can be mentioned when the decision maker uses a model for the decision-making process:

a) models force decision makers to state explicitly their goals;

b) models force identification and storage of different decisions that influenced the goals;

c) models force identification of variables to be included and the means their will be quantified;

d) models force recognition of limitations.

Among the main decision making methods, the AHP method is significantly important. From the 1960s on, decision making methods were designed, such as the Elimination and Choice Translating Reality (ELECTRE) and the AHP, which propose the mixture of solutions based in real decision procedures (Barin, 2012, p.44). at the same time, other methods arose, such as Fuzzy Logic, Promethee, Macbeth, Borda count method, Variable Interdependent Parameters Analysis, and Todim.

AHP Method

One of the first methods developed to solve decision making problems under the existence of multiple criteria, quantitative and qualitative ones, was the hierarchical analysis method, also known as the AHP method. It was designed in the 1970s by the University of Pennsylvania professor Thomas L. Saaty. During the first years, however, the mathematical formulation of AHP differed from the method used in the following years, presented by Saaty in his first book regarding the topic (Gomes, 2007, p. 38). Three versions were developed for the Classic AHP method: the Referenced AHP Method, presented by Watson and Freeling (1982); the AHP

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B-G method, proposed by Belton and Gear (1985); and, finally, the Multiplicative AHP method, presented by Lootsma (1993) (FREITAS et al., 2008, p. 137).

The basic premise of the AHP method is that it is a complex decision making system must be defined according to a hierarchical structure composed by many levels, which include the elements characterized by similar elements. The structuring the problem under this paradigm enables the observed characteristics to be easily identifiable, especially in the cases in which the goal of the decision-making system consists in the selection of according to multiple attributes. One of the main aspects of the AHP method is that it recognizes the subjectivity inherent to the decision-making problems, and uses value judgment as means to treat it scientifically. This propriety of the method is extremely useful when there is a challenge to acquire information from probabilistic sources (Veras, 2014, p. 76).

The AHP technique has been studied and refined since its origin. It provides a comprehensive and rational proceeding to structure a certain problem, to represent and quantify its elements, to relate these elements with global targets, and to evaluate alternative solutions. It is used all over the world in a wide variety of decision making situations, in areas such as the government, business, industry, health, and education (Veras, 2014, p. 77).

The operation of AHP is similar to the natural method of operation to solve problems by the human mind, which understanding is considered so important as well as the collection of data. The method is widely used in multi-criteria studies to decision making due to its simplicity and easiness in operations.

The application of the AHP method can be divided in five stages:

a) building the hierarchical decision process;

b) comparison between elements of the hierarchy;

c) relative prioritizing of criteria;

d) evaluation of the consistency of priorities;

e) calculus of the global values of preference.

The structure of the hierarchy is presented in Image 2. The goal of the decision is the general objective to the reached, followed by the associated criteria to the decision making problem, and to the available alternatives that can be adapted to the problem studied.

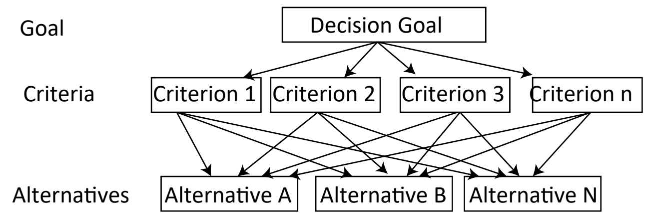

Image 2. Generic hierarchical structure in decision making problems
Source: SAATY, Thomas (1986, p.842)

After building up the hierarchy, it is necessary to establish priorities between the elements present in each level. For Costa (2002, p.16), the adjustment of priorities in AHP is supported by the ability of human beings to perceive the relationship between objects and situations observed, comparing by pairs in the light of a certain focus or criterion (joint judgments). In AHP, it is possible to evaluate the model of prioritization build regarding its consistency.

There are pair comparisons between the various elements of the hierarchy, from the alternatives – regarding the goals or criteria situated in hierarchical level immediately above them – to the goals and criteria compared to each other, from the point of view of the objective to be fulfilled in an upper level (Gomes, 2007, p. 39).

The scale of value for joint judgments varies from 1 to 9, and it is called Saaty's Fundamental Scale, as seen on Table 1, in which each element is associated to a priority value above other elements, permitting the comparison of alternatives. The scale varies from having the same level of importance of the activities described, to an absolute importance of one activity over another one.

Table 1. Saaty's Fundamental Scale

1	Equal importance	The two activities contribute equally to the goal.
3	Small importance of one over the other	Experience or judgment lightly favors one activity over the other.
5	Essential or large importance	Experience or judgment strongly favors one activity over the other.
7	Demonstrated or significantly large importance	One activity is significantly favored over the other. It can be demonstrated in practice.
9	Absolute importance	Evidences favor one activity over the other, with a higher level of security.
2, 4, 6, 8	Intermediate values	When there is a condition for compromise between two definitions.

Source: SAATY, Thomas (1986, p. 843)

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The results of the comparisons are presented in a matrix form represented in the Image 3, with the element of the matrix of judgments A satisfying the conditions a, b, and c.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ 1/a_{n1} & 1/a_{n2} & \cdots & 1 \end{bmatrix}, \text{onde:} \quad \begin{array}{l} a_{ij} > 0 \Rightarrow \textit{positiva} \\ a_{ij} = 1 \therefore a_{ji} = 1 \\ a_{ij} = 1/a_{ji} \Rightarrow \textit{recíproca} \\ a_{ik} = a_{ij} \cdot a_{jk} \Rightarrow \textit{consistência} \end{array}$$

Image 3. Matrix of generic decisions, with its respective conditions
Source: Marins et al., (2009, p. 1780)

Therefore, the decision maker must have n(n-1)/2 comparisons, being n the number of elements in the analyzed level. In a square matrix, there is aij, for every i = 1, 2, ..., n, and j = 1, 2, ..., n. There matrixes are always positive reciprocal. The comparison pair to pair is performed in every hierarchical level. Each element aij of the vector line of the dominant matrix represent the domination of the alternative Aj. The main diagonal of the dominant matrix is filled with an estimated value, which represents the non-dominance of an alternative over the other (Gomes et al., 2004, p.43).

The resolution of matrix A comes from the eigenvector of priorities, which demonstrates the importance related to each criterion, or weights. The most recommended format to calculate is to elevate the matrix to arbitrary high powers, dividing the sum of each line by the sum of the elements in the matrix, or in other words, normalizing the results of the matrix (Saaty, 1991a, p.363; Gartner et al., 2009, p.150).

In some problems, the restriction of pair to pair comparisons over a scale from 1 to 9 forces the decision maker to have inconsistencies, as for example, when considering A five times more important than B, and B five times more important than C. Then, to be consistent, A needs to be 25 times more important than C, but it is not possible under the scale used (Gomes, 2007, p.42).

Hence, according to Costa (2002, p.70), a way to measure the intensity of level of inconsistency of a matrix of joint judgments is to evaluate how much the highest eigenvalue of this matrix is away from the order of the matrix. Saaty proposes the following equation to calculate the Consistency Index (CI).

Inconsistency is an inherent fact to the human being. Therefore, there must be a tolerance for its acceptance. It is proposed an acceptance of judgments that may generate an inconsistency of CI < 0.1 (Saaty, 1991a, p. 105).

From the relative importance of the criteria and the level of preference of the alternatives, the overall value of each alternative is reached, according to an operation of weighted sum:

$$V(a) = \sum_{j=i}^{n} w_j \, v_j(a) \qquad (1)$$

With $\sum_{j=i}^{n} w_j = 1$ and $0<w_j<1 (j = 1, \ldots, n)$, where is the overall value of the analyzed alternative; is the relative importance of the criterion ; is the level of preference of the alternative for the criterion (Gartner; Gama; 2005, p. 150).

2.7 Method

For the present article, the multi-criteria analysis is done using the AHP methodology. The method has a vast and easily accessible theoretical referential, thus permitting a detailed application and an elevated level of confidence of the final results, which will be compared for the defined scenario.

The data was collected through the Internet, from a real estate webpage, called Canal do Imóvel (Real Estate Channel, in Portuguese. Available at http://www.canaldoimovel.com.br/), for the convenience of the researcher, with searches performed for the whole city of Rio de Janeiro, during the month of May 2015. A databank was created and organized, with 73 building sites available for residential or commercial use; for the present research, only the commercial sites were considered, resulting in ten alternatives to be analyzed.

The selection and the relevance of the criteria to evaluate the alternatives of vacant land were defined through an interview with specialists (two professional construction investors) in interviews, with an open questionnaire that had the following questions:

1. Which are the main factors to choose an empty site for building?

2. What is the the order of importance of these factors for commercial buildings? What are your justifications?

The interviews were answered according to the viewpoint of an investor in the process of purchasing/investing in lots for future commercial buildings.

The analysis of the AHP methodology was performed through the free access software *Super Decisions*, developed by Thomas Saaty.

After performing the method, by the compilation of data, the best alternatives were presented, permitting a comparison of the results found by the different methodologies available.

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3. RESULTS AND DISCUSSION

3.1 Data survey

3.1.1 Definition of criteria

The interviews to select and prioritize the criteria were performed separately, and through an open questionnaire. The interviewed professionals had the following characteristics:

Specialist 1: male, 45 years old, civil construction investor.

Specialist 2: male, 29 years old, architect, working in civil construction.

The selection of the factors was the same for both interviewees, who mentioned location, price, dimensions, surroundings, format, and documentation. The opinions were different in the prioritizing the factors. While Specialist 1 considered the price as one of the most important criteria, Specialist 2 defined price as a variable factor, passible of negotiation, prioritizing the fixed factors, location, dimensions, and surroundings. In the Chart 4, the full prioritizing of the factors by the interviewees.

Chart 4. Chart of priorities of criteria by the interviewees

Priority	Specialist 1	Specialist 2
1	Location (Zoning)	Location (Zoning)
2	Price (R$)	Dimensions(m²); Surroundings
3	Dimensions (m²)	Price (R$)
4	Surroundings	Format
5	Format	Documentation
6	Documentation	-

Source: designed by the authors (2015)

The criterion price is determinant; however, it is directly related to location. Hence, considering the large variation of prices in selling/buying, and in how much it is possible to offer/bargain, the evaluation and the application of the method will be based on the scenario of the Specialist 2, where the most precise factors are prioritized over the criterion price.

Next, there is the description of each criterion, justifying their position in the priority scale described by the Specialist 2, and the defined format of evaluation:

- <u>Location (Zoning):</u> the first filter to select a land is to observe if it is possible to build in the zone it is located. It is not possible to build residential structures in industrial zones. After this analysis, the location continues to be a priority factor, but in a sense the selected lot is in a valued and important zone for commercial purposes. As all selected lots of the databank were located in allowed zones for building, the factor of comparison among the lots will be the number of other commercial zones near the lot under analysis.

- <u>Dimensions(m²)</u>: they influence directly in the size of the building. For the present study, there are no pre-defined type of edification. Therefore, the best areas are considered are the most valorized, permitting a larger flexibility for the investor.

- <u>Surroundings</u>: the third factor in the preferential order, however, has the same importance as the criterion dimensions. The analysis of the surroundings is extremely important to select the lot, once it reflects the development around the place to have a new building. It is necessary to investigate the public transportation network, if the land has easy access, and if in the surroundings there are other buildings that may harm the enterprise, as well as other essential factors. For the present study, the standard used to evaluate the surroundings is the Human Development Index (HDI) of the district, which include other data, such as GDP and the Purchasing Power Parity (PPP) per capita, indicators of quality of life.

- <u>Price (R$)</u>: it is the monetary value expressed numerically given to the land.

- <u>Format</u>: it contemplates the geometrical format of the site and its inclination. These variables do not significantly influence the purchasing of the land, once present technologies can adequate projects to the many possible formats of construction sites.

- <u>Documentation</u>: it is a complex and variable criterion according to the location. It can impede some construction, but there are rare occasions with irregular documentation, once the lots for sale are normally with their documentation up to date.

Location, dimensions, and surroundings are criteria to maximize the search for a construction site. Hence, once the number of commercial zones increase, larger are the dimensions of the land; as higher is the HDI of a certain location, the better it is. The criterion price tends to minimize the number of alternatives. The lower the price, the better it is.

For the criteria format and documentation, it is necessary to design a scale to better evaluate the lots. For documentation, items vary between:

a) irregular;

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b) with restrictions;

c) regular.

The option regular is the priority. For the format, the variation goes:

a) irregular;

b) partially regular;

c) regular;

d) inclined;

e) lightly inclined;

f) flat.

The best evaluation for the criterion format goes with the combination of factors regular and flat.

3.1.2 Building the databank

The sites were chosen from the Canal do Imóvel website (http://www.canaldoimovel.com.br/), a portal of significant importance in online real estate classifieds, during the period from May 11th to May 22nd 2015. The access to data in one single research source aimed to minimize potential sources of errors and detours.

There were found 73 lots (63 residential and 10 commercial). For greater reliability of the results and an effective comparison pair to pair, the method was shifted to the applied only on the commercial sites. The main characteristics of the 10 commercial sites selected are described as follows.

After defining the databank for research, it is necessary the definition of the criteria that will be used to evaluate the selected alternatives.

3.2 Application and data analysis

3.2.1 Application of the AHP methodology

The first step to implement the AHP method is to build the hierarchical structure, represented in the definition of the global objective, the criteria, and the alternative for comparison. The hierarchical structure to select commercial building sites in the city of Rio de Janeiro is represented in Image 4.

With the defined hierarchical structure, the criteria pair to pair comparison was performed based on the fundamental scale proposed by Saaty, with the goal to observe the order of importance of the criteria observed.

To define the preference of the criteria, weights were given according to the relevance given by the Interviewee 2 for the criteria dimensions, documentation, surroundings, format, location, and price. The weights of the criteria and the evaluation

Table 2. Characteristics of the commercial sites in the city of Rio de Janeiro.

Lot	District	HDI	Commercial Zone	City Zone	Total Area (m2)	Format	Documentation	Prince, in million (R$)
L1	Botafogo	0.952	3	South	311	Partially regular and flat	Complete	2.800
L2	Barra da Tijuca	0.959	13	West	3,800	Regular and flat	Complete	14.000
L3	Barra da Tijuca	0.959	13	West	7,186	Regular and flat	Complete	17.975
L4	Madureira	0.831	2	North	1,109	Irregular and flat	Complete	2.600
L5	Vila Isabel	0.901	1	North	616	Regular and flat	Complete	4.000
L6	Jacarepaguá	0.769	0	West	5,668	Partially regular and flat	Complete	7.000
L7	Vargem Grande	0.746	0	West	15,000	Irregular and lightly inclined	Irregular	5.800
L8	Jacarepaguá	0.769	0	West	427	Irregular and flat	Complete	0.850
L9	Botafogo	0.952	3	South	300	Irregular and lightly inclined	With restrictions	5.000
L10	Engenho de Dentro	0.857	0	North	1,452	Irregular and lightly inclined	Complete	3.100

Source: Designed by the authors (2015)

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of the consistency index can be seen on Image 5. The consistency index for the criteria was acceptable, as they were below the tolerance value of 0.1. It is observed that the order of priority of the criteria in the selection of the lot: location, surroundings, dimensions, price, documentation, and format. With the order of importance of the criteria defined, the next step is to perform the comparisons of the selected alternatives.

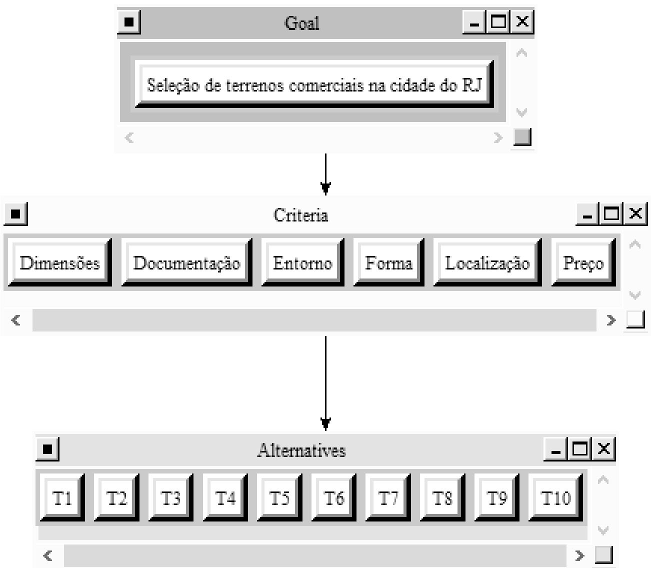

Image 4. Hierarchical structure to select commercial sites in the city of Rio de Janeiro

Source: designed by the authors (*Super Decisions*), 2015

Inconsistency: 0.05855	
Dimensões	0.16729
Documenta~	0.11826
Entorno	0.21934
Forma	0.03522
Localizaç~	0.32666
Preço	0.13322

Image 5. Weight of the criteria and consistency index

Source: designed by the authors (*Super Decisions*), 2015

Legend: Dimensões = Dimensions; Documenta~ = Documentation; Entorno = Surroundings; Forma = Format; Localizaç~ = Location "Preço"→ "Price

In a first analysis, the comparison of the alternatives was performed, following the criterion dimensions (m^2). The consistency index found was 0.04090, as seen on Image 6, showing that the comparative values are between the acceptable limit (below 0.1), and the order of preference of the alternatives for the criterion dimensions is L7>L3 >L6 >L2>L10>L4>L5>L8>L1>L9.

On the second analysis, there was the comparison of the alternatives according to the criterion documentation, according to Image 7. The consistency index achieved was 0.00611 and the order of priorities of the alternatives for the criterion documentation is L1 = L2 = L3 = L4 =L5 = L6 = L8 = L10 > L9 > L7.

Inconsistency: 0.04090	
T1	0.02846
T2	0.11584
T3	0.18168
T4	0.06581
T5	0.04372
T6	0.14558
T7	0.29387
T8	0.02940
T9	0.02526
T10	0.07039

Image 6. Weight of alternatives regarding the criterion dimension and consistency index

Source: designed by the authors (*Super Decisions*), 2015

Legend: T1 = L1; T2 = L2; T3 = L3; T4 = L4; T5 = L5; T6 = L6; T7 = L7; T8 = L8; T9 = L9; T10 = L10

Inconsistency: 0.00611	
T1	0.11844
T2	0.11844
T3	0.11844
T4	0.11844
T5	0.11844
T6	0.11844
T7	0.01833
T8	0.11844
T9	0.03415
T10	0.11844

Image 7. Weight of alternatives regarding the criterion documentation and consistency index

Source: designed by the authors (Super Decisions), 2015

Legend: T1 = L1; T2 = L2; T3 = L3; T4 = L4; T5 = L5; T6 = L6; T7 = L7; T8 = L8; T9 = L9; T10 = L10

On the third analysis, there was the comparison of the alternatives according to the criterion surroundings, as seen on Image 8. The consistency index achieved was 0.03322, and the order of priorities of the alternatives for the criterion surroundings is L2 = L3 > L1 = L9 > L5 > L10 > L4 > L6 = L8 > L7.

Inconsistency: 0.03322	
T1	0.15349
T2	0.20224
T3	0.20224
T4	0.05428
T5	0.07875
T6	0.03082
T7	0.02544
T8	0.03082
T9	0.15349
T10	0.06843

Image 8. Weight of alternatives regarding the criterion surroundings and consistency index

Source: designed by the authors (*Super Decisions*), 2015

Legend: T1 = L1; T2 = L2; T3 = L3; T4 = L4; T5 = L5; T6 = L6; T7 = L7; T8 = L8; T9 = L9; T10 = L10

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On the fourth analysis, there was the comparison of the alternatives according to the criterion format, as seen on Image 9. The consistency index achieved was 0.03002, and the order of priorities of the alternatives for the criterion format is L2 = L3 > L1 = L6 > L4 = L5 = L8 = L10 > L7 = L9.

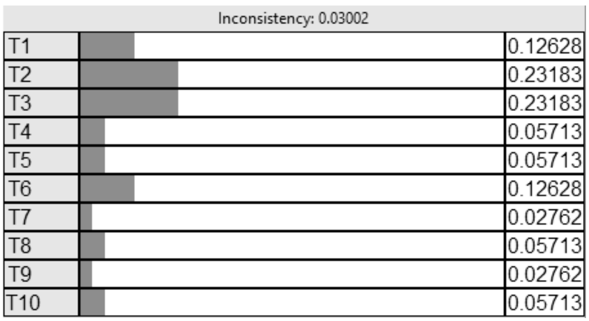

Image 9. Weight of alternatives regarding the criterion format and consistency index

Source: designed by the authors (*Super Decisions*), 2015

Legend: T1 = L1; T2 = L2; T3 = L3; T4 = L4; T5 = L5; T6 = L6; T7 = L7; T8 = L8; T9 = L9; T10 = L10

On the fifth analysis, there was the comparison of the alternatives according to the criterion location, as seen on Image 10. The consistency index achieved was 0.06865, and the order of priorities of the alternatives for the criterion location is L2 = L3 > L1 = L9 > L4 > L5 > L6 = L7 = L8 = L10.

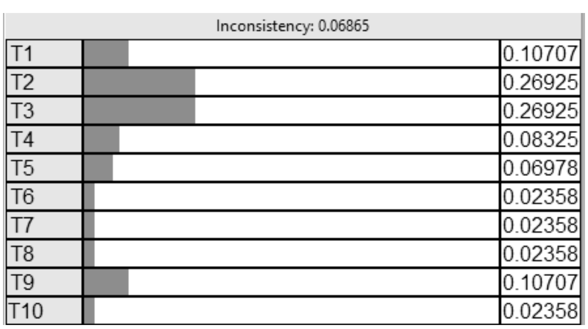

Image 10. Weight of alternatives regarding the criterion location and consistency index

Source: designed by the authors (*Super Decisions*), 2015

Legend: T1 = L1; T2 = L2; T3 = L3; T4 = L4; T5 = L5; T6 = L6; T7 = L7; T8 = L8; T9 = L9; T10 = L10

On the sixth and last analysis, there was the comparison of the alternatives according to the criterion price, as seen on Image 11. The consistency index achieved was 0.03019, and the order of priorities of the alternatives for the criterion price is L8 > L4 > L1 > L10 > L5 > L9 > L7 > L6 > L2 > L3.

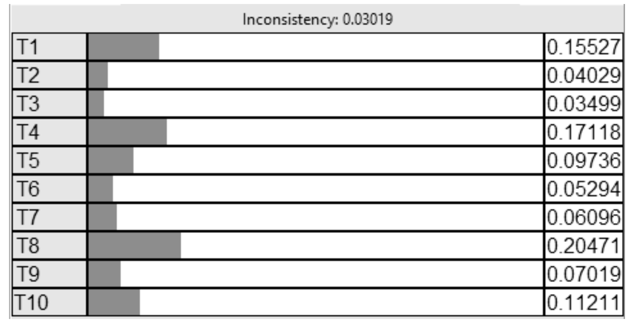

Image 11. Weight of alternatives regarding the criterion price and consistency index

Source: designed by the authors (*Super Decisions*), 2015

Legend: T1 = L1; T2 = L2; T3 = L3; T4 = L4; T5 = L5; T6 = L6; T7 = L7; T8 = L8; T9 = L9; T10 = L10

With the attribution of weights to the criteria and to the alternatives, the global priority vector is defined, as represented on Image 12. For the studied scenario, the best alternative is the Lot L3, and the final order of global priority is presented as L3 > L2 > L1 > L4 > L9 > L7 > L5 > L10 > L6 > L8.

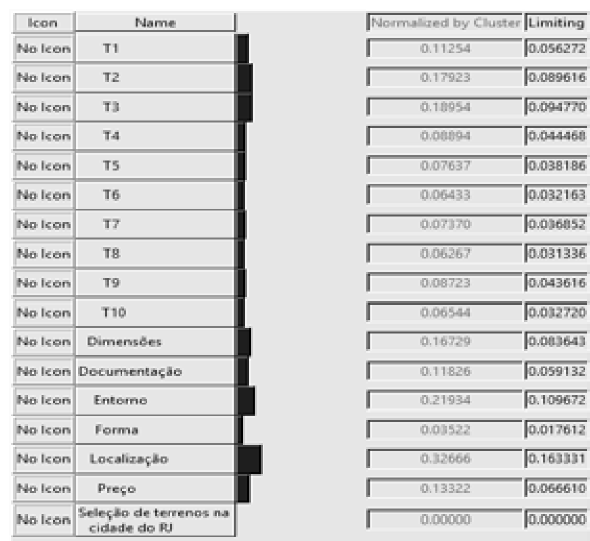

Image 12. Global priority vector and weight of criteria

Source: Designed by the authors (Super Decisions), 2015.

Legend: T1 = L1; T2 = L2; T3 = L3; T4 = L4; T5 = L5; T6 = L6; T7 = L7; T8 = L8; T9 = L9; T10 = L10; Dimensões = Dimensions; Documentação = Documentation; Entorno = Surroundings; Forma = Format; Localização = Location; Preço = Price; Seleção de terrenos na cidade do RJ = Selection of comercial sites in the city of RJ

4. CONCLUSIONS

This paper evaluated and classified commercial building sites by a databank created with alternatives found in the city of Rio de Janeiro, and as reference the use of a decision-making method, the AHP method. After the survey of the characteristics of the selected alternatives, the application

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of methodologies, and the analysis of the results found, it was possible to observe that a valid solution was given to the decision to invest in lands for future commercial buildings, from the point of view of the buyer, using the AHP method and the software *Super Decisions*.

The AHP method demonstrated a hierarchical organization of the alternatives, permitting the classification of the final result.

The alternative that were given priority have common characteristics of extremely importance for the interviewed specialists, such as a good location and its surroundings, criteria that influence directly in the buildings. The two alternatives with best evaluation results, L3 and L2, are located in the Barra da Tijuca district, which presents the highest HDI (0.959) and the largest number of commercial zones (13) among the alternatives.

It was also seen that the criterion price is represented by large values in the group of the best evaluated alternatives. It is justified with the selection of the scenario observed, which follows the prioritization of the factors by Specialist 2, for whom the price is not a priority, and immutable factors, such as dimensions and surroundings, are considered more important.

The alternative with the worst evaluation results are characterized by being located where HDI values are the lowest, and have none or few commercial zones surrounding the land. Besides that, some of these alternatives present impeditive factors for construction, such as irregular documentation, or ones with restrictions. The final results for the method applied is satisfactory, and tends to clearly incorporate all preferences chosen by the decision-making agents. This can be observed in the analysis of prioritized building sites, where all have essential characteristics brought up by the Specialists.

The decision-making methodologies applied are generic and can be applied in the evaluation of any site, since all necessary aspects for the decision process are incorporated to achieve a final objective.

The research found, as a challenge and a limitation element, the access to the information of the sites, which became the most difficult challenge to produce a result. Many real estate agencies do not have complete data regarding the sites on sale. Valuable information, such as specific dimensions (front and depth), and site format, took time to be found and provided, delaying the process of analysis and evaluation.

To continue the proposed study in this article, it is suggested to apply the Analytic Network Process (ANP), to solve one of the limitations of the AHP method used here: the necessity of interdependency between elements in a same hierarchical level. Therefore, the number of criteria could be amplified, allowing a more specific evaluation. Another suggestion is having the evaluation process without the criterion price, which can result in another perspective from the results. Besides that, the present study has shown how the use of the AHP method can make decision making in civil engineering more effective, thus bringing to light the importance that Engineering School should consider the inclusion of such techniques in their curricula.

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