FLOOD MANAGEMENT IN ALTO DO RODRIGUES/RN THROUGH THE ANALYTIC HIERARCHY PROCESS

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ABSTRACT: The municipality of Alto do Rodrigues was flooded several times (1964, 1974, 1985, 2004, 2008 and 2009). Because of this situation, this research aims to identify the best option within the alternatives and assist in determining priorities for managing flood risk in this municipality, based on management conducted in 2009 and through the Analytic Hierarchy Process (HAP) developed by Thomas L. Saaty (1972) and indicators produced by Cardona et al. (2005). The results expose great options to follow when comparing with the local reality.

Keywords: Risk; Vulnerability; Disaster; Flood; Management.

INTRODUCTION

As studies by many researchers, floods are the most common natural disasters affecting the said societies around the world. To prove this fact, Jonkman (2005) examined the emergency events database EM-DAT maintained by the Centre for Research on Epidemiology of Disasters (CRED) in Brussels and found that in the last decade of the 20th century problems related to floods victimized about 100 thousand and affected more than 1.4 billion people. Dilley et al. (2005) estimated that more than a third of the land area of the world is flooding affecting about 82 percent of the world population. The United Nations Program for Development (UNDP) in 2004 noted that approximately 196 million people in more than 90 countries are exposed to catastrophic flooding, and that approximately 170,000 deaths were associated with floods worldwide between 1980 and 2000 (MACHADO; AHMAD, 2006, p.1).

According to a study by the Catholic University of Louvain, Belgium, Brazil , between 2000 and 2007, the flood was the first in the list of incidence of natural disasters said with 58 % of registered cases then is dry (14 %) slip (11%), winds (8%), extreme temperatures (6%) and epidemics (3%) (Maffra; MAZOLLA, 2007, p.10).

The municipality of Alto do Rodrigues situated in Vale do Açu micro-region, located in the state of Rio Grande do Norte, Brazil, has been flooded several times with dated in 1964, 1974, 1985, 2004, 2008 and 2009 records, impacting on different sectors (economic, social and environmental) and on various scales (local, regional, national and international).

Over the years it is seen that such events have occurred in shorter periods with respect to time, and with greater intensity, with respect to impacts. Among the first three floods cited the turnaround time of this event was between nine and ten years. Already between 2004 to 2008 the maximum time without the action this episode was three years. After that last year the flood occurred the following year and in 2011. Floods in this region Of the seven, the 2008 was the one that had the lowest annual rainfall (778.1 mm), but was the most devastating, while that of 2009 was the second largest of the six floods this period (with a total rainfall of 1,126.9 mm) and the impacts were not as intense as the previous year (COSTA , 2009).

Due to these factors, it is necessary to study the environmental, social and managerial dynamics of this city will flood related, so that later environmental management policies and adapt their productive capacities are realized.

However, to facilitate understanding of the problem and guide the decision making before, during and after the occurrence of the flood, this article aims to identify the best option within the possible alternatives and aid in determining priorities for managing flood risk in the county Alto do Rodrigues, based on management performed in 2009, by means of the Analytic Hierarchy Process (AHP) developed by Thomas L. Saaty (1972) and indicators prepared by Cardona et al., (2005).

The Analytic Hierarchy Process (AHP) is an efficient method for decision making, because it identifies the best option within the possible alternatives and aid in determining priorities, considering both quantitative and qualitative aspects. By reducing complex decisions alongside comparative decisions together. AHP is divided into structuring, judgments and summary of results (BESTEIRO et al. 2009).

The Analytic Hierarchy Process is characterized by splitting a decision problem through its planning in hierarchical levels. A complex problem with multiple criteria, one can structure a hierarchy with many levels, reaching the main objective of the problem on the first level , the definition of the criteria in the second level and so on. Thus the decision maker must provide a single global goal and share the system with criteria and indicators reaching this goal (GOMES, 2006).

AHP is a multicriteria or multiobjective mathematical process developed by Thomas L. Saaty of the Wharton School, University of Pennsylvania (USA). He seeks to reproduce what appears to be a method of operation of the human mind, when faced with a large number of controllable elements or not, that contains a complex situation. In this condition, the elements are grouped according to common properties (Gomes, 2009).

When searching on the AHP related to flood management, the closest to this proposed work is the thesis Cortes (2009), whose title is "Systematic decision support for selecting alternative control urban flooding" because most work is in the area of administration. Regarding the environmental area, this methodology is more related to erosion, landslides and others.

METHODOLOGY

To apply the AHP four worksheets prepared by Cardona et al were used. (2005, p. 133-136).

Subsequently, the sheets were filled in accordance with the judgments issued by civil defense coordinator for each county in the study, using a scale ranging from 1 to 9, named by Saaty (1991 apud GOMES, 2009) by Primary Scale (Table 1).

Table 1 - Scale fundamental Saaty

Intensity of Importance	Definition	Explanation
1	Same importance.	Two criteria contribute equally to the objective.
3	Importance of a little over another.	Experience and judgment slightly favor one criterion over another.
5	Importance large or essential.	Experience and judgment strongly favor one criterion over another.
7	Importance demonstrated very large.	One criterion is strongly favored over another; their domination of importance is demonstrated in practice.
9	Absolute importance.	The evidence favoring one criterion over another with the highest degree of certainty.
2, 4, 6, 8	intermediate values between adjacent values.	When seeking a condition of compromise between two definitions
Reciprocals of the values above zero	If activity i receives a designation above zero if the activity i receives the designation above Zero When Compared to the activity j, then j has the reciprocal value When Compared with a reasonable designation i.	A reasonable description.

Rational	reasons resulting scale	If consistency is to be forced to obtain values

Source: Saaty (2000 apud GOMES, 2006).

The result is a matrix of pairwise comparisons or parity matrix, the result of judgments from one level under a certain criterion/indicator decision of the next higher level, which can be seen the results in Table 2 .

Table 2 - Arrays of preference for each criterion and the total

Indicators	IR1	IR2	IR3	IR4	IR5	IR6
IR1	1					
IR2	1/4					
IR3	1/4					
IR4	1/3	1/2				
IR5	1/2	1/2	1/2	1/3		
IR6	1/4	1/4	1/2	1/4	1/4	
Total	24/7	63/4	91/2	74/7	9 1/4	19

Subsequently the matrices normalized so that the sum of all its elements equals to 1 (Table 3).

Table 3 - Normalization of arrays

Indicators	IR1	IR2	IR3	IR4	IR5	IR6
IR1	1/5	1/7	1/7	2/5	1/5	1/5
IR2	2/5	2/7	1/7	1/4	1/3	1/5
IR3	0	1/7	0	0	0	1/7
IR4	0	1/7	2/7	1/8	1/5	1/7
IR5	1/5	1/7	2/7	1/8	1/5	1/4
IR6	0	0	0	0	0	0
Total	1	1	1	1	1	1

Then get the average of each criterion and the result, by converting fractions to decimals and is the arithmetic average of each row of the normalized matrix. The result is a vector representing a given criterion (Table 4), these values represent the best option (decision) to be followed.

Where aij indicates how much more important is the i-ésimo element relative to the j-ésimo element on the scale of Table 8. Matrices are positive parity comparisons, identical, reciprocal and consistent (Saaty, 2000, apud GOMES, 2009), serving three special properties:

1. identity - All the diagonal elements of the matrix compared are equal to 1, that is, for every is necessary that ii = 1. This is because each main diagonal element is compared to itself, or of equal importance;

2. Reciprocity - Each element below the diagonal of the comparison matrix of parity is equal to the inverse of the corresponding element above the diagonal, that is, aij=1 / aji. For example, if the attribute is deemed more important than 2 times the attribute B, then B is of importance attribute has the attribute; and

3. Consistency - Matrix of comparisons must satisfy the property of transitivity, which means that I is preferable that a j and j is preferable to k, I is preferable to k. For example, for any three attributes A, B and C, if A is judged to x times more important than B, and B is considered to z times larger than C, then A must be sometimes more important x times than C. According to this property, the columns of the parity matrix are scalar multiples compared with each other, so that the normalized columns (where each cell is divided by the sum of column) are identical, and any of them can represent relative values of alternatives. This occurs when you have a perfect cardinal transitivity, comparisons were made perfectly consistent (SILVA, 2003). However, according to Morita (1998 apud GOMES, 2009), this does not usually happen in practice and it is necessary to use the eigenvalue method to analyze the consistency of comparisons (GOMES, 2009).

The AHP uses the method of eigenvalue (eigenvalue) to determine the weights of the elements of the paired matrix, the order of priority and a measure of consistency of judgment. The elements of the parity matrix with normalized columns comparisons are called weights. In case of perfect consistency, the matrix is composed of lines of identical elements, while the sum of each column is equal to unity and can be represented by a vector of n elements W, which are the Wi, i = 1,…n weights (GOMES, 2009). The weights are calculated by Equation 2.

$$Wi = \frac{\sum_{j=1}^{n} aij}{n} \qquad [2]$$

The elements of the parity matrix comparisons relate to weights using Equation 3.

$$aij = \frac{Wi}{Wj} \quad {}_{i,j=1,\ldots n} \qquad [3]$$

Equation 3 is equivalent to Equation 4.

$$aij\frac{Wj}{Wi} = 1 \quad {}_{i,j=1,\ldots n} \qquad [4]$$

Consequently, we arrive at Equation 5.

$$\sum_{j=1}^{n} aijWj\frac{1}{Wi} = n \quad {}_{i=1,\ldots n} \qquad [5]$$

This is equivalent to Equation 6:

$$AW = nW \qquad [6]$$

By the theory of matrices, the vector W that satisfies Equation 6 is an eigenvector with eigenvalue n. In this equation, A is the pairwise matrix. In practical cases, where reciprocity of parity comparisons matrix is not perfect, the aij elements deviate from the ideal ratio wi/wj and Equation 16 is not valid. However, by combining the following two properties of the theory of matrices, it follows that the diagonal of the matrix A consists of unitary elements (aij=1), and if it is consistent, then small changes in aij maintain the maximum eigenvalue λmax close ne other eigenvalues near zero (GOMES, 2009) .

If λ1, λn are numbers satisfying the equation Ax=λx, so are eigenvalues of A, and if aij=1, then it is Equation 7.

$$\sum_{i=1}^{n} \lambda i = n \qquad [7]$$

If aij elements of a reciprocal matrix were modified in small quantities, the eigenvalues change in small quantities.

Thus, to find the priority vector, one should find the vector w that satisfies Equation 8.

$$Aw = \lambda \max w \qquad [8]$$

Where A is the pairwise matrix W and the vector is maximum eigenvalue λmax.

The distance between λmax n is thus a measure of consistency. From these concepts, Saaty (1980 apud GOMES, 2009) recommends the following procedure to verify the consistency of judgments and consolidate priorities.

Initially, the calculation is made of the approximate eigenvector way through three steps:

1. Sum total of each column of the comparison matrix;

2. Normalize the second matrix by dividing each element by the sum of its respective column, generating the Aw matrix shown in Equation (9); and

3. Calculate the arithmetic average of each row of the normalized matrix, generating the vector C shown in Equation (10) .

$$Aw = \begin{bmatrix} \frac{a11}{\sum_{i=1}^{m} ai1} & \frac{a12}{\sum_{i=1}^{m} ai2} & \dots & \dots & \frac{a1m}{\sum_{i=1}^{m} ai1} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \frac{am1}{\sum_{i=1}^{m} ai1} & \frac{am2}{\sum_{i=1}^{m} ai2} & \dots & \dots & \frac{amm}{\sum_{i=1}^{m} aim} \end{bmatrix} \quad [9]$$

$$C = \begin{bmatrix} c1 \\ \dots \\ \dots \\ \dots \\ cm \end{bmatrix} = \begin{bmatrix} \dfrac{\frac{a11}{\sum_{i=1}^{m} ai1} + \frac{a12}{\sum_{i=1}^{m} ai2} + \dots\dots + \frac{a1m}{\sum_{i=1}^{m} aim}}{m} \\ \dots \\ \dots \\ \dots \\ \dfrac{\frac{am1}{\sum_{i=1}^{m} ai1} + \frac{am2}{\sum_{i=1}^{m} ai2} + \dots\dots + \frac{amm}{\sum_{i=1}^{m} aim}}{m} \end{bmatrix} \quad [10]$$

The vector C is the eigenvector of the criteria/indicators for decision at each level. The same process should be applied to each matrix of comparisons spanning the entire hierarchical structure of the problem. Ci elements represent the relative degree of importance of the i-ésimo element in the column vector of importance weights .

Then, multiply the matrix of comparisons parity (A) vector estimated by the self solution (Vector C), resulting in a column vector called by Morita (1998 cited in Gomes, 2009) vector consolidated priorities as shown in Equation 11.

$$A.C = \begin{bmatrix} 1 & a12 & \ldots & a1m \\ a21 & 1 & \ldots & a2m \\ \ldots & \ldots & \ldots & \ldots \\ am1 & am2 & \ldots & 1 \end{bmatrix} \begin{bmatrix} c1 \\ \ldots \\ \ldots \\ \ldots \\ cm \end{bmatrix} = \begin{bmatrix} x1 \\ \ldots \\ \ldots \\ \ldots \\ xm \end{bmatrix} \quad [11]$$

When normalized columns are not identical appear to inconsistency of the parity matrix comparisons, requiring an evaluation of the consistency. The consistency of a positive reciprocal matrix requires its λmax value equals the number of rows (or columns) of the matrix n parity comparisons. The closer λmax is n, the result will be more consistent. λmax is calculated using Equation 12 .

$$\lambda \max = \frac{1}{n} \sum_{i=1}^{n} \frac{i-ésima.entrada.em.AxC}{i-ésima.entrada.em.C} = \frac{1}{n} \sum_{i=1}^{n} \frac{Xi}{Ci} \quad [12]$$

The consistency index IC matrix comparisons of parity is used to show how the value of λmax is away from the expected theoretical value of n, so the variance is given by (λmax -n) . This difference is measured in the number of degrees of freedom of this matrix (n-1). Thus, the consistency index is given by Equation 13.

$$IC = \frac{\lambda máx - n}{n-1} \quad [13]$$

If IC is sufficiently small, the comparisons are probably consistent decision maker to give useful estimates of the weights of the objective function. The consistency index is compared with the randônico index (IR) value for n (the number of the parity comparison matrix) to determine the degree of consistency is satisfactory. The randônico index represents the value that would be obtained in an array of parity comparisons that n order in which they were not made logical judgments, filling the elements with random values. The index values of random matrices for the parity matrix type comparisons were calculated by Saaty (1980) and are shown in Table 2.

Table 2 - Randônico Index as a function of order of the parity matrix comparisons

Dimension of matrix	Random consistency
3	0,52
4	0,89
5	1,11
6	1,25
7	1,35
8	1,40
9	1,49
10	1,51

Source: Saaty (1980 apud GOMES, 2009) .

The consistency ratio used to analyze the degree of violation of proportionality and transitivity judgments of the decision maker. The consistency ratio is calculated by Equation 14.

$$RC = \frac{IC}{IR} \quad [14]$$

Parameter: that is adopted IC/IR<0.10, the degree of consistency is satisfactory, but if IC/IR>0.10, there may be inconsistencies and AHP can not give significant results. When the degree of consistency is poor (index greater than 0.10 consistency), more information is needed in comparisons of criteria, so perform a collection of information from a new review of trials (GOMES, 2009) .

RESULTS AND DISCUSSION

Table 3 presents the results of the AHP for Indicators of Risk Identification to be prioritized in municipality of Alto do Rodrigues.

The result of AHP addresses that should first prioritize the systematic inventory of disasters and losses (37.1%), because it is through this that has the size of the losses and disaster, which exposes the places which should be invested, so, provide structural measures or not.

Table 3 - Results for AHP for Indicators of Risk Identification

Indicators of Risk Identification to be prioritized	% of AHP
IIR1 - Systematic cataloging of disasters and losses	37,1
IIR2 - Monitors threats and prognosis	19,1
IIR3 - Evaluation of threats and their representation on maps	10,4
IIR4 - Vulnerability Assessment and Risk	16,3
IIR5 - Public information and community participation	12,3
IIR6 - Training and education in risk management	5,0

Then AHP suggested to invest in monitors threats and prognosis (19.1%), because the city no monitors. This municipality is based on data supplied by the EMPARN Ipanguaçu (precipitation) and Natal (forecast rainfall). In addition to these agencies, government administrators get information on Acu DNOCS as the volume of the dam Mr. Armando Ribeiro Gonçalves. Allied deployment of monitors and forecasts should deploy warning systems.

The municipality should also prioritize the issue of vulnerability assessment and risk (16.3%), because despite identifying the elements exposed in areas prone city using the AVADAN and conduct a general study of physical vulnerability to flooding using Google Earth for delimiting these, taking into account other water body within the municipality. However, this map covers only the general water resources of the municipality and pavements damaged access, general physical vulnerability studies are needed using a Geographic Information System (GIS) taking into account other compromised infrastructure such as homes, flooded areas, other infrastructure and others. And beyond this factor should take into account detailed risk studies, using probabilistic techniques, taking into account the economic and social impact caused by flooding, vulnerability analysis of the most essential buildings (schools, hospitals) and general risk assessment, considering physical, social, cultural and environmental factors.

In sequence, the AHP addresses that need to engage in public information and community participation (12.3%), since the information on risk management in the year 2009 was passed by these sporadically and under normal conditions. The managers of this town could well make disclosure to the press and broadcasting of radio and TV programs, guiding the population to prepare in case of emergency; fabricate illustrative materials on flooding to reduce vulnerability and perform work with communities and NGOs regarding the flood.

Another item that should be taken into consideration is the assessment of threats and their representation on maps (10.4%). Although the municipality undertake delimitation of flood stricken through Google Earth areas, such action should be improved through extensive coverage with risk maps resolution and large scales; perform micro zoning and zoning of the city with and without probabilistic techniques. Besides this factor, the municipality lacks training and education in risk management (5.0%), which is not performed. However, should incorporate risk management into the curricula, instructional fabricate high quality materials and conduct frequent training courses population.

Regarding the indicators of risk reduction (Table 4), the AHP states that, first the integration of risk in the definition of land use and urban planning (23.7%) should be performed through the approval and control compliance with plans and legislation for spatial planning and development including the risks as determinants and generalize the provisions of urban security.

Table 4 - Results for AHP for Indicators of Risk Reduction

Indicators of Risk Reduction to be prioritized	% of AHP
IRR1 - Integration of risk in the definition of land use and urban planning	23,7
IRR2 - in watershed and environmental protection	22,4
IRR3 - Implementation of Data Protection and Flood Control	9,6
IRR4 - Improvement of property and relocation of settlements (residential) of prone areas	19,7
IRR5 - Updating and control of the implementation of standards and building codes	6,5
IRR6 - Strengthening and Intervention vulnerability of public goods	18,1

Then you need: intervention and environmental protection of river basins (22.4%) by means of contingency plans and environmental protection ; improving housing and relocation of settlements (residential) prone areas (19.7%), taking into account the outstanding control of risk areas of the city and relocation of most houses built in risky areas immitigable; strengthening intervention and the vulnerability of public goods (18.1%) with the massification of strengthening of key public buildings and infrastructure lifelines (roads, schools, hospitals etc.) and permanent incentive programs for rehabilitation of housing for socioeconomic strata of low-income ; implementations of techniques for protection and flood control (9.6%) through the implementation of mitigation plans and appropriate design and construction of stability, cushioning, dissipation and control with the purpose of protection of the population and social investments. And to finish this item the focus should be given to update and control the application of standards and building codes (6.5%), making the manufacture and permanent updating of codes and other safety standards, implementation of a regulation for construction the city based on zoning control and compliance.

With respect to indicators of Disaster Management (Table 5), the AHP displays that must first be investing in the organization and coordination of emergency operations (32.2%), because from this practice is that accrue outlets decision for the population that is vulnerable to disaster.

Table 5 - Results for AHP for Indicators of Disaster Management

Indicators of Disaster Management	% of AHP
IMD1 - Organization and coordination of emergency operations	32,2
IMD2 - Planning response in case of emergency and warning systems	19,5
IMD3 - Allocation of staff, tools and infrastructure	18,2
IMD4 - operative Training, simulation and test of interagency response	4,7
IMD5 - Preparation and community empowerment	11,1
IMD6 - Planning for the rehabilitation and reconstruction	14,2

Then you should invest: response planning in case of emergency and warning systems (19.5%) through comprehensive plans and contingency and the associated public information and warning in most localities or districts systems; the appropriation of teams, tools and infrastructure (18.2%), so to obtain institutional support networks of centers between reserves and Emergency Operations Center (EOC) permanently running, ample facilities reporting, communications, transportation and supply in case of emergency; planning for rehabilitation and reconstruction (14.2%) by carrying out plans and programs for the recovery of the social fabric, sources of labor and production resources to the affected population; preparation and training of the community (11.1%), which can be done with the realization of common courses with the population at risk of flood preparation, prevention and risk reduction. And finally, realize operational training, simulation and test of institutional response (4.7%), permanent training of response teams, test plans and contingency and update operating procedures based on simulation exercises in most locations .

And with regard to indicators of Governance and Financial Protection (Table 6) AHP sports that must be invested primarily in inter-institutional, multi-sector and decentralized (34.8%) by means of continuous and decentralized execution project management of risks associated with environmental protection, energy, sanitation and poverty reduction programs.

Table 6 - Results for AHP for Indicators of Disaster Management

Governance Indicators and Financial Protection to be prioritized	% of AHP
IPF1 - Inter- Organization of multiple sectors and decentralized	34,8
IPF2 - Funds reserves for institutional strengthening	5,5
IPF3 - Location and resource mobilization and budget	21,4
IPF4 - Implements networks and social security funds	7,7
IPF5 - Insurance coverage and loss transfer strategies of public assets	16,2
IPF6 - Cover insurance and reinsurance of property	14,4

Then you must take care to provide: location and mobilization of resources and budget (21.4%), by determining the values aimed at reducing vulnerability, set up fees for environmental protection and safety and operating budget loans requested by the city with the purpose of reducing risk on suppliers credit agencies; insurance coverage and loss transfer strategies of public assets (16.2%), through the analysis and implementation of strategies for retention and transfer of losses on public assets, considering consortia of reinsurance for catastrophe bonds, etc; insurance coverage and reinsurance of property (14.4%); implement networks and social security funds (7.7%) through the development of social protection programs and poverty reduction and mitigation activities and risk prevention flooding in the city and finally application of reserve funds for institutional strengthening (5.5%).

CONCLUSIONS

The criteria (Risk Identification, Risk Reduction, Disaster Management and Governance and Financial Protection) were related to sub criteria (six each) allowing the assembly of consistent solution. From the alternatives, parity judgments and consistency analysis were made, in an ascending hierarchical structure, through the sub - criteria and criteria to reach the goal is to determine what action should prioritize among others.

Thus, the Analytic Hierarchy Process helped set among the items of each indicator which should prioritize and thereby improve the management will flood the city under study.

Before applying this methodology, surveys and studies were performed as flood action and unplanned. Currently there is a guideline to focus on risk management to the phenomenon under consideration, aimed not commit the flaws mentioned above.

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