Evaluation of urban development proposals An ANP approach

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Abstract— In this paper a new approach to prioritize urban planning projects in an efficient and reliable way is presented. It is based on environmental pressure indices and multicriteria decision methods.

The paper introduces a rigorous method with acceptable complexity of rank ordering urban development proposals according to their environmental pressure. The technique combines the use of Environmental Pressure Indicators, the aggregation of indicators in an Environmental Pressure Index by means of the Analytic Network Process method and interpreting the information obtained from the experts during the decision-making process.

The ANP method allows the aggregation of the experts' judgments on each of the indicators into one Environmental Pressure Index. In addition, ANP is based on utility ratio functions which are the most appropriate for the analysis of uncertain data, like experts' estimations. Finally, unlike the other multicriteria techniques, ANP allows the decision problem to be modelled using the relationships among dependent criteria.

The method has been applied to the proposal for urban development of La Carlota airport in Caracas (Venezuela). The Venezuelan Government would like to see a recreational project develop on the abandoned area and mean a significant improvement for the capital. There are currently three options on their table which are currently under evaluation. They include a Health Club, a Residential area and a Theme Park.

The participating experts coincided in the appreciation that the method proposed in this paper is useful and an improvement from traditional techniques such as environmental impact studies, life-cycle analysis, etc. They find the results obtained coherent, the process seems sufficiently rigorous and precise, and the use of resources is significantly less than in other methods.

Keywords— Environmental pressure indicators, Multicriteria decision analysis, Analytic Network Process.

I. Introduction

La Carlota airport is located in the valley of the City of Caracas (Venezuela). It covers an approximate land area of 100 Ha. It was inaugurated in 1946 for civil and military use and was shut down by the National Executive Department in 2005 with the intention of using the land for other purposes. Since then, different proposals for the recreational, urban and cultural use of the land have been formulated.

Three different proposals of land use have currently been presented to the Government of Venezuela, but the proposals have not been evaluated nor selected yet. The proposals consist of three different projects of urban development: a residential area, a health club and a theme park.

The residential complex was proposed by the City Council of the Municipality of Chacao, which is located next to the airport. The project arose in August 2006 as a response to the need for more housing. Although the National Government is in favour of the construction of a residential area in the land of the airport, it presented an alternative project that considered a higher population density. None of the projects was positively welcomed by the local community, who considered that the construction of a residential area would increase traffic problems and worsen local public services.

On the other hand, the recreational and Health club was proposed by the architect Fruto Vivas in 2000 with the purpose of offering more recreational and leisure areas to the people of Caracas. The architect mentions that the city only counts with 0.2 square metres of green areas per inhabitant. The development of this proposal was demanded by the National Government, which has not made any decision on it yet. However, the local communities seem to agree with this land use of the airport, provided its implementation does not involve negative impacts on public services and the corresponding authorities commit themselves to environmentally preserve the area.

As regards the theme park, it was proposed by the architect Ivan León in 2007 with the purpose of giving the Libertador Simón Bolívar a zone in which Bolivarism can be seen by Venezuelans as a respect to the activities and achievements of this leader throughout his life. This proposal has not been taken into consideration by the National Government or by the local communities, so that the promotion of the proposal has been led by the architect himself.

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Fig. 1. Location of La Carlota airport at Caracas, Venezuela.

The three urban development proposals involve environmental impacts which have not been properly assessed yet. Actually, none of them has completed the Environmental Impact Assessment (EIA) analysis as stated in the Constitución de la República Bolivariana de Venezuela (1999).

The present work proposes a new method for the environmental prioritization of these projects of urban development based on the technique known as Analytic Network Process (ANP) that allows the analysis of different carefully selected variables with the aim of making efficient and reliable decisions based on the opinion and judgments of a group of experts.

II. The Complexity of Environmental Assessment for Sustainable Urban Development.

As a project becomes more and more complex, environmental impact assessment also becomes more complex (EIA refers to both the analysis and the assessment of environmental impact). This has led several authors to discuss the reliability and accuracy of EIA as a decision-making tool for ranking different alternatives when they show complex interactions with the environment along their life cycle. This is even more so if the environmental impacts occur in the long term during the phases of "Exploitation" and "End of Life" of the product [1].

Urban planning projects can be included in this category. According to [2], [3], [5], [6], they are projects with significant and complex environmental impacts that greatly affect environmental sustainability. On the other hand, they are projects with long life cycles in which the biggest impacts mainly occur during the exploitation phase. The exploitation phase may last several decades which makes it difficult to assess its values. Thus, EIA techniques are necessarily based on estimates and assumptions for the determination of the most relevant impacts. We can affirm that the sophisticated and accurate analysis tools are of little use when the information available is inaccurate and uncertain.

EIA presents another drawback when making decisions on different urban planning projects, as the results obtained from the assessment process for each project are not comparable. Actually, each assessment team may take into consideration different environmental impacts [7]. But even if they select the same impacts for all the alternatives, a second problem is how to compare alternatives that stand out in the analysis of different environmental impacts. For example, one project causes greater effects on the climate change, another project on a higher consumption of non-renewable resources, and a third one on toxicity, Which environmental impacts are to be considered more important?

There is extensive literature on alternatives to Environmental Impact Assessment of Urban Development [8]. These alternatives try to solve the problems of EIA, i.e. lack of rigor, lack of accuracy and non-comparable results. Additionally, on certain occasions or for some decision-makers, EIA procedures can be too cumbersome or slow for the degree of reliability and accuracy obtained [7], [8], [9].

To solve such problems the most widely used approaches are those that combine a simpler procedure of data collection and environmental impact assessment, and the clustering of the results into indices [10]. These indices receive different names: Environmental Quality Index [7], [11], Sustainability Index [12], Environmental Sustainability Index [13], Environmental Impact Index [10], etc. The differences among these indices can be grouped into two index design strategies:

a) How to estimate the relationship between the activity and the environment

b) How to cluster the results of the estimates into one single value, i.e. the index

The first strategy for index design is related to how we can simplify the search for measurable environmental factors and their conversion into environmental impacts. And all this with a sufficient degree of reliability and accuracy. There are several approaches:

a) To consider only indicators of environmental pressure [14], [15] assuming that the lower the environmental pressure the smaller the environmental impact

b) To use Environmental Performance Indicators [10]. It is a simplification of the first approach in which, on one hand the search is restricted to the most significant environmental aspects, and on the other hand usually to the "life cycle" phase of the project considered as the phase with the highest environmental impact

c) To take into consideration the opinion of experts [11], [16], [17]. In this case, there are no estimates, and the information used comes from the opinion on the project by experts of renowned experience and knowledge of the case.

The second strategy for index design consists of clustering the assessment results into an index that allows for the comparison of the alternatives. Within this approach we can find the following methods:

a) To use transfer or utility-ratio functions [18]. In order to convert the different environment aspects' values to the same scale utility-ratio functions are used and the results, either weighted or not, are clustered into an end value

b) To use transfer or utility-interval functions [19], [1]. The standard procedure consists of using value intervals between a maximum and a minimum value to which the different variables of the problem are compared. The results of the comparisons, either weighted or not, are then clustered into an end value

Finally, when the information available is biased and uncertain, as in urban development planning environmental impact assessments, it is necessary to make estimates. In such cases, experience and knowledge of the problem are more important than the assessment technique itself. Therefore, it is preferable to focus the efforts on finding a renowned group of experts and get them involved in the process. Similarly, [20] reports that for problems with biased or non-quantifiable data, the utility-ratio functions are more efficient for prioritization purposes.

In the present work an approach based on a combination of the experts´ judgments on the problem and the utility-ratio functions is proposed. The experts help to classify the different alternatives according to the environmental pressure that the alternatives will exert along their life cycle if they are implemented. [10] prove that this data is enough to select the best projects from the viewpoint of environmental impact. The experts select the environmental pressure indicators (EPRI) depending on the characteristics of the project and its life cycle, the conditions of the local and general environment, and the estimated environmental impacts resulting from the environmental pressure of each alternative

In order to cluster all judgments on the different environmental pressures into a single "Environmental Pressure Index" that simplifies the ranking of urban planning alternatives, a new technique based on Multicriteria Decision Analysis (MCDA), namely the Analytic Network Process, is proposed in the present work. This method, based on the use of utility-ratio functions, is particularly suitable for problems with little and uncertain information, using qualitative criteria which are not independent of each other [21], [22].

III. The use of MCDA techniques for Environmental Assessment

Authors like [16] or [1] have indicated the importance of accurately modelling reality when making decisions on projects that will affect the environment in one way or another. In particular, [23] has proved the effects on the end model of the problem when the aim of the decision is the preservation of the environment. Therefore, the selection of the environmental pressure indicators (which will act as criteria) and how they are assessed and clustered to calculate the indices should be done carefully to maximize the correlation between the index values obtained and the quality to be measured.

MCDA techniques are very appropriate to solve this type of problems. The expression MCDA is used as an umbrella term to describe a number of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter [24]. More information about MCDA can be found in [24], [25].

Several authors introduce the use of MCDA techniques for Environmental Assessment. Many of them focus on the use of the Analytic Hierarchy Process [20] which has been accepted as a leading multi-criteria decision model [26], [16], [11] to assign priorities to the criteria or indicators involved. Others introduce the use of outranking techniques such as Electre [27] and Promethee [28] in order to avoid the compensation problem of the traditional methods [29], [30], [1]. This compensation problem is inherent to all aggregation methods based on sums: an extreme value of one criterion may compensate the moderate values of other criteria giving a global result that may not correspond to the experts' opinion. All these MCDA techniques work well under the assumption of the independence of criteria. However, this assumption is not always realistic, and for sure not in the field of Environmental Assessment. Thus, bias can occur when using any of these methods and this can lead to non-optimal evaluations.

For that, the Analytic Network Process (ANP) is chosen as it takes into account the interdependence among the criteria and avoids to a great extent the problem of compensation.

The Analytic Network Process (ANP) is a method proposed by [21]. It provides a framework for dealing with decision making or evaluation problems. It presents its strengths when working in scenarios with scarce information. Similar to the AHP, the ANP is based on deriving ratio-scale measurements to be used to allocate resources according to their ratio-scale priorities, whereas ratio-scale assessments, in turn, enable considerations based on trade-offs [31]. AHP models assume a top-down relationship among decision levels, which means that bias could occur when the criteria and subcriteria are correlated with each other. However, ANP does not require this strictly hierarchical structure and allows for more complex inter-relationships among the decision levels. ANP generalizes the problem modelling process using a network of criteria and alternatives (all called elements), grouped into clusters. All the elements in the network can be related in any possible way, i.e. a network can incorporate feedback and interdependence relationships within and between clusters. This provides an accurate modelling of complex settings and allows handling the usual situation of interdependence among elements in Environmental Assessment Scenarios.

Some of the most recent applications involving ANP are found in construction project selection [32]; resource allocation in transportation [33]; strategic policy planning [34]; forest management [35],; evaluation of alternative fuels for electricity generation [13], strategic e-business decision analysis [36]; asset valuation [37], [17]; determination of the appropriate energy policy [38] or financial crisis forecasting [39].

It is very important to count on the participants involved throughout the evaluation and interpretation processes and use of the results. Therefore, the aim of this proposal is not to substitute the work of any of the environmental assessment experts but on the contrary to ease and facilitate it. The experts´ opinions and judgments are the only ones to be taken into account and to be the input data in the evaluation model.

IV. Theoretical Background of the ANP Model

Details on the Analytic Network Process (ANP) can be found in Saaty (1996), however, the main steps are summarized here for completeness.

(i) Pairwise comparisons on the elements and relative weight estimation

The determination of relative weights in ANP is based on the pairwise comparison of the elements in each level. These pairwise comparisons are conducted with respect to their relative importance towards their control criterion based on the principle of AHP and measured using Saaty's 1-to-9 scale (see table I). The score of a_{ij} in the pairwise comparison matrix represents the relative importance of the element on row (i) over the element on column (j), i.e., $a_{ij} = w_i/w_j$.

TABLE I
SAATY´S COMPARISON FUNDAMENTAL SCALE

Degree of importance	Definition	Explanation
1	equal importante	the two elements contribute equally to the objective
3	moderate importante	experience and judgment slightly favor one element over another
5	strong importante	experience and judgments strongly favor one element over another
7	very strong importance	an element is favored very strongly over another; its dominance is demonstrated in practice
9	extreme importance	the evidence favoring one element over another is of the highest possible order of affirmation

With respect to any criterion, pairwise comparisons are performed in two levels, i.e. the element level and the cluster level comparison.

If there are n elements to be compared, the comparison matrix A is defined as:

$$A=\begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ & & & \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix}\dots$$

After all pairwise comparisons are completed the priority weight vector (w) is computed as the unique solution of

$$Aw = \lambda_{\max} w$$

Where λ_{max} is the largest eigenvalue of matrix A and w is its eigenvector.

The consistency index and consistency ratio of the pairwise comparison matrix could then be calculated by:

$$CI = \frac{\lambda_{\max} - n}{n-1}, \quad CR = CI/RCI$$

RCI being a Random Consistency Index provided by Saaty (1980)

In general, if CI is less than 0.1, the judgment can be considered as consistent.

(ii) Construction of the original supermatrix (unweighted supermatrix).

The resulting relative importance weights (eigenvectors) in pairwise comparison matrices are placed within a supermatrix that represents the interrelationships of all elements in the system. The general structure of the supermatrix is described in table II, where C_i denotes the ith cluster, e_{ji} denotes the j_{th} element of the i_{th} cluster and W_{ik} is a block matrix consisting of priority weight vectors of the influence of the element in the i_{th} cluster with respect to the k_{th} cluster.

TABLE II
GENERAL STRUCTURE OF THE SUPERMATRIX

		C₁	C₂	…	Cₙ
		e_{11} e_{12} … e_{1n}	e_{21} e_{22} … e_{2n}	…	e_{n1} e_{n2} … e_{nn}
C_1	e_{11} e_{12} … e_{1n}	W_{11}	W_{12}		W_{1n}
C_2	e_{21} e_{22} … e_{2n}	W_{21}	W_{22}		W_{2n}
…	…				
C_n	e_{n1} e_{n2} … e_{nn}	W_{n1}	W_{n2}		W_{nn}

(iii) Constructing the weighted supermatrix

The following step consists of the weighting of the blocks of the unweighted supermatrix, by the corresponding priorities of the clusters, so that it can be column stochastic (weighted supermatrix). The weighting of the clusters has to be conducted again by means of standard AHP.

(iv) Calculation of the global priority weights

Raising the weighted supermatrix to limiting powers until the weights converge and remain stable the limit supermatrix will be obtained. In this matrix, the elements of each column represent the final weights of the different elements considered.

The priority of each alternative is a non-dimensional value that will be considered the Environmental Pressure Index (EPRI).

In order to endow the results with a higher value, it is advisable to have several experts involved in solving the problem of prioritization. In this case a group of five experts have been contacted: one member of a public entity who is an expert in urban planning; an academic coordinator of a Master in Urban Planning; a professional environmentalist; a contractor-builder of important projects and a university teacher who is an expert in environmental management.

V. Case study on the choice of the best alternative for the future exploitation of the La Carlota Airport in Caracas (Venezuela)

V.1. The alternatives

At this stage of the problem the required data for standard EIA analysis are not known yet. However, to rank order the alternatives from the environmental point of view it is still necessary. This means that we are dealing with a problem with little information and thus suitable for the use of ANP as this method is based not on data but on comparisons made by experts

Alternative 1: Residential area

This alternative consists of developing a residential complex with 145,000 m2 of sports areas, 11,500 dwellings, and 30,000 m2 of green zones which will benefit 60,000 people. It is estimated that the execution of this plan can take 36 months and the generation of 6000 jobs. The residential area is intended to use all the available airport land, i.e. 99.6 Ha. The 11,500 dwellings are distributed into 80m2 apartments (70%) and 66m2 flats (30%). Within the 145,000 m2 of sports areas the project also includes the construction of an Olympic stadium (30,000 m2) and a baseball stadium (30,000 m2), a sports centre (54,000 m2), five-a-side pitches (13,000 m2) and a swimming centre (18,000 m2). This recreational area will also include large green zones that will be connected to the Parque del Este underground. The project also comprises the construction of squares, a cultural centre, a shopping centre and 15,000 car park slots. In brief, the plan includes 75 blocks of flats and five sports centres that will create jobs for about 60,000 people. It is a wide urban project with a total budget of 727 million dollars.

Fig. 2. Residential area project scale model.

Alternative 2: Health Club

This alternative uses all the airport land and creates a corridor with the Parque del Este. The project plan includes school-farms, water parks, aquariums and contact farms, a heliport for emergencies, sports areas and a large area of green zones for recreational use. The original plan considers taking the water from the Parque Nacional de Avila for water supply purposes. According to the data supplied by the plan designer, 14.62% of the land is for public use and 48.69% has restricted access.

The Park preserves the runways of the airport for eventual emergencies and a change in the use of the Building of the Comandancia General de la Aviación as a Hospital, a Big Lake with artificial waves that collects the water coming from the three water basins of El Avila, and the construction of a large Health Club for economically disadvantaged people. The project also includes a Hospital of Civil Protection and an extensive farm land that would be the basis of the School of Horticulture of Caracas in which people not only can learn to grow plants but also buy fruits and vegetables.

Fig 3. Health Club project drawing

Alternative 3: Theme Park

This alternative covers all the land of the airport and involves both the private and public sectors. It is a comprehensive plan, which pays homage to the Libertador Simón Bolivar, including the construction of a Mausoleum. The Parque del Este extends to La Carlota forming a big

Metropolitan Park, and the runways disappear, although the plan also considers a high-tech heliport for emergencies. The Project includes a Monument to the Libertador consisting of a concrete tower, with a central part of lifts, a restaurant and a balcony that offers a panoramic view of Caracas. It also includes a Convention Hall and an Auxiliary Underground-Bus terminal connected to the Caracas underground system, a large multi-purpose area, car parks, pedestrian crossings and roads. The building of the Comandancia General de la Aviación is transformed to house the Fundación Monumento Unico al Libertador, the Instituto Nacional de Parque, and the Museo de Transporte; and the Comandancia General de la Aviación is moved to the site now occupied by the Instituto Nacional de Parques and the Museo Nacional de Transporte.

Caracas underground is connected to La Carlota through a suspended monorail system. The project includes the development of Rio Guaire Boulevard, from Caricuao to La Carlota and from Petare to La Carlota. This project does not include residential areas, shopping centres or sports centres. The multi-purpose area is an open area with facilities capable of holding from 30 to 50 thousand visitors.

Taking profit of the project for cleaning the Guaire river bed, the idea is to divert the river to the Monumento Unico al Libertador to be used as water supply system for the different water units, like water screens, fountains, watering of the green zones, etc. This will also allow the development of a large Boulevard around the Monument.

Fig 4. Theme Park project drawing

Following the steps needed to find the priorities of these urban plan alternatives are stated.

V.2. Selection of the criteria

Criteria are variables that justify or explain the environmental impact of the urban development proposals (alternatives). They are chosen depending on the characteristics of the alternatives. It is necessary to have enough information about the criteria chosen so as to allow for comparison among the alternatives.

For environmental pressure assessment the criteria used belong to a set of Environmental Pressure Indicators (EPRI), which was obtained following the experts' opinions. Then, the experts discussed the whole set and agreed the Paretto EPRI, i.e. the EPRI that exert the greatest influence on the final decision and the least discrepancy among experts. Interestingly, there was little discussion and no other EPRI was argued to have a comparable importance as the ones finally selected.

Thus, the EPRI selected as criteria for the ANP were:

- Land Area: amount of available land used in the project
- Population density: maximum expected population density within the project area.
- Energy consumption: estimated amount of energy consumed during the project's life cycle
- Water consumption: estimated amount of water consumed during the project's life cycle
- Waste generation: amount of waste generated during the project's life cycle

V.3. Representation of the evaluation problem as a network

The complex task of representing the evaluation problem as a network of interdependent elements distributed into clusters can be decomposed into the following steps: (i) to identify the elements (alternatives and criteria), (ii) to group them into clusters and (iii) to determine the influences on each other.

For our case study the following network with three clusters has been built:

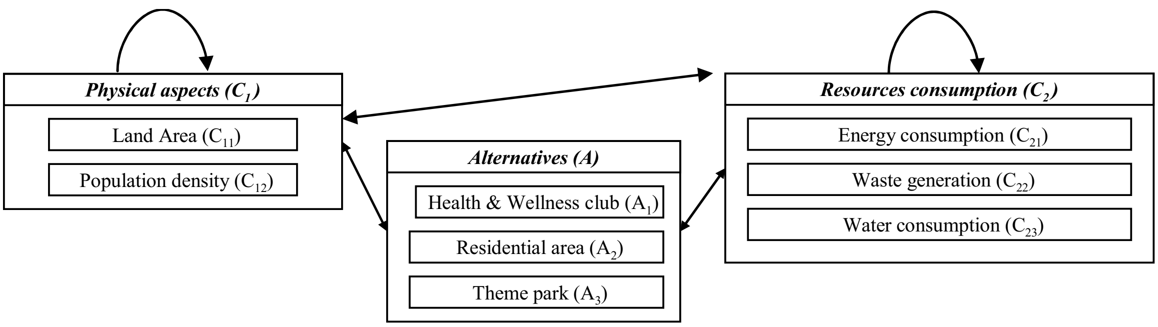

Fig 5. Network model for the case study

The five criteria were grouped into two clusters, one cluster referring to the physical aspects of the project (including the land area and population density criteria), and another cluster about resource consumption (that includes the water consumption, solid waste generation and energy consumption criteria). The third cluster consists of the alternatives criteria, which include the three urban development proposals for the airport land under study.

The two-way arrows indicate mutual influence between clusters. On one hand, the influence of the criteria on the alternatives values (IEI), so that the criteria have to be weighted in order to estimate their contribution to the alternatives value. On the other hand, inverse influence means that the alternatives have to be weighted in order to measure their dominance with respect to each criterion. Feedback means that there is influence among the internal elements of the cluster. For example, the amount of waste generation affects both water consumption and energy consumption.

V.4. Solution of the ANP environmental evaluation problem. Calculation of the EPRI indices

The aim of this step is to obtain an Index for each alternative which indicates the degree of environmental pressure according to all the criteria considered. The higher the value of the index the worse the proposal is.

In the process of expert selection the expert's professional fields both in the public and private sectors were taken into account. The group of experts selected includes a member of the official sector, an academic member belonging to the university, and private professionals working in the field of environmental impact. The selection of the five experts was based on their expertise in the area of projects and their relationship with environmental issues applied to urban planning projects. The experts were interviewed and they were informed on the ANP methodology and its applications in alternatives' prioritisation. Subsequently, they were informed on the characteristics of the alternatives to analyze. After solving any questions asked by the experts, a questionnaire was designed using paired questions in order to allow for the comparison analysis.

Table III shows a sample of the questionnaire used for criteria comparison.

TABLE III
SAMPLE OF QUESTIONNAIRE USED FOR CRITERIA COMPARISON

C1: Area vs C2: Population Density

Which approach do you consider more important?	C1 **X**	C2			
To what extent?	1	3	5 **X**	7	9

In order to alleviate the mathematical burden the following calculations were implemented through the software Superdecisions ©. Upon completion of all pairwise comparison matrices, the unweighted supermatrix is built:

TABLE IV
UNWEIGHTED SUPERMATRIX FOR THE CASE STUDY

		Alternatives			Physical aspects		Resources consumption		
		Health and Wellness club	Residential area	Theme park	Area	Population density	Energy consumption	Waste generation	Water consumption
Alternatives	Health and Wellness club	0	0	0	0.479	0.307	0.351	0.331	0.734
	residential area	0	0	0	0.370	0.568	0.524	0.563	0.199
	Theme park	0	0	0	0.151	0.125	0.126	0.106	0.067
Physical aspects	Area	0.757	0.160	0.605	0	1	0.160	0	0.250
	Population density	0.243	0.840	0.395	0	0	0.840	1	0.750
Resources consumption	Energy consumption	0.099	0.321	0.417	0	0.205	0	0	0.265
	Waste generation	0.203	0.151	0.359	0	0	0.420	0	0.735
	Water consumption	0.697	0.528	0.225	1	0.795	0.580	0	0

The corresponding priorities of the clusters have been obtained and used to weight this matrix:

TABLE V
WEIGHTED SUPERMATRIX FOR THE CASE STUDY

		Alternatives			Physical aspects		Resources consumption		
		Health and Wellness club	Residential area	Theme park	Area	Population density	Energy consumption	Waste generation	Water consumption
Alternatives	Health and Wellness club	0	0	0	0.2394	0.1024	0.1169	0.1653	0.2446
	residential area	0	0	0	0.185	0.1894	0.1746	0.2817	0.0663
	Theme park	0	0	0	0.0756	0.0415	0.0419	0.053	0.0225
Physical aspects	Area	0.3783	0.0798	0.3024	0	0.3333	0.0532	0	0.0833
	Population density	0.1217	0.4202	0.1976	0	0	0.2801	0.5	0.25
Resource consumption	Energy consumption	0.0497	0.1605	0.2083	0	0.0683	0	0	0.0882
	Waste generation	0.1017	0.0757	0.1793	0	0	0.1401	0	0.2451
	Water consumption	0.3486	0.2639	0.1124	0.5	0.265	0.1933	0	0

Raising the weighted supermatrix to limiting powers until the weights converge and remain stable the limit supermatrix will be achieved

TABLE VI
LIMIT SUPERMATRIX FOR THE CASE STUDY

		Alternatives			Physical aspects		Resources consumption		
		Health and Wellness club	residential area	Theme park	Area	Population density	Energy consumption	Waste generation	Water consumption
Alternatives	Health and Wellness club	0.1327	0.1327	0.1327	0.1327	0.1327	0.1327	0.1327	0.1327
	residential area	0.1159	0.1159	0.1159	0.1159	0.1159	0.1159	0.1159	0.1159
	Theme park	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
Physical aspects	Area	0.1542	0.1542	0.1542	0.1542	0.1542	0.1542	0.1542	0.1542
	Population density	0.1897	0.1897	0.1897	0.1897	0.1897	0.1897	0.1897	0.1897
Resource consumption	Energy consumption	0.0642	0.0642	0.0642	0.0642	0.0642	0.0642	0.0642	0.0642
	Waste generation	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
	Water consumption	0.2202	0.2202	0.2202	0.2202	0.2202	0.2202	0.2202	0.2202

V.5. Results

Several results can be obtained by careful analysis of these matrices

The priority of each alternative is a non-dimensional value that will be considered the Environmental Pressure Index. This global priority can be obtained from the values in any of the columns relative to the alternatives.

TABLE VII
RESULTS FOR THE ALTERNATIVES

	Priority limit matrix	EPRI
Health and Wellness club	0.1327	**0.48**
residential area	0.1159	**0.41**
Theme park	0.032	**0.11**

Which means:

$EPRI_{Health\ and\ Wellness\ club} = 0.48$

$EPRI_{residential\ area} = 0.41$

$EPRI_{theme\ park} = 0.11$

The weights of the different criteria analyzed can also be obtained.

TABLE VIII
RESULTS FOR THE CRITERIA

	Priority in limit matrix	Global priority	Weight (%)
Area	0.1542	0.214	21.4
Population density	0.1897	0.264	26.4
Energy consumption	0.0642	0.089	8.9
Waste generation	0.091	0.126	12.6
Water consumption	0.2202	0.306	30.6

The results show that the alternatives with the highest environmental pressure are the Health Club and the Residential Complex and then by a far distance the Theme Park. Thus it can be concluded that there are two types of alternatives: the ones that imply a relatively high EPRI and the one with a relatively low EPRI. However since Health Club and Residential Complex obtain similar EPRI results, it would be necessary to carry out a sensitivity analysis to further differentiate them. As stated above, to obtain a high EPRI will mean a higher environmental impact on the flora, the fauna, the physical aspects and, in general, the environmental quality of the city.

On the other hand, the most significant criterion according the group of experts was water consumption, followed by population density and used land area. Far behind are the criteria of waste generation and energy consumption.

As two alternatives obtained similar EPRI a sensitivity analysis was performed to determine the robustness of the solution. The results show that the rank order of these two alternatives may vary with slight changes in the importance (weight) of some criteria; for example, a reduction of 8% for criterion population density, an increase of 2.7% for water consumption and a reduction of 3.7% for waste generation.

Moreover, some other results can be obtained from this thorough analysis and thus can be related to the intermediate results of the matrices. In the weighted matrix (table IV) the results of the alternatives with respect to only one criterion can also be obtained. That would mean the environmental pressure of each alternative considering one particular criterion and without considering the dependences among criteria. This is the way some other MCDA techniques such as the weighted sum or the AHP, proceed.

For example, for the case of the most important criterion, i.e. water consumption, the partial results are:

TABLE IX
PARTIAL RESULTS FOR CRITERION WATER CONSUMPTION

	Priority in limit matrix	Local priority for water consumption
Health and Wellness club	0.2446	0.734
residential area	0.0663	0.199
Theme park	0.0225	0.067

Which means:

Water consumption Indicator $_{Health\ club} = 0.73$

Water consumption Indicator $_{residential\ area} = 0.20$

Water consumption Indicator $_{theme\ park} = 0.07$

For this particular impact analysis the alternative Health and Wellness and Wellness Club has the highest impact (more than three times the next one) so it is by far the worst.

The same analysis can be carried out with the rest of the criteria.

V.6. Degree of satisfaction with the procedure

Experts were asked about their opinion on the decision procedure carried out. The aim being to assess its difficulty, efficiency and satisfaction compared to the type of information and the use of resources. Opinions were gathered by means of the following questionnaire [40]. In the following table the scores obtained for each of the aspects evaluated are shown in the form of average of all the experts.

a) In your opinion, the task was:
Very easy 1 2 3 4 5 6 7 Very difficult

b) In your opinion, the process was:
Efficient 1 2 3 4 5 6 7 Inefficient

c) How do you feel regarding the quality of the group solution?
Satisfied 1 2 3 4 5 6 7 Not satisfied

TABLE X
RESULTS OF THE PROCESS SATISFACTION QUESTIONNAIRES

	Difficulty of the task	*Efficiency*	*Satisfaction*
Average result	5,40	3,80	3,60

Through the analysis of the values contained in Table IX the following can be concluded: firstly, the scores awarded to the question about efficiency and satisfaction (b and c) obtained an average lower than 4, which means that experts are satisfied with the process. However, question a shows that experts did find the task to be quite difficult. In our opinion this dissatisfaction with the difficulty of the task might be due to complexity of dealing with decision network models. These models prescribe comparisons that occasionally get to be hard to understand for experts not familiarized with the method.

Closely related to that the procedure was quite time consuming.

VI. CONCLUSIONS

This paper presents a new approach to prioritize urban planning projects in an efficient and reliable way based on environmental pressure. The method consists of the combination of Environmental Pressure Indicators to assess the environmental burden caused by the implementation of each urban plan, the aggregation of the indicators into an Environmental Pressure Index by the ANP method and the experts' opinion during the decision making process.

Environmental Pressure Indicators are well-known and widely used analysis tools. For highly uncertain environmental impacts, like in the case of urban development due to the long-term life cycles of the projects, working with environmental pressure indicators is more accurate than working with environmental impact indicators. Environmental pressures are usually synergetic and therefore interdependent. The ANP method allows the aggregation of the experts' judgments on each of the indicators into one "environmental Pressure Index", which avoids the compensation operations of the methods based on weighted sums. In addition, ANP is based on utility ratio functions which are the most appropriate for the analysis of uncertain data, like experts' estimations. Finally, unlike the other multicriteria techniques, ANP allows the decision problem to be modelled using the relationships among dependent criteria.

The method presented in this paper has been applied to the proposal for urban development of La Carlota airport in Caracas (Venezuela). Different urban plans for the use of the nearly 100 Ha of land in the city centre of Caracas have been developed and it is necessary to assess their environmental pressure impact before investing more time and money in the projects. Three urban development alternatives for La Carlota land use have been selected in this study and they have been analyzed using the Environmental Pressure Index proposed in this paper. The urban development alternatives are: a Health Club, a Residential Complex and a Theme Park.

The experts have identified the environmental pressure indicators to be used as ANP criteria. The selected criteria are, on one hand, used land area and population density, and on the other, energy consumption, water consumption and waste management during project life cycle. By using goal-oriented questionnaires designed by the authors, the experts have determined the importance of the ANP criteria, the relationships among criteria, and the relationships between the criteria and the urban development alternatives. The resulting data show that water consumption is the most important environmental pressure factor, and the Theme Park project is by far the urban development alternative which exerts the least environmental pressure on the area.

ANP also allows performing a sensitivity analysis on the resulting data. This analysis has also confirmed that the Theme Park is the urban development alternative with the lowest Environmental Pressure Index value, whereas a variation in the ranking order of the other two alternatives was observed, yet both with environmental index values far worse than that of the Theme Park.

The experts involved in the application of the method expressed their satisfaction not only in the efficacy and traceability of the procedure but also in the results of the elaboration of the index. On the other hand, they agreed in indicating the efficiency of the model compared to other conventional approaches, like Environmental Impact Analysis, Life Cycle Analysis, etc., as it involves the use of fewer resources.

Nevertheless, as above mentioned the use of ANP is not free of criticism. In fact, during the ANP application to the case study the following difficulties were observed. Firstly, ANP prescribes comparisons that occasionally get to be complex to understand for experts not familiarized with the method. Hence, much attention must be devoted to the elaboration of the questionnaires and the comparison process must be helped by a facilitator. Besides, to arrange an experts' panel with adequate number of participants of sufficient qualification can pose the major problem of the method. Finally, ANP gets much more laborious as the number of alternatives and/or criteria grows, and therefore, it gets much more difficult to apply with rigour and efficiency.

Despite these difficulties, the results obtained in this work allow to conclude that ANP is a suitable tool for environmental assessment. It allows obtaining an Index for each alternative which aggregates different information related to environmental indicators, be these of pressure, state, driving forces, response or impact. Although the new proposal has been specifically applied to the evaluation of urban development proposals, this tool can be adapted to any type of decision-making problem, provided the criteria are correctly identified and there are some dependencies among them. This tool constitutes a very promising future research line in the field of Environmental Assessment.

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