A MULTICRITERIA DECISION MAKING MODEL FOR THE EVALUATION OF A PUBLIC INVESTMENT PROJECT IN MEDELLÍN: A STAKEHOLDER PERSPECTIVE

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ABSTRACT

This paper presents a multicriteria model for a case study of public investment evaluation. This tool can be used for decision-making process to allocate the financial resources in environmental projects. Developed for Moravia's Hills in Medellín, Colombia, it permits to evaluate the different dimensions of sustainability. Results show that there is a 'very strong or demonstrated importance' of environmental dimension on financial dimension; financial dimension emphasizes durability; economic dimension prioritizes the generation of alternative business opportunities; for environmental dimension the priority are environmental risks; and in social contexts, culture and education prevail.

Keywords: *public investment, evaluation, analytic hierarchy process, stakeholders, Medellín.*

1. INTRODUCTION

Investment has been considered a classic area of research in decision-making theory. When establishing criteria for evaluating investment alternatives, generally technical and financial factors are considered, where the decision maker chooses the appropriate scale for each criterion and evaluates alternatives according to them. Although, in situations involving environmental decisions, the scenario of actors with different positions to support decision-making and whose opinion must be taken into account is broadened; hence, future measures imply a high degree of responsibility.

In words of Simões et al. (2008), however, investment decisions should not be based solely on the opinions of a group of actors, which tend to concentrate on economic factors, since all stakeholders are jointly responsible for finding the most appropriate ways of protecting the environment, where there are multiple related dimensions framed in sustainability that comprise, not only environmental, but also social, cultural and technical aspects. Hence, a reality faced by public planners around the world is defining sets of priorities in the allocation of the limited resources they have to make public investment. Then, executors of the expense are continually engaged in the hierarchical choice of project proposals and the achievement of their budget through alternative sources of financing. This challenge is particularly sensitive when environmental realities that compromise present and future generations are involved. In addition, there are financing deficits since they involve resource projection for the following decades.

Then, each investment option must be evaluated and tested before investment decision is materialized. However, Baranauskiene & Alekneviciene (2014) argue that the valuation of public projects is difficult due to the complexity of assessing the social benefits they represent for the population, given that the expected impact of public project must effectively meet the needs of the society to which it is addressed. Thus, the set of academic tools to support decision-making applied in these contexts presents a series of challenges in real practice given the specificity of each project and the various degrees of analytical and technical capacity, as well as the quality of existing data at governmental level. However, in public investment projects considering evaluation of environmental resources, several techniques stand out as valuation alternatives. Thus, it is possible to find traditional methods of revealed preferences that include versions of hedonic prices or travel costs (Munda, 1996, Poor et al., 2007, Chen & Jim, 2010); costing methods such as replacement costs or avoided costs (Honey-Rosés et al., 2013); cost-benefit analysis including contingent valuations and other support metrics (Cameron, 1997, Almansa & Calatrava, 2007, Martínez-Paz et al., 2014); evaluation of environmental impacts (Pope et al., 2004); similarly, multiple criteria techniques are used (Joubert et al., 1997, Prato, 1999, Simões et al., 2008, Cinelli et al., 2014, Ameyaw & Chan, 2015); and also techniques based on geographical information systems (Johnson et al., 2011; Girard et al., 2012). In the same argumentative line, Simões et al. (2008) suggests that decision-making methods can be seen as a valuable tool in relation to the environment, although only a few of them are suitable for the selection of an optimal strategy, on occasions when decision-making shall respect problem restrictions; situation also highlighted by Baranauskiene & Alekneviciene (2014).

The previous context poses a general scenario of public investment in environmental settings, mediated by existing valuation techniques. Thus, this work aims to exemplify this situation from the general to the specific in the case of a project carried out in Medellin, a city that has undergone an important transformation in various dimensions in the last two decades. Public administrations in charge of managing resources have implemented various projects in order to facilitate the development of the city and promotion of depressed and poor areas.

One of the projects launched was the transformation of degraded urban areas of Moravia's Hill, which included the participation of various national and international entities. The purpose of that project was to improve socio-economic and environmental conditions of the inhabitants of Moravia and their surroundings by supporting the initiative of government institutions for recovery and environmental restoration of degraded areas of Moravia's Hill; strengthening at the same time the urban transformation process through the use of sustainable technologies for decontamination and integral and sustainable management of water (see Figure 1).

Figure 1. Moravia's Hill Project

(2008) (2014)

In this way, the general objective of this article is to evaluate the perception of a group of actors who participated in the design and execution of this project. Thus, it is possible to determine differences in perception among them, which allows us to consider these elements during the evaluation of public investment projects involving environmental settings for application in other planning scenarios at local, regional, and national levels. As a result, the perspective of a participatory planning approach could emerge in decision-making environment.

The management of natural resources, especially financing process, is essential to achieve the implementation of projects that generate sustainable development. In this sense, Costa & Menichini (2013) suggest that evaluating the perception of interest groups supposes a subjective point of view, related to the experience and opinion of people involved in the analysis, thus, to incorporate these value judgments is essential to ensure the success of formulation and execution of any public policy. Evaluation of financial resources investment is a sensitive issue since management of environmental problems is at stake at the same time with an inhabited area, generating conflicting views between residents and executors of the investment. Thus, this project involves various dimensions ranging from financial, economic, and environmental, until social. The main evaluated factors associated to these dimensions were selected and defined based on the theory of utility under multiple attributes, and numerical evaluation was carried out applying analytic hierarchy process (Saaty, 1990).

This work is divided into six sections including the introductory one. Section two exposes the main features of the study area. Third, bibliographic review is presented. Materials and methods contained in the identification of methodologies in the field studied are presented the fourth part. Discussion of results is developed as a fifth point, finally, conclusions are presented.

2. STUDY AREA

Moravia's Hill arises because of inadequate environmental practices in the old open-air garbage dump of Medellín, where all waste coming from the city from 1977-1984 was deposited without an adequate separation. In the area there are high pollutant loads, reported in different studies carried out by universities and local entities. In the year 2000 the Metropolitan Area of the Aburrá Valley indicated the presence of toxic gases and heavy metals; as well as the presence of high concentrations of Pb, Cr, Cd and Ni, in the artificial 'soil' formed by tons of waste deposited.

The high risk situation due to toxicity in the rubbish pit is largely due to the concentration of pollutants and inadequate treatment of waters that converge in the area, in this respect it is worth noting the infiltration of rainwater and surface runoff, which has an important role both in the formation of a leachate with high pollutant loads and destabilization of the slopes that make up the waste hillock. Environmental recovery strategy implemented by the sustainable water management group of UNESCO Sustainability Chair of Universitat Politècnica de Catalunya - BarcelonaTech, INTEGRA Research Group of Tecnológico de Antioquia - University Institution, and Metropolitan Area of the Aburrá Valley, is oriented towards the correct management of water in a degraded urban area. The aim is to use sustainable design approaches that implement appropriate technologies with low environmental impact. In the case of developing countries, these appropriate technologies have additional advantages, such as low construction cost, operation, and maintenance (Sawaittayothin & Polprasert, 2006).

The intervention was approached mainly from socio-environmental dimension. In social perspective, restoration and landscape intervention activities, urban transformation, participatory citizen awareness in each of the parties involved in the project (public administration, universities, research groups, and inhabitants of the hill) were developed.

3. STATE-OF-THE-ART IN THE EVALUATION OF PUBLIC INVESTMENT PROJECTS

Decision making related to public investment projects subject to modeling in academic settings is not always compatible with real practice. Empirical works typically focus on precise and sophisticated assumptions to adequately support decision analysis, converging in scenarios where availability of information is high and analytical resources have high degrees of freedom. However, in practice there are different degrees of analytical capacity and techniques based on data quality, as well as restrictions associated with the decision maker. Then, the challenge is to identify alternative tools to use in different contexts, in a more useful way for policymakers and governments to base their investment decisions.

3.1. Applied papers in the evaluation of public investment in Colombia

At the level of applied studies for the Colombian case there are diverse types of exercises around the valuation or evaluation of projects that combine, either investment of public resources or environmental projects. Works published in academic journals address various methodological positions. Thus, for example, Rosales et al. (2007) highlight that social and environmental components appear marginally in evaluations, and a large part of projects only include traditional financial evaluations with simple assembly indicators, flow of funds, analysis over time, net present value, internal rate of return, cost / benefit ratio, and sensitivity analysis.

On the other hand, Polanco (2009) combines principal component method and hierarchical classification into the analysis of resource allocation for the protection of forests. Meanwhile, Carvajal & Vélez (2014) propose an economic and social evaluation for analyzing non-viable projects cases from financial point in areas not interconnected to the electric power service. Chaves (2011) proposed the application of multicriteria techniques in environmental sustainability of agricultural systems. Another evaluative exercise was developed by Ospina (2012), where multiple criteria techniques and linear programming carry out an economic valuation of environmental assets. On the other hand, Hurtado (2014) carries out a pre-feasibility study through a cost-effectiveness analysis for the implementation of a wastewater treatment system. A final work evaluates productive systems using a sustainability approach based on

Delphi and multiple criteria techniques to get a sustainable management model of natural resources (Beltran, 2014).

3.2. Applied literature in the evaluation of public investment at international level

At global level, there are different types of methodologies applied to the evaluation of natural resources conservation projects. The proposal of Joubert et al. (1997) where they perform a comparative analysis between multiple criteria techniques (MCDM) and cost-benefit analysis (CBA) applied to aqueduct service supply. In Prato (1999), decision-making approach is used under multiple attributes in an evaluative framework for decision-making in problems associated with soil and water resources management systems. On the other hand, Nijkamp et al. (2002) use diffuse techniques by comparing qualitative features of various public-private partnerships (PPP) in projects of revitalization and urban transformation. Simões et al. (2008), use multiple criteria techniques in solid waste management.

In the work developed by Pannell et al. (2012) a valuation exercise that can be used for restoration of natural assets is proposed. Meanwhile, in the work of Martínez-Paz et al. (2014) a cost-benefit analysis (CBA) is used combined with probabilistic simulation methods to evaluate socioeconomic profitability of an environmental rehabilitation project. Ameyaw & Chan (2015), evaluate and prioritize various risk factors associated with management of water projects. Several works show methodological complementarities to multiple criteria analysis, CBA analysis and contingent valuations.

Thus, Anagnostopoulos & Petalas (2011) use CBA together with diffuse multiple criteria techniques to evaluate land irrigation projects. Similarly, Mosadeghi et al. (2015) make a comparison of this type of techniques, but combining them with geographic information systems in land use planning. Also, it is possible to find other works that have applied Analytic Hierarchy Process in scenarios for valuation of environmental projects. Vilas Boas (2010), applies this method in the choice of alternative policies, programs and projects related to management of water resources. Chowdary et al. (2013), show the application in basin prioritization process. Kurka (2013), assesses regional sustainability of bioenergy projects. Nazeri et al. (2014), does it in location of forest roads. Mosadeghi et al. (2015), defined the extension of land use zones in large-scale urban planning scenarios. Two more studies focused on hierarchizing public policies directed towards peasant families (Petrini et al., 2016); and selection of public investment projects at urban level (Pujadas et al., 2017).

4. MATERIALS AND METHODS

4.1. Assignment of weights and their normalization

Analytic Hierarchy Process (AHP) is a comprehensive methodology that incorporates both empirical data and subjective opinion of experts to support the decision-making process (Saaty, 1990). It also associates several substantial aspects as inconsistent to derive the mathematical reasons and synthesize the scale of priorities to make complex decisions. In this way, it is possible to identify and weigh selection criteria, analyze data collected and issue concepts based on the decision-making process.

Prioritization of factors within each level of hierarchy is accompanied by the evaluation of each set of elements as paired comparisons belonging to proposed categories. Each comparison allows forming a matrix system based on the fundamental scale, which ranges from 1 (equal importance) to 9 (absolute significance). Thus, in AHP model, each pair of factors in a particular category of elements is examined at the same time, considering their relative importance. Then, a matrix of comparisons is conformed mathematically by elements $a_{ii} = 1$ and $a_{ji} = 1 / a_{ij}$. Weights of superior criteria and decision sub-criteria are calculated using the maximum eigenvalue that solves the equation system, once all criteria have been normalized.

The AHP method was selected to structure decision rules to prioritize value judgments issued by the experts participating in the study. The weight assigned to each dimension assessed by each group of actors followed eigenvalues and eigenvectors method proposed by Saaty (1990), and its aggregation was made using geometric mean given the heterogeneity of participants.

The above is expressed by equations as follows:

$$\lambda max = \frac{1}{n}\sum_{wi}^{n}\frac{(AW)i}{wi} \quad (1)$$

$$AW = (a11\ldots a1n)x(w) \quad (2)$$

$$CI = \frac{\lambda max - n}{n - 1} \quad (3)$$

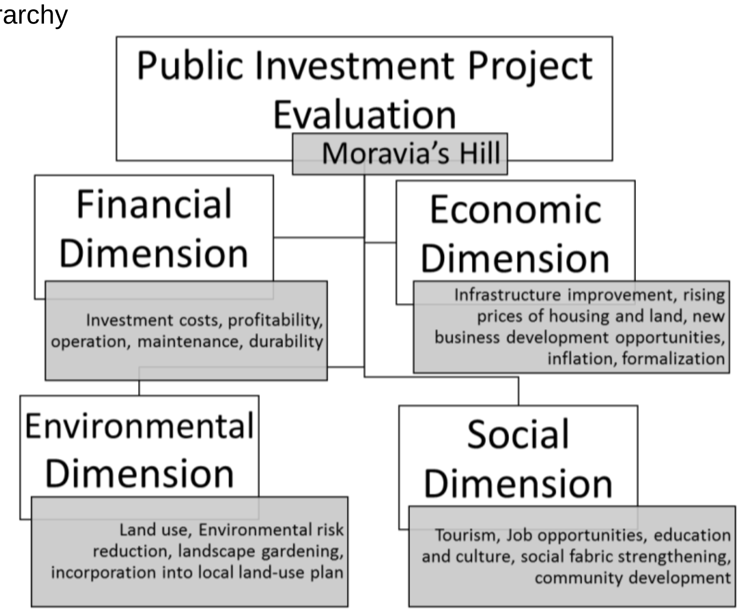
$$CR = \frac{CI}{RCI} \quad (4)$$

These equations mean that the eigenvalue must be computed using eigenvector technique, where *W* is the corresponding eigenvector λmax and *wi*$(i = 1, \ldots, n)$ is the vector of weights reached. With this information, the consistency index (*CI*) of judgment matrix is estimated, where λmax is its maximum or main eigenvalue and *n* the order of the matrix. Finally, the consistency rate (CR) of the equation system is calculated, a rate that must be less than or equal to 0.1 to represent an adequate solution; this results from dividing CI by a random consistency index (*RCI*). Matrices of paired comparisons were tabulated for each interest group, and global results of the model were grouped using geometric mean.

4.2. Modeling structure

Dimensions and factors evaluated in this study reflect financial, economic, environmental and social component (see figure 2) present in any type of environmental project. These have been identified by reviewing advanced literature (Sólnes, 2003; Anagnostopoulos & Petalas, 2011; Baranauskiene & Alekneviciene, 2014; Ameyaw & Chan; 2015; Gumus 2017), as well as with experts in the area, in order to contextualize them into reality of the evaluated project, 19 subfactors were considered within these four dimensions. In this way, a questionnaire was used to collect groups of interest perception; respondents were asked to make comparisons between and within each evaluated dimension. In this way, a questionnaire was used to collect groups of interest perception; respondents were asked to make comparisons between and within each evaluated dimension.

Figure 2. Factor Hierarchy



Source: own elaboration

4.3. Sample

The group of experts selected for the evaluation process consisted of 11 people who have evaluative experience in various environmental projects. There are academic actors, engineers, coordinators, project leaders and managers.

5. RESULTS AND DISCUSSION

Results of the AHP analysis (grouped assessments and weights expressed as percentages) derived from the applied instrument show the subjective importance of sustainability dimensions associated with a socio-environmental transformation project.

Table 2 summarizes standardized priority matrices for main dimensions of analysis. Rows and columns of the matrix register each comparison, where the upper diagonal reflects global aggregation of stakeholders' preferences. It is noteworthy that consistency indexes of matrices register tolerable limits, although they are not necessarily at individual level, that is, the existence of a perfect consistency that respects equation four conditions.

Values are read based on the fundamental scale. Thus, the highest average value was 7,783, column 1 and row 3 of the matrix, a result that compares environmental dimension with financial dimension; which means that there is a 'very strong or demonstrated importance' of the first over the second.

In general, it is highlighted that social (0.4621) and environmental (0.3953) aspects were the categories with greater weight; the first is within the framework of primary effects that a public administrator wants to show as investment management. Environmental category is mostly part of the perspective of experts in a specific area.

Table 2. Global matrix of comparisons for general dimensions

Dimension	F	E	A	S	Weights
Financial (F)	1,000	0,320	0,128	0,182	0,0538
Economics (E)	3,127	1,000	0,136	0,130	0,0888
Environmental (A)	7,783	7,378	1,000	0,644	0,3953
Social (S)	5,509	7,689	1,553	1,000	0,4621
CI: 0,105					

Source: own elaboration

However, in each sub factor associated with the dimensions evaluated (Table 3, column 5), those perceived as more relevant can be observed. Thus, it is observed that the issue of durability of project over time is highlighted in the financial dimension. On the other hand, in the economic aspect, generation of alternative business opportunities stands out, while for environmental dimension are the environmental risks; and in the social aspect, culture and education appear; although followed closely by job opportunities and generation of social fabric.

Table 3. Local and global weightings, determining factors in the evaluation of a public investment project

Dimension	Weights	Order	Sub-dimensions	Local weights	Total weights	Order
Financial	0,054	4	Investment costs	0,072	0,004	18
			Profitability	0,056	0,003	19
			Operation	0,165	0,009	15
			Maintenance	0,273	0,015	14
			Durability	0,434	0,023	9
Economics	0,089	3	Infrastructure improvement	0,243	0,022	12
			Rising prices of housing and land	0,073	0,006	16
			New business development opportunities	0,383	0,034	8
			Inflation	0,065	0,006	17
			Formalization	0,236	0,021	13
Environmental	0,395	2	Land use	0,058	0,023	11
			Environmental risk reduction	0,516	0,204	1
			Landscape gardening	0,121	0,048	7
			Incorporation into local land-use plan	0,305	0,121	4
Social	0,462	1	Tourism	0,050	0,023	10
			Job opportunities	0,267	0,123	3
			Education and culture	0,269	0,124	2
			Social fabric strengthening	0,258	0,119	5
			Community development	0,156	0,072	6

Source: own elaboration

Previous weights give rise to priority vectors, that is, based on these scores, local and global weights are reached (Table 3, last column). It can be seen that social dimension has the highest participation, followed by the environmental one. At sub factors level, environmental risks received the highest ratings, followed by culture and education, generation of job opportunities, incorporation of zones in the urban development plan, strengthening of social fabric, and landscaping matter. It is also observed that economic and financial components were weighted with lower relative values, hence, their sub factors are in last positions. It is noteworthy that the generation of alternative business opportunities and durability are those that figure in highest positions.

Based on the above, social dimension and its associated factors meet the highest standardized weights. This hierarchical order shows differences in perception among actors consulted. Thus, for professional level positions and project leaders, this dimension is considered the most relevant, while managerial or coordination positions consider the environmental as more preponderant. This may lead to the conclusion that greater contact with inhabitants of the area of influence of the project gives rise to established preferences.

An important point to note is that in almost all cases financial dimension was ordered in last place, where, additionally, actors' weights were quite close. In fact, durability factor presented higher average weights than other factors in other dimensions. Financial factors, and even the economic ones in the case of this socio-environmental project, apparently are accepted as given general conditions, and evaluators did not pay adequate attention to these characteristics in relation to their area of performance. However, coordinators and project managers must be more involved not only with design and with implementation, but also with derived impacts and associated costs.

6. CONCLUSIONS AND LIMITATIONS

Dimensions associated with environmental projects are relevant to study, and their appropriate choice presents great advantages with a view to an adequate implementation process, in order to make the project effective for the locality and improve their performance and conditions. However, selection, implementation and execution always bring complexities, and few practical applications in the country have been addressed to study this problem. This work presented a multiple criteria model to evaluate dimensions associated with Moravia's Hill Project in Medellin. It was proposed in particular a method of Analytic Hierarchy Process to obtain the most important dimensions and factors that the start-up of this project brought about. This application has shown that different perspectives and criteria can be evaluated based on expert judgments. The proposed model can be useful for public planners in order to increase the efficiency in the allocation of public resources in socio-environmental transformation projects decision-making process.

The great variety of factors concurring in the evaluation of the investment in environmental projects shows the complexity of approaching this problem. Public participation in decision-making regarding management of financial resources destined to the environment is fundamental for planning and approaching sustainable development. Any type of projects involving the allocation of public financial resources, including environmental ones, involve multiple dimensions for their proper selection, with specific criteria that can be used in decision-making process. These criteria depend both on the nature of the problem under study, as well as on the information flows required. In this sense, in the analysis of public investment different criteria are used in order to determine their optimal allocation. More specifically, with respect to socio-environmental transformation projects, it is obvious that the cost and impact they would generate act in dominance to the selected evaluation criteria. In contrast, technical criteria that show the support process to decision-making are often not made explicit or are not considered in most studies. Consequently, for an optimal evaluation of the investment, cost and impact are considered fixed parameters in many of the cases reviewed.

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