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RCMOS – Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year V, v.1 2025. | submission: 07/17/2025 | accepted: 07/19/2025 | publication: 07/21/2025

Sustainable water management in shopping centers

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Felipe José Amancio Holanda

Diego Angeles Carvalho Macedo

SUMMARY

Urban regions have been seeking alternatives to guarantee a continuous supply of water. Academic literature suggests that the water crisis is often associated with urban expansion; however, the most relevant factor lies in increased demand, which can occur independently of population growth. This is primarily due to behavioral patterns that can be modified through more conscious daily habits.

In the business sector, concerns go beyond financial savings or environmental issues—the priority is autonomy, as instability in water access has intensified. Large establishments, such as shopping malls, can consume water volumes comparable to that of communities with up to 5,000 inhabitants. To understand the perspective of professionals involved in the planning and management of these enterprises, this study adopted the AHP method, using questionnaires and integrated data analysis. The results indicate that participants' level of knowledge is not always aligned with water conservation principles, highlighting the need for greater coordination between the scientific community and the commercial sector.

Keywords: water conservation; shopping mall; sustainable buildings; alternative sources of water.

ABSTRACT

Urban areas have been seeking alternatives to ensure a continuous water supply. Academic studies often associate the water crisis with urban expansion; However, the most significant factor lies in the increasing demand, which can occur regardless of population growth. This is mainly due to behavioral patterns that can be changed through more conscious daily habits. In the business sector, concerns go beyond financial savings or environmental issues—the priority is autonomy, as instability in water access has been growing. Large establishments, such as shopping centers, can consume water volumes comparable to those used by communities of up to 5,000 people. To understand the perspective of professionals involved in the planning and management of these enterprises, this study employed the AHP (Analytic Hierarchy Process) method, using questionnaires and integrated data analysis. The results indicate that participants' knowledge levels are not always aligned with water conservation principles, highlighting the need for stronger collaboration between the scientific community and the commercial sector.

Keywords: water conservation; shopping malls; sustainable buildings; alternative sources of water;

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ISSN: 2675-9128. São Paulo-SP.

INTRODUCTION

The world faces a serious crisis related to water scarcity. Faced with the increasing limitation of water availability, practices such as recycling and reuse have gained prominence, acting as ways to offset intensive water use. At the same time, widespread consumption results in large volumes of discharged wastewater. Nunes (2006) states that there is a need for research in commercial segments, focusing on services and entertainment, and for large commercial enterprises, such as shopping malls, since most existing cases of water conservation developments focus on research, thus rectifying the

choice of theme.

Based on searches conducted on the CAPES portal, seven journals by leading authors were identified: four addressing topics related to consumption and purchasing behavior, and three focusing on commercial buildings. Figure 1 lists the authors associated with these studies. However, no articles were found specifically exploring the application of the AHP method to water conservation in shopping malls, highlighting a gap in the literature. This absence reinforces the need to investigate the relationship between water use and large-scale commercial enterprises, recognized as significant consumers of water resources.

Figure 01 - Published articles.

Autores	Título	Ano	Fonte	Shopping ou edifício comercial	País	Afiliação
Bint *et al.*	"Alternative water sources in New Zealand's commercial buildings"	2019	*Water Supply*	Comercial	Nova Zelandia	BRANZ / Institute of Environmental Science and Research
Cook, Sharma e Gurung	"Evaluation of alternative water sources for commercial buildings: A case study in Brisbane, Australia"	2014	*Resources, Conservation and Recycling*	Comercial	Australia	CSIRO Land and Water Austrália, Highett / Griffith University
De Gois, Rios e Costanzi	"Evaluation of water conservation and reuse: A case study of a shopping mall in southern Brazil"	2015	*Journal of Cleaner Production*	Shopping	Brasil	Universidade Tecnológica Federal do Paraná
Joustra e Yeh	"Framework for net-zero and net-positive building water cycle management"	2015	*Building Research and Information*	Comercial	EUA	University of South Florida
Wang, Chang e Nunn	"Lifecycle assessment for sustainable design options of a commercial building in Shanghai"	2010	*Building and Environment*	Comercial	China	Shandong University, China / Faithful Gould, United Kingdom
Sousa, Silva e Meireles	"Performance of water efficiency measures in commercial buildings"	2019	*Resources, Conservation and Recycling*	Shopping	Portugal	University of Lisbon / University of Aveiro
Sousa, Silva e Meireles	"Technical-financial evaluation of rainwater harvesting systems in commercial buildings-case ase studies from Sonae Sierra in Portugal and Brazil"	2018	*Environmental Science and Pollution Research*	Shopping	Portugal	University of Lisbon / University of Aveiro

Source: primary

Shopping malls are a category that consumes large amounts of water throughout Brazil, due to the growing number of users and unit consumption. Commercial buildings are potential water consumers, and 50 to 90% of their use is allocated to toilet flushing and cooling towers. Alternative sources should be explored to reduce drinking water consumption (BOYLE, 2005; FREIRE, 2011).

In this study, the AHP method was considered the most appropriate because of its ability to handle complex decisions involving multiple interests and potential conflicts. Applying the tool in the Vila Velha context allowed us to understand the perceptions of stakeholders involved in the planning of large projects, such as shopping malls, providing a structured view of their priorities and judgments.

To operationalize the method, the Expert Choice software was used, which

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ISSN: 2675-9128. São Paulo-SP.

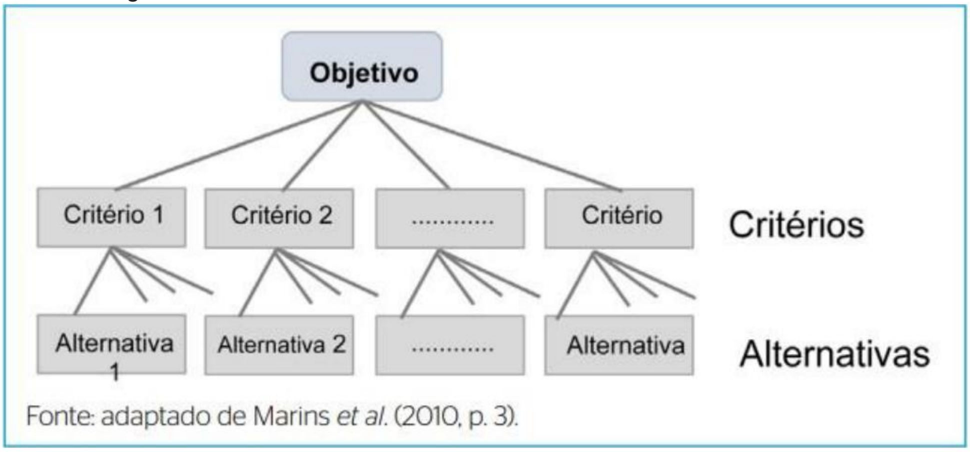
based on mathematical models and pairwise comparisons. The analysis structure was organized into hierarchical levels—objective, criteria, and alternatives—enabling the creation of individual graphs for each participant, as well as the consolidation of collective results. The objective was to quantify participants' opinions and assess how their perceptions relate to the technical and scientific guidelines that underpin current standards.

Decision-making, in this context, was understood as the choice between different alternatives, seeking the one with the best performance in relation to the established criteria.
The alignment between decision-makers' expectations and the most appropriate alternative to the demands of sustainable water management was also assessed.

1. METHODOLOGY

To design the study and listen to participants, the most popular Analytic Hierarchy Process (AHP) Multi-Criteria Decision Making (MCDM) was used to make and analyze decisions. AHP was developed by Thomas L. Saaty in 1977 as a method of
decision analysis through the structuring of decision components, that is, in addition to being able
By analyzing multiple alternatives and comparing them quickly, one can derive the reason for a series of related comparisons (TRENTIM, 2012). Design of the AHP method to assist the process in situations where there are multiple decision makers. Using it, problems
complexes can be divided into subsections. Description, according to the degree of
classification (BOTTERO; COMINO; RIGGIO, 2011; Jatap; Bivor, 2017). For Ribeiro and Costa (1999, p. 7), the method is based on three levels of analytical thinking (Figure 2).

Figure 02: Basic hierarchical structure.



Source: adapted from Marins et al. (2010, p)

The hierarchy should follow the following order: the general objective of the question, Objectives, criteria and, finally, options. The first task is to decompose factors according to their interrelationships and affiliations, and the factors are concentrated at different levels. Then, by organizing the problem in the form of a multilevel analytical structural model, one can solve
assigning relative weights to different levels, starting with the lowest to the highest (representing general goals), or good and bad (KURTILA et al. 2000). To determine the priorities, decision-makers begin the process of assigning relative importance to the elements at each level. For each level of the hierarchy, each criterion and subcriteria has a different weight. In this way, the alternatives for each standard will be different.

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(CHEN, 2006). The steps to determine priority are as follows:

Pairwise judgments: Here, pairwise comparison is proposed using a pairwise comparison matrix. The results are represented in the judgment matrix, which is used to make pairwise comparisons and represents the importance of the elements between the current and previous levels (WANG et al., 2018). The elements of the matrix are calculated by Equation 1:

(1)

$$aij > 0, aij = \frac{1}{aif}, aij \ = 1$$

Where:

A = the comparison matrix; n = the alternatives;

aij = the preference measure of the alternative in row i when compared with the alternative in column j.
Both i and j range from 1 to n (Equation 2).

(2)

$$A \begin{bmatrix} 1 & a12 \cdots & a1n \\ \vdots & \vdots & \vdots \\ {}^{1}/_{an1} & {}^{1}/_{an2} \cdots & 1 \end{bmatrix} \left| {}^{1}/_{a21} \quad 1 \ \cdots a2n \right| \\ \vdots$$

The values of the elements in the judgment matrix follow Saatye's determinations and vary from 1 to 9, as mentioned in Table 1 below:

Escala de comparação dos Critérios com as Alternativas A e B								
9	7	5	3	1	3	5	7	9
Extremamente	Bastante	Muito	Pouco	Igual A=B	Pouco	Muito	Bastante	Extremamente
valores para A em relação a B					Valores para B em relação a A			

Table 01: Saaty numerical scale
Source: Primary

• Normalization of matrices: according to Costa, Rodrigues and Felipe (2008, p. 8), to to normalize it is necessary to "add each column of the matrix, divided by all the elements of each column by the sum corresponding to the column";
• Calculation of local average priorities (LAPs): these are the arithmetic averages of the columns and rows of the tables;
• Calculation of global priorities: the purpose of this step is to identify a global priority vector (PG) that is capable of storing the priority linked to each alternative in relation to the main focus. To do this, it is necessary to combine the PMLs in the priority vector global. Logical consistency: to be useful, the AHP method must have logical consistency Pairwise judgment. Consistency is defined by the formula: aij x ajk = ajk. When the comparison matrix is consistent, the largest eigenvalue is (ÿmax) will be equal to n. When there is consistency, a deviation (ÿmax-n) occurs and, in turn, this measure is divided by n-1, resulting in the average of the eigenvectors (ABEDI; TORABI; NOROUZI, 2013). The

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consistency index (CI) is obtained using Equation 3:

$$CI = (\lambda_{max} - n)/(n - 1)$$

To determine whether the evaluations are consistent, it is necessary to calculate the consistency ratio (CR). This index is the ratio between the CI and the random index (RI). The formula would then be as follows: form: CR = CI/RI. The random index is the degree of consistency that appears automatically when the matrix is completed with values on the scale of 1–9 (Table 2) (MACHARIS et al., 2004). The accepted CR limit is less than 0.10, otherwise it will be necessary to redo the evaluation process to find consistency (TEMIZ; CALIS, 2017). The empirical data of this research are presented through the AHP method.

1.1 Application of the method: analytic hierarchy process.

To understand the perspectives of professionals involved in the construction and operation of shopping malls, the AHP method was used to develop structured questionnaires. Responses were obtained from six mall managers and eight management companies, one of which represents a chain responsible for approximately 40 malls nationwide. A total of 40 technical professionals participated in the survey, including 20 architects and 20 engineers, all working in the state and with at least five years of experience in the sector.

The questionnaire was divided into two distinct stages, administered according to the respondents' category. The first stage consisted of comparing criteria and subcriteria, while the second focused on comparing criteria and alternatives.
The categories of participants were segmented between technical professionals (architects and engineers) and company representatives and operational managers, working in areas related to hygiene, supply, sustainable management and operation of shopping centers.

After the completed questionnaires were sent and returned, the data were entered into a value matrix in Expert Choice software, a tool developed specifically for applying the AHP method. The program allowed for mathematical processing of the results and the generation of partial (individual) and combined (collective) graphs, representing the analysis of participants' judgments.

According to the AHP principles, the analysis structure was organized into hierarchical levels, consisting of objective, criteria, subcriteria and alternatives, which served as a basis for the elaboration of the collection instruments, as represented in Figure 2.

In the first questionnaire (called "Questionnaire 1"), participants compared the main criteria, followed by comparisons between criteria and subcriteria. This step generated both individual graphs and consolidated graphs with the judgments of all respondents. In the second instrument ("Questionnaire 2"), the comparisons between criteria were maintained to ensure consistency within the three-level structure required by the AHP method. Next, comparisons between criteria and alternatives were made, also resulting in individual and aggregate graphs.

Figure 3 presents the consolidated results of Questionnaire 1, which involved all participating groups (managers, companies, architects, and engineers). At this stage, the environmental criterion was identified as the most relevant, obtaining a weight of 30.9% in the combined judgment of the respondents. Next came the economic (22.3%), technical (16.5%), social (15%), and, lastly, operational (9.8%) criteria. The subcriteria that make up the environmental criterion include: reducing pressure on water sources, reducing the use of chemicals, reducing liquid effluents, reusing and recycling water, and considering embodied energy.

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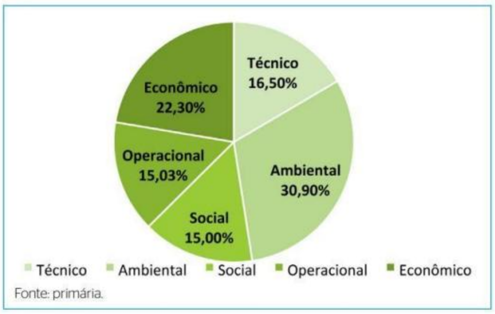
ISSN: 2675-9128. São Paulo-SP.

of liquid effluents, reuse and recycling and, finally, embodied energy.

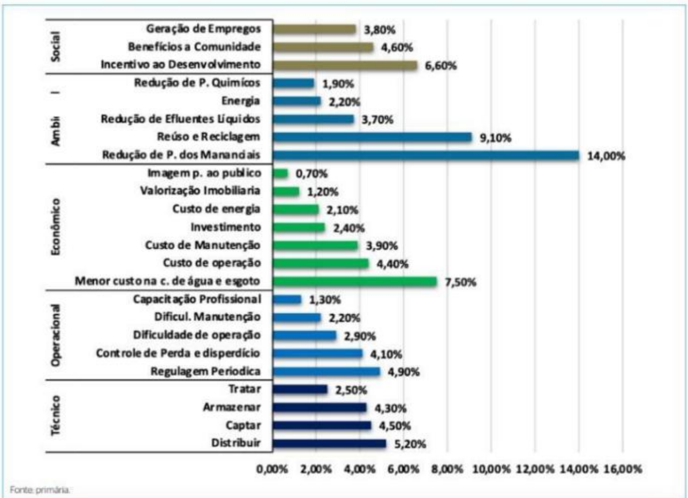
Figure 03: Criteria × criteria/professionals, managers, companies.



Source: primary

In questionnaire 2, applied to all categories (Figure 4), the result is defined between the criteria and the alternatives, considering that in this case the alternatives are the subcriteria that form the criteria.

Figure 04: Criterion × Alternatives (subcriteria)/professionals, managers, companies.



Source: primary

In the analysis of the subcriteria, the technical criterion highlighted "distribution" as the most relevant item (5.2%), followed by "collection" (4.5%), "storage" (4.3%), and "treatment" (2.5%). In the operational criterion, "periodic adjustment" was considered the most important (4.9%), ahead of "loss control" (4.1%), "maintenance difficulty" (3.9%), "operation difficulty" (2.9%), and "professional training" (1.3%).

In the economic aspect, the highlight was the subcriterion "lower water and sewage costs" (7.5%), followed by "operating costs" (4.4%) and "maintenance costs" (3.9%). In the environmental criterion, "reducing pressure on water sources" had the greatest weight among all subcriteria (14%), followed by "reuse and recycling" (9.1%).

Regarding the social criterion, the most valued sub-criterion was "incentive to local development" (6.6%), followed by "benefits to the community" (4.6%) and "job creation" (3.8%).

Adding up all the judgments, the most relevant subcriterion for the participants

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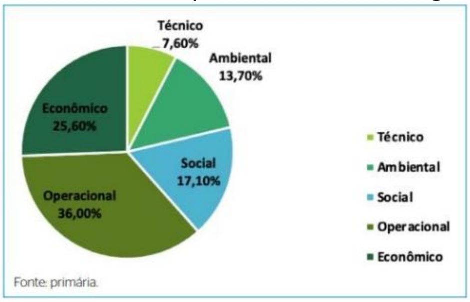
was "reducing pressure on water sources" (14%), surpassing even economic factors, demonstrating a greater emphasis on environmental considerations in water management decisions in shopping malls. Figure 5 presents the consolidated results of Questionnaire 2, which involved comparisons between criteria and alternatives.

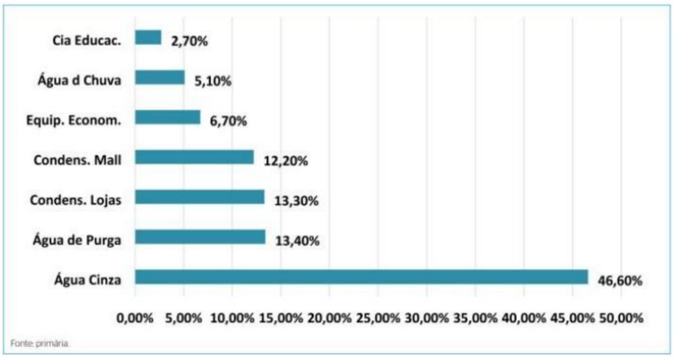
Figure 05: Criteria × criteria/professionals, managers, companies.



Source: primary

For the judgment of alternative sources, Figure 6 presents the most important item: importance, in the view of the combined participants, of gray water.

Figure 06: Criteria × alternatives (sources)/professionals, managers and companies



Source: primary

For a partial analysis between each criterion and the alternatives, the results are presented in Figures 7, 8, 9, 10 and 11.

Figure 07: Technical criterion.

Source: primary

Figure 08: Operational criterion.

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ISSN: 2675-9128. São Paulo-SP.

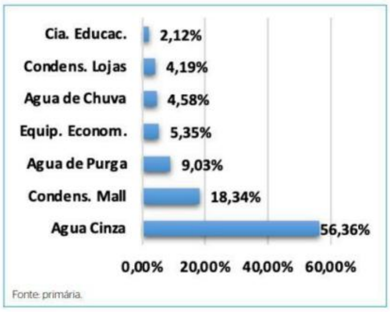
Source: primary

Figure 09: Economic criterion

Source:

primary Figure 10:

Environmental criterion.



Source:

primary Figure

11: Social criterion.

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ISSN: 2675-9128. São Paulo-SP.

Source: primary

2. RESULTS

The perceptions of the participants—including professionals, managers, and companies—were obtained through a combined analysis of their judgments. The questionnaires aimed to understand how these stakeholders think and act, considering their practical experiences in the project design and development phases, as well as in shopping center management. The intention was to capture the reasoning adopted during the decision-making process, especially regarding the integration of sustainable practices and efficient water resource management.

Figure 12 expresses the summarized result of each subcriterion relative to the criterion reference.

Figure 12: Subcriteria results.

Source: Primary

The subcriterion “reduction of pressure on water sources” (environmental criterion) was the item with the greatest weight, with 14%, from the perspective of professionals, managers and companies, with the sub-criterion “lowest cost in the water and sewage bill” having 7.50% (economic criterion), followed by the subcriterion “incentive to local development”, with 6.60% (social criterion), then by the subcriterion “distribute”, with 5.20% (technical criterion), and, finally, by subcriterion “periodic adjustment” (4.9%), in the operational criterion.

The design of a shopping center begins with the architectural design, based on a needs program developed based on technical studies and economic feasibility analysis, aligned with the project's expected results. It is clear that the connection between scientific research and the stakeholders involved in the process—such as designers and business owners—is essential to achieving more efficient and sustainable solutions. Therefore, knowledge generated by research and dialogue with the business sector must be promoted and practically incorporated into the planning and execution stages.

3. CONCLUSION

The adoption of measures aimed at managing water supply and demand—including the use of alternative sources, as well as strengthening operational and maintenance capacity—represents one way to guarantee strategic supply and the autonomy of projects.

According to experts, a real reduction in drinking water consumption in shopping malls and other large-scale projects essentially depends on continuous monitoring and efficient consumption control. This management must integrate technological solutions with behavioral changes, promoting a more effective and sustainable approach to water resource use. This action should precede investment.

in equipment and the use of alternative sources. With this activity alone, it will be possible to obtain gains

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in reducing water, as there is no point in introducing new technologies without first controlling what already exists (KIPERSTOK, 2008).

It's essential that a hydraulic fire brigade be prepared to perform regular maintenance and precise adjustments to water-saving equipment, ensuring the ideal flow rate for each application. A well-designed project, aligned with water conservation principles, directly contributes to the effectiveness of the project management team's actions.

Daily monitoring of consumption data and reduction targets should be a practice for administrators, with these indicators being made publicly available as a way to encourage responsible use. This transparency can raise user awareness and generate economic, social, and environmental benefits, integrating into an ongoing sustainability education strategy.

It is worth noting that the use of alternative sources, such as water reuse or rainwater harvesting, does not, in itself, constitute consumption optimization —
This is a source substitution. True optimization is related to the effective reduction in water use, measurable, for example, by specific consumption (liters per user).

Reuse is advantageous in water scarcity situations and can reduce water and sewage costs, while rainwater harvesting also helps reduce runoff. However, as Mierzwa (2002) argues, real consumption reduction depends primarily on user behavior changes, coupled with the project's operational and maintenance efforts.

Finally, the results point to the need for a systemic vision, beginning in the project design phase and extending throughout the mall's operations. Knowledge and its practical application are essential to promoting the responsible use of water. To this end, it is essential that project professionals have access to academic research, fostering greater integration between the market and science, and contributing to the development of more sustainable projects in environmental, social, and economic terms.

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