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USING THE AHP METHOD FOR CHOICE OF TREATMENTS OF CUTTING FLUID FOR WATER REUSE

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Abstract. *Reconciling the constant search for competitiveness with the growing need to conserve natural resources, especially water is of the greatest challenges of companies in the world today, especially in the metal-mechanical industry, which is increasingly pressed on performance indicators and accountability social and environmental. This article presents the application of multi-criteria decision analysis, AHP (Analytical Hierarchy Process), to choose a method of treatment of water used in the preparation of emulsifiable cutting fluids, aiming its reuse in the machining process. Cutting fluids are mixtures of water and oils that are intended to facilitate the cutting process by reducing the temperature and friction between the cutting tool and workpiece. The AHP allowed to organize the problem in a hierarchical structure whose weighting among the main criteria (cost, volume and water quality reused) and alternatives (treatments physical, chemical, or radiation hybrid) supported the decision on priority scale, that would fit over the expected goals. Naturally happen in any decision-maker's priorities agent directly influence the outcome of the decision. At the end of the decision analysis showed that the wastewater treatment by evaporation, though more expensive, showed how treatment which best met the priorities.*

Keywords: *Cutting fluid, water reuse, Analytic Hierarchy Process (AHP)*

1. INTRODUCTION

The process of metal machining is characterized by generating high cutting temperatures and accompanied by excessive friction between the tool and workpiece. The cutting fluid appear in this process to reducing the temperature by friction with the cooling and lubrication.

One type of cutting fluid used in most industrial environments are emulsions, physical mixtures between water and oil (vegetable or mineral base) by the aid of chemical emulsifiers, which show high capabilities coolant and lubricant.

The soluble cutting fluids forms a highly attractive environment for the proliferation of bacteria, these fluids have a life at the end of which should be discarded. This disposal process generates an additional cost to the company, both with treatment with the emulsion as the destination of the treated water.

In the context of studies in the environmental area, analysis with objectives multiple have received increasing importance, particularly in water reuse, since the decision maker to choose always smaller or lower cost impact, since they are extremely more effective treatments expensive.

This scenario is changing with recent climate change that led to environmental policies more costly. Now accepting major impacts for the company is not necessarily lower costs, since it may be triggered by environmental authority, generating fines.

By means of four different treatments proposed (physical, chemical, ultraviolet lamp and hybrid) suggest a treatment which aims to close the loop, where the incoming water for the preparation of cutting fluid will not supply network and rather the treatment itself, a mixture of freshly discarded. The loss of water volume leaks occur solely by the process, and at the end of the treatment, the water returns to the same process.

Only as a source of motivation, it is noteworthy that apart from the obvious environmental damage that are generated, with the continuous use of this technology conventional treatment, the monthly expenses with the water bills in large companies in the automotive and aeronautical sectors of Vale do Paraíba (São Paulo, Brazil) are around R $ 10.000.000,00 / year, according to prior interviews with professionals in these corporations.

This alternative reuse aims to reduce environmental impacts in addition, the costs to both the water uptake as with its disposal. It is expected that for a well-dimensioned cycle, the consumption of water for this purpose fall dramatically.

Quantify the preferences of users and system developers emulsion treatment is a difficult task and represents a multicriteria decision problem. A critical part of the decision is to assign weights to the different criteria. For this research work, it considered the opinions of the researchers involved, where, for example, the quality of the treated water becomes more urgent than reducing costs. It is evident, however, that for the industrial development of this process, cost reduction should take a higher priority, which can be simulated by AHP method proposed in this work.

The AHP (Analytical Hierarchy Process) is a versatile decision support scenarios for multicriteria like this foregoing. It converts subjective information in tangible data that allow the decision-maker organize and evaluate the relative importance of its objectives, alternatives and / or solutions (Oddershede et al. 2007).

Section 2 contains a description of the context of the problem in expanding the concept of water reuse in the manufacture of cutting fluids vegetable base. Section 3 describes the application of AHP to solve the problem and provides the results of pairwise comparison.

2. REUSE OF WATER IN MANUFACTURING CUTTING FLUIDS OF VEGETABLE BASE

Until a few decades ago, the classic books used in economics courses, worldwide, considered water, oxygen, salt, etc., as well as examples of uneconomic due to abundance (Hespanhol et al., 1997).

Water scarcity as a raw material in the production processes and the increasing demands for the quantity and quality of effluents, in order to preserve the environment, is increasing costs significantly, both in its supply and in its disposal (Lavrador, 1987).

Cutting fluids have the ancillary function in the basic machining process temperature control, with the increase of the cooling system and increase lubrication in the cutting region further assist in chip removal. Cutting fluids are classified into integral, and synthetic emulsions (Gonçalves, 2013).

The use of cutting fluids in machining processes has been providing, in most cases, better results of cutting and productivity in manufacturing processes of metal and mechanical industry.

Even with the trend of development of new cutting technologies independent of the use of this product, it is clear the volume of its use in the process of cutting various metals and this volume can be observed at the time of disposal. Hence the concern in reuse that water present in this mixture as used nowadays (Mann et al., 1999).

Although widely used in industry, there is still lack of information when it comes from a qualitative and quantitative analysis of the environmental impacts caused by the use of cutting fluids. Obtaining parameters as biochemical oxygen demand (BOD), chemical oxygen demand (COD) and Total Organic Carbon (CTO) among others, is important in the process of monitoring industrial effluents, such as cutting fluid, but is not enough to describe their impact on the environment (Gonçalves, 2013).

The metalworking fluids circulating in the machine, pour on the storage tanks and then is pumped to the point of contact between the workpiece and tool and recirculated to the tank. In the fluid path, maybe there are a leak machine, hydraulic oil, with different composition can be mixed with the cutting fluid, demanding greater attention at the time of treatment of this fluid, because different components will be present in this water. Often this component stranger may be the main reason for not being able to treat the water with ideal properties to be utilized, or even reused for that same purpose (Gonçalves, 2013).

This article seeks to, through AHP, find what the best option for water treatment resulting from cutting fluid. Will be offered four different types of water treatment and among those which will be chosen the most viable option for this type of reuse.

The four types of treatments are proposed:

- Chemical treatment;
- Physical treatment;
- Treatment with ultraviolet light;
- Hybrid treatment (chemical + physical).

The chemical treatment takes place by means of the combination of reagents placed in water so that they can break the polymer chains are formed in the cutting fluid composition. Such treatment causes some losses during the process due to the s mixtures are made. There is a treatment that uses a lot of energy which makes it feasible for large-scale production. Furthermore, each treatment chemical reaction generates a sludge containing a percentage of water, a reduction of the volume recycled (Silva et al., 2002).

In physical treatment reagents are not used, but a closed system that heats the water until it vaporizes. This way the water will be vaporized without impurities in the mixture. This type of treatment is very efficient because the resulting water treatment is completely free of impurities that were previously present in its composition. It is also a treatment that does not generate water loss during the process, but it is a treatment that consumes a lot of energy, which makes it very expensive and practically infeasible for industrial use that is made on a large scale.

Treatment with ultraviolet lamps, primarily is used, a chemical pretreatment and after this phase a current is passed through this water brightness of the ultraviolet lamp which in turn is responsible for breaking the chains of impurities contained in this solution.

In the hybrid treatment, there will be a mixture of the first two treatments mentioned in a mechanical device, which will be able to do the chemical and physical simultaneously, while consuming less energy as possible and avoiding the most losses in the process.

2.1 Defining the Problem

The problem is to establish an ordering "ranking" of treatments to identify the most appropriate water reuse of cutting fluids in the production new emulsions.

3. APPLICATION OF AMD: AHP

The use of Multi Criteria Decision Analysis allows you to organize complex problems in a structure that can best be analyzed by the decision maker. This decision process based on the AHP can be systematized n the six steps presented in Fig.1 (Oddershede, 2007; Gomes, et al., 2004; Samuel, 2005; Vaidya, et al., 2006).

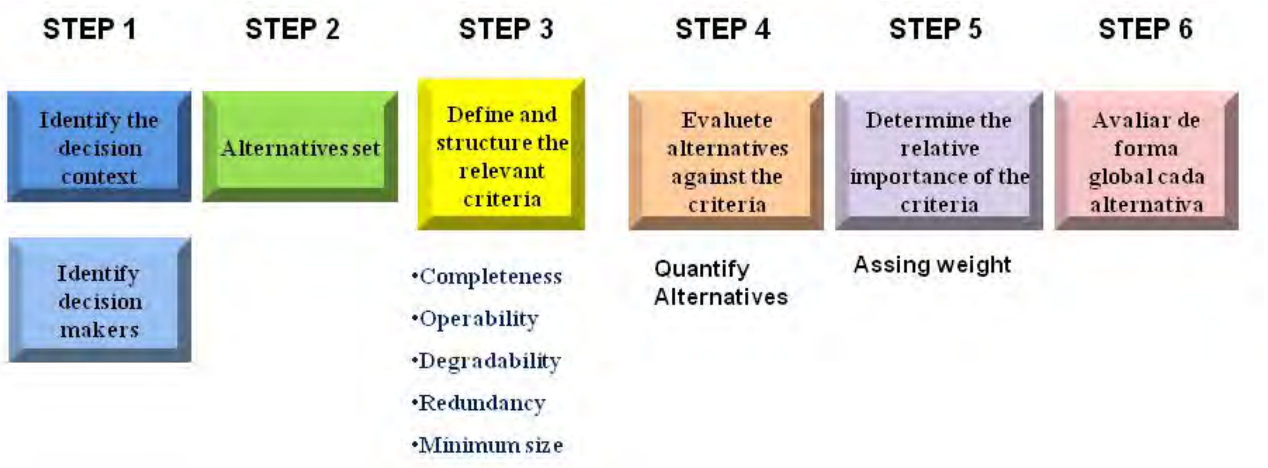

Figure 1. Stages of structuring the problem under the AHP (Oddershede, 2007).

4. OBJECTIVE

The aim of this work is to use the concept of multi-criteria decision analysis (AMD) for reuse of water found in cutting fluids (emulsions and solutions), so that it is used in the preparation of new emulsions. The reasons for closing this circuit reuse of water are due to the following factors:

- Current pricing systems for water;
- Service the requirements of environmental control agencies and;
- Environment preservation.

There are several ways to reuse water, but most of the water treated is not used for the same purpose, because there aren't effective treatments and the low energy consumption. Generally, this type of water retained in its composition elements harmful to the environment, which are difficult to degradation. Another point to be considered is the high costs of this type of process, which ultimately impeding the industrial practice of treatments that target the reuse of water for the same purpose.

4.1 Definition of Alternatives

Alternatives as a solution to the problem in question were the four analysis techniques with different failure characteristics designated by: chemical treatment, physical treatment, radiation treatment and hybrid treatment (Table 1).

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Table 1. Summary of Proposed Treatments.

Treatment Types	**Descriptive**
Chemical Treatment	This treatment is done with reagents
Physical Treatment	It consists in heating water in a closed system until it is vaporized, then separating water from the oil and impurities
Treatment for Radiation	The basic procedure of this treatment is the use of an ultraviolet lamp to break the polymer chains present in the water to be treated.
Hybrid Treatment	Use of a device that makes the physical-chemical treatment of water.

4.2 Definition of Criteria

The criteria considered by experts were:

- Cost of treatment application – how much each type of reuse treatment costs for the company.
- Volume reused - if the treatment provides the smallest possible losses, in other words, it has the best yield of reclaimed water volume after treatment.
- Treatment Quality - water quality for each treatment, to be used in the same purpose (manufacturing of new cutting fluids).

5. HIERARCHICAL STRUCTURE OF THE PROBLEM

Considering the overall goal "Choice of Treatment Process of Cutting Fluids for Water Reuse", was formulated a hierarchical structure into three levels based on the criteria and the alternatives considered by the researchers. Fig. 2 shows the basic structure where the levels represent the following factors:

- Level 0 – Overall goal of "Water Reuse";
- Level 1 - Contains the criteria that most affect the main objective;
- Level 2 - Consists of alternatives that directly impact the variation in the criteria of the previous level.

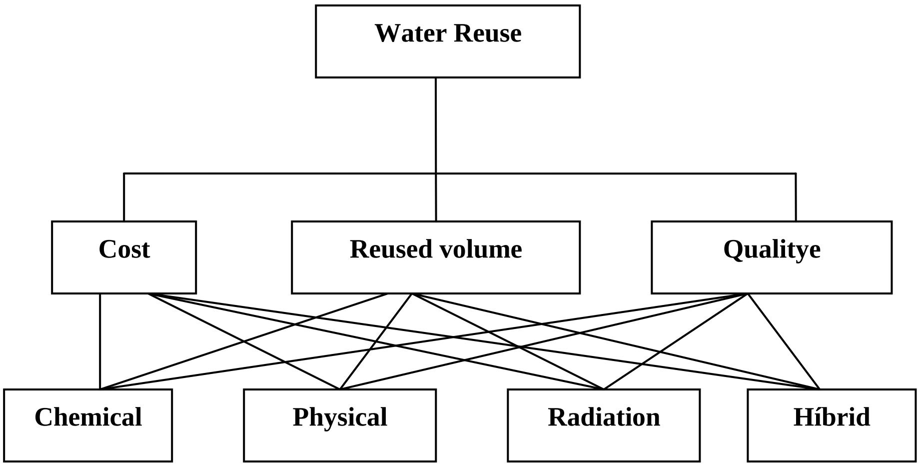

Figure 2. Hierarchical Structure of the Problem.

6. RESULTS OF PAIRWISE COMPARISON

6.1 Pairwise comparison of alternatives according to the criteria: COST

The table 2 shows the results of analyzes following pairwise comparisons for the criterion COST.

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Table 2. Results according the criteria COST.

Cost	Chemical	Physical	Hybrid	Radiation	**Priority**
Chemical	1,00	9,00	3,00	5,00	55,8%
Physical	0,11	1,00	0,14	0,20	4,2%
Hybrid	0,33	7,00	1,00	3,00	26,8%
Radiation	0,20	5,00	0,33	1,00	13,3%
Σ	**1,64**	**22,00**	**4,48**	**9,20**	**1,000**

The Fig. 3 shows the prioritization of analyzes following pairwise comparisons in relation to the COST criterion.

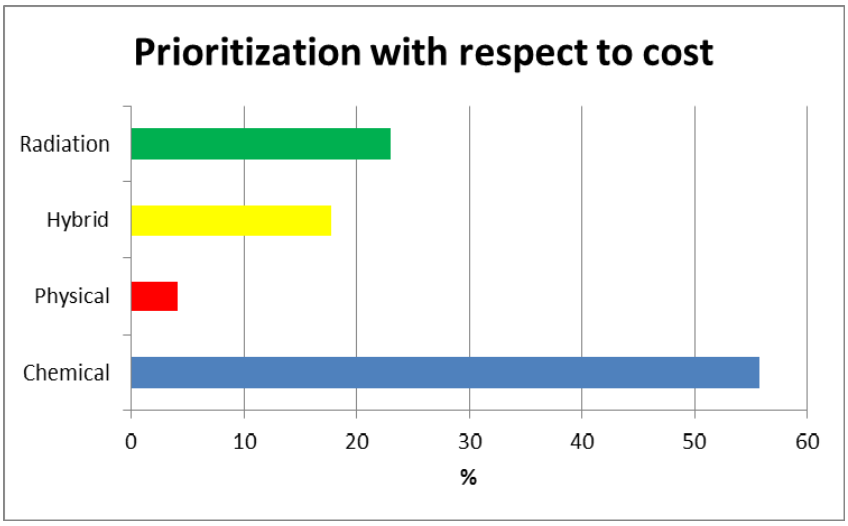

Figure 3. Prioritization of alternatives according to cost criteria.

6.2 Pairwise comparison of alternatives according to the criteria: Volume tapped

The table 3 shows the results of analyzes following pairwise comparisons for the criterion Volume reused.

Table 3. Results according the criteria VOLUME REUSED.

Vol. Reused	Chemical	Physical	Hybrid	Radiation	**Priority**
Chemical	1,00	0,11	0,33	0,20	5,0%
Physical	9,00	1,00	5,00	7,00	64,1%
Hybrid	3,00	0,20	1,00	3,00	18,1%
Radiation	5,00	0,14	0,33	1,00	12,9%
Σ	**18,00**	**1,45**	**6,67**	**11,20**	**1,000**

The Fig. 4 shows the prioritization of analyzes following pairwise comparisons for the criterion Volume reused.

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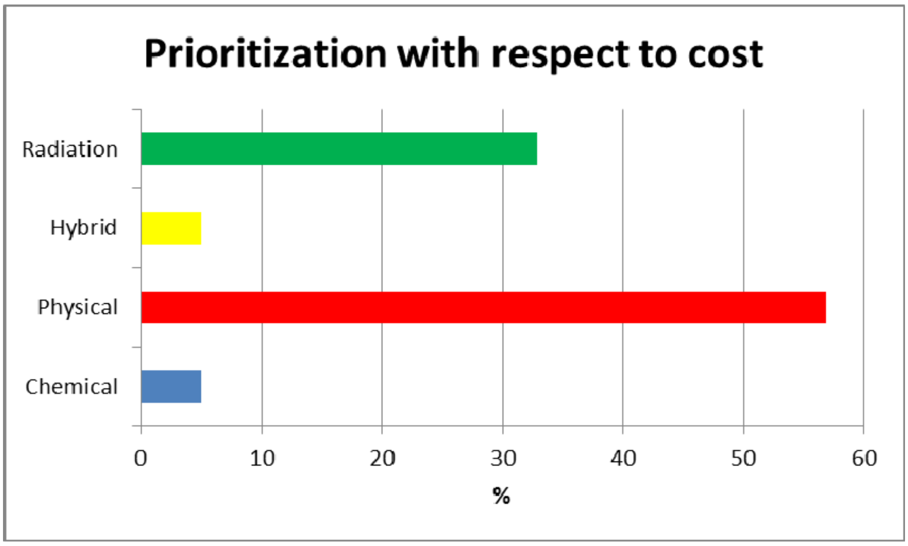

Figure 4. Priorization of alternatives at the Volume reused criteria.

6.3 Pairwise comparison of alternatives according to the criteria: Quality

The table 4 shows the results of analyzes following pairwise comparisons for the criterion Quality.

Table 4. Results according the criteria QUALITY.

Quality	Chemical	Physical	Hybrid	Radiation	**Priority**
Chemical	1,00	0,11	0,20	3,00	8,1%
Physical	9,00	1,00	5,00	9,00	63,2%
Hybrid	5,00	0,20	1,00	7,00	24,4%
Radiation	0,33	0,11	0,14	1,00	4,3%
Σ	**15,33**	**1,42**	**6,34**	**20,00**	**1,000**

The Fig. 5 shows the prioritization of the alternatives after pairwise comparisons in relation to quality criteria.

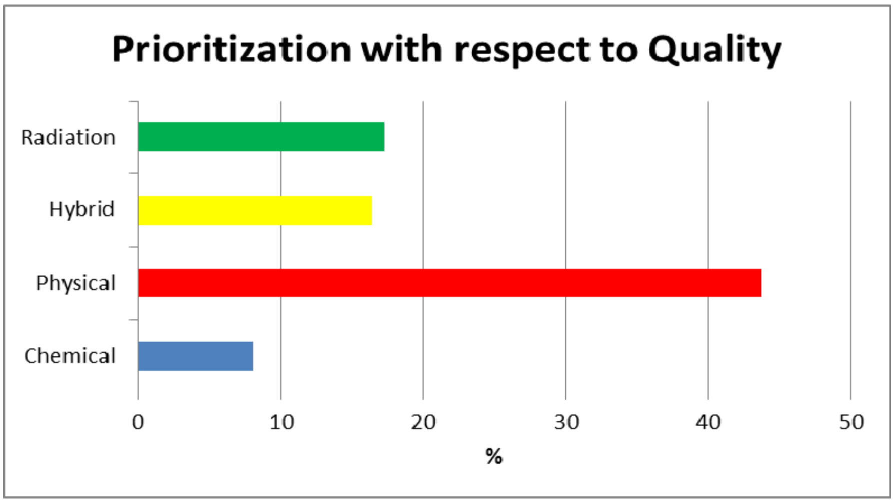

Figure 5. Prioritization of alternatives according to quality criteria.

6.4 Judging criteria between pairwise

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The table 5 shows the results (numbers) of prioritization criteria after pairwise comparisons in relation to the main objective.

Table 5. Results according the criteria Main Objective.

Objective	Cost	Vol Reuse	Quality	Priority
Cost	1,00	0,20	0,14	7,4%
Vol. Reuse	5,00	1,00	0,33	28,3%
Quality	7,00	3,00	1,00	64,3%
Σ	**13,00**	**4,20**	**1,48**	**1,000**

The Fig. 6 shows the prioritization criteria after pairwise comparisons in relation to the main objective.

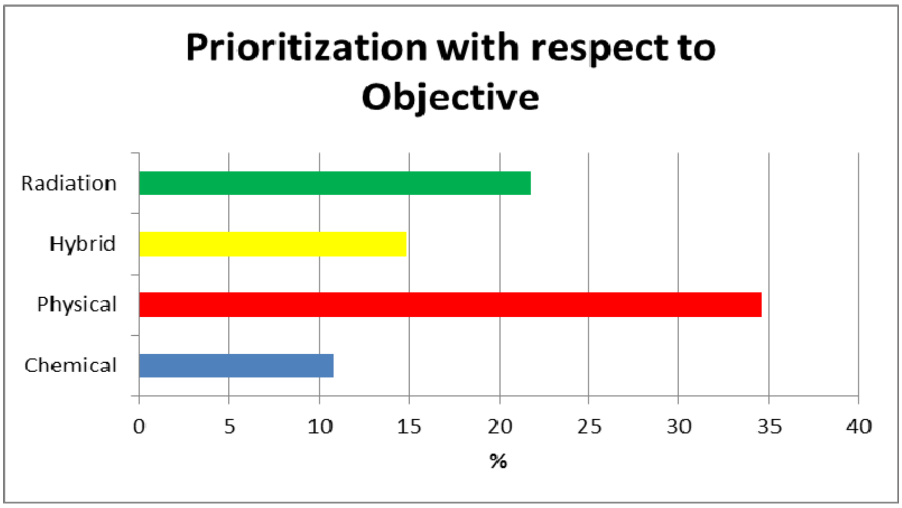

Figure 6. Prioritization of criteria according to the main objective.

6.5 Global Ranking

The priority vector was synthesized in an array of global priorities through the product of the matrices formed by the vectors priorities. Thus obtained a global ordering establishing the ranking of alternative techniques for analyzing the failure mode of the problem as illustrated in Fig.7.

$$\begin{pmatrix} 0{,}558 & 0{,}050 & 0{,}081 \\ 0{,}042 & 0{,}641 & 0{,}632 \\ 0{,}268 & 0{,}181 & 0{,}244 \\ 0{,}133 & 0{,}129 & 0{,}043 \end{pmatrix} \mathbf{X} \begin{pmatrix} 0{,}074 \\ 0{,}283 \\ 0{,}643 \end{pmatrix} = \begin{pmatrix} \mathbf{10{,}8\%} \\ \mathbf{59{,}1\%} \\ \mathbf{22{,}8\%} \\ \mathbf{7{,}4\%} \end{pmatrix}$$

Figure 7. Ranking of alternative priority defined by the vector.

It has established the following order, from best to worst alternative:
0, 591> 0 228> 0 108> 0 074
Physical> Hybrid> Chemical> Radiation

6.6 Consistency Analysis

The consistency analysis of the judgments issued by the maker decision should be made for each be criterion and the main goal.

- Cost Criteria

The cost criterion, it has been $\lambda_{max\ L}$ given by:

$$\begin{vmatrix} 1.00 & 9.00 & 3.00 & 5.00 \\ 0.11 & 1.00 & 0.14 & 0.20 \\ 0.33 & 7.00 & 1.00 & 3.00 \\ 0.20 & 5.00 & 0.33 & 1.00 \end{vmatrix} \mathbf{X} \begin{vmatrix} 55.8\% \\ 4.2\% \\ 26.8\% \\ 13.3\% \end{vmatrix} = \begin{vmatrix} 2.4006 \\ 0.16847 \\ 1.14423 \\ 0.5421 \end{vmatrix}$$

$\lambda_{max\ L}=$ 4,1747

- The consistency index is:

IC = ($\lambda_{max\ L}$ - 4) / (4 – 1) = (4,1747 – 4) / 3 = 0,05823

- Consistency Reason: RC = IC / IR = 0,058 / 0,9 = 0,0647 < 0,09. Therefore, the consistency judgment of the criterion cost is acceptable.

- **Criterion volume reuse**

The criteria reuse volume, it has been $\lambda_{max\ L}$ given by:

$$\begin{vmatrix} 1.00 & 0.11 & 0.33 & 0.20 \\ 9.00 & 1.00 & 5.00 & 7.00 \\ 3.00 & 0.20 & 1.00 & 3.00 \\ 5.00 & 0.14 & 0.33 & 1.00 \end{vmatrix} \mathbf{X} \begin{vmatrix} 5.0\% \\ 64.1\% \\ 18.1\% \\ 12.9\% \end{vmatrix} = \begin{vmatrix} 0.207085 \\ 2.894717 \\ 0.84502 \\ 0.53032 \end{vmatrix}$$

$\lambda_{max\ L}=$ 4,3652

- Consistency Index is:

IC = ($\lambda_{max\ L}$ - 4) / (4 – 1) = 0,1217

- Consistency Reason: RC = IC / IR = 0,1217 / 0,9 = 0,1353 > 0,09

Therefore, the consistency of the judgment criterion reuse volume is not acceptable.

- **Quality Criteria**

The quality criterion is $\lambda_{max\ L}$:

$$\begin{vmatrix} 1.00 & 0.11 & 0.20 & 3.00 \\ 9.00 & 1.00 & 5.00 & 9.00 \\ 5.00 & 0.20 & 1.00 & 7.00 \\ 0.33 & 0.11 & 0.14 & 1.00 \end{vmatrix} \mathbf{X} \begin{vmatrix} 8.1\% \\ 63.2\% \\ 24.4\% \\ 4.3\% \end{vmatrix} = \begin{vmatrix} 0.329459 \\ 2.968891 \\ 1.07778 \\ 0.175201 \end{vmatrix}$$

$\lambda_{max\ L}=$ 4,3108

- The consistency index is:

IC = (λmax L - 4) / (4 – 1) = 0,1036

- Consistency Reason: RC = IC / IR = 0,1036 / 0,9 = 0,1151 > 0,09

Therefore, the consistency of the judgments to the quality criterion is not acceptable.

- Central objective

The main objective has λmax L given by:

$$\begin{vmatrix} 1.00 & 0.20 & 0.14 \\ 5\ 00 & 1.00 & 0.33 \\ 7.00 & 3.00 & 1.00 \end{vmatrix} \mathbf{X} \begin{vmatrix} 7.4\% \\ 28.3\% \\ 64.3\% \end{vmatrix} = \begin{vmatrix} 0.222253 \\ 0.866163 \\ 2.008311 \end{vmatrix}$$

$\lambda_{max\ L=}$ 3,0655

- The consistency index is:

IC = ($\lambda_{max\ L}$ - 3) / (3 – 1) = 0,0328

- Consistency Reason: RC = IC / IR = 0,0328 / 0,58 = 0,0565 > 0,05

Therefore, the consistency of judgments about the Central Purpose (central objective) is not acceptable. Table 6 summarizes the results of consistency analysis of the problem.

Table 6. Results of the consistency.

Factor	Eigenvetor	n	IC	IR	RC	Rcmax	Consistency
Cost	4,1747	4	0,0582	0,90	0,0647	0,09	OK
Vol. Reuse	4,3652	4	0,1217	0,90	0,1353	0,09	NO
Quality	4,3108	4	0,1036	0,90	0,1151	0,09	NO
Central objective	3,0655	3	0,0328	0,58	0,0565	0,05	NO

7. CONCLUSION

It is noticed that the consistency analysis generated three values are not acceptable. However the CR values calculated were very close to RC_{max} acceptable, indicating that a little more care and attention in the allocation of values and priorities would generate an analysis consistent.

The conclusion is therefore that for an initial design phase, researchers must choose the physical treatment process according to the AHP applied.

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10. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.