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USE OF THE HIERARCHICAL ANALYSIS METHOD (AHP) IN THE ANALYSIS OF ALTERNATIVES FOR THE NATIONAL AUTOMATIC VEHICLE IDENTIFICATION SYSTEM – SINIAV

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Abstract: This work aims to analyze alternatives for the technological model, institutional model and regulatory instruments for the implementation of the National Automatic Vehicle Identification System – SINIAV, through the use of radio frequency identification technology (RFID). For this purpose, the Analytic Hierarchy Process was used.AHP)), for which the available alternatives and the respective evaluation criteria were identified. The results showed that, for the technological model, the IAV (Automatic Vehicle Identification) protocol must be revised to contemplate the technological evolution, in a non-restrictive way, allowing any type of tag that meets the SINIAV requirements to be homologated. For the regulatory model, it is recommended that the SINIAV be provided for by law and regulated by CONTRAN resolution, in order to provide greater legal certainty, meet technical aspects and guarantee the necessary flexibility to contemplate the technological evolution of systems and equipment. As for the institutional model, although the cost aspect has been relevant for the State Departments of Transit (DETRAN),
Keywords: RFID, SINIAV, ITS, AHP, Hierarchical Analysis.

INTRODUCTION

The National System for Automatic Identification of Vehicles - SINIAV was created by the National Traffic Council (CONTRAN, 2006, with the initial objective of being one of the instruments of the National Policy for Preventing and Combating Robbery and Theft of Vehicles and Cargo, in compliance with the provisions of Complementary Law No. 121/2006 (Brazil, 2006). The SINIAV consists of the electronic identification of vehicles by radiofrequency (RFID), through a tag (chip), whose technical specification, information and approval procedures were established by resolutions of the National Traffic Council – CONTRAN.

According to studies carried out by Barbosa (2017), this delay in the implementation of the SINIAV was mainly due to inconsistencies identified in the technological and institutional models adopted for its implementation and, consequently, in the published regulatory instruments. In this sense, the studies presented here seek to identify, evaluate and propose alternatives for these three aspects, through the application of the Analytic Hierarchy Process (AHP).

HIERARCHICAL ANALYSIS METHOD

The AHP Method, introduced by Thomas L. Saaty in the 1970s, is an effective tool to deal with complex decision making, and consists of helping the decision maker to establish priorities and make the best decision. According to Saaty (1980), by reducing complex decisions to a series of pairs of comparisons, and then synthesizing the results, AHP helps to identify the subjective and objective aspects of a decision, incorporating a useful technique to verify the consistency of evaluations. , reducing subjectivity in the decision-making process.

According to Saaty (2008), to make a decision in an organized way, it is necessary to establish priorities, breaking down the decision into the following steps: (1) Identify the problem and determine the type of knowledge sought; (2) Structure the hierarchy of decisions from the top, with the objective of the decision to be taken, in a broad perspective, passing through the intermediate levels in which the criteria are defined, on which the subsequent elements depend, reaching the highest level down, which is the set of possible alternatives (Figure 1 (3) Construct a set of pairwise comparison matrices, where each element in a higher level is used to compare, relative to it, the elements in the immediately lower level; (4) Use the priorities obtained from the previous comparisons to establish weights for the priorities of each element of the level immediately below, adding their weighted values (weighted) to obtain the global priority. Continue this “weighing and adding” process until you get the final priorities of the alternatives at the lowest level.

According to Marins et al. (2009), the hierarchical construction facilitates a better understanding of the problem, whose structure brings in the first level the general purpose of the problem, the second level corresponds to the adopted criteria and the third presents the possible alternatives for the solution of the problem, as presented in the Figure 1 Still according to Marins et al. (2009) the definition of priorities in AHP is based on the human being’s ability to perceive the relationship between observed objects and situations, comparing pairs of alternatives, in the light of a certain focus, criterion or parity judgments.

ASSEMBLY OF THE JUDGMENT MATRIX

The generic judgment matrix $A=[a_{ij}]_{nxn}$ proposed by Saaty (1991) in the AHP methodology is composed of nxn elements, as shown below.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{n1} & 1/a_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

Where:

$$a_{ij} > 0 \Rightarrow \textbf{positiva}$$

$$a_{ij} = 1 \therefore a_{ji} = 1$$

$$a_{ij} = 1/a_{ji} \Rightarrow \textbf{recíproca}$$

$$a_{ik} = a_{ij} . a_{jk} \Rightarrow \textbf{consistência}$$

The elements of the matrix actually establish a comparison between a pair of alternatives as to their importance, for the criterion or objective immediately above. As described by Costa et. al. (2010), the element a_{ij} represents the relative importance of attribute E_i in relation to attribute E_j, so that $a_{ij}>1$, if and only if E_i is more important than E_j and,$a_{ij}=1/a_{ji}$, for any pair (i , j). What really matters is that the basic properties of the reciprocal and transitive matrix are respected, that is, a_{ij} x a_{ji} = 1 for all i,je even if E_i is K_1 times more important than E_j and this K_2 times more important than E_k, so E_i must be $K_1.K_2$ times more important than E_k (proportionality). The assembly of the judgment matrix is based on the fundamental scale of importance (Table 1) of an activity or alternative in relation to the other, proposed by Saaty (1991).

Costa (2003) presents the scale proposed by Saaty (1991) in a very didactic way, allowing a better understanding of the level of importance of an alternative or activity over the other, for the adopted criterion, as highlighted in the Figure 2

CONSISTENCY ANALYSIS

According to Prazeres et al. (2010), if the judgments issued by the decision makers are perfectly consistent, we have the eigenvector λ_{max}=**n** and $\mathbf{a_{ij}} = \mathbf{w_i/w_j}$. However, an eventual inconsistency in the judgments can be verified, which can be measured by the proximity of λ_{max} with n (the closer, the greater the consistency). Therefore, λ_{max} **– n** is an indicator of consistency. The eigenvector is obtained by equation 2.

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} w_i \frac{Aw_i}{w_i} \quad (2)$$

Where $\mathbf{Aw} = \lambda_{max} \times \mathbf{w}$ and **n** corresponds to the number of alternatives or elements compared.

The consistency index (**CI**), calculated by

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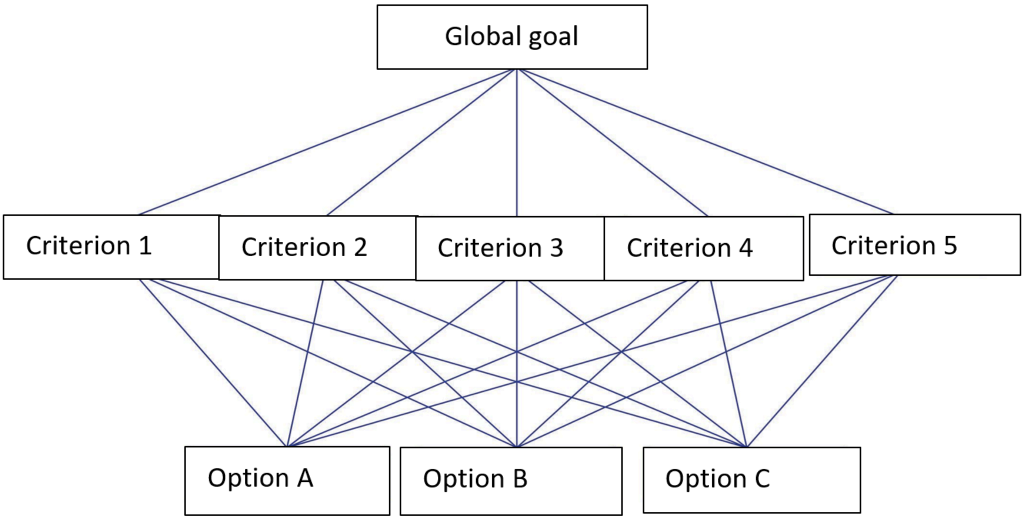

Figure 1: Hierarchical Analysis Method (adapted from Saaty, 2008).

Intensity of importance	Defining the importance of one over the other	Description
1	**Equal**	Both activities or alternatives contribute equally to the objective.
2	Intermediate level of importance between 1 and 3	
3	**moderate**	Experience and judgment slightly favor one activity/alternative over another.
4	Intermediate level of importance between 3 and 5	
5	**Strong**	Experience and judgment strongly favor one activity/alternative over the other.
6	Intermediate level of importance between 5 and 7	
7	Very strong	One activity/alternative is very strongly favored over the other; its domination of importance is demonstrated in practice.
8	Intermediate level of importance between 7 and 9	
9	**absolute**	Evidence favors one activity/alternative over another with the highest degree of certainty.

Table 1. Fundamental assessment scale for the AHP methodology (adapted from Saaty, 1991).

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Quite	Much	Little	Equal	Little	Much	Quite	Extremely
LESS IMPORTANT... ←								**...MORE IMPORTANT** →

Figure 2 Criteria comparison scale (adapted from Costa, 2003).

equation 3, allows assessing the proximity of the scale established by Saaty (1980) to the scale of ratios or quotients that would be used if matrix **A** were fully consistent (Prazeres et al., 2010) .

$$\mathbf{IC} = \frac{\lambda_{max} - \mathbf{n}}{\mathbf{n} - 1} \quad \textbf{(3)}$$

To check whether the consistency index (**CI**) is adequate, Saaty (2008) suggests calculating, through equation 4, a consistency ratio (**RC**), whose matrix will be considered consistent if the ratio is less than 10%.

$$\mathbf{RC} = \frac{\mathbf{IC}}{\mathbf{IR}} < 0{,}1 \sim 10\% \quad \textbf{(4)}$$

Where **IR** is the random consistency index, fixed as a function of the number n of evaluated criteria, as shown in Table 2

The verification of any inconsistency must always be done, until the judgments issued by the decision makers are perfectly consistent, that is, the eigenvector$\lambda_{max} = \mathbf{n}$ and $\mathbf{a}_{ij} = \mathbf{w}_i/\mathbf{w}_j$.

ANALYSIS OF ALTERNATIVES TO SINIAV BY THE AHP METHOD

The analysis of the alternatives identified by the specialists, regarding the choice of the technological model (Figure 3), regulatory instruments (Figure 4) and institutional model (Figure 5), is carried out by applying the AHP, whose evaluation criteria are presented in the highlighted figures, corresponding to the respective aspects.

The evaluation of the technological model consists of ranking the possible alternatives for RFID technologies (active, semi-active or passive tags), according to the following criteria: (1) Cost: the best alternative will be the one with the lowest implementation cost; (2) Availability: the best alternative is the one with the greatest availability in the market; (3) Security: the best alternative is the one that offers greater security for the information recorded in the tag; (4) Interoperability: the best alternative is the one with the best interoperability conditions; and (5) Durability: the best alternative is the one with greater durability (useful life).

The evaluation of SINIAV's regulatory instruments consists of ranking the possible alternatives for legal provisions (law approved in the National Congress, CONTRAN resolution or DENATRAN ordinance), according to the following criteria: (1) Legal Security: the best alternative is the one with the least susceptibility changes (less fragility); (2) Flexibility: the best alternative is the one with the greatest flexibility to adapt to technological innovations; (3) Technicality: the best alternative is the one that enables the best description (specification) of technologies and systems.

The evaluation of SINIAV's institutional model consists of ranking the possible alternatives for the implementation process, considering possible business models for the user, DETRAN or third parties, evaluated according to the following criteria: (1) Cost: the best alternative is the one on which the cost of implementation will have the least impact; (2) Installation: the best alternative is the one that would be more likely to be responsible for installing the tag; and (3) Usability: the best alternative is the one that shows the greatest interest in the implementation of SINIAV, regarding the use of the system.

The evaluation matrices were obtained from the application of comparative evaluation forms pair by pair of the established alternatives, according to the criteria defined by the team of specialists. These assessment instruments/forms are specific to the highlighted aspects regarding the choice of technological model, regulatory instruments and institutional model of SINIAV. The data collected through were then submitted to evaluation according to the Hierarchical Analysis Method (AHP),

n	1	2	3	4	5	6	7	8	9	10
GO	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Tabela 2. Criteria comparison scale (Saaty, 1991).

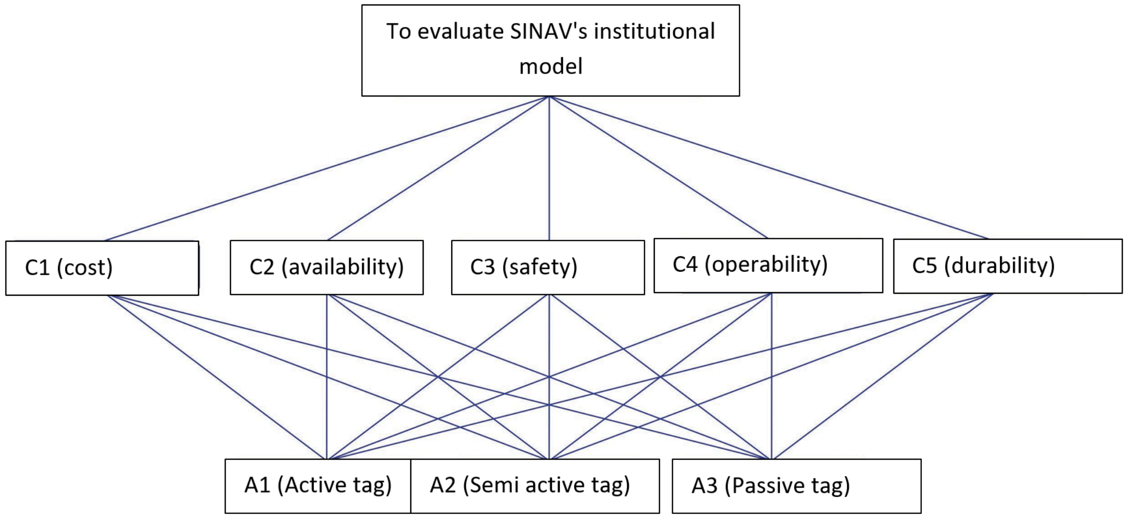

Figure 3 - AHP diagram for the evaluation of the SINIAV technological model.

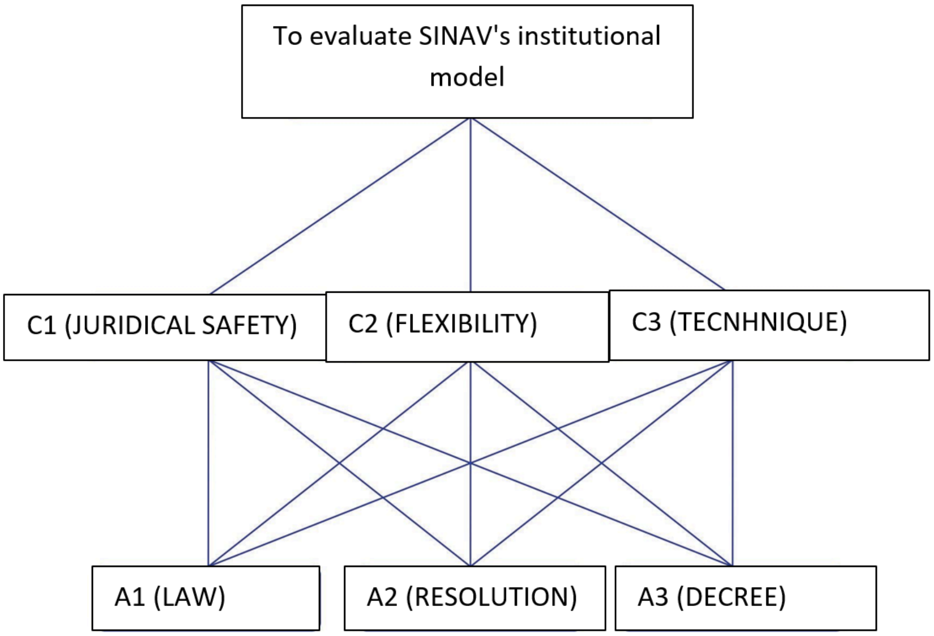

Figure 4 - AHP diagram for the evaluation of SINIAV’s regulatory instruments.

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in view of the need for a multicriteria analysis of the previously identified alternatives. Below are the analyzes of possible alternatives for the technological model, institutional model and regulatory instruments, carried out through the application of the AHP methodology.

CRITERIA ANALYSIS MATRIX

The graphs presented below show the relative priorities (weights) of the criteria adopted to evaluate the technological model (Figure 6), regulatory instrument (Figure 7) and institutional model (Figure 8), whose evaluation and verification of the consistency ratio were carried out according to the AHP methodology.

For the evaluation of the technological model, the most relevant criterion is interoperability, followed by cost and security of the tag. The availability of the tag in the market (number of suppliers) and its durability are less relevant. Legal certainty was widely highlighted as the most important criterion in choosing the regulatory instrument for the SINIAV, while the cost of implementation stands out even more relevantly in terms of the institutional model to be adopted in the implementation.

ANALYSIS OF ALTERNATIVES TO THE TECHNOLOGICAL MODEL

The graph shown inFigure 9shows the evaluation of technological model alternatives proposed for SINIAV, for each criterion adopted. THEFigure 10shows relative priority (selection of alternatives), whose evaluation and verification of the consistency ratio were carried out according to the AHP methodology.

For most criteria, the passive tag presents the best evaluation, which ends up highlighting it in the final evaluation as the best alternative, with a relative priority of 44.9% in relation to the semi-active (22.6%) and active (32 .5%). The cost factor, availability of the technology in the market and the durability of the tag had the greatest impact on this decision. This assessment corroborates the current market behavior, which tends to use the new Gen2V2 passive tags, which have a significantly lower cost, as it is an open protocol. In addition, they are as effective in reading as the others and are more durable as they do not need an internal battery.

ANALYSIS OF ALTERNATIVES TO REGULATORY INSTRUMENTS

The graphics shown inFigure 11show the evaluation of alternative regulatory instruments proposed for SINIAV for each criterion adopted, as well as the type of legal instrument recommended.

The results showed that SINIAV's greatest fragility in terms of regulation is legal uncertainty, resulting from the numerous normative acts published. This result is reflected in the choice of the type of legal act recommended for SINIAV, and its provision in law is recommended. Evidently, a law will not be able to bring the technical aspects nor have the necessary flexibility to contemplate the frequent technological evolutions.

The ordinance is, in fact, the instrument that has the greatest flexibility, as it constitutes a discretionary act by the top director of DENATRAN. However, while this flexibility is positive, it is opposed to legal certainty, a criterion of greater weight according to the evaluation carried out. As for the technical aspects of SINIAV, both the ordinance and the resolution fully meet the needs of the system.

ANALYSIS OF ALTERNATIVES TO THE INSTITUTIONAL MODEL

The graph shown inFigure 12shows the evaluation of the proposed institutional model alternatives for the SINIAV for each criterion adopted, as well as the relative

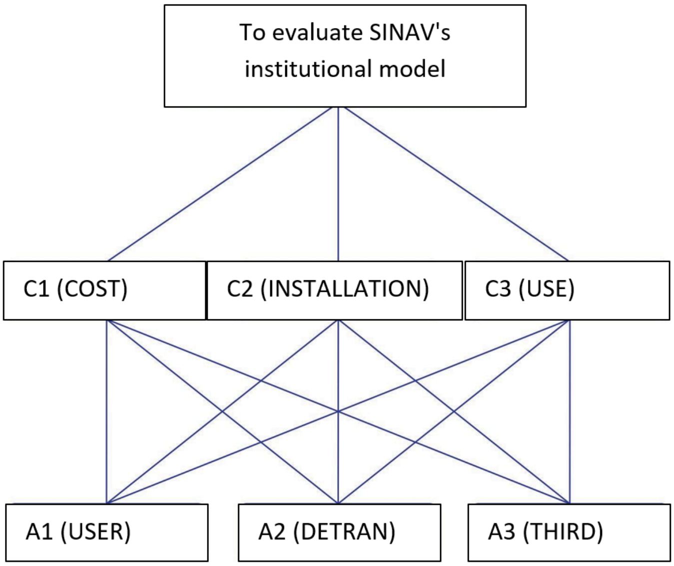

Figure 5 - AHP diagram for evaluating the institutional model of SINIAV.

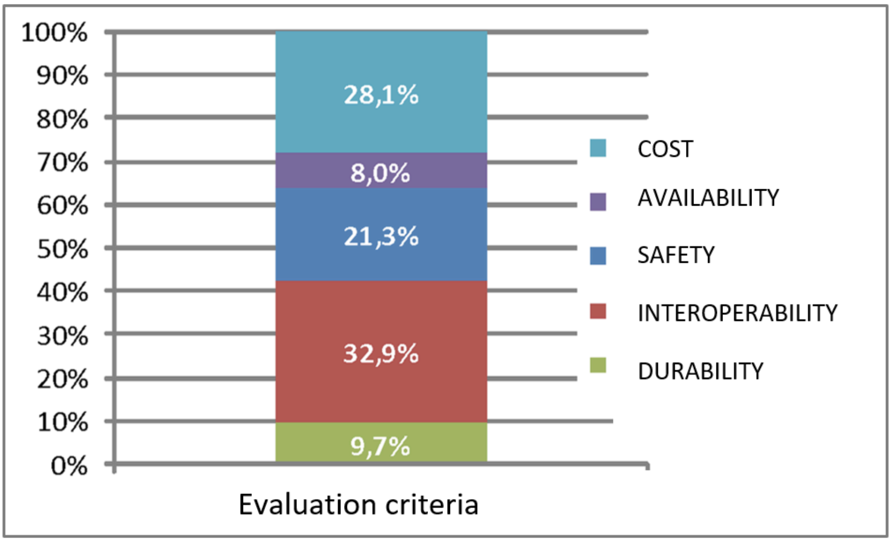

Figure 6: Relative priority (weights) of the criteria adopted for the technological model.

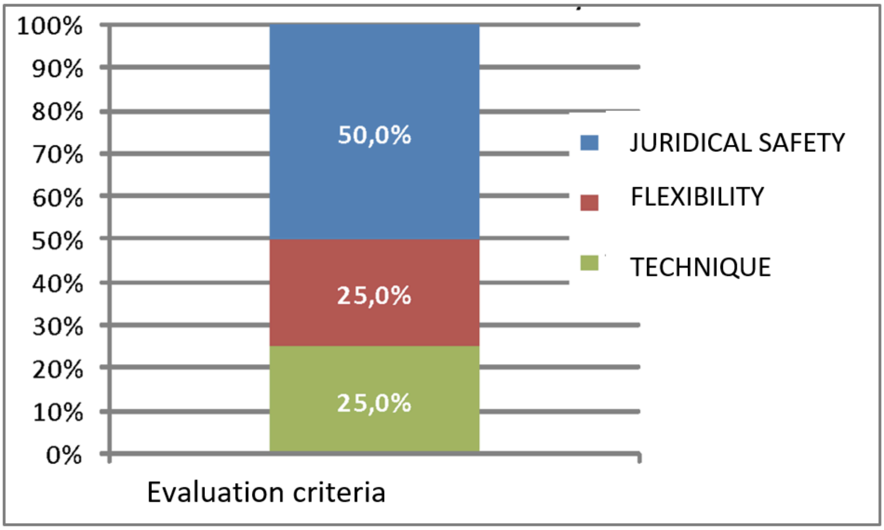

Figure 7: Relative priority (weights) of the criteria adopted for the regulatory instrument.

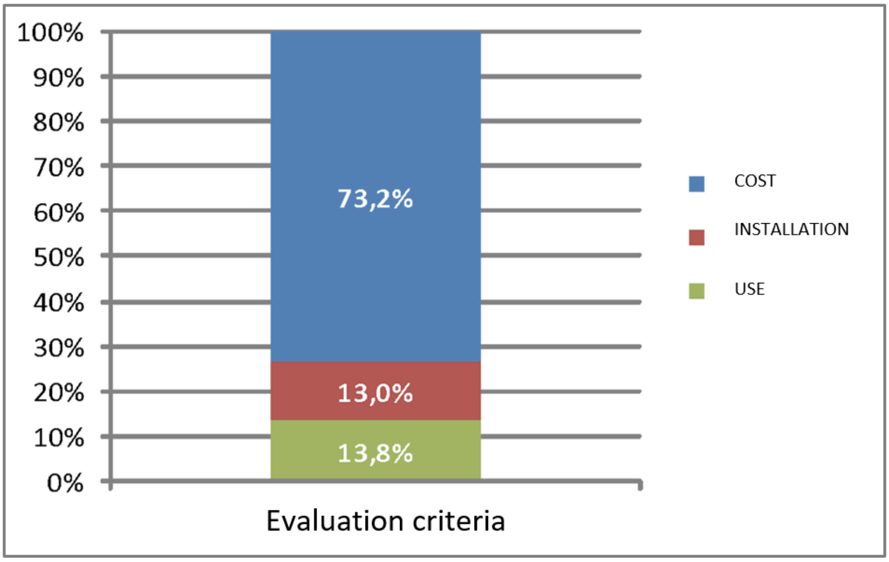

Figure 8: Relative priority (weights) of the criteria adopted for the institutional model.

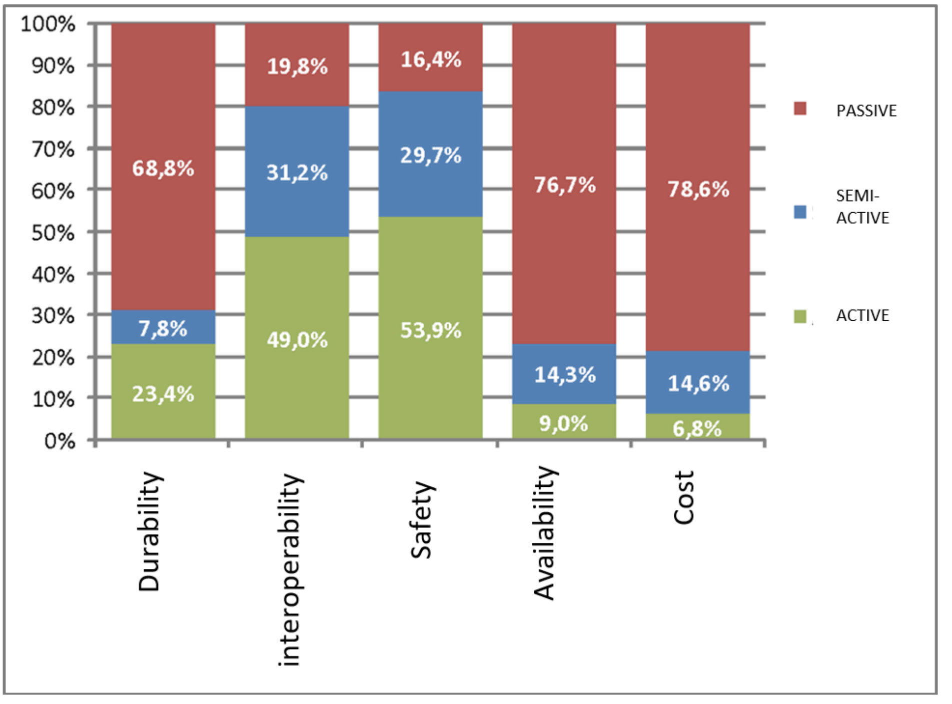

Figure 9: Technological Model Assessment – Assessment for each criterion.

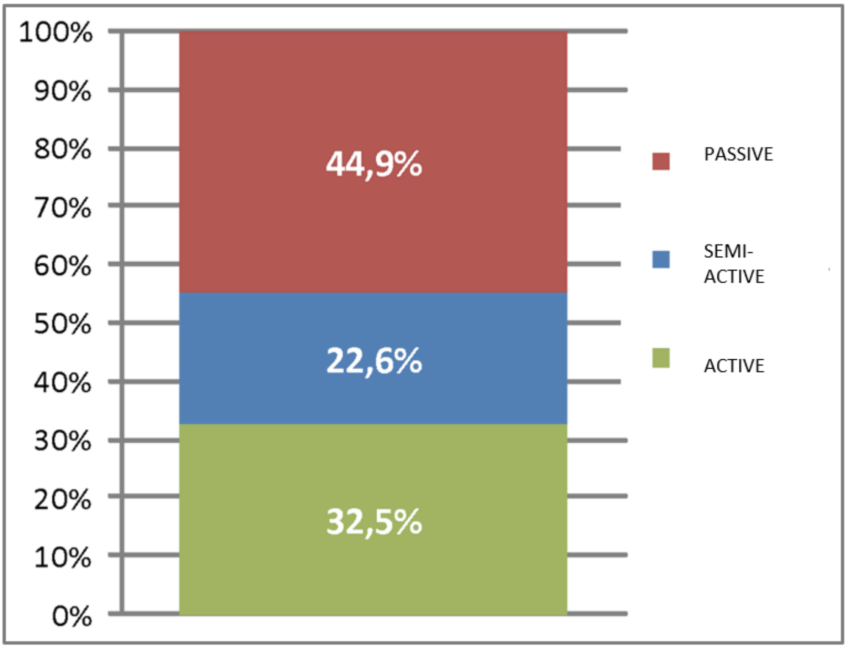

Figure 10: Technological Model Assessment – Selection of alternatives.

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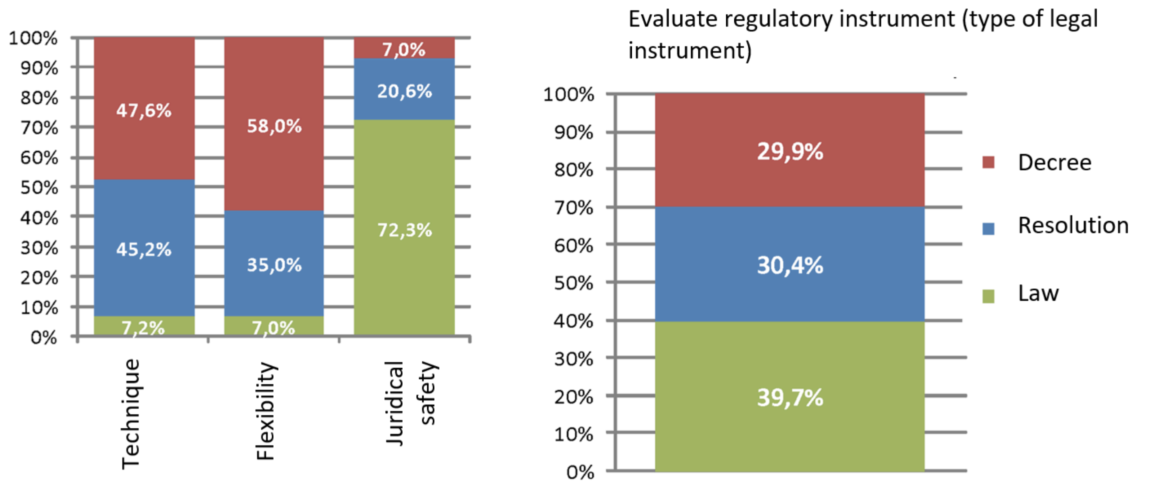

Figure 11 Evaluation of the Regulatory Instrument.

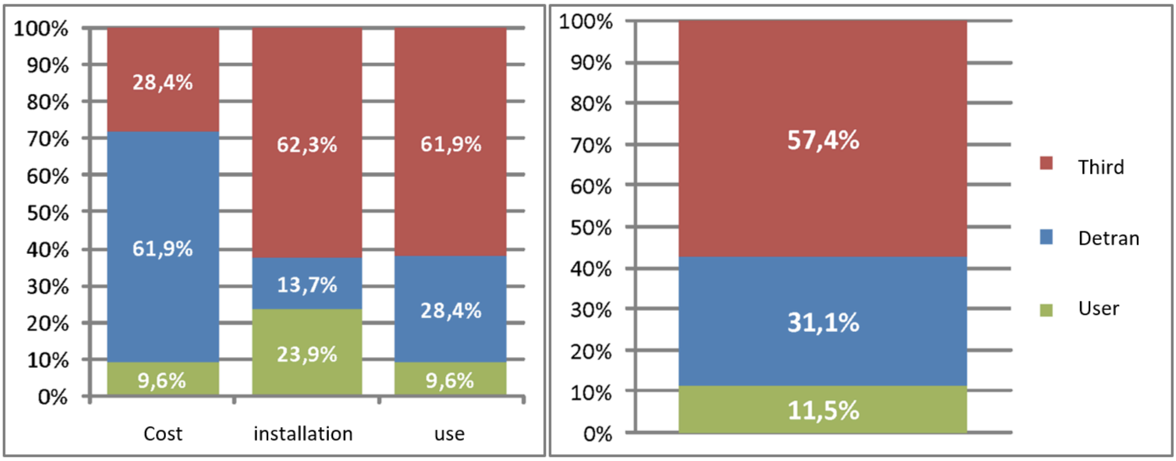

Figure 12: Evaluation of the Institutional Model.

priority (selection of alternatives).

According to the evaluation carried out, the implementation cost will have less impact if absorbed by the DETRAN. Even because these bodies will be the main beneficiaries of the implementation of SINIAV, which can be used as an instrument to control tax evasion (IPVA, licensing and mandatory insurance). According to the current regulations, this inspection using the SINIAV could only occur as a selective instrument for vehicles in default, in inspection operations with the presence of the transit authority or its designated agent. However, CONTRAN may regulate the electronic inspection of IPVA, licensing and mandatory insurance through SINIAV. For the other criteria, the role of the provision of services by third parties was relevant,

CONCLUSIONS

The AHP method proved to be consistent in all requirements, in the analysis and selection of alternatives by multiple criteria, corroborating the assumptions initially adopted and significantly contributing to decision-making regarding the establishment of guidelines for the implementation of SINIAV .

For the technological model, the results showed that the IAV (Automatic Vehicle Identification) protocol must be revised to contemplate the technological evolution, in a non-restrictive way, allowing any type of tag that meets the SINIAV requirements to be homologated. Thus, the choice of the type of technology to be acquired or implemented, whether in the provision of services or even by the DETRANs, is a market choice and not a restrictive determination by CONTRAN. Additionally, it is recommended that a test and procedures booklet be established for the approval of equipment and systems in order to standardize this process with the OCDs, LIDs and DENATRAN, in view of the changes to be made in the IAV-SINIAV protocol.

For the regulatory model, it is recommended that the SINIAV be provided for by law and regulated by CONTRAN resolution, since the resolution provides greater legal certainty, meets the technical aspects and has the necessary flexibility to contemplate the technological evolution of systems and equipment . As long as there is no explicit provision in the Brazilian Traffic Code - CTB, the SINIAV can be defined, from a legal point of view, as mandatory equipment established by CONTRAN, pursuant to art. 105 of the CTB.

As for the institutional model to be adopted, although the cost aspect has been relevant for DETRANs, the selection of alternatives highlights the implementation of SINIAV as a priority by offering services to the market. However, for DETRANs, SINIAV represents an investment with a short-term return, both for the electronic inspection of IPVA and for the effective recovery of revenues resulting from automation and, consequently, the gain in scale in these operations, carried out uninterruptedly through SINIAV.

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