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PERFORMANCE INDICATORS FOR THE ENVIRONMENTAL MANAGEMENT OF ROAD MAINTENANCE SERVICES

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ABSTRACT

Environmental performance assessments, although widely used in several industrial sectors, is still scarcely practiced in construction, maintenance and road operation activities. Thus, there is a need for studies to interpret the state of environmental management in relation to the complexities of the road sector. In this context, the aim of the present study is, therefore, to develop performance evaluation indicators for the environmental management of road maintenance services. For this purpose, the Multicriteria Decision Analysis Constructivist (MCDA-C) model was used, involving workshops comprising professionals specialized in several areas related to the technical, academic and research sectors that could contribute to environmental management practiced in highways. In view of these considerations, 185 concepts generated from the participants' opinions were obtained, filtered into 82 criteria, and divided into 10 areas of interest. Among these, water and road safety groups presented the highest weights among the areas of interest and are thus, noteworthy. Subsequently, the descriptions of the indicators and their respective weights were determined. Managers, researchers, and technicians responsible for highway maintenance may thus apply the indicators generated in this research, to aid in environmental control of the road environment, allowing for identification of points which may stand for improvement.

Keywords: Impacts; Transport Infrastructure; Criteria; MCDA-C.

RESUMO

Indicadores de desempenho para a gestão ambiental dos serviços de manutenção rodoviária.

A avaliação de desempenho ambiental, embora amplamente utilizada em diversos setores industriais, ainda é pouco praticada nas atividades de construção, manutenção e operação de estradas. Assim, há necessidade de estudos que interpretem o estado da gestão ambiental em relação às complexidades do setor rodoviário. Neste contexto, o objetivo do presente estudo é, portanto, desenvolver indicadores de avaliação de desempenho para a gestão ambiental dos serviços de manutenção rodoviária. Para tanto, foi utilizado o modelo Multicritério de Análise de Decisão Construtivista (MCDA-C), envolvendo workshops com profissionais especializados em diversas áreas relacionadas aos setores técnico, acadêmico e de pesquisa que pudessem contribuir para a gestão ambiental praticada em rodovias. Diante dessas considerações,

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foram obtidos 185 conceitos, a partir das opiniões dos participantes, que foram filtrados em 82 critérios e divididos em 10 áreas de interesse. Dentre estes, os grupos de água e segurança viária apresentaram os maiores pesos entre as áreas de interesse e, portanto, merecem destaque. Posteriormente, foram determinadas as descrições dos indicadores e seus respectivos pesos. Gestores, pesquisadores e técnicos responsáveis pela manutenção das rodovias podem, assim, aplicar os indicadores gerados nesta pesquisa, para auxiliar no controle ambiental do entorno rodoviário, permitindo a identificação de pontos que podem ser melhorados.

Palavras-chave: Impactos; Infraestrutura de Transporte; Critérios; MCDA-C

INTRODUCTION

Irreversible environmental damages may occur during road works, such as soil deterioration processes and damage to flora and fauna, as well as changes in rivers. Road maintenance services also generate large amounts of waste. Therefore, the professionals responsible for these processes must implement efficient systems, despite the scarce resources coming from the government.

This indicates the importance of considering integrated projects in highway implementation and maintenance through an environmental perspective, associated to more effective management actions by both the government and private companies belonging to this sector, so that the sustainability is employed from highway conception to preservation. Thus, environmental indicators can be applied as tools for management decision-making processes since these are easily understood data.

Environmental management considers numerous attributes used to evaluate the level of environmental impact of road maintenance services. However, it is common practice to use a set of indicators to analyze various parameters and aspects regarding the problem at hand. Therefore, multicriteria decision support methodologies are used to assist managers in decision-making processes (Roy, 2005).

In this context, the present study adopts the MCDA-C analysis, which uses subjective factors, in addition to objective and quantitative criteria, in the decision-making process. The system of actors applies certain parameters to define the MCDA-C action participants, as follows, according to Ensslin et al. (2001): *Deciders:* who have control over the means for the conclusion of the decision and who will be able to validate the process after its conclusion; *Interveners:* those who can directly influence the decisions of the decision-maker by their value system; *Acted ones:* they are those affected by the decisions taken, that do not have influence or power to interfere directly in the decision-making process and *Facilitator:* responsible for assisting in the construction of the evaluation model, guiding the information gathering and understanding the consequences of the decision. At higher levels of organization, can prepare recommendations for the decision-maker.

Next, it is necessary to define a reference problem that allows for the clearly identify the structuring and evaluation situations for the decision context modeling. At structuring phase the problem is defined through the generation of knowledge and knowledge-related element systematization. The following is the evaluation phase, which will build the model to "account" for the impacts regarding the previously defined criteria (Ensslin et al., 2000). According to these authors, decision-making recommendations are given after completing the evaluation process. Therefore, interactions and the participation of the decision-makers are essential to generate conclusions from the applied models. The MCDA-C deals with knowledge structuring and decision support, and can be applied in different areas, such as in the evaluation of organizational company performance, supplier evaluation, customer service and in the educational area (Jesus, 2015).

Despite several studies performed on road sector, the premise of taking into account pavement effects does not yet consider environmental aspects (Santero et al., 2011). In the transport infrastructure sector, some studies are related to the development of indices and environmental indicators to assist in decision-making processes in this area. For example, Sinay et al. (2005) proposed certain environmental indicators that comprise the road group, namely water, air, soil and flora quality, river flow, soil degradation, noise, endemism, invaded borders, mass movements, energy consumption, fuel consumption and waste generation.

Costa and Sánchez (2010) developed an environmental performance evaluation index for paved road maintenance considering environmental non-conformities, the Critical Environmental Nonconformity Index (CENI), that determines the weights of each of the three levels of non-conformity based on the opinion of transportation experts. Gomes and Malheiros (2012) present an analysis of the criteria applied to identify the strengths and weaknesses of environmental indicators and their implementation procedures.

In the study performed by Viviane et al. (2014), the Unpaved Roads Management Index (URMI) was developed. The URMI indicators were hierarchized through multicriteria analysis techniques. The contribution of each of the 21 indicators was based on the opinion of experts in the field, according to a scale provided by the authors.

In Brazil, studies aimed at the development of environmetal indicators for road maintenance still are scarcelly available, and, when they do exist, they are specific for the region where the study is conducted. The surveys conducted by Lisboa (2002), Martins (2005), Paiva (2004), Ciciliato (2016), Leite et al. (2018) and Sequinel et al. (2019) indicate the increasing development of environmental indicators related to the road environment. Thus, the need for more studies focusing on environmental impacts in the road maintenance area is clear, seeking the standardization of environmental indicators, as well as dissemination of the concern about these impacts and the need for continuous monitoring.

In this context, the aim of this research is to develop indicators for the evaluation of environmental performance, by applying the MCDA-C model, to be used by managers as a tool to support environmental management in road maintenance.

MATERIALS AND METHODS

The following section describes the planning of the experimental procedure and its stages. The procedure was applied to two distinct teams, where brainstorming was carried out with professionals from several areas related to the environmental theme and highway maintenance.

Actor Selection

In the MCDA-C approach, a system of actors is responsible for creating knowledge applied to a certain problem. In both teams, the researchers assumed the role of facilitators, encouraging the participation of stakeholders and recording their opinions. The acted ones in the present study were highway system users and the deciders. Team 1 participants were postgraduate students studying at the State University of Londrina (*Universidade Estadual de Londrina* – UEL). The second team comprised managers and other technical professionals from the Paraná Roads Department (*Departamento de Estradas e Rodagem do Estado do Paraná* - DER/PR). Figure 1 displays an illustrative scheme of the actors' selection and the academic formation of the participants. Regarding Team 2, workshops were held in the five host cities of the regional DER/PR offices, namely Cascavel, Curitiba, Londrina, Maringá and Ponta Grossa.

Initial Research Presentation

A brief presentation of the environmental management context in highway maintenance and an explanation of the MCDA-C approach were given in the first meeting, to detail the environmental problem at hand and the stages of the research method. The estimated time for this stage was 30 minutes, 15 minutes for an oral presentation by the facilitator and 15 minutes for discussions and doubts that may have arisen.

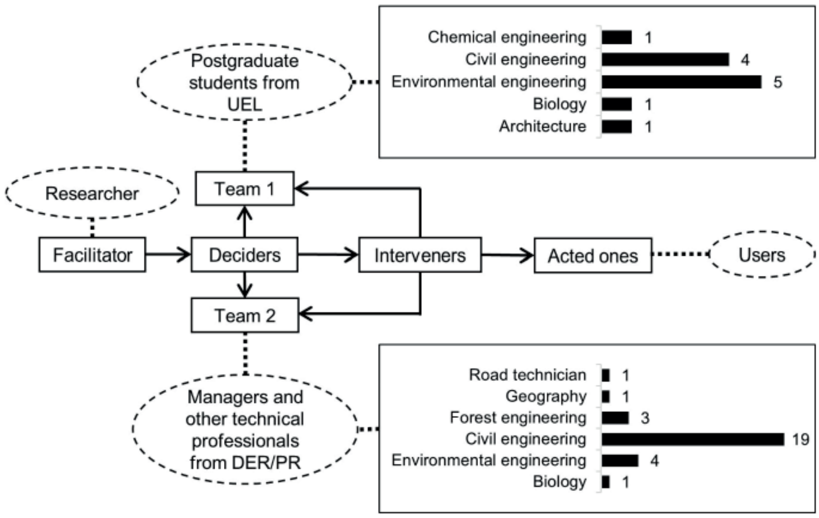

Figure 1. Illustrative scheme of actor selection.

List of Primary Evaluation Elements (PEE)

The PEE survey in both teams followed the same procedure, occurring at different times for each group. After the initial presentation, the elements related to the environmental problem were listed and the participants discussed the ideas, goals, objectives or perspectives through the brainstorming technique. The maximum of possible concepts was recorded on a spreadsheet, as exemplified by table 1, which lists the brainstorming elements obtained in Curitiba. These concepts were broken down in the column "Elements related to the problem".

After this, "Action-oriented concepts" were added, which were supplemented with considerations that reflected the positive actions to be taken. At the end of this stage, the concepts related to the "negative pole", which is the psychological opposite of the action, were added, to aid in understanding the problem. In this step, it was emphasized that the sentences should refer to a complementary aspect of the "action-oriented concepts". The next step was to create groups that displayed the characteristics of the "Elements related to the problem". This evaluation lasted about two hours, with a one-week break between each workshop to analyze the obtained opinions.

Table 1. Concept collection worksheet – Curitiba.

ID	Elements related to the problem	Action-oriented concepts	Negative pole
18	Solid waste (disposal, control)	Ensure the adequate destination of solid waste	Generate environmental liabilities

Means-End Relations Map

At this point, the PEE and action-oriented concepts were collected and separated into clusters.

The means-end relations maps were then graphically constructed with the Cmap Tools software. The relations of the influence between the concepts (in the sense of means for the ends) were represented with arrows. Figure 2 presents the structure of a frame for a cluster, as well the map of means and ends generated for the materials group according to the elements raised by the DER/PR experts at Curitiba. Each arrow that leaves the cluster represents a medium function and each arrow that arrives represents an end function.

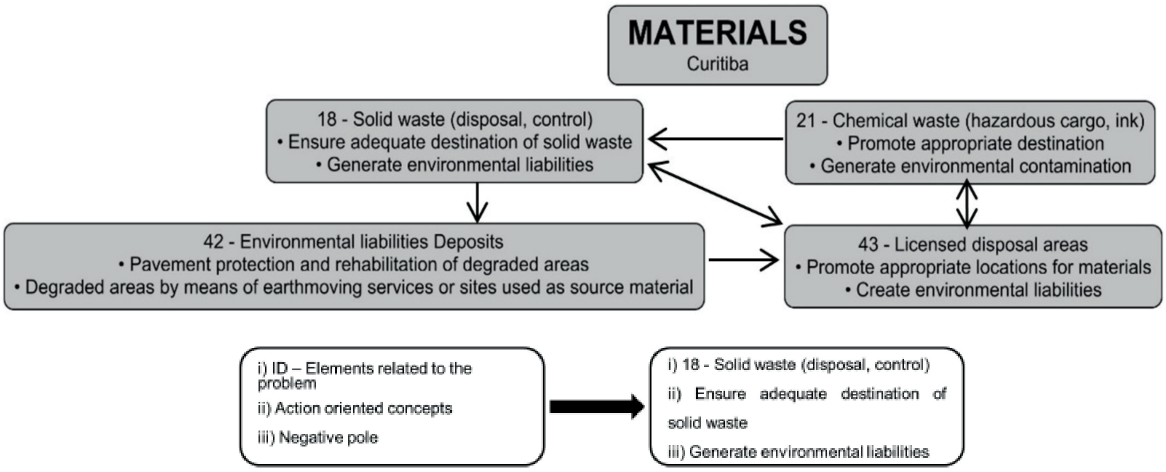

Figure 2. Detail of a Cluster for material group and the group Means-end relations map.

Team 1 participants separated the criteria groups and performed the interactions through the means-end relations maps. This was not performed by the regional DER/PR office participants (Team 2), due unavailability of schedules for joint meetings. Thus, the interactions were defined by the researchers.

After identifying the points with the most relationships, it was possible to define Fundamental Viewpoints (FV) and Elementary Viewpoints (EV) and organize them into hierarchical arborizations, in other words they may be displayed in the form of hierarchical trees. This facilitates the understanding of the problem, indicating the dimension in which factors should be judged first and which factors are the most important.

FV and EV Determinations

The next step was to verify the representativeness of each concept, listing those that presented the most interactions, such as FV. The items that reflect the strategic objectives and the fundamental aspects for evaluation considered by the decision-makers were identified in the means-end relations maps. In order to better understand each of these FVs, some EV were generated when necessary. FV candidates should be essential, controllable, complete, measurable, operational, insurable, non-redundant, concise and understandable. Criteria were specified for each FV for further evaluation according to their performance in each point of view.

Criteria Weights

An online questionnaire of the constant sum type was applied at the Qualtrics.com platform, with a total sum value of 100 points. The questionnaire items were generated during the workshops attended to by both groups of participants. At this time, only the DER/PR professionals were responsible for assigning weights to the criteria. One condition was applied for the respondent to be able to continue the questionnaire filling process: that all questions should be filled with 100 points, otherwise, the respondents would not be allowed to proceed.

A brief explanation of each point of view was listed below each alternative for each question, to aid in participant judgment. In addition, participants were asked to suggest indicators for the answers, leaving their comment in each item. Participants were informed by e-mail about the 30-day deadline to answer the questionnaire. After obtaining the answers, the degree of importance of each theme was identified by adding up the points for each answer.

Data normality was tested by the Shapiro-Wilk statistical test, with a level of significance of 5%. Parametric tests could not be applied, since some variables were not normally distributed. In these cases, the Kruskal-Wallis test was applied, with comparisons of independent multiple samples, to verify the hypothesis that the data have medians with the same distribution.

The significance level adopted was of 5%, i.e. if the p-value was less than 5%, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. If it was greater than 5% the null hypothesis was accepted. This research defined the following hypotheses:

- H_0: the data groups present the same distribution of values;
- H_1: the data groups do not present the same distribution.

After checking the items in which H_0 was rejected, Dunn's test was performed to identify significant differences between samples taken two by two. Statistical tests aid in verifying if the data is compromised, applied herein to examine the distributions among the weights assigned in the workshops performed with Team 2 participants.

Criteria Weight Standardization

This step consisted in normalizing the assigned weights, so that a standard score of the indicators could be recorded. The range from zero to one [0,1] was chosen. Equation 1 was applied for normalization:

$$Weight_{norm} = \frac{weight}{\sum weight_i} \quad (1)$$

Where: $Weight_{norm}$ = Final standard weight; Weight = Weight assigned in the questionnaire and $\Sigma weight_i$ = Sum of the weights of the group. Thus, the indicators created from the FV and EV reflect results between 0 (zero) and 1 (one), relative to each interest group, by their sum.

Indicator Creation

Initially, some indicators were created by Team 1, through the opinions of the postgraduate stu0dents given during the workshop to explain the items resulting from the arborization. In addition, the authors also refined the definitions of the indicators through a literature review. On the other hand, no workshop was conducted with Team 2 to discuss the arborizations. Thus, some indicators were maintained and others were created by the researchers by taking into account the opinions of the DER/PR professionals collected in previous workshops.

The next step was an indicator analysis by the DER/PR professionals, where participants were encouraged to contribute with new indicators. However, due to the small contribution of the DER/PR professionals, the indicators adopted herein were those compiled from all the workshops and a bibliographic review of technical reports, standards, procedures, articles and technical research.

RESULTS AND DISCUSSION

The results section contains the compilation of the data from Teams 1 and 2 regarding the determination of the criteria to be evaluated. These data were obtained through participant opinions given in the workshops and developed based on the MCDA-C approach.

Regarding Team, 1 the procedure took place between the facilitator and the participants, where indicators where created and analyzed by the authors of the research. Regarding Team 2, the DER/PR specialists conducted the workshop discussions and answered the questionnaire to suggest the weights for each criterion. After a bibliographical review of standards, procedures, articles and technical research, the indicators compiled by both teams were listed.

The gathering of expert opinions during the meetings took place through workshops. During the procedure, groups of elements that comprised all the concepts listed and related to the problem were identified. Table 2 presents the expressions created during this stage with Team 1.

Table 2. Groups of elements related to the problem of road maintenance services – Team 1.

ID	Expression	Alternatives
A	Management	Activities which have an effect on management.
B	Biotic Environment	Impacts related to fauna, flora and vegetation.
C	Operation Highway	Effects on the operation of the highway, pavement, works.
D	Socio-environmental	Affects society and its relationship with the environment.

During this stage, participants also provided three elements for concept characterization: problem-related elements, action-oriented concepts and negative poles. The workshops conducted with Team 2 followed the same procedure as for Team 1. At Cascavel, DER/PR professionals provided 17 suggestions; at Curitiba, 36; at Londrina, 49; at Maringá, 34 and, finally, at Ponta Grossa, 24, totaling 160 opinions that expose, in a general manner, how experts think about what is important when evaluating environmental performance. Table 3 lists the groups generated after analyzing the opinions obtained during the workshops, with the alternatives that best define each group.

Table 3. Groups of elements related to the problem of road maintenance services –Team 2.

ID	Expression	Alternatives
A	Water	Control, monitoring and execution of services related to drainage and water courses.
B	Management	Activities which have an effect on management.
C	Juridical	Juridical or legislative aspects.
D	Materials	Materials used in pavement, environment, maintenance and equipment.
E	Biotic Environment	Impacts related to fauna, flora and vegetation.
F	Road safety	Aspects related to the security of users and the environment (that benefit society).
G	Socio-environmental	That affect society and its relationship with the environment.

The workshops contributed greatly to this research and are justified by the use of the MCDA-C as a basis for the discussion of ideas and elaboration of critical thinking among participants. The next step of the research was the creation of the means-end relations maps. The presentation of the map structure was based on the groups of alternatives suggested by the experts.

After the elaboration and analysis of these maps, the interactions between the concepts were quantified. The interaction data were tabulated, allowing for the determination of FV and EV in order to create the environmental performance indicators. Subsequently, a representation of the hierarchical arborization of the concepts was created, with the purpose of facilitating the visualization and correctly defining the interest groups, namely FV and the EV.

Obtaining the FV and EV through participant opinions given during the workshops was an essential step in selecting the performance indicators applied in road environmental management. In general, Team 1 experts expressed their opinions through their knowledge on the topic. However, it is evident that that Team 2 participants displayed improvements of their ideas, due to the contribution of people with different experiences. Figure 3 presents, the areas of interest addressed separately in the FV and their respective EVs obtained by Teams 1 and 2, in an arborization form.

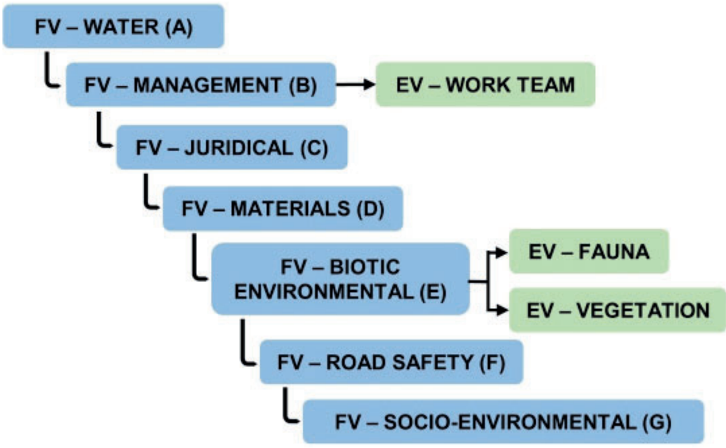

Figure 3. Arborization of FV and EV – Teams 1 and 2.

The FV data were evaluated through boxplot graphs, which present the distribution of the values of this study and indicate the interval, median and outliers (atypical values of the quartile distribution). The upper and lower rods indicate the largest and smallest weights, respectively. The center rectangle shows the data distribution separated by quartiles. The lower quartile contains 25% of the lowest values and the upper quartile contains 75% of the highest values.

Figure 4 indicates that the "A - Water" group showed a higher number of distant participant opinions, with four extreme values. Item "F - Road safety" presented a weight of 40, and was characterized as outlier. With the exception of the "A - Water" group and the "F - Road Safety" group outlier, the groups presented a score range between 0 and 25; such amplitudes of the weights given to the other areas reflect the dispersion between the data, characterizing the lack of homogeneity between the opinions of the specialists. It is observed by the position of the median that it is an asymmetric distribution of data. Finally, the "A - Water" group, "F - Road Safety" group and "G - Socio-environmental" group were the three most important in the assessment of areas of general interest.

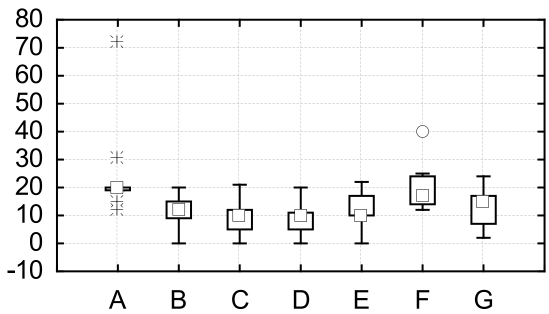

Figure 4. Areas of general interest.

Figure 5a indicates that half of the items present atypical values that do not correspond to the data distribution. This demonstrates disagreements among the professionals who judged the placement of the item in an evaluation for the "water" group and those that gave the item a high degree of importance. It is observed from the values received that the items of greatest concern were "A8 - Maintenance of drainage systems" and "A1 - Surface water on the pavement".

Figure 5b indicates that items B1, B12, B15, B16, and B17 present atypical values, indicating that participants did not reach a consensus for these items. In addition, the medians are very close to each other, except for item "B13 - Rural patrol", the less graded item. This can be explained by the number of evaluated items with close opinions. In Figure 5, it can be seen from the position of the median that it is an asymmetric distribution of the data.

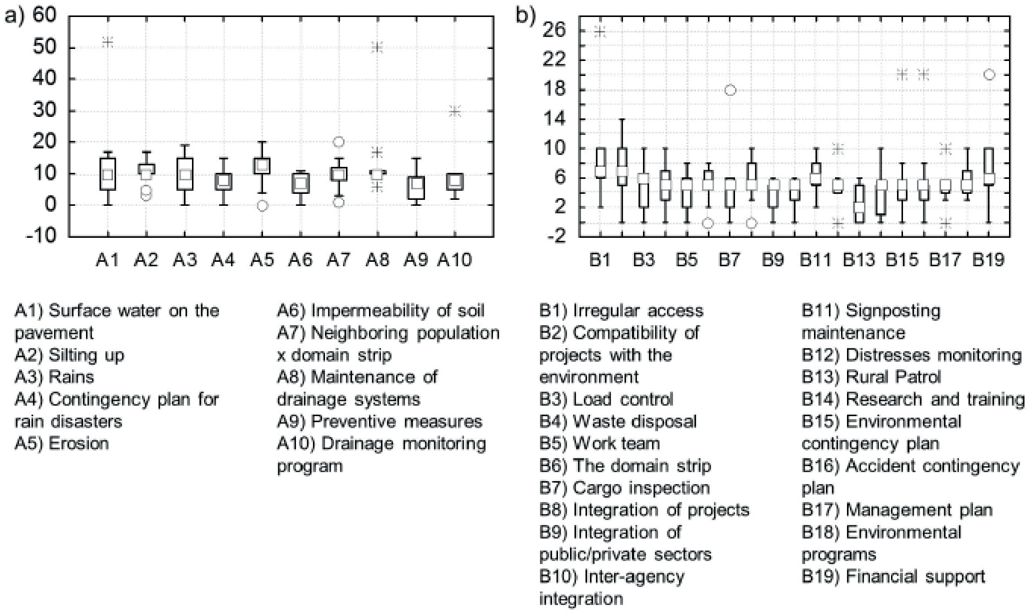

Figure 5. FV-Water (a) and FV-Management (b).

Figure 6a indicates that most deviant weight is "B66 - training", with a maximum score of 85, increasing the average value of this item. Along with item B66, item "B62 – Multidisciplinary Team" stands out, indicating that participants are concerned with training and multidisciplinary teams for road maintenance. Figure 6b displays the weight distribution for "FV - Juridical" and reinforces the similarity between specialists' weights for all items and their disparity for item "C6 - Legal Structure". This indicates that the participants moslty have the same opinion regarding the legal sector and bureaucracy issues in dealing with the environmental aspects of highway maintenance. Finally, looking at figure 6, it can be seen that the item "B61 - Contractor" is the only item with normally-distributed data.

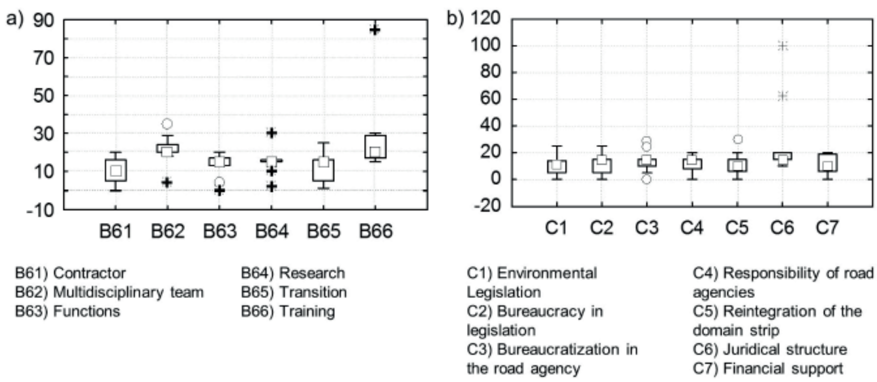

Figure 6. EV-Work team (a) and FV-Juridical (b).

Figure 7a describes the weight distributions, reinforcing the idea that the items of greatest concern are "D1 - Control of materials", "D3 - Allocation of solid waste" and "D9 - Recycling of residues" demonstrating the importance that specialists give to the control of materials after they are removed. In figure 7b, despite showing close average values, the judged items also presented extreme values, indicating divergent opinions of some participants. In general, checking the position of the median in figure 7, the data are asymmetrically distributed.

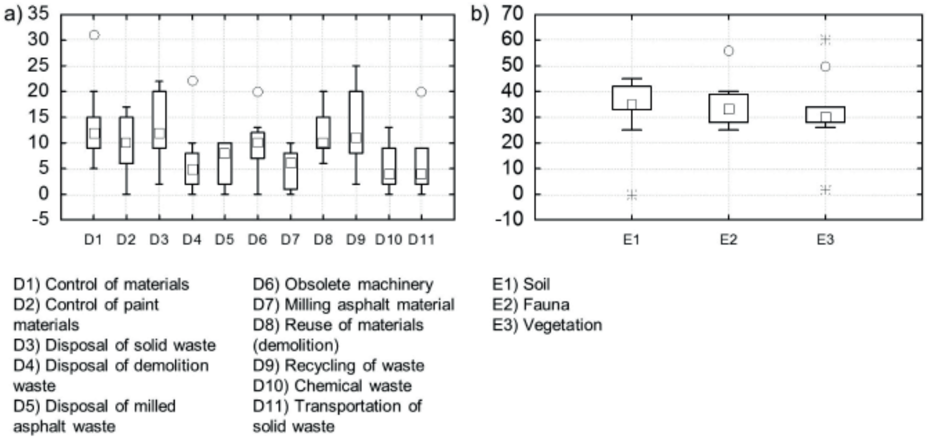

Figure 7. FV-Materials (a) and FV-Biotic Environment (b).

Figure 8a presents the distribution of the assigned weights, indicating that it does not follow a symmetrical trend, characterizing a high dispersion of the evaluated judgments, with the greatest concern of the specialists being the item “E24 – Passage for animals”. In the figure 8b, among the weights attributed by the specialists, it is possible to notice the biggest concern is with the exotic trees in the domain strip (item E31) and the characterization of the species suitable for the highway (item E33), furthermore it is possible to notice that there are discrepant values for items “D32 – Destination of tree pruning” and “D33 – Suitable species”.

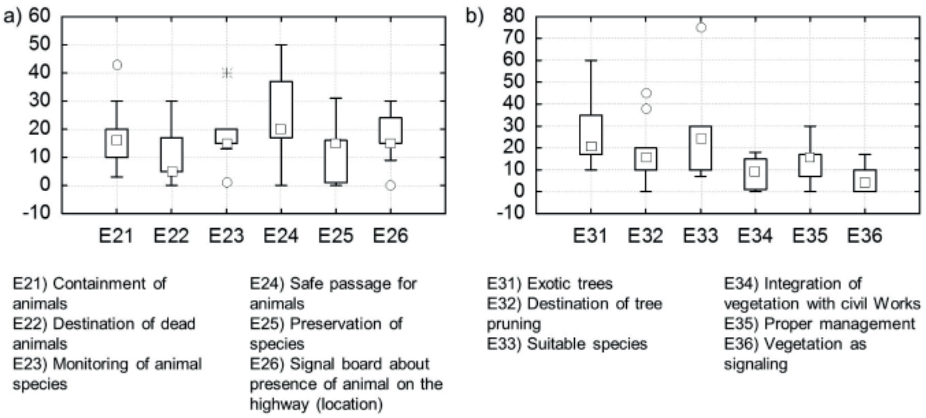

Figure 8. EV – Fauna (a) and EV-Vegetation (b).

Figure 9a indicates that the greatest distributions were observed for “F1 - Trees in the surroundings” and “F6 - Signaling”, indicating that these items show greater weight variability, with significantly differing opinions. Besides that, it can be seen the item “F1 – Trees in the surroundings” was the most notable in terms of weights, which demonstrates the concern of specialists with the management necessary to guarantee the safety of highways in the State. Figure 9b shows a good distribution of the weights given by the specialists, except for “G1 – Irregular access” which was the item of greatest socio-environmental concern.

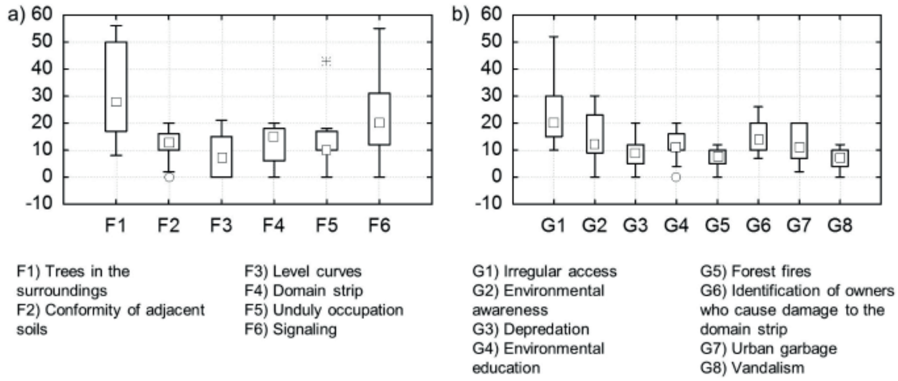

Figure 9. FV-Road safety (a) and FV-Socio-environmental (b).

The Kruskal-Wallis test was applied to verify significant differences between the data obtained from the workshop participants. Table 4 displays the results for both teams.

Table 4. Kruskal-Wallis test – Teams 1 and 2.

Groups	A	p-value	Situation	
			Accept H_0	Reject H_0
Areas of general interest	0.05	0.0055		x
FV – Water	0.05	0.2873	x	
FV – Management	0.05	0.0880	x	
EV – Work team	0.05	0.0107		x
FV – Juridical	0.05	0.3761	x	
FV – Materials	0.05	0.0113		x
FV – Biotic environmental	0.05	0.8182	x	
EV – Fauna	0.05	0.2750	x	
EV – Vegetation	0.05	0.0016		x
FV – Road safety	0.05	0.0495		x
FV – Socio-environmental	0.05	0.0053		x

The following groups presented statistical differences: Areas of general interest; EV – Work team; FV - Juridical; FV - Materials; FV - Biotic environmental; EV - Fauna. To determine which items were different, Dunn's test was applied, where averages followed by the same letter were not significantly different. The results can characterize items that could present higher and lower priority in the assessment of environmental management performance during road maintenance services. Table 5 list the averages and medians of the groups analyzed by the DER/PR professionals, with significantly differing items, as well as a conclusion related to the applied test.

Dunn's test performed in this research compared the items two by two, verifying the statistical differences between the weights with 5% of significance. The results of this test can characterize the items that should have higher and lower priority in the evaluation of environmental management performance for road maintenance services.

After obtaining the weights for each criterion, the degree of importance given to each one by the DER/PR professionals was evaluated. The statistical differences observed for each criteria are relevant to the opinions of the maps of means and ends assemblages, since the participants had only one meeting in which they could express their opinions, and could not intervene in the final FV and EV assembly. Therefore, the observed differences were expected, and the statistical tests carried out proved these differences.

Table 5. The Dunn's test.

Group	ID	Mean	Median		Conclusion
Area of general interests	A	25.44	20.00	a	Item "A - Water" differs statistically from group "D - Materials"; the other items do not differ significantly from each other.
	F	19.89	17.00	ab	
	G	13.11	15.00	ab	
	E	11.67	10.00	ab	
	B	11.11	12.00	ab	
	C	9.89	10.00	ab	
	D	8.89	10.00	b	
EV – Work team	B66	27.56	20.00	a	Items "B66 - Training" and "B62 - Multidisciplinary team" differ significantly from all other values.
	B62	21.11	20.00	a	
	B64	14.89	15.00	b	
	B63	13.22	15.00	b	
	B65	12.22	15.00	b	
	B61	11.00	10.00	b	
FV – Materials	D1	13.67	12.00	a	Averages with the same letter do not differ significantly from each other.
	D3	13.11	12.00	a	
	D8	11.89	10.00	ab	
	D9	12.78	11.00	ab	
	D6	9.44	10.00	ab	
	D2	9.22	10.00	ab	
	D11	7.11	4.00	bc	
	D4	6.67	5.00	bc	
	D5	5.78	8.00	c	
	D10	5.11	4.00	c	
	D7	5.22	6.00	c	
EV – Vegetation	E31	28.44	21.00	a	Averages with the same letter do not differ significantly from each other. No statistically significant differences are observed between items E31, E33, E32 and E35 and between E32, E35, E34 and E36, while items E31, E32 differ significantly from E34 and E36.
	E33	25.44	16.00	a	
	E32	18.67	24.00	ab	
	E35	14.00	9.00	ab	
	E34	8.22	16.00	b	
	E36	5.22	4.00	b	
FV – Road safety	F1	31.44	28.00	a	No statistically significant differences between items F1 and F6, between F6, F5, F2 and F4 and still between F5, F2, F4 and F3. However, significant differences between items F1 and F3 are observed.
	F6	22.56	20.00	ab	
	F5	14.11	10.00	bc	
	F2	11.78	13.00	bc	
	F4	11.44	15.00	bc	
	F3	8.67	7.00	c	
FV – Socio-environmental	G1	24.33	20.00	a	Statistical differences are verified according to the different letters between each item.
	G2	14.89	12.00	ab	
	G3	9.11	9.00	ab	
	G4	11.67	11.00	ab	
	G5	6.78	8.00	b	
	G6	14.78	14.00	ab	
	G7	11.67	11.00	ab	
	G8	6.78	7.00	b	

After a bibliographical review of standards, procedures, articles and technical surveys, the compiled indicators by both teams were listed. Tables 7, 8 and 9 present the areas of concentration, the evaluation criteria and the respective indicators. The indicators created by the postgraduate students that were maintained are identified with by (*), while those maintained but adapted for better definition are identified by (**).

Table 7. Road environmental performance indicators (part I).

Area	ID	Criterion	Indicators
FV – WATER	A1	Surface water on the pavement	Pavement area presenting drainage deficiency (%).
	A2**	Silting up	Checking of silting-up points.
	A3	Rains	Maintenance amounts caused by rainfall.
	A4	Contingency plan for rain disasters	Existence of a contingency plan for rain disasters.
	A5	Erosion	Number of erosion *foci*.
	A6	Impermeability of soil	Impermeable area of the domain strip (area/stretch).
	A7	Neighboring population x domain strip	Identification of owners who cause damage to the domain strip.
	A8*	Maintenance of drainage systems	Number of servicing serviced by the number of defective devices (%).
	A9	Preventive measures	Actions to identify possible interventions in drainage systems.
	A10	Drainage monitoring program	Existence of a monitoring program for drainage systems.
FV – JURIDICAL	C1	Environmental Legislation	Compliance with environmental legislation.
	C2	Bureaucracy in legislation	Time to solve bureaucratic problems.
	C3	Bureaucratization in the road agency	Difficulty in performing a certain service or project.
	C4	Responsibility of road agencies	Determination of the responsibilities of each road agency.
	C5**	Reintegration of the domain strip	Measures to reintegrate the domain strip.
	C6	Juridical structure	Existence of a juridical department at the superintendence of the road agency.
	C7	Financial support	Monetary values destined for environmental programs.
EV – WORK TEAM	B61	Contractor	Percentage of attendance regarding environmental plans.
	B62	Multidisciplinary team	Diversity of professionals for environmental tasks.
	B63	Functions	Specification of functions.
	B64	Research	Research time within the environmental sector.
	B65	Transition	Time for professional position transition.
	B66	Training	Training regarding environmental issues.

Table 8. Road environmental performance indicators (part II).

Area	ID	Criterion	Indicators
FV – MANAGEMENT	B1	Irregular access	Number of closed accesses due to the number of irregular open accesses (%).
	B2	Compatibility of projects with the environment	Number of executive projects containing environmental projects.
	B3	Load control	Existence and functionality of scales for load control
	B4	Waste disposal	Proper disposal of maintenance waste.
	B5	Work team	Attendance of the EV – Work team.
	B6	The domain strip**	Verification of conformities regarding the initial design.
	B7	Cargo inspection	Measures to verify hazardous cargo.
	B8	Integration of projects	Measures to integrate technical and environmental projects.
	B9	Integration of public/private sectors	Standardization of services between technical sectors.
	B10	Inter-agency integration	Attendance to problems that relate to different agency and competences.
	B11*	Signposting maintenance	Ratio between signposting devices held by those having a defect.
	B12*	Distresses monitoring	Distress monitoring program.
	B13	Rural Patrol	Rural Patrol Program.
	B14	Research and training	Road agency environmental management trainings.
	B15*	Environmental contingency plan	Existence of an environmental contingency plan.
	B16*	Accident contingency plan	Existence of an accident contingency plan.
	B17**	Management plan	Existence of a management plan.
	B18	Environmental programs	Existence of environmental plans already taken care of.
	B19	Financial support	Monetary funds for environmental projects.
	B66	Training	Training regarding environmental issues.
FV – MATERIALS	D1	Control of materials	Percentage of materials spent per period.
	D2	Control of paint materials	Amount of paint materials spent per period.
	D3	Disposal of solid waste	Percentage of solid waste destined correctly.
	D4	Disposal of demolition waste	Percentage of solid waste disposed correctly.
	D5	Disposal of milled asphalt waste	Percentage of milled asphalt waste disposed correctly.
	D6	Obsolete machinery	Number of machines disabled.
	D7	Milling asphalt material	Control of milling asphalt material.
	D8	Reuse of materials (demolition)	Percentage of material removed from the highway and reused.
	D9	Recycling of waste	Percentage of recycled material.
	D10	Chemical waste	Control of chemical residues.
	D11	Transportation of solid waste	Control of waste transportation by third parties on the highway.
FV – ROAD SAFETY	F1	Trees in the surroundings	Removal of trees around the highway (percentage withdrawn).
	F2	Conformity of adjacent soils	Verification of soil topography according to projects.
	F3	Level curves	Verification and improvement of the topography of adjacent soils for the highway.
	F4**	Domain strip	Program monitoring factors that have impact on the domain strip.
	F5	Unduly occupation	Percentage of domain strip unoccupied.
	F6	Signaling	Signaling maintenance.

Table 9. Road environmental performance indicators (part III).

Area	ID	Criterion	Indicators
FV – SOCIO-ENVIRONMENTAL	G1	Irregular access	Percentage of closed accesses.
	G2	Environmental awareness	Awareness programs.
	G3	Depredation	Environmental education programs directed towards against depredation.
	G4	Environmental education	Environmental education programs.
	G5	Forest fires	Period-controlled fire rate.
	G6	Identification of owners who cause damage to the domain strip	Verification of problems attended in relation to the neighboring population.
	G7	Urban garbage	Environmental education programs focused on the problem of urban garbage on highways.
	G8	Vandalism	Environmental education programs against vandalism.
FV - BIOTIC ENVIRONMENTAL	E1	Soil	Percentage of area of impacts to the ground caused by the highways in maintenance.
	E2**	Fauna	Attendance to the EV – Fauna.
	E3	Vegetation	Attendance to the EV – Vegetation.
FV – FAUNA	E21	Containment of animals	Measures to contain animals.
	E22	Destination of dead animals	Amount of correctly destined dead animals.
	E23**	Monitoring of animal species	Existence of a monitoring program for animal species.
	E24	Safe passage for animals	Appropriate animal passages.
	E25	Preservation of species	Existence of a program to preserve animal species.
	E26	Signal board about presence of animal on the highway (location)	Existence of appropriate signs alerting to animals on the road.
EV – VEGETATION	E31	Exotic trees	Identification and removal of exotic trees.
	E32	Destination of tree pruning	Percentage of m³ of pruning correctly destined.
	E33	Suitable species	Verification of the vegetation species for maintenance stretches.
	E34	Integration of vegetation with civil Works	Incentive program for the implantation of vegetation in civil works.
	E35	Proper management	Vegetation management program.
	E36	Vegetation as signaling	Integration of vegetation as signaling.

After criteria weighing by the DER/PR professionals, the indicators underwent the normalization process in an interval between [0,1]. Tables 10 and 11 show the normalized weights by area and by environmental performance indicators for each criterion. Table 12 display the EV-related criteria weights.

Table 10. Weights for areas and road environmental performance criteria (part I).

ID	Area of interest	Weight	ID	Criteria	Weight
A	Water	0.254	A1	Surface water on the pavement	0.136
			A2**	Silting	0.103
			A3	Rains	0.098
			A4	Contingency plan for rain disasters	0.074
			A5	Erosion	0.119
			A6	Impermeability of soil	0.067
			A7	Neighboring population x domain strip	0.100
			A8*	Maintenance of drainage systems	0.144
			A9	Preventive measures	0.062
			A10	Drainage monitoring program	0.097
B	Management	0.111	B1	Irregular access	0.090
			B2	Compatibility of projects with the environment	0.075
			B3	Load control	0.050
			B4	Waste disposal	0.045
			B5	Work team	0.039
			B6**	The domain strip**	0.050
			B7	Cargo inspection	0.051
			B8	Integration of projects	0.058
			B9	Integration of public/private sectors	0.038
			B10	Inter-agency integration	0.037
			B11*	Signposting maintenance	0.063
			B12*	Defect monitoring	0.048
			B13	Rural Patrol	0.025
			B14	Research and training	0.038
			B15*	Environmental contingency plan	0.057
			B16*	Accident contingency plan	0.055
			B17**	Management plan	0.046
			B18	Environmental programs	0.060
			B19	Financial support	0.075
C	Juridical	0,099	C1	Environmental Legislation	0.106
			C2	Bureaucracy in legislation	0.111
			C3	Bureaucratization in the road agency	0.138
			C4	Responsibility of road agencies	0.120
			C5**	Reintegration of the domain strip	0.119
			C6	Juridical structure	0.295
			C7	Financial support	0.111
D	Materials	0.089	D1	Control of materials	0.137
			D2	Control of paint materials	0.092
			D3	Disposal of solid waste	0.131
			D4	Disposal of demolition waste	0.067
			D5	Disposal of milled asphalt waste	0.058
			D6	Obsolete machinery	0.094
			D7	Milling asphalt material	0.052
			D8	Reuse of materials (demolition)	0.119
			D9	Waste recycling	0.128
			D10	Chemical waste	0.051
			D11	Transportation of solid waste	0.071
E	Biotic environmental	0.117	E1	Soil	0.325
			E2**	Fauna[1]	0.348
			E3	Vegetation[1]	0.327
F	Road safety	0.199	F1	Trees in the surroundings	0.314
			F2	Conformity of adjacent soils	0.118
			F3	Level curves	0.087
			F4**	Domain strip	0.114
			F5	Unduly occupation	0.141
			F6	Signaling	0.226

Observation: [1] these are elements that have elementary criteria

Table 11. Weights for areas and road environmental performance criteria (part II).

ID	Area of interest	Weight	ID	Criteria	Weight
G	Socio-environmental	0,131	G1	Irregular access	0.243
			G2	Environmental awareness	0.149
			G3	Depredation	0.091
			G4	Environmental education	0.116
			G5	Forest fires	0.068
			G6	Identification of owners who cause damage to the domain strip	0.148
			G7	Urban garbage	0.117
			G8	Vandalism	0.068

Table 12. EV-related road environmental performance criteria weights.

ID	EV	ID	Criteria	Weight
B5	Work team	B61	Contractor	0.110
		B62	Multidisciplinary team	0.211
		B63	Functions	0.132
		B64	Research	0.149
		B65	Transition	0.122
		B66	Training	0.276
E2	Fauna	E23	Animal containment	0.181
		E22	Destination of dead animals	0.101
		E23**	Monitoring of animal species	0.172
		E24	Safe passage for animals	0.247
		E25	Species preservation	0.126
		E26	Signal boards about presence of animals on the highway (location)	0.173
E3	Vegetation	E31	Exotic trees	0.284
		E32	Destination of tree pruning	0.187
		E33	Suitable species	0.255
		E34	Integration of vegetation with civil works	0.082
		E35	Proper management	0.140
		E36	Use of vegetation as signaling	0.052

In this research, 83 indicators were generated, distributed among 10 areas of interest. It is noticed that the empirical experience of the specialists of team 2, directed the indicators for the routine services and implications in their functions within the state road agency. In addition, the areas of water and road safety received the highest weights and, therefore, are the most important according to the experts' point of view.

Finally, with regard to the statistical tests, it is not possible to remove from the analysis any of the outliers that are outside the distributions because they are personal judgment values about each item. The statistical differences prove that there are items that may have reservations when evaluated within the groups.

CONCLUSIONS

This research allowed for the identification of important aspects related to environmental management, and demonstrated that management procedures are present in technician analyses, thus promoting discussions among workshop participants and emphasizing the importance of the issue in routine road maintenance activities.

In all, 83 indicators were generated, distributed in 10 areas of interest. The empirical experience of the components of team 2 reflected in the generation of indicators related to the routine of services and their functions within the highway agency.

Among all of them, water and road safety groups presented the highest weights among the areas of interest and are thus, noteworthy. However, several weights given by the participants were significantly different, such as Areas of general interest, EV - Team, FV - Materials, EV - Vegetation, FV - Road Safety and FV - Socio-environmental. A data variability was noticed, because weights or grades can vary greatly due to differing expert opinions, regions, experiences and ways of working. However, as these are personal judgment values for each item, it is not possible to remove any of the outliers that are outside the distributions. Statistical differences prove that there are items that may have reservations when evaluated within groups. As the MCDA-C method was applied, statistical analyses were not performed to determine sample size, since this method does not recommend a maximum or minimum number of participants.

Performance indicators are advantageous, since they allow for simpler quantitative and global visualization of the behavior of the evaluated elements with certain interpretations, increasing clarity and aiding in the guidance of environmental management.

Method standardization to evaluate environmental management in the road sector reflects the use of instruments such as the ones applied herein, which can be used by managers, researchers and technicians responsible for road maintenance.

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