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Perception Of Traffic Safety In School Areas: A Multi-Criteria Approach

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Abstract:
Schools are indispensable social structures for communities and, therefore, the efficient performance and safety of their environments have been crucial goals for public managers. As such, it is important that traffic safety around schools is investigated and, with this, safety and sustainability actions in the field of urban mobility can be made possible. In Brazil, the National Traffic Department and the Ministry of Health have warned about traffic conflicts and the risk of being run over around schools, due to frequent safety problems in most of the country's cities. In a local context, the city of São Mateus (Espírito Santo - Brazil) has recorded high annual accident rates, with specific characteristics that serve as a warning to educational and traffic authorities about the risks around urban school areas. Given the scenario of budget restrictions, prioritizing safety strategies becomes an important and complex management decision and, for these reasons, in this work we set out to verify the opinion of teachers regarding their preference for actions that contribute to traffic safety in school surroundings. The methodological approach consisted of a survey applied to a sample of teachers from the Municipal Public Education Network (São Mateus - Espírito Santo - Brazil), with the support of the Analytic Hierarchy Process. The results suggest that the Education strategy should be a priority and that traffic enforcement in school areas needs to be rigorous, by notifying offending drivers, with a view to ensuring the safe use of roads and infrastructure by stakeholders in the school community and, in the long term, enabling the development of a culture of safety. In addition, the alternative chosen indicates that interventions need to be planned and carried out in conjunction with these stakeholders.

KeyWords*: AHP; School surroundings; Public management; Urban mobility; Multiple criteria*

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I. Introduction

Urban traffic can be understood as a relevant dimension linked to the right to mobility and, notoriously, its prominence in Public Management emerges from the inconvenience generated by accidents, which annually account for large numbers of deaths, physical and psychological trauma and economic losses (World Health Organization, 2015; World Health Organization, 2018; United Nations, 2018; Carvalho, 2020). As a result, it has become a major problem in terms of public health, which has led to a reduction in quality of life and life expectancy, particularly for young people and adolescents (Corazza et al., 2020).

Broadly speaking, the literature advocates that traffic is the main element that consolidates urban mobility and, therefore, safe interaction between internal and external school community stakeholders who use it can be considered an essential point for achieving adequate performance in the urban reality (Dolati Neghabadi et al., 2019; Zhou et al., 2019; Kaffash et al., 2021). On the other hand, with regard to traffic dysfunctions in school areas, progress is needed that results in concrete proposals for improvement, outlining possible causes and ways to help decision-making. It is also worth noting that the literature exposes gaps for work that brings together the opinions of internal and external school community stakeholders, in order to provide planning and actions that lead to progress in urban mobility (Zhou et al., 2019; Kaffash et al., 2021). Thus, the importance of this work is justified by the interest in contributing to increased safety in Brazilian urban traffic and reducing the occurrence of problems that have affected the daily lives of school stakeholders and the academic community, made up of students, teachers, technicians and managers), as well as the government, funding agencies and society in general (Mainardes et al., 2013).

Within this context, traffic safety has come to be recognized as a critical public health issue (Kim et al., 2017; Najaf et al., 2017; Heydari et al., 2019; Rahman et al., 2019). According to Zhang et al. (2021), even with the fight against the Covid-19 pandemic, the panorama of urban mobility and transportation safety remains a key public agenda. This is justified by the estimated 1.35 million annual deaths resulting from traffic accidents, forcing the World Health Organization (WHO) to call for joint efforts to change this reality, with special attention to children (World Health Organization, 2018).

In this context, schools are indispensable social structures for communities and, therefore, the efficient performance and safety of their environments are seen as crucial goals for public managers (Shaaban & Abdur-Rouf, 2019; Shaaban & Abdur-Rouf, 2020). From this perspective, Baser (2020) emphasizes that schools need to be well-located and designed within a systematic plan, safe and efficiently operated to contribute to the development of the society in which they are established.

That said, concern about traffic safety in school areas in developed countries was motivated above all by the decrease in independent child mobility that typified student travel between the 1960s and 2000s, which prompted research on this topic (Torres et al., 2017). This trend coincided with the spread of motorized transport for school trips, especially by private vehicles, as reported by Teixeira et al. (2019) and Rahman et al. (2020).

Parallel to this, under different economic and social aspects, developing countries have heavy pedestrian and vehicle traffic in neighborhoods near schools and educational institutions, resulting in congestion and sometimes traffic accidents (Pati, 2017). As a reflection of this situation, Brazilian schools have started to generate high traffic flows in their vicinity, resulting from disordered urban growth, entailing risks for significant portions of the population who routinely circulate in these places, as demonstrated in technical studies (National Traffic Department, 2000; Institute for Transport and Development Policies, 2020).

As a result, national and international authorities have begun to converge on their concern about this problem, especially due to excessive vehicular speed and the intense movement of children and adolescents in school areas (Brazil, 1997; World Health Organization, 2015). Therefore, considering its effects on the transportation system, Bina et al. (2021) argue that the problem of traffic around schools needs to be investigated to help create safe and sustainable mobility.

This information highlights the importance of traffic safety for schools, which should consequently position them as central elements of public health and safety policies. Planned in collaboration with other public infrastructures, these factors should be accessible and facilitate a desirable standard of urban mobility (Giles-Corti et al., 2016), i.e. urban planning and transportation policies and actions in cities can have a positive impact on preventing traffic problems.

In Brazil, on the other hand, the study of this issue is essential, although the traffic statistics published do not go into enough detail to establish a relationship between schools and accidents in their surroundings. This lack, however, does not detract from its relevance, since Bull et al. (2018) warn that policies based exclusively on traffic accident records may suffer limitations in their analysis and proposed solutions. In addition, there is recurrent mention of the underreporting of these records, restricting the knowledge needed to guide safety policies and outline effective strategies (Wegman, 2017; Rolison et al., 2018).

Therefore, in order to gain a reliable understanding of the daily dynamics of risk in traffic, it is also necessary to consider the experiences, perceptions and opinions of users, preferably before accidents occur. Imbued with this understanding and the challenge of filling gaps between existing research and practice, this study aimed to verify how teachers prioritize actions that contribute to traffic safety in school surroundings, considering as a research universe the reality of the urban area of the municipality of São Mateus (Espírito Santo - Brazil), using a multi-criteria method, with the aim of proposing actions to improve traffic safety in school areas.

In order to propose actions to improve the traffic system, the work uses the Analytic Hierarchy Process (AHP) methodology, which Elvik (2019) cites as still being a gap, as it is rarely used in the field of road safety.

II. Traffic management and the school environment from a public sector perspective

Transportation is undoubtedly a right and a social necessity that affects the quality of human life (Elvik, 2019). On the other hand, Mcilroy et al. (2019) expose its paradoxical condition: it is essential for economic progress and sustainable urban development, as it enables access to activities that meet human needs, but is associated, in return, with the inconvenience caused by road accidents. Globally, these accidents have become more frequent in recent decades, correlated with the processes of population growth and urbanization, posing challenges for traffic safety management (Ivan et al., 2019).

According to the United Nations, the world's population exceeds 7.6 billion, with the majority (55%) living in urban areas, and this scenario is expected to increase in the coming decades (United Nations, 2018). At the same time, there are an estimated 2 billion motor vehicles around the world (World Health Organization, 2018). However, Stevenson et al. (2016) assess that such phenomena have not followed effective urban planning, in terms of integrating housing, transportation and land use policies, expanding the demand for mobility and its associated effects.

Despite signs of progress in reducing traffic deaths and injuries, the World Health Organization (2018) estimates that accidents cause 1.35 million deaths annually worldwide, ranking as the eighth cause of human mortality and the first in the 5-29 age group (World Health Organization, 2018). In addition, they injure around 50 million people a year, with the vast majority of victims (90%) coming from low- and middle-income countries (United Nations, 2018), as one of the negative effects of mass motorization, representing an excessive burden with consequences for individuals and health systems.

Thus, due to the constant problems caused by traffic disorder, urban planners have been concerned with creating pleasant, functional and organized environments through land use management, admitting that the built environment of urban areas can have an impact on road safety (Rothman et al., 2017; Ajala & Kilaso, 2019). In this way, Cervero and Kockelman (1997) mention that numerous urban design philosophies, such as "new urbanism", "transit-oriented development" and "traditional urban planning", have become popular, notably in recent years, in an attempt to guide the demand for travel, having in common the following expectations: to reduce the quantities and distances of motorized travel and increase the share of non-motorized travel in order to reduce traffic accidents around the world.

In the specific case of schools, Yu and Zhu (2016) argue that they are spaces that influence mobility preferences and, consequently, the composition of urban traffic. Therefore, the choice of individual motorized modes to access these units tends to intensify congestion and the risk of traffic accidents in their surroundings (Bunnarong & Upala, 2018). Sharing this view, specifically with regard to school land use, Merlin et al. (2020) identified a probable association with the incidence of accidents.

Adopting a similar understanding in Brazil, considering technical aspects, the National Traffic Department (2000) instructed that schools be considered traffic generating centers, also called traffic attracting centers, since several dangerous situations occur in their surroundings. In this logic, once the classification as a traffic-generating center has been confirmed, the installation of these units must be preceded by studies detailing potential negative impacts for the sites and their surroundings (Alves et al., 2016).

In the search for solutions, researchers agree that active mobility, such as walking or cycling, benefits student health, as long as the built environment favors this mode of transport (Chen et al., 2018; Shaaban & Abdur-Rouf, 2019; Rahman et al., 2020). It was with this in mind that Safe Routes to School (SRTS) programs were adopted in European countries, the United States, Australia and New Zealand, based on the project started in Odense, Denmark, in the late 1970s (Brachman & Church, 2019).

In the composition of SRTS, according to Dimaggio et al. (2016), resources are invested in engineering, education and inspection projects to provide active and safe student travel. However, although it promotes desirable regular physical activity, the effectiveness of the active mode has been challenged by multiple constraints: motor vehicle ownership (Ding et al., 2017; Ajala & Kilaso, 2019), parental concern about traffic (Teixeira et al., 2019), distance to schools and crime (Chen et al., 2018), risk or perception of risk (Rothman et al., 2017; Bull et al., 2018) and exposure to traffic (Shaaban & Abdur-Rouf, 2020).

Similarly, Silva et al. (2020) report difficulties in establishing a pattern of active mobility in student travel among adolescents in Brazil. These authors emphasize that the effectiveness of this modality is conditioned by the distances between homes and schools and, notably, the conditions of urban mobility infrastructure (signage, bike lanes, sidewalks, etc.) in the vicinity of the institutions, which influence the choices of travel modes.

With a view to effectively meeting targets, speed management is seen as an effective mechanism for safety planning on roads adjacent to schools (World Health Organization, 2017; Quistberg et al., 2019). In this process, a crucial resource is the installation of traffic calming, such as speed humps and traffic circles, which are used around the world to decrease vehicular speed and the frequency and severity of injuries (Joo et al., 2019). In response, drivers tend to instantly reduce their speed, which can lead to a drop in accident rates, especially where children are present, according to Pichayapan et al. (2020).

Children, in particular, face greater complexity in the road environment than other users (Hwang et al., 2017; Pati, 2017; Trifunović et al., 2017; Holm et al., 2018). They are vulnerable because their physical and cognitive aspects, which are still developing, limit accurate risk assessments, making them vulnerable to unpredictable and dangerous behavior in traffic (Shettar & Patil, 2016; Bunnarong & Upala, 2018; Heydari et al., 2020). Legitimizing this assumption, Alonso et al. (2018) report that this group mostly suffers accidents as pedestrians, in proportions ranging from 5% to 10% in high-income countries and from 30% to 40% in low- and middle-income countries.

Influenced by these factors, in the United States there are road segments adjacent to schools or demarcations on the ground that indicate activities related to these educational units, namely school zones (Federal highway administration, 2010). These zones cover streets along schools and the area of one to two blocks, on average, around these units. When traveling in these spaces, at peak school commuting times, drivers are required to reduce their speed, commonly to 20 miles per hour - about 32 km/h - due to the presence of children on the roads, as explained by Quistberg et al. (2019).

Based on country-specific guidelines, school zones should be demarcated with special signage to warn drivers about child crowding in these areas (Zhao et al., 2016). In addition, engineering solutions should be employed on a case-by-case basis to limit vehicular speed and encourage active mobility (World Health Organization, 2017). However, Bina et al. (2021) consider that the introduction of speed limits in these areas does not guarantee effective legal compliance by drivers, demonstrating the influence of human behavior on the effectiveness of this restrictive intervention.

On this issue, evidence suggests limiting the use of commercial land around schools, since its predominance is associated with conflicts between vehicular traffic and pedestrians, according to findings by Yu and Zhu (2016), Hwang et al. (2017), Bunnarong and Upala (2018) and Heydari et al. (2020). It is also essential to locate schools away from highways, if feasible, since these roads allow higher speed limits, resulting in constant accidents, and can affect students' health and performance (Yu & Zhu, 2016; Kweon et al., 2018; Baser, 2020).

Nevertheless, achieving progress in road safety requires the inclusion of various stakeholders (Mainardes et al., 2013) in the urban policy planning process (World Health Organization, 2018). On this issue, Wegman (2017) mentions a lack of involvement of the public sector, academia, non-governmental organizations (NGOs) and the private sector in the construction of safety policies in developing countries. Thus, in order to meet the dynamism of urban traffic, it is necessary to consider the opinions and preferences of all the actors who interact in the road space so that they can collaborate in formulating public policies that are compatible with the reality and specificity of the environments and locations of each school.

Students, specifically children, spend a substantial amount of time in schools and it is therefore important that these environments promote the health and well-being of these individuals (Kweon et al., 2018). From this perspective, Torres et al. (2020) point out that it is essential to understand children's perceptions in order to formulate actions appropriate to their interests, which can improve the application of their knowledge in the real situations of the environment in which they circulate.

Similarly, Hassan et al. (2018) add that teachers have knowledge of road safety problems around schools and are therefore key to improvement strategies. In this logic, other school employees, whether administrative (principals, secretaries, pedagogues, etc.) or operational (security guards, servants, janitors, etc.), can also provide relevant insights on the subject, due to the regularity with which they circulate in these spaces (Departamento Nacional de Trânsito, 2000).

In addition, with regard to enforcement, Rolison et al. (2018) highlight the importance of police officers in identifying risks prior to the occurrence of traffic accidents, since these professionals are familiar with the routine of urban traffic, including around schools, as emphasized by Bull et al. (2018). Among other duties, they can work in partnership with traffic agents to organize the flow of urban traffic, through user guidance and notification procedures, in order to adjust the behavior of road users to ensure fluidity and safety around school units.

III. Multicriteria analysis with the Analytic Hierarchy Process (AHP)

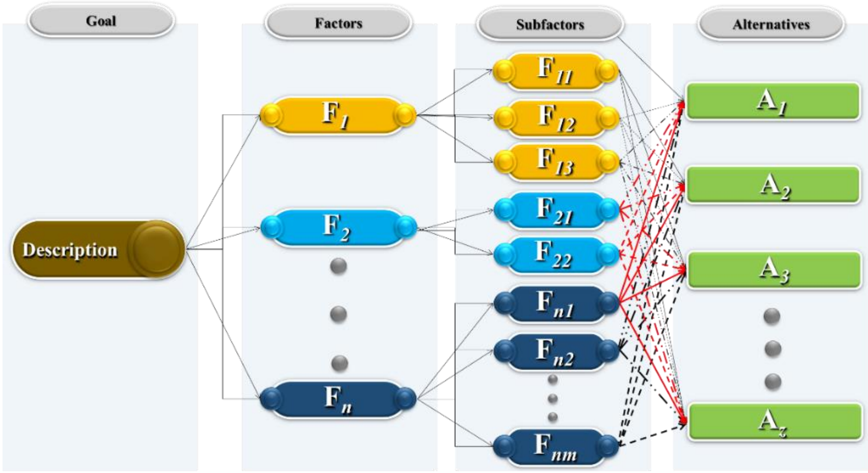
Making decisions is intrinsic to human beings, due to the problems that arise on a daily basis and require choices that fully meet their needs. However, some problems become complex because they involve multiple interfering factors, something that requires time for analysis and a satisfactory conclusion to the process. The literature covers a significant number of Multi-Criteria Decision Analysis, which contribute to decision-making in both the public and private sectors, including the Analytic Hierarchy Process (AHP), the Analytic Network Process (ANP), ELimination Et Choix Traduisant la RÉalité (ELECTRE), Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and fuzzy logic (Saaty, 1978; Gonçalves, 2016; Pereira et al. , 2019; Vatankhah et al., 2023).

Among the Multi-Criteria Decision Analysis, the AHP stands out as a prestigious tool for supporting research and decision-making (Forman & Peniwati, 1998; Vaidya & Kumar, 2006). This is due to its operational efficiency, as well as its flexibility in the simultaneous use of other multi-criteria methods and mathematical techniques, which helps decision-makers to proceed assertively when choosing alternatives, as concluded by Han et al. (2020). However, in cases where specialized software is not available, the method requires a long time to implement and analyze (Obregón-Biosca et al., 2018).

Despite its popularity and application in a wide variety of fields of knowledge, Elvik (2019) cites the scarcity of AHP uses in the field of road safety. However, some researchers have used the method individually or in combination with other MCDAs, proving its versatility and applicability in this field (Najaf et al., 2018; Obregón-Biosca et al., 2018; Joo et al., 2019; Pereira et al., 2019; Farooq et al., 2019; Han et al., 2020; Moslem et al., 2020; Sarraf & MCguire, 2020).

Based on Saaty's (1978) reflections, the AHP consists of four stages: (1) defining the problem to be solved; (2) drawing up a hierarchical structure (Figure 1) made up of objectives, factors and sub-factors, as well as alternatives related to decision-making; (3) constructing a matrix that allows for equal comparisons between these factors, sub-factors and alternatives at the respective hierarchical levels; and (4) calculating the priority weights resulting from these comparisons. This operational chain can be summarized in the following phases: building a hierarchical structure, assigning preferences and calculating results (Obregón-Biosca et al., 2018).

Figure 1: Elements of a decision in the AHP method



Source: Saaty (1978)

In order to enable pairwise comparisons, Saaty (1978) proposed a scale of importance (Table 1), which makes it possible to visualize the predominance of one element over another at the same hierarchical level (Saaty, 1978; Joo et al., 2019; Santos et al., 2019; Han et al., 2020). This numerical scale serves as a parameter in both quantitative and exclusively qualitative evaluations (Dweiri et al., 2016), demonstrating the method's versatility for solving problems in different contexts.

Table 1. Numerical scale for operationalizing the AHP method

Numerical scale	Verbal scale
1	Elements are of equal importance
3	Moderate importance of an element
5	Strong importance of an element
7	Very strong importance of an element
9	Extreme importance of an element
2, 4, 6 e 8	Intermediate values between adjacent opinions

Source: Saaty (1978)

In the AHP, expert prioritizations are expressed through judgment matrices, also known as pairwise comparison matrices (Gonçalves, 2016). To obtain a generic judgment matrix A, equation 1 must be considered:

$$n(n-1)/2 \quad (1)$$

Where n is the number of elements in the matrix A, shown below:

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

Where:

$$A \begin{cases} a_{ij} > 0 \rightarrow positive; \\ a_{ij} = 1 \therefore a_{ji} = 1; \\ a_{ij} = 1/a_{ji} \rightarrow reciprocal; \\ a_{ik} = a_{ij}.a_{jk} \rightarrow consistency \end{cases}$$

Sarraf and McGuire (2020) mention that the next step is to calculate the prioritization vector, which shows the relative preference of the various elements involved in the comparisons, in order to obtain the eigenvector with the maximum eigenvalue ($\lambda_{máx.}$). A simple way to calculate this vector, for $n \leq 3$, is to divide each value belonging to the columns by the overall sum of the corresponding column (normalization); and then calculate the simple average of the new values for each row, the authors explain.

Next, the consistency of the comparison matrix is analyzed by calculating $\lambda_{máx.}$, since it affects the consistency of the experts' judgments. This value can be obtained after a series of mathematical operations: (a) the original judgement matrix multiplies the matrix formed by the prioritization vector, generating a new "intermediate" vector; (b) the elements of this new vector divide the corresponding elements of the prioritization vector, giving rise to a final vector with consolidated values; (c) finally, the simple average of these values is calculated and the $\lambda_{máx.}$ (Sarraf & MCguire, 2020).

In order to assess the consistency of the judgments and minimize distortions in the final decisions, Han et al. (2020) state that the AHP calculates the Consistency Index (CI) and Consistency Ratio (CR) values, based on equations 2 and 3:

$$CI = \left(\lambda_{máx.} - n\right) / n - 1 \quad (2)$$

Where $\lambda_{máx.}$ is the maximum eigenvalue of the pairwise judgment matrix and *n* is the number of elements that make it up. The CI result must be compared to the Average Random Consistency Index (RI), derived from a reciprocal matrix with random values (Table 2), to obtain the CR. RI values vary according to the size of the pairwise comparison matrix, as explained by Santos et al. (2019).

Generally, assigning weights to parameters depends on human perception and therefore involves imprecision. Therefore, calculating the CR (Equation 3) is one of the notable advantages attributed to the method, as it aims to ensure consistency in judgments and, consequently, reliability in decision-making (Joo et al., 2019). To this end, Saaty (1978) stipulated that the CR must be less than or equal to 0.10 (10%), under penalty of revision or even rectification of equal judgments.

Table 2. Random matrix for RI sizing

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

Source: Moslem et al. (2020)

$$CR = \frac{(\lambda_{máx.} - n)/(n-1)}{RI} \text{ or } CR = CI/RI \quad (3)$$

The complementary stage of the decision-making process is the sensitivity analysis of the pairwise comparisons, in which the weights assigned are slightly altered to observe possible impacts on the final decision. This procedure allows the decision-maker to check the stability of the results throughout the process, in the face of changes in the size of the preferences assigned (Dweiri et al., 2016; Farooq et al., 2019; Moslem et al., 2020).

IV. Methodological approach

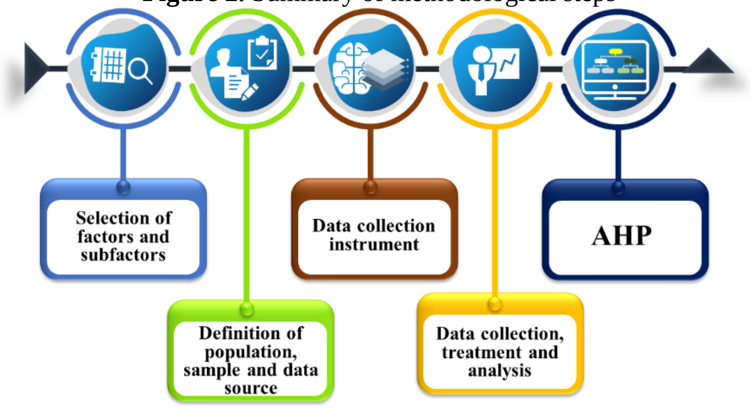
The methodological approach used in this work integrates suggestions and evidence highlighted in the literature, accompanied by a survey and the Analytic Hierarchy Process (AHP) method with the aim of verifying how teachers prioritize actions that contribute to traffic safety in school environments (Vaidya & Kumar, 2006; Dweiri et al., 2016; Torres, 2017; Hassan et al., 2018; Lopes, 2018; Baser, 2020; Corazza et al., 2020).

With regard to the quantitative aspects, a survey was carried out which, according to Tortorella et al. (2019), provides elements that help in the investigation and understanding of phenomena, as well as broadening the characterization of the population and research unit. In addition, a questionnaire was developed as a data collection technique (Kiesler & Sproull, 1986; Chung et al., 2019; Moslem et al., 2020), which served to support the identification and selection of interfering factors for safety in school environments and, at the same time, to extract opinions from the target audience on strategic improvement actions.

With the support of a Microsoft Excel® spreadsheet, the qualitative data was consolidated and then converted into quantitative information (Suting et al., 2018). Statistical techniques were then used to carry out preliminary screening and analysis and, essentially, to enable the performance of the AHP, using the resources available in the Expert Choice Trial software (Gonçalves, 2016; Kumar et al., 2017; Obregón-Biosca et al., 2018). The stages of the methodological approach are presented below (Figure 2).

The research began with a literature search for factors and sub-factors that contribute to road safety around schools. Synchronously, a framework was developed which served as a guide for defining the set of these factors and sub-factors, applying the survey and carrying out the AHP (Saaty; 1978; Gonçalves, 2016).

Figure 2. Summary of methodological steps



Source: Authors (2023)

Immediately after researching the literature, the factors and sub-factors found were selected. This mechanism was assisted by a survey (pre-test), with the collaboration of 5 experts on the subject of this work. This technique was adopted in line with the precepts of Chung et al. (2019) and Tortorella et al. (2019), who propose framing technical-professional profiles according to the experiences of the subject under study.

The construct of the second stage, comprising the definition of the population, sample and data source, aimed to examine the peculiarities of the research unit (Lopes, 2018). Under this premise, in order to obtain an approximate picture of the reality of urban mobility and traffic safety in the region covered, a sample calculation was established, containing the 90% statistical confidence level, the representativeness of the population and the research error limit (Santos, 2013), to enable statistical treatment of the data collected and the generalization of the results to the population consulted.

The third stage consisted of producing the data collection instrument, which was designed to support the applicability of the AHP, as a means of talking to the target population (Gonçalves, 2016). Thus, in order to strengthen the relationship between the scientific field and the practice experienced by the population, a new survey was carried out, as a test, with a group of teachers from the municipal public school system. Using the contributions received, the instrument was adjusted as necessary, including in terms of the time it took to complete (Rocha, 2020).

In the next stage, a hierarchical structure was drawn up comprising the factors and sub-factors surveyed, in order to create the final version of the instrument adapted to the concepts of the AHP (Saaty, 1978). Following the adjustments made during the testing phase, the questionnaire was made available to the population of interest in the form of an electronic form, with no contact between the population and the researchers (Rocha, 2020). In this case, participants received an email, sent directly by the Department of Education, containing a link to access the document.

After the deadline for filling in the form had expired, the data collected was processed and analyzed. Initially, this data was put into an electronic spreadsheet and, at the same time, received quantitative coding to optimize the analyses corresponding to the sampling (Gonçalves, 2016; Rocha, 2020). For the outcome of this stage, which involved a robust volume of data, the Statistical Package for the Social Science (SPSS) software trial version was used (Hassan et al., 2018; Holm et al., 2018; Suting et al., 2018; Poswayo et al., 2019).

Once the data processing had been completed and any distortions in the sample had been eliminated, the last stage involved operationalizing the AHP, using as a reference the hierarchical structure on which the final version of the collection instrument was based (Saaty, 1978). As part of this procedure, the data was entered into the Expert Choice Trial software, which provided visibility and insights into the behavior of the phenomenon studied (Rocha, 2020).

Given the complex, dynamic, contemporary and little-explored nature of the research topic, the use of a quantitative approach allows, in addition to a broader view of phenomena and possible paradoxes, to learn the opinions of stakeholders (Yu; Zhu, 2016; Hwang et al., 2017; Zhou et al., 2019; Kaffash et al., 2021). That said, according to Tortorella et al. (2019), the definition of a data source must be in harmony with the research method in order to maximize the performance of this approach.

Alharbi (2018) instructs that the verification of any research gap, as well as cooperation in the advancement of scientific knowledge, is linked to the indication of parameters that support elucidating arguments. On the other hand, assigning values to these parameters requires identifying and measuring the perceptions and characteristics of a population, the author points out. For this reason, before analyzing phenomena, it is essential to choose a data source that allows them to be integrated and then converted into objective and congruent information (Tortorella et al., 2019).

Traditionally, according to Venkatesh et al. (2013) and Gonçalves (2016), the first extraction of data denotes the level of coherence in the choice of its source. However, bearing in mind the use of AHP in this work, which requires the reliability and suitability of primary data, the respective source needs to have an acceptable level of uniformity (Molina et al., 2021). It is therefore necessary for the population to understand the content of the instrument of dialog with the researcher, otherwise the performance of the AHP could be compromised and controversial results generated (Vaidya & Kumar, 2006).

Therefore, in order to test the usefulness and effectiveness of the method proposed in this work, the research data source consisted of a primary database, which originated from responses to a survey of teachers from the São Mateus Municipal Public School System in the state of Espírito Santo (ES). This decision was based on the representativeness of the group in relation to the subject of this work, since the effectiveness of multi-criteria methods requires assertiveness in the choice of participants associated with the problem studied (Saaty, 1978). In addition, we considered the accessibility of obtaining the data and the deadlines for completing the research procedures (Gonçalves, 2016).

In the composition of the research framework, the selection of the population must take into account that it is made up of a broad group of elements (people, organizations, objects, etc.) that have common properties of interest to the researcher (Moyo, 2019). Defending this view, Gonçalves (2016) interprets that a population can also be defined as the totality of stakeholders or units of research interest.

This stage consisted of a prior assessment of possible variations in the size and shape of the target population. To do this, we consulted the statistics of the São Mateus (ES) Department of Education - Brazil, from which we extracted a total of 1,461 teachers, distributed between Early Childhood Education (282) and Primary Education (1,179) professionals, belonging to the Municipal Public Network.

Based on the precepts of the literature, Tortorella et al. (2019) point out that sometimes the population can be readily computed, falling under the concept of a finite population. In this sense, for the construction of coherent opinions, their representativeness needs to be adequately dimensioned (Gonçalves, 2016). Therefore, the sample was delimited while maintaining its satisfactory significance in relation to the total population.

However, in the field of Applied Social Sciences, it is not always feasible for the researcher to cover all the elements of a population when collecting data (Kiesler & Sproull, 1986). Instead, it is usual to define a portion that represents it, giving rise to generalist inferences, and serves as the minimum value of the sample to be met, even after removing outliers and missing values (Hapsari et al., 2017; Chung et al., 2019). In this sense, the sample proportion was determined using the work of Gonçalves (2016) as a sizing parameter (Equation 1).

$$n = \frac{N \cdot Z^2 \cdot p \cdot (1-p)}{Z^2 \cdot p \cdot (1-p) \; + \; e^2 \cdot (N-1)} \tag{1}$$

Where: n is the sample size; N expresses the size of the population; Z is the normal variable; p is the probability of the phenomenon occurring and; e represents the sampling error.

In the calculation projection, the presence of unusable forms was estimated, either due to random filling or the absence of values in the answers, which were promptly removed from the sample (Hapsari et al., 2017). In order to improve the conditions for statistical analysis, a reliability of 90% and a sampling error of 5% were stipulated. Then, to confirm the quantitative robustness of the data collection, the minimum sample (n) of 229 respondents was calculated using the calculator devised by Santos (2013).

In the methodological configuration of this study, data convergence was sought through the concept of triangulation (Venkatesh et al., 2013). In this way, using the Analytic Hierarchy Process, it became possible to parameterize the data, adapting it to the method's performance requirements, as well as providing an understanding of the phenomenon under investigation.

Since its conception, the data collection instrument should be a facilitator of dialogue between the researcher and the population. Based on this premise, throughout the structural construction of the tool, there was cooperation from actors related to the theme and objectives of this research. As a result, in order to make it intuitive and understandable to respondents, it was built in three complementary phases: pre-test, test and final version.

The initial version of the instrument (pre-test) was developed on the basis of a framework from the literature (Chart 1) and was subsequently screened by five experts on the subject of the research (a military police officer, a technical manager linked to traffic activities and actions and three teachers from the Municipal Public Education Network in the city of São Mateus), who were chosen at random. This phase aimed to harmonize the findings in the literature and the technical and practical knowledge relating to the research scenario, with the help of an electronic form made available on the Google Forms platform.

In the second phase (testing), using the notes of these experts, the instrument was adjusted with additional suggestions related to the factors and sub-factors. The new version of the questionnaire was then submitted to a random sample of the target population to ensure that its language was appropriate. In turn, the test was carried out and three responses to the survey were obtained.

Once the testing phase was over, the need for specific adjustments to the text and resizing of the time to complete the questionnaire was met, resulting in the final version of the instrument. The questionnaire (final version) was then made available online on the Google Forms platform. At the time, an e-mail was sent to the population of interest, containing the link to access the form, through the intermediary of the Municipal Department of Education.

In all the aforementioned phases, the content of the form was molded to the principles of the AHP method (Dweiri et al., 2016). In this way, questions related to pairwise comparisons between factors, sub-factors and alternatives, defined with the support of the literature and expert opinions (Table 1), received evaluations based on the scale of importance recommended by Saaty (1978) and thus enabled the initial precepts of this work to be fulfilled.

At the same time, it should be noted that the application of the data collection instrument must guarantee the reliability of the answers. Molina et al. (2021) recommend using Cronbach's alpha as a coefficient to check the level of positive correlation between items. To this end, according to these authors, in this study Alpha > 0.7 was set as the benchmark.

After the data collection deadline, 342 teachers participated, equivalent to 23.41% of the eligible population. The answers generated were coded in an electronic spreadsheet in order to help use the AHP, and then entered into SPSS software to check for outliers, and consistency was re-analyzed after these values were removed from the sample (Gonçalves, 2016).

According to Chung et al. (2019), this procedure is essential to guarantee the robustness of the sampling, in order to produce coherent and acceptable responses. Ratifying the importance of this stage, Shen et al. (2020) recommend checking for possible outliers in samples of more than 100 elements, considering $Z\ score$ with an interval of $|z| < 3$ for a value of $p < 0{,}001$. Therefore, in this study, this interval served as an indicator for this check, given the minimum sample size stipulated (229).

With regard to detecting missing values, the concept of a "complete questionnaire" was applied, in which priority is given to fully completed questionnaires in order to form a valid sample (Montagna et al., 2018). In addition, a rejection rate of up to 10% of the forms with missing data or non-compliance with the set scale was stipulated (Gonçalves, 2016). Once this stage had been carried out, it was found that there was no extrapolation of this limit in the sampling, thus ruling out the need for a new collection.

V. Results and discussion

The Municipal Department of Education in São Mateus (Espírito Santo - Brazil) has the mission of ensuring that the learning process is organized and promoting early childhood education and primary education. In this context, due to the increase in road accidents in the city, it can be said that its objective includes collaborating to ensure the safety of the players involved in this mission.

Specifically, this Secretariat manages a variety of interlocutors in the educational sphere, including students, teachers and administrative staff, as well as issues related to the management of a group of more than 100 schools, including Municipal Children's Educational Centers (CEIMs), Municipal Elementary Schools (EMEFs) and school units in Communities and Districts belonging to the municipality.

In this study, the population surveyed was made up of teachers employed by the aforementioned department, using a survey on traffic safety in school areas, with 342 professionals taking part. The data relating to the participants' responses was then analyzed in accordance with the methodological configuration of this study (Figure 2).

Using a spreadsheet and SPSS software to analyze the data obtained, 5 missing values and 40 outliers were detected and promptly discarded from the sample, resulting in a valid and significant figure of 297 questionnaires (Table 3). Next, the answers corresponding to the profile characterization were parameterized, making it possible to see the sample constitution.

Thus, understanding this characterization made it possible to infer satisfactory levels of experience and understanding of the respondents on the subject, due to the percentage (around 57%) living in urban areas. Solidifying this inference is the high percentage (over 70%) of participants from other municipalities, with their own particularities in terms of infrastructure and traffic enforcement, helping to enrich the analysis and possible proposals for solutions.

Based on the triangulation of information extracted from this context (Venkatesh et al., 2013), we can see that teachers are likely to commute to their workplaces. Similarly, the experiences of these professionals over time and/or in other cities may indicate ways to help create optimized security policies.

Finally, but equally relevant, the literature indicates that the attributes gender and age may have influenced teachers' prioritizations, as they are influential in the context of traffic safety (Najaf et al., 2017; World Health Organization, 2017; Alonso et al., 2018; Holm et al., 2018; Rolison et al., 2018; Heydari et al., 2019). Thus, the imbalance in gender representation and the significant age diversity may have led to responses that were sensitive to personal expectations rather than collective ones.

This work included statistical treatment of the 342 responses to the questionnaire, culminating in the removal of 45 atypical responses (missing values and outliers) from the sample (Table 3) because they did not conform to acceptable response standards. In turn, the Cronbach's alpha coefficient is higher than 0.8, which guarantees satisfactory internal consistency and reliability (Molina et al., 2021). The 297 valid answers were then processed sequentially using a spreadsheet and the SPSS and Expert Choice Trial software to enable the AHP to be linked.

Prior to this, the literature was examined to find the attributes that influence the improvement of traffic safety in school areas, the result of which culminated in the development of a theoretical framework. This framework was submitted to 5 experts who, by pre-testing the instrument, helped to mine it and form a framework (Chart 1) to be used in the research.

Table 3. Preliminary analysis of the collection instrument

Items	Quantity and/or Value
Cronbach's alpha	0.813
Initial sample	342
Missing Values	5
Outliers	40
Valid sample	297

Source: Authors (2023)

As a result, the suggested interventions were grouped into three factors ("Engineering", "Education" and "Enforcement"), which represent the traditional approach to traffic safety, from which five main correlated sub-factors were obtained ("Urban mobility infrastructure", "Use of roads and infrastructure", "Training and safety culture", "Guidance" and "Notification"). In addition, two possible solution alternatives were indicated ("Alternative 1 - ALT1: Improve traffic management in school areas" and "Alternative 2 - ALT2: Involve the school community in traffic safety planning and actions in school areas"), which were then evaluated and inserted into the questionnaire.

Subsequently, a test was carried out to check comprehension and the possible existence of attributes not characterized in the questionnaire. Once this stage was completed, and there were no indications that would modify the hierarchical structure (Figure 3) developed based on the compiled framework, the AHP tool was used to model the complex nature of decision-making, which involved proposing solutions for traffic safety in school areas in São Mateus (ES), and the preferences of the respondents from the valid sample were inserted into the Expert Choice Trial.

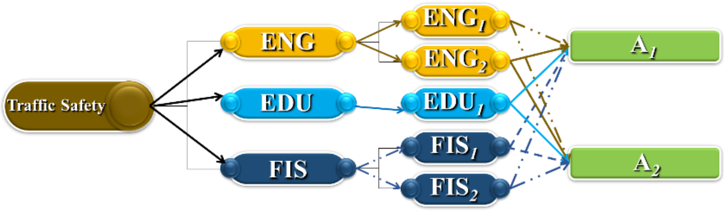
Frame 1. Strategic attributes for traffic safety around schools

Factors	Subfactors	Literatures
Engineering (ENG)	Urban mobility infrastructure (ENG 1)	Bull et al. (2018); Bunnarong e Upala (2018); Briz-Redón et al. (2019); Ivan et al. (2019); Quistberg et al. (2019); Shaaban e Abdur-Rouf (2019); Heydari et al. (2020); Pichayapan et al. (2020); Torres et al. (2020); Bina et al. (2021).
	Road use and infrastructure (ENG 2)	Bull et al. (2018); Bunnarong e Upala (2018); Briz-Redón et al. (2019); Ivan et al. (2019); Quistberg et al. (2019); Shaaban e Abdur-Rouf (2019); Heydari et al. (2020); Pichayapan et al. (2020); Torres et al. (2020); Bina et al. (2021).
Education (EDU)	Training and safety culture (EDU1)	Alonso et al. (2018); Bull et al. (2018); Bunnarong e Upala (2018); Hassan et al. (2018); Holm et al. (2018); Ajala e Kilaso (2019); Ivan et al. (2019); Alonso et al. (2020); Heydari, Miranda-Moreno e Hickford (2020); Bina et al. (2021).
Inspection (FIS)	Guidance (FIS1)	Bull et al. (2018); Bunnarong e Upala (2018); World Health Organization (2018); Ajala e Kilaso (2019); Heydari et al. (2020); Bina et al. (2021).
	Notification (FIS2)	Bull et al. (2018); Bunnarong e Upala (2018); World Health Organization (2018); Ajala e Kilaso (2019); Heydari et al. (2020); Bina et al. (2021).

Source: Authors (2023)

With regard to comparing the results of the survey and related work, as mentioned above, gaps were filled, since no recent scientific publication was identified that used the AHP method to select traffic safety strategies for school areas. In view of this, there is no similar data available to compare these results. However, the literature provides indicators and evidence that correlate with the results extracted from the survey, making interpretations and propositions possible.

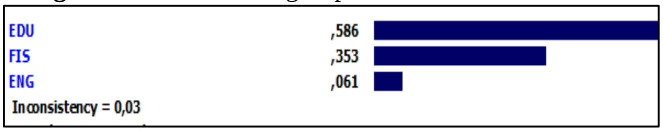
Figure 3. Applying AHP to decide on school traffic safety



Fonte: Saaty (1978)

Under the 3% inconsistency pointed out by the Expert Choice Trial, satisfactorily meeting the AHP consistency condition, the results obtained from the teachers' responses (Figure 4) show that the "Education (EDU)" factor is seen by 58.6% as the strategic segment that should be prioritized in order to improve the perception of traffic safety in urban school areas in São Mateus (ES). Next, the factors "Enforcement (FIS)" and "Engineering (ENG)" received 35.3% and 6.1% of the participants' preference, respectively.

Figure 4. Global ranking of preferences between factors



Source: *software Expert Choice Trial*

In opposition to the prioritization of teachers, the literature seems to indicate a preference for interventions in the road environment around schools, associated with the "Engineering" factor, especially through traffic control devices (Zhao et al., 2016; Hwang et al., 2017; Ajala & Kilaso, 2019; Rahman et al., 2019; Shaaban & Abdur-Rouf, 2019; Rahman et al., 2020). This can be explained by skepticism about the effectiveness of pedestrian safety education, while the creation of safe environments around schools is seen as a powerful strategy for protecting pedestrians (Rothman et al., 2017).

Favoring the "Engineering" factor, the Safe System approach, considered promising for traffic safety, advocates that the road system should be designed to mitigate the consequences of human errors, which are seen as inevitable (World Health Organization, 2015; National Transport Confederation, 2018; Welle et al., 2018; World Bank, 2019; Turner et al., 2020). To illustrate this issue, in the funding of the international "Safe Routes to School (SRTS)" program, US legislation determines that the majority of the funds (70 to 90%) should be allocated to engineering and infrastructure projects, while the remaining percentage should be distributed in education, encouragement and enforcement activities (Dimaggio et al., 2016).

One possible explanation, according to Alonso et al. (2018), is that behavioral approaches and traffic safety education, without modifying the traffic environment, are viewed with suspicion regarding their effectiveness in preventing pedestrian accidents, especially in low- and middle-income countries with poor traffic conditions. Along the same lines, when evaluating interventions common to these countries, Turner et al. (2020) concluded that training or education programs in schools, just like educational campaigns carried out in isolation, have not proven to have significant beneficial effects on safety.

The World Bank reinforces this thesis by citing evidence of modest or non-existent effects of educational measures, including school education, on traffic safety strategies (World Bank, 2019). This relativity of the effectiveness of educational programs around the world was also reported by Alonso et al. (2020), who included costs and complexity as possible limiters of this strategy. In addition, Obregón-Biosca et al. (2018) point out that the educational strategy needs to be improved in developing countries, but the lack of resources invested has limited the potential for improving road safety in these locations.

In fact, although the financial issue is also considered the main barrier to engineering interventions (Mcilroy et al., 2019), they, like enforcement interventions, can be easily assessed for success or failure, as they are usually physical, visible, measurable and provide immediate effects (Assailly, 2017). As an example, according to the World Health Organization (World Health Organization, 2017), speed limits of 30 km/h, especially around schools, combined with measures such as the installation of automatic radars, have proven effective in protecting pedestrians and cyclists in traffic, especially children, and in reducing injuries caused by accidents.

The literature highlights the importance of engineering measures for traffic safety in school areas, such as traffic signals (Bunnarong & Upala, 2018; Heydari et al., 2020) and traffic and speed control mechanisms (Hwang et al., 2017; Ivan et al., 2019; Joo et al., 2019; Quistberg et al., 2019; Corazza et al., 2020; Bina et al., 2021). These measures, according to Yu and Zhu (2016), provide favorable environments for the use of active transport and help improve pedestrian safety in school traffic. Thus, these findings corroborate the high importance attributed by teachers (87.5%) to the sub-factor "Use of roads and infrastructure (ENG2)", in relation to "Urban mobility infrastructure (ENG 1)".

In short, these findings confirm the recommendation of the World Health Organization (World Health Organization, 2017) regarding the need to design or reconfigure environments around schools to prioritize pedestrians and cyclists, as part of child health policies. Expanding on this discussion, the creation of compact urban areas with substantially connected infrastructure increases the likelihood of choosing non-motorized travel (Ding et al., 2017). Thus, Najaf et al. (2018) conclude that transport network connectivity is a component of urban form [or land use] that indirectly contributes to traffic safety, as it favors non-motorized modes of transport and therefore reduces the risk of traffic fatalities.

From another perspective, although they recognize the influence of infrastructure on risk behaviors, Bina et al. (2021) understand that the analysis of improper conduct and traffic violations in school surroundings is important for understanding factors that can improve mobility and safety, highlighting the need to prioritize the behavioral aspect in strategic interventions. Sharing this opinion, researchers suggest promoting the educational aspect, for example, to raise awareness among students, in order to reduce the incidence of pedestrian accidents (Bunnarong & Upala, 2018; Ivan et al., 2019).

With convergent thinking, several authors suggest the positive influence of educational actions on traffic safety in general, health and the environment (Alves et al., 2016; Shettar & Patil, 2016; Najaf et al., 2017; Pati, 2017; Alonso et al., 2018; Hassan et al., 2018; Holm et al., 2018; Obregón-Biosca et al., 2018; Zare et al., 2019; Alonso et al., 2020). Corroborating the literature, studies by the World Health Organization (World Health Organization, 2017) cite that education is, for example, one of the factors that considerably interferes with the choice of speed in traffic. Assailly (2017), in turn, adds that investments in education, despite not immediately yielding beneficial results, guarantee the balance and social acceptability of other strategies.

Furthermore, the lack of innate human knowledge about traffic safety also justifies the essentiality of the educational factor and the priority given to it by teachers. Thus, in any traffic safety planning, human factors must be fully considered, especially in developing countries, since people are also essential components of transportation networks (Najaf et al., 2017). Corroborating this understanding, Farooq et al. (2019) point out that these factors have the predominant impact on the risk of accidents and this finding, according to Aghdam et al. (2020), calls for the implementation of educational programs for traffic safety.

These programs aim to influence human behavior, based on three levels (knowledge, attitudes and skills) with interdependent and complementary objectives, namely: promoting knowledge of situations and rules; developing skills through training and experiences; and strengthening and/or modifying attitudes for one's own safety and that of other users (Assailly, 2017). As effects, they can contribute to behavioral change and increased awareness which, theoretically, would result in improved perception of traffic safety and a reduction in fatalities and injuries from accidents (Goniewicz et al., 2016). Based on this understanding, Obregón-Biosca et al. (2018) emphasize that the first step is to identify users and specific aspects that need to be improved.

At the top of the priorities, the literature indicates that drivers should receive special attention, considering that they are usually involved in actions that cause safety inconveniences for themselves and other traffic users (Moslem et al., 2020). Some recent findings show that their behaviors, evaluations and beliefs, as well as their physical and psychological conditions, influence the operation of driving vehicles (Molina et al., 2021) and the propensity to accidents seems to be correlated to the gender and age of these individuals (Rolison et al., 2018). Thus, Farooq et al. (2019) suggest that specific behavioral aspects of drivers be focused on in the planning of traffic safety education campaigns or courses to improve risk perceptions and critical attitudes in vehicle driving.

Although drivers are considered central elements for reducing accidents, something that calls for collaboration between driver training centers (Aghdam et al., 2020), the literature also indicates other relevant elements that need to be considered in educational strategies. The National Transport Confederation (2018), for example, recommends both driver and pedestrian training, as well as encouraging social awareness, as a resource that can prevent and help reduce accident rates. This is because the risky behaviors of both are the main reasons that result in road accidents (Pichayapan et al., 2020).

Trifunović et al. (2017) argue that children, in addition to being kept away from potential dangers, need to receive comprehensive training in real traffic situations, guided by education to generate desired changes in their safety behaviors, skills and attitudes. Other researchers suggest including parents/guardians as targets of educational and training programs to encourage them to adopt safety behaviors that will serve as role models for their children in the future (Holm et al., 2018; Bina et al., 2021). Equally important, according to Hassan et al.

(2018), are investments in education and training for teachers, considering the direct responsibility of these professionals in transmitting knowledge and raising student awareness of appropriate behavior in traffic.

This recognition of the need for educational measures reinforces the importance of involving school units in planning and decision-making on mobility and road safety (World Health Organization, 2017). In addition, researchers advocate the teaching of traffic safety in schools to enhance the student learning process, including the development of a specific curriculum focused on the subject or its link to the teaching of regular subjects, provided there are sufficient links with reality (Alves et al., 2016; Shettar & Patil, 2016; Hassan et al., 2018; Holm et al., 2018; Ajala & Kilaso 2019; Heydari et al., 2019; Aghdam et al., 2020).

However, according to Pati (2017), road safety education is generally not part of the school curriculum in developing countries. In the Brazilian context, in particular, the CTB determines the teaching of "traffic education" in pre-schools and first to third grade schools, through planning and coordinated actions by the bodies and entities of the traffic and education areas of the federative entities (Brazil, 1997). However, Carvalho (2020) evaluates the approach to road safety in Brazilian schools as insufficient and, for this reason, calls for government attention so that the subject is included in the national school curriculum and, as a result, teachers are trained to transmit knowledge on the subject to students.

In this regard, it is worth noting that school education and teacher training are among the educational precepts that guide the National Traffic Policy (Brasil, 2014). Few initiatives, as reported by the National Transport Agency (2017), have consisted of teacher training programs and publications of materials for the creation of transversal projects, with some successful pioneering experiences such as the training promoted by the São Paulo Traffic Engineering Company.

On the other hand, thinking broadly, Assailly (2017) believes that road safety education should not be considered a simple school subject, but a continuous learning process to be implemented from pre-school (kindergarten) onwards. This author goes on to propose the adoption of personalized interventions and goals for users, considering different age groups and mobility patterns, under regular evaluation and quality control of the effects to ascertain the need for adjustments to the approach.

Based on this understanding, other initiatives, outside the school environment, are also seen as drivers of the road safety education strategy, such as advertising campaigns and the mass media, for example, which can favor the appropriate modeling of users' conduct in general (Alonso et al., 2018). However, the classification of activities as educational interventions is conditional on the development of action curricula on the subject of road safety and related issues, which are capable of continuously monitoring and evaluating the results, according to Alonso et al. (2020).

From a different point of view, the literature also provides evidence that education interventions are only effective when integrated with regulatory measures (Pan American Health Organization, 2013; Goniewicz et al., 2016; Heydari et al., 2019). In this understanding, for example, it is advocated that public education campaigns be comprehensive, continuous and linked, in content and timing, to enforcement efforts (Turner et al., 2020). Based on this principle, some authors suggest combined education and enforcement interventions as a mechanism for improving traffic behavior in school areas (Nascimento, 2014; Bull et al., 2018; Ajala & Kilaso, 2019; Heydari et al., 2020; Bina et al., 2021).

According to Mcilroy et al. (2019), enforcement is advantageous for shaping driver behavior and generating income at the same time, unlike engineering and education which, in most circumstances, require investments with no revenue counterpart. In school environments, international experiences show that speed enforcement revenues can be applied to traffic safety improvements in these environments and, likewise, to educational programs on this subject (Quistberg et al., 2019). According to this line of thinking, the successful combination of education and enforcement can reinforce social awareness of the need for safe attitudes in traffic around schools.

On the other hand, the analysis of the survey results also revealed an apparent contradiction, since the teachers gave preference (88.9%) to the "Notification (FIS2)" sub-factor over (11.1%) the "Guidance (FIS1)" sub-factor, when judging the sub-factors related to the "Enforcement" factor. Notably, the prioritized element has a regulatory character, suggesting that penalties are perceived as the most efficient way to change traffic behavior in school areas, contradicting, in part, the overall prioritization given by teachers to the "Education (EDU)" factor in relation to the Enforcement factor (Figure 3).

One possible interpretation of the choice of the "Notification" sub-factor may be related to a perception of the ineffectiveness of legal enforcement. In other words, maintaining the feeling of insecurity, even in the face of the vast national legislative framework on safety and urban mobility (World Health Organization, 2018), probably induced teachers to recommend strict enforcement near schools in order to consequently improve the perception of safety among users who circulate in these environments. This thinking is in line with current national regulations, since 5% of traffic fines must be used to fund educational programs (Brazil, 1997), which generally means that strict enforcement encourages traffic education.

However, from a systemic perspective, policies also need to consider the actors in the road transport system in order to achieve a level of excellence in road safety (Kim et al., 2017). By analogy, this implies allowing the participation of school professionals, students, parents/guardians, police officers and local residents in the construction and implementation of these policies, since these actors invariably detect road safety problems around schools (World Health Organization, 2017). According to the literature, these problems can be identified through perceptions, simulations, inspections, audits and statistical analysis of accidents and traffic volume (Shettar & Patil, 2016; Bull et al., 2018; Suting et al., 2018; Briz-Redón et al., 2019; Ivan et al., 2019; Joo et al., 2019; Rahman et al., 2019; Shaaban & Abdur-Rouf, 2020; Torres et al., 2020).

Based on this information and with the support of institutions and stakeholders (Mainardes et al., 2013) from various sectors, such as education, urban planning, health, community leadership, transport and the police, traffic authorities will be able to develop effective policies and target safety interventions in school areas (Yu & Zhu, 2016; Hwang et al., 2017; World Health Organization, 2017; Bull et al., 2018; Bunnarong & Upala, 2018). In this way, the teachers' (88.8%) priority choice for Alternative 2 (ALT2) over Alternative 1 (ALT1) is consistent, since considering the opinions and needs of all the actors involved when making decisions is, from a management point of view, a stance that makes solutions robust.

On this issue, Hassan et al. (2018) reflect that the success of educational interventions requires joint development and mutual support between teachers, parents and authorities responsible for traffic safety to reduce accidents around schools. Corroborating and expanding this opinion, Alonso et al. (2018) highlight the importance of the engagement of the entire education system, as well as its stakeholders, to consolidate learning about traffic safety for all individuals, from childhood onwards, in order to generate positive effects on their attitudes during adulthood.

It is important to note, however, that each school unit produces particular and complex issues for traffic safety management, due to the diversity of profiles, experiences and numbers of users, as well as characteristics relating to exposure to risks in their surroundings (Zhao et al., 2016; World Health Organization, 2017; Chen et al., 2018; Briz-Redón et al., 2019; Heydari et al., 2020). For this reason, it is imperative to understand the nuances of the problem in order to propose specific and optimized solutions, something that, in the opinion of Shettar and Patil (2016), calls for expertise in traffic safety and support from school communities in building and preserving a safe environment for their players.

The findings of the survey therefore indicate that the involvement of the stakeholders mentioned above can significantly help in the formulation of projects and actions that result in interventions in the physical environment, educational and enforcement actions, in order to provide safety in the movements carried out around schools. In Brazil, this participation is encouraged by Denatran (2000), which even emphasizes the need to create plans for safe routes for schoolchildren, through mutual collaboration between school communities and traffic authorities at all stages, to encourage active and safe travel on routes to schools.

In summary, the results of this study suggest that the Education (EDU) strategy should be a priority for improving the perception of traffic safety in urban school areas in São Mateus (ES). It should also be noted that enforcement in these areas needs to be rigorous, by notifying offending drivers (FIS2), in order to ensure the safe use of roads and infrastructure by stakeholders in the school community (ENG2) and, in the long term, enable the development of a culture of safety (EDU1), according to the prioritization of sub-factors (Table 4). In addition, the alternative chosen by the group surveyed (Alternative 2 with 88.8%) indicates that interventions relating to school traffic safety need to be planned and carried out in conjunction with these stakeholders (ALT2).

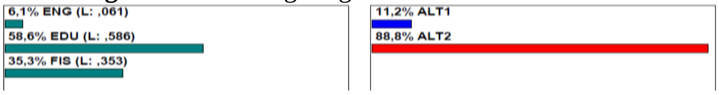
Table 4. Ranking of subfactors

Subfactor	Weight
Training and safety culture (EDU1)	100%
Notification (FIS2)	88.9%
Use of roads and infrastructure (ENG 2)	88.9%
Guidance (FIS1)	11.1%
Urban mobility infrastructure (ENG 1)	11.1%

Source: Software Expert Choice Trial

However, since the assignment of weights is generally based on highly subjective evaluations, the literature recommends testing the stability of the ranking of alternatives, under various factor weightings, through sensitivity analysis of pairwise comparisons (Saaty, 1978; Dweiri et al., 2016; Farooq et al., 2019; Moslem et al., 2020). To this end, changes (increases or decreases) must be made to the weights of the factors evaluated, in order to observe the level of robustness of the original result (Figure 5). A sensitivity analysis of the teachers' choices was then carried out, using Expert Choice Trial resources, to ascertain possible changes in the prioritization of alternatives in the face of different scenarios.

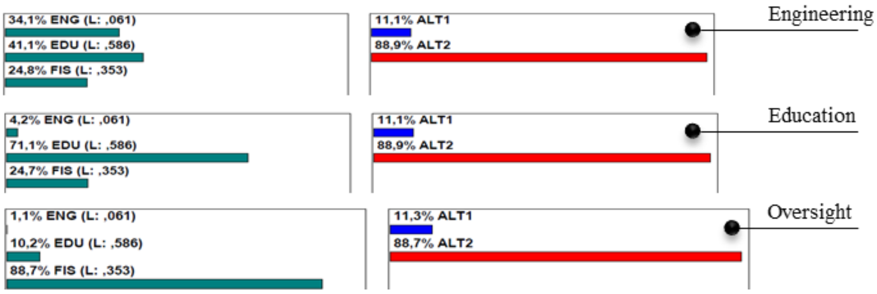
Figure 5. Real weighting of factors and alternatives



Source: *Software Expert Choice Trial*

At this stage, weight simulations were carried out, based on a scale between 0% and 100%, for each of the three factors involved in the evaluation ("Engineering - ENG"; "Education - EDU"; and "Inspection - FIS"). This experiment, shown respectively in figure 6, only detected variations in the percentages of the alternatives from the following weightings of the factors: "Engineering" (34.1%), "Education" (71.1%) and "Inspection" (88.7%). However, as can be seen, the variations obtained were minimal and incapable of altering the interpretations of the results, which indicates the stability of the possible decisions to be made.

Figure 6. Sensitivity of factors



Source: *Software Expert Choice Trial*

It should also be noted that the teachers' prioritization of the "Education (EDU)" factor does not imply that the other factors are neglected. In fact, the literature advocates that the three factors be operated synchronously to improve the safety of road users (Mwebesa et al., 2018). Therefore, the purpose of this work, conceived with the support of the AHP method, is to demonstrate how different factors affect the composition of a traffic safety policy and, based on this, suggest possible directions for planning, actions, investments, among others, that can contribute to improving traffic safety in school areas in the urban region of São Mateus (ES).

From the point of view of investments, for the purposes of cost-benefit analysis of safety policies, Elvik (2019) explains that social welfare is enhanced when the balance of benefits in relation to costs reaches the maximum level. This result can be estimated, for example, in terms of lives saved and reductions in traffic injuries (Shinar, 2019). Therefore, in the specific case addressed in this work, possible interventions should be evaluated periodically for their impact on reducing traffic accidents near schools in the region covered.

However, according to Obregón-Biosca et al. (2018), limited investment resources condition the implementation of measures and strategies to improve traffic safety education in developing countries, requiring prior analysis of the available economic panorama. There is also the possible difficulty in reproducing the educational practices of developed countries in developing countries, due to specificities in the education system, legislation, exposure to risk and traffic culture of the latter (Heydari et al., 2019). With regard to this complicating factor, Wegman (2017) explains that successful strategic principles can be reproduced, provided that action plans are properly adapted to local circumstances.

VI. Final considerations

Traffic safety in school areas is a highly relevant issue for Public Management, as it involves complex decision-making that requires the valuation of health, economic and environmental aspects. This study therefore proposes a multi-criteria approach to this issue, from the perspective of teachers in the city of São Mateus (Brazil), in order to identify priority actions for improving road safety in urban school areas.

In the methodological procedures, the proposed evaluation structure made it possible to suggest an ideal alternative, based on the opinion of teachers, considering factors and sub-factors related to traditional traffic safety strategies. By applying a questionnaire, formatted according to the Analytic Hierarchy Process (AHP) method, the results of the aggregate analyses show that teachers prioritized the "Education" factor and the "Safety training and culture", "Notification" and "Use of roads and infrastructure" sub-factors as attributes to be considered in school traffic safety policy. With regard to the ranking of alternatives, the vast majority prioritized "Involving the school community in traffic safety planning and actions in school areas".

It is worth highlighting an important finding of this work, which is the recommendation of a 30km/h speed limit around schools, with the aim of reducing traffic deaths and injuries, as well as the environmental benefits. In fact, the recent "Stockholm Declaration" on Road Safety, approved at the 3rd Global Ministerial

Conference on Road Safety on February 20, 2020 in Sweden, which aims to halve traffic deaths and injuries by 2030, emphasizes that countries should focus on speed management, especially with regard to requiring this limit in areas where there is frequent and planned interaction of vehicles and vulnerable users, except where there is robust evidence that higher speeds are safe. For this reason, the creation of "school zones" with functioning and variable speed limits, based on technical parameters, has been evaluated internationally as successful for student safety in traffic around schools.

These insights provide some insight into the importance of policies that ensure safe mobility around schools. Although general guidelines on speed limits are set by the government, it is necessary for municipal authorities to have the ability to stipulate limits that meet local specificities and that are not, however, set in isolation, but as part of a comprehensive policy. This means, in general terms, that reducing speed limits, unaccompanied by changes in road design, permanent enforcement efforts or social awareness, will probably not have the desired impact.

Despite this complex social problem, programs such as Safe Routes to School and School Area Road Safety Assessment and Improvements, generally implemented in developed and developing countries, respectively, show that it is possible to formulate effective policies and strategies for improving traffic safety in São Mateus school areas, with the collaboration and integration of stakeholders from the school community, public and private managers, researchers, Non-Governmental Organizations and society in general. To this end, a number of actions are essential: a) developing and funding a safety policy; b) monitoring and evaluating the impact of evidence-based and data-driven interventions; c) promoting public awareness of the importance of these interventions; and d) defining a leadership committed to managing this process.

In view of the above, and considering possible financial limitations in the region investigated, a systematic and balanced safety approach is suggested, through education, engineering and enforcement strategies, to achieve satisfactory traffic results in school areas:

- Analyze the environment: to identify critical school areas, supported by evidence such as traffic volume data, accident frequency and infrastructure aspects. In addition, the analysis should include issues related to active transport, risky behavior and infractions by students, parents, school professionals, drivers and other users who circulate in these areas.
- Engage relevant stakeholders: once priority areas and aspects have been identified, a heterogeneous group should be selected, consisting mainly of parents, students, school professionals, residents' associations, researchers, health professionals, driver training centers and the local traffic and urban planning authorities, to lead the process of improving safety in school areas.
- Developing an action plan: to formalize the commitment to improving school traffic safety, emphasizing objectives and targets; modes of execution, monitoring and evaluation, deadlines and individual responsibilities.
- Implementing the interventions: to gradually make the road environment around schools safer for the school community and other users, seeking to keep them informed of any developments in improvement actions and, especially, encouraging them to collaborate for the efficiency of the results.
- Monitoring and evaluating progress: these are necessary to measure levels of participation and satisfaction, verify the effect of a project over a given period of time, ensure that objectives and targets are being met, identify the need for procedural adjustments and improve evaluation tools.

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