



Normative Perception of Traffic and Environmental Noise Control Measures among Urban Motorcyclists in a Structurally Informal City



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Abstract: Environmental noise generated by motorcycle traffic constitutes a critical challenge for intermediate cities of the Global South, where high motorization rates intensify exposure to stressful acoustic environments. In Florencia (Caquetá, Colombia)—a city in which motorcycles represent 96.6% of the vehicle fleet—noise functions not only as an environmental pollutant but also as a psychosocial trigger associated with irritability, stress, and aggressive driving behaviors among young riders. This study evaluates urban motorcyclists’ perceived effectiveness of regulatory measures aimed at noise and traffic control, considering how education level and driving experience shape normative perceptions. Using a non-experimental, cross-sectional design, data were collected from 502 motorcyclists. Kruskal–Wallis tests and Spearman correlations revealed a significant positive association between higher education and favorable perceptions of regulatory effectiveness, while no association was observed for driving experience. An exploratory factor analysis (EFA) confirmed a two-factor structure (54.3% variance), differentiating structural/collective measures from individual/educational ones. Overall, structural and educational interventions were perceived as more effective than coercive approaches. These findings highlight the need for context-sensitive regulatory frameworks that integrate social legitimacy, cultural adaptation, and psychological determinants of behavior. The study contributes empirical evidence for designing participatory and education-centered strategies for noise management and mobility governance in structurally informal urban contexts such as Florencia.

Keywords: Environmental justice; Sustainable mobility; Urban informality; Environmental noise; Motorcyclists

1 Introduction

The intensive use of motorcycles in urban environments represents a growing challenge for transport sustainability, public health, and urban environmental quality. While motorcycles offer affordable mobility in the face of insufficient public transport, they generate significant negative externalities, such as high road accident rates and noise pollution. This noise is a critical environmental factor that adversely affects human health and urban ecosystems [1–3]. Globally, road crashes cause more than 1.35 million deaths per year, with motorcyclists being a highly vulnerable group, particularly in emerging economies [4]. This pattern is widely documented in Africa, Asia, and Latin America, where motorcycles are a dominant component of the vehicle fleet [5–7].

The weight of motorcycles in the urban fleet leads to high accident rates, pressure on infrastructure, and frequent traffic violations [2, 8]. Additionally, motorized traffic density in informal cities contributes to high levels of environmental noise; prolonged exposure is associated with cardiovascular disease, sleep disorders, and impaired psychological well-being [9]. The relationship between road informality, institutional weakness, and low regulatory compliance is particularly relevant in peripheral regions, where strategies must be tailored to specific socio-territorial conditions [10].

Previous research has shown that psychosocial variables, such as institutional trust, have a decisive impact on willingness to comply [4, 11, 12]. Furthermore, individual factors such as educational level and driving experience influence attitudes toward road regulations [13–15]. In cities with high structural informality, formal education is associated with greater voluntary compliance, even in weak-enforcement settings [4, 16].

Despite these advances, important knowledge gaps remain. Empirical evidence on how motorcyclists perceive specific regulatory measures, such as noise control or congestion mitigation, is still limited. Motorcycle noise not only affects health but also generates environmental conflicts and exacerbates inequalities in exposure to pollutants [17, 18]. However, little work has explored how motorcyclists themselves interpret such measures in cities with weaker regulatory frameworks [8]. This gap is even more pronounced in intermediate cities in the Global South, where systematic knowledge of motorcyclist behavior is fragmentary and a significant information deficit persists in evidence-based policy design [14].

Florencia, the most populous city in the Colombian Amazon, presents a critical case in which motorcycles are the main means of transport [19]. Local authorities have implemented measures such as speed limits, noise controls, and horn restrictions; however, their effectiveness depends on the degree of acceptance and ownership among users. While previous studies have examined accident rates or risk behaviors, very few have provided systematic evidence on how motorcyclists perceive the effectiveness of specific environmental noise regulations in structurally informal cities. Moreover, the combined influence of educational attainment and driving experience on these perceptions has remained largely unexplored.

The general objective of this research is to analyze urban motorcyclists' perceptions of the effectiveness of traffic and noise control regulatory measures in Florencia (Caquetá), considering the impact of educational level and driving experience. This study aligns with the objectives of sustainable mobility and urban environmental justice by providing empirical evidence to inform the formulation of integrated public policies.

In contrast to previous research focused predominantly on road accidents or technical noise modeling, the novelty of this study lies in its focus on the normative perception of control measures within an ecosystem of high structural informality. While existing literature often treats motorcyclists as passive study objects or statistical offenders, this work positions them as critical evaluators of institutional legitimacy. The original contribution lies in analyzing how individual factors—specifically, educational level and driving experience—shape acceptance of environmental and road interventions in a city where motorcycles constitute the vast majority of the vehicle fleet. This approach identifies that the effectiveness of noise regulation in the Global South depends not only on technique or sanctions, but on social legitimacy built through education and environmental justice.

2 Literature Review

The theoretical framework of this study is structured around three key thematic axes that provide a multidimensional understanding of the motorcycle phenomenon in intermediate cities.

2.1 Motorcycle Traffic and Environmental Noise

Motorcycle traffic is not only a mobility issue but a primary source of environmental degradation in the Global South. Unlike four-wheeled vehicles, motorcycles often lack efficient acoustic insulation, and their high density in informal urban areas contributes significantly to noise pollution [1, 9]. Previous research has established that prolonged exposure to traffic noise is associated with cardiovascular diseases, sleep disorders, and psychological stress [2, 3]. In cities with high motorization rates, such as those in Southeast Asia and Latin America, noise is a persistent environmental pollutant that exacerbates urban inequality, as residents in dense, low-income areas are often most exposed to high decibel levels [17, 18].

2.2 Behavioral and Compliance Studies among Riders

Understanding why motorcyclists comply with or defy regulations requires an analysis of psychosocial factors. Literature has traditionally focused on “risky behaviors”—such as lack of helmet use or speeding—linking them to individual variables like health beliefs and locus of control [4, 11]. Recent studies in Brazil and Ghana suggest that educational level and driving experience play a dual role. While formal education tends to favor voluntary compliance by increasing risk awareness [16], years of experience in highly informal environments can sometimes lead to the normalization of infractions if the perceived risk of sanction is low [13, 14].

2.3 Institutional Legitimacy and Traffic Regulation

Beyond technical measures, the effectiveness of traffic policy depends on its perceived legitimacy. Following Tyler's framework [12] of procedural justice, individuals are more likely to comply with the law when they perceive the authorities as fair and legitimate, rather than merely out of fear of punishment [20]. In contexts of structural informality, this “normative perception” is critical. If motorcyclists perceive noise control or speed limits as purely revenue-generating measures rather than tools for the common good, compliance remains low [8, 10]. Therefore, the legitimacy of environmental regulation is a cornerstone for sustainable urban governance.

2.4 Research Hypotheses

Based on the research goal of determining the impact of educational level and driving experience on the normative

perception of traffic and noise control measures in Florencia, the following hypotheses are proposed:

H1: Higher levels of formal education are positively associated with the perceived legitimacy and effectiveness of environmental and road regulations. This suggests that schooling acts as a proxy that may support the development of collective responsibility and institutional trust.

H2: Driving experience significantly influences the acceptance of noise control interventions, reflecting a process of socio-environmental adaptation. It is hypothesized that in contexts with high structural informality, accumulated years on the road lead to a “normalization of risk”, where more experienced riders develop a specific resistance to measures perceived as purely punitive or disconnected from the daily reality of the transit environment.

3 Methods and Materials

3.1 Study Area

Florencia, the capital of the department of Caquetá, stands as the main administrative and commercial hub of the Colombian Amazon. In recent decades, the city has experienced accelerated, largely unplanned urban growth, resulting in road infrastructure that remains insufficient to meet the increasing demand for mobility. Within this context, motorcycles have emerged as the predominant mode of transport, driven not only by their economic affordability but also by their ability to navigate a constrained and congested road network.

Mobility reports reveal a strong concentration of the private vehicle fleet in motorcycles, with approximately 74,827 units compared to only 2,660 private vehicles, representing 96.6% of the total [19]. This marked imbalance reflects a structural dependence on this mode of transport, significantly exceeding the national average. In practice, motorcycles serve a dual role: they are the primary private mode of transport for families and, simultaneously, the backbone of an informal economy for transporting passengers and goods, compensating for deficiencies in the public bus system [2, 8]. This configuration gives rise to an urban dynamic characterized by high levels of congestion and constant exposure to vehicular noise [21]. In this sense, Florencia constitutes a particularly relevant case for analyzing the perception of regulatory measures in intermediate cities marked by high institutional informality [10].

3.2 Study Design

This study adopted a non-experimental, cross-sectional, comparative-correlational, quantitative design [22]. This type of design is suitable for describing relationships between variables without manipulating them, allowing us to capture subjective perceptions in real and natural contexts [23]. The study focused on analyzing the perception of the effectiveness of different regulatory measures aimed at urban motorcyclists, considering educational level and driving experience as independent variables, and the perception of regulatory effectiveness as the dependent variable.

This model assumes that certain individual characteristics, such as formal schooling and years of experience, influence the subjective willingness to value different forms of traffic regulation as effective. Thus, the focus is on the relationship between psychosocial factors and regulatory legitimacy in urban contexts with high structural informality, considering Florencia city as a representative case study of an intermediate city in the Global South.

We explicitly acknowledge that the use of convenience sampling and self-reported perceptions imposes limitations in terms of representativeness and possible social desirability bias. However, these limitations are common in exploratory perception studies in contexts with limited registries and restricted access to the full population. To mitigate these issues, we applied clear inclusion criteria, conducted pilot testing, and complemented the analysis with robustness checks.

3.3 Participants and Sampling

In this study, a non-probabilistic convenience sampling was used, which is a common technique in exploratory perception studies where there are restrictions on access or distribution to the target population [24]. This choice was specifically dictated by the high levels of structural informality in Florencia, where a comprehensive and updated official census of active motorcyclists is unavailable.

This strategy allowed us to capture contextual variability without compromising the analytical focus of the study. The sample consisted of 502 urban motorcyclists from Florencia (Caquetá, Colombia), who met the following inclusion criteria: being 18 years of age or older; having at least one year of motorcycle riding experience; and residing in the urban area of the city. According to Cohen’s parameters [25], this sample size ($n = 502$) is adequate to detect effects of moderate magnitude ($d = 0.5$) with a statistical power greater than 0.80 at a 0.05 significance level.

While this strategy ensured a robust sample size ($n = 502$), it entails limitations in terms of representativeness. The hybrid data collection approach (70% online and 30% face-to-face) may have favored the participation of riders with higher levels of digital literacy or formal education. To ensure the internal validity of this mixed-mode administration, a Mann–Whitney U test was conducted comparing responses between the online ($n = 351$) and face-to-face ($n = 151$) sub-samples across the six regulatory measures and the main perception variables (noise perception and risk behaviors). No statistically significant differences were found for any variable (all $p > 0.12$). For example, for M2

(strategies to reduce traffic congestion caused by motorcycles), the test yielded $U = 24,876.5$, $p = 0.347$. These results support the integration of both sub-samples into a single dataset for subsequent analyses.

Given that the majority of participants reported having completed technical or secondary education, the observed relationship between education and regulatory acceptance should be interpreted primarily as reflecting these segments rather than the broader population of motorcyclists, particularly those with lower educational levels or greater degrees of informality. Nevertheless, considering the exploratory nature of the study and the lack of prior baseline data in the region, this approach provides a valuable foundation for understanding rider–regulation dynamics in intermediate Amazonian cities.

3.4 Collection Instrument

The data collection instrument was a structured questionnaire consisting of 19 items, strategically organized into five sections to capture the multidimensional nature of the motorcyclist's profile and their normative perceptions. The sections were distributed as follows:

- Demographic profile (4 items): Collected data on gender, age, educational level, and primary occupation to establish the socio-economic baseline of the participants.
- Riding experience (3 items): Inquired about the number of years as an active driver, daily hours of motorcycle use, and the primary purpose of travel (work, study, or personal).
- Risk behaviors (2 items): Evaluated self-reported frequency of common infractions, such as speeding or non-use of safety equipment, providing context for the participant's relationship with traffic norms.
- Perceptions of environmental noise (4 items): Assessed the perceived intensity of urban traffic noise and its subjective impact on the driver's levels of stress and irritability.
- Assessment of regulatory measures (6 items): This core section required participants to rate the perceived effectiveness of specific interventions using a five-point Likert-type scale (1 = Not at all effective; 5 = Highly effective), according to the recommendations of Boone and Boone [26].

The six items assessed in the final section, which constitute the core dependent variables of the study, were: M1 (noise restrictions on exhaust systems), M2 (road infrastructure improvements), M3 (use of hearing protection), M4 (noise awareness campaigns), M5 (restrictions on horn use), and M6 (establishment of low-noise zones). For analytical purposes, these measures were grouped into three categories: coercive regulation (M1, M5), structural intervention (M2, M6), and educational and preventive actions (M3, M4).

The use of the Likert scale is widely accepted in perception studies for its ability to capture subjective nuances and facilitate comparisons between groups, even when non-parametric analyses are applied [21, 27]. Regarding data integrity, missing responses represented less than 2% of the total dataset; following standard practice, listwise deletion was applied when incomplete responses occurred in key variables.

Content validity was assessed by a panel of three experts in urban mobility and environmental education, who reviewed the items for clarity, relevance, and conceptual coherence. This panel included a psychologist with experience in perception studies, which allowed us to refine the wording of items to reduce ambiguity. Also, a pilot test was conducted with 25 motorcyclists, which allowed us to identify the ambiguity of some words, which were adjusted.

The internal reliability of the questionnaire was estimated using Cronbach's alpha coefficient, reaching a value of 0.81. This value is considered adequate for social studies aimed at measuring attitudes and perceptions [28]. The questionnaire was inspired by previous instruments used in studies of traffic behavior and environmental perception [11, 13, 14] and adapted to the local context to ensure cultural relevance. For transparency and reproducibility purposes, the complete questionnaire used in this study is provided in the supplementary material.

3.5 Procedure and Data Analysis

Data collection was conducted during the first semester of 2024 using a hybrid administration approach (70% digital and 30% face-to-face). Data obtained from both formats were integrated into a single dataset for subsequent analysis.

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable data protection regulations. All participants were provided with detailed information regarding the study's purpose, data confidentiality, and their right to withdraw at any time. Informed consent was obtained as a mandatory prerequisite for participation. The research protocol and survey instrument were reviewed and approved by the Ethics Committee of the Universidad de la Amazonia (Administrative Act No. 029, April 3, 2024).

The statistical analysis was organized into four sequential stages:

- Descriptive statistics: Central tendency measures (mean and median) and dispersion measures (standard deviation) were calculated for each of the six regulatory interventions. The ordinal nature of the Likert-type scales and the distribution of the data guided the selection of non-parametric tests for the subsequent analytical phases [27].
- Comparative and inferential analysis: The Friedman test was utilized to determine the existence of statistically significant differences in perceived effectiveness across the various measures [29]. To quantify the level of agreement

among participants, the effect size (W) derived from this test was calculated. Specific pairwise differences were identified through a post-hoc analysis using Conover’s test with Bonferroni correction. Additionally, Kruskal-Wallis tests were employed to evaluate the influence of socio-demographic factors—specifically educational level and driving experience—on normative perceptions [30].

- Correlation analysis: Spearman’s rank correlation coefficients were calculated to identify and describe the associations and perceived synergies between the six noise and traffic control measures [31].

- Dimensionality reduction: An exploratory factor analysis (EFA) was conducted to identify the underlying latent structures that group motorcyclists’ perceptions. This analysis was performed using the Maximum Likelihood (ML) extraction method with varimax rotation. Sampling adequacy was verified through the Kaiser–Meyer–Olkin (KMO) index and Bartlett’s test of sphericity, while factor retention was based on the eigenvalue >1 criterion and the inspection of the Scree Plot.

3.6 Sample Characterization

The sociodemographic characterization of the participants ($n = 502$) is presented below:

- Educational level: 39.4% reported technical education, 34.3% secondary school, 10.6% technological studies, 9.0% undergraduate professional education, 5.6% postgraduate, and 1.2% primary education. The sample is thus concentrated in intermediate levels of schooling, with lower representation at the extremes (primary and postgraduate).

- Driving frequency: Most participants reported driving daily (57.0%), while 15.9% drive rarely, 13.7% several times a week, and 13.3% occasionally.

- Years of driving experience: 33.9% had 1–3 years of experience, 18.9% between 7–10 years, another 18.9% more than 10 years, 17.1% between 4–6 years, and 11.2% less than 1 year.

- Helmet use: 69.3% reported always wearing a helmet, 26.1% sometimes, and 4.2% never.

Additionally, the noise perception index showed a mean score of 3.02 (SD = 0.99) on a 1–5 scale, reflecting a moderate perception of environmental noise impact. However, the frequency distribution revealed the coexistence of subgroups with low perceptions (≤ 2) and high perceptions (≥ 4), confirming heterogeneity in the way participants interpret the phenomenon and assess regulatory measures.

4 Results

Results are presented in the following order: descriptive statistics of the six regulatory measures, comparisons across measures, effects of socio-demographic factors, inter-measure correlations, and EFA.

4.1 Overall Perception of Regulatory Measures

The descriptive analysis reveals a clear hierarchy in the effectiveness perceived by motorcyclists (Table 1). Results show that structural and mobility-based interventions achieved the highest consensus, led by M2 (traffic congestion strategies) with a mean of 3.73 and a median of 4.

Table 1. Perceived effectiveness of regulatory measures

Code	Measure	Mean	Median	Standard Deviation
M1	Regulation of exhaust system noise levels in motorcycles	2.98	3	1.34
M2	Strategies to reduce traffic congestion caused by motorcycles in urban areas	3.73	4	1.35
M3	Individual hearing protection for motorcyclists	2.39	2	1.25
M4	Awareness programs for motorcyclists about the effects of noise on health and the environment	3.05	3	1.30
M5	Regulation and restriction of horn use by motorcycles in urban areas	2.91	3	1.34
M6	Implementation of noise control zones specifically targeting motorcycles	3.07	3	1.35

Note: Descriptive statistics based on $n = 502$ participants. Five-point Likert scale (1 = Not at all effective, 5 = Highly effective).

In practical terms, the high scores for road infrastructure (M2) and low-noise zones (M6) indicate that riders view physical changes to the urban environment as the most reliable way to reduce noise and congestion. Conversely, lower scores for horn restrictions (M5) and exhaust limits (M1) reflect a “resistance to enforcement”.

4.2 Comparisons Between Regulatory Measures

The Friedman test was utilized to determine if significant differences existed in how motorcyclists perceived the effectiveness of the various measures. The results confirmed statistically significant differences across the six interventions ($\chi^2 = 357.46, p < 0.0001$). The calculated effect size ($W = 0.35$) indicates a moderate level of agreement among the participants regarding this hierarchy of effectiveness.

To pinpoint where these differences occurred, a post-hoc analysis using Conover's test with Bonferroni correction was conducted (Table 2). The findings reveal a clear distinction in rider preferences:

- Preference for structural over technical: There is a highly significant divergence between the perception of road infrastructure improvements (M2) and technical exhaust restrictions (M1) ($p < 0.001$), with riders strongly favoring environmental management over vehicle-specific bans.

- Legitimacy of collective vs. individual measures: Participants expressed a much higher regard for educational programs (M4) compared to individual mandates like hearing protection (M3) ($p < 0.001$).

- Contextual resistance: While some measures like awareness campaigns (M4) and exhaust noise regulation (M1) showed equivalent levels of acceptance ($p = 1.000$), there was a statistically significant preference for implementing specific low-noise zones (M6) over general horn restrictions (M5) ($p = 0.029$).

Overall, these results suggest that in the structurally informal context of Florencia, motorcyclists perceive structural and collective interventions as significantly more effective and legitimate than individual behavioral bans or personal equipment.

Table 2. Pairwise comparisons between regulatory measures (Conover's test with Bonferroni correction)

Comparison	Measures Evaluated	<i>p</i> -Value	Significant	Perceptual Interpretation
M1 vs. M2	Exhaust noise vs. Road infrastructure	<0.001	***	High divergence: Riders significantly prefer structural changes over technical vehicle restrictions.
M1 vs. M4	Exhaust noise vs. Awareness campaigns	1.000	ns	Equivalent: There is no significant difference in the acceptance level between these two measures.
M2 vs. M3	Road infrastructure vs. Hearing protection	<0.001	***	Strong preference: Participants value urban management far more than personal protective equipment.
M3 vs. M4	Hearing protection vs. Awareness campaigns	<0.001	***	High divergence: Educational programs carry much higher legitimacy than individual protective mandates.
M4 vs. M5	Awareness campaigns vs. Horn restrictions	0.179	ns	No significant difference: Perception of effectiveness is comparable between education and horn regulation.
M5 vs. M6	Horn restrictions vs. Low-noise zones	0.029	*	Moderate difference: Specifically targeted noise control zones are favored over general horn bans.

Note: Significance levels: *** $p < 0.001$; * $p < 0.05$; ns = non-significant. *p*-values were adjusted for multiple comparisons using the Bonferroni method.

4.3 Comparisons and Socio-Demographic Influence

The Friedman test confirmed significant differences across measures ($\chi^2 = 357.46, p < 0.0001, W = 0.35$). Pairwise comparisons, as detailed in Table 2, indicate that motorcyclists value structural and collective interventions significantly more than individual bans or personal equipment.

- Educational level: A Kruskal–Wallis test revealed statistically significant differences in the perceived effectiveness of regulatory measures according to participants' educational level ($H = 11.93, df = 5, p = 0.036, \eta^2 = 0.04$). Due

to the small number of participants in the extreme educational categories (primary education: 1.2%; postgraduate: 5.6%), post-hoc pairwise comparisons were not conducted. Examination of the mean ranks showed a tendency for participants with higher educational levels (undergraduate and postgraduate) to report higher perceived effectiveness compared to those with primary or secondary education. These findings support H1, indicating that higher formal education is positively associated with more favorable perceptions of regulatory effectiveness.

- Riding experience: In contrast, no significant differences were observed regarding years of driving ($H = 4.59$, $df = 4$, $p = 0.332$), leading to the rejection of H2. This suggests that the “normalization of traffic habits” and noise exposure in Florencia’s informal context occur independently of the time spent on the road, where both novice and experienced riders appear equally habituated to existing urban dynamics.

4.4 Correlations Between Regulatory Measures

Spearman’s correlation coefficients showed statistically significant associations between several of the measures assessed (Figure 1). The most relevant correlations were:

- Regulation of horn use (M5) and implementation of noise control zones (M6): This pair showed the strongest association in the study, with $r = 0.69$ ($p < 0.0001$), indicating a high degree of perceived synergy between restricting horn use and establishing specific acoustic control areas.

- Awareness programs (M4) in relation to M1, M5, and M6: These correlations ranged between $r = 0.49$ and 0.62 (moderate to strong). This suggests that educational efforts regarding health and environmental effects are perceived as a central axis that reinforces both the regulation of exhaust system noise (M1) and active control measures (M5 and M6).

- Regulation of exhaust system noise (M1) and individual hearing protection (M3): A low correlation was observed ($r = 0.26$, $p = 0.002$), reflecting a weaker link between vehicle-level regulations and personal protective measures used by motorcyclists.

Overall, these correlations suggest a perception of internal consistency between the measures, especially those aimed at noise control and environmental education.



Figure 1. Spearman correlation matrix of regulatory measures

4.5 Exploratory Factor Analysis

An EFA using the ML extraction method and varimax rotation was conducted to identify the underlying latent dimensions in the normative perceptions of environmental noise and regulatory measures. Sampling adequacy was confirmed by a KMO index of 0.82 and a significant Bartlett’s test of sphericity ($\chi^2 = 1135.01$, $p < 0.001$).

The analysis revealed a two-factor solution that explained 54.3% of the total variance, with eigenvalues of 2.89 (Factor 1) and 0.37 (Factor 2). The factor loadings after varimax rotation are presented in Table 3, showing a clear distinction between structural/collective measures and individual/educational measures. As illustrated in the Scree Plot (Figure 2), there is a clear “elbow” after the second component, confirming the retention of a two-factor structure.

Table 3. Factor loadings matrix after varimax rotation

Measure	Factor 1 (Structural/Collective)	Factor 2 (Individual/Educational)
M2	0.82	0.18
M6	0.77	0.25
M5	0.68	0.31
M4	0.22	0.74
M3	0.15	0.72
M1	0.35	0.61

Note: Factor loadings greater than 0.60 are shown in bold.

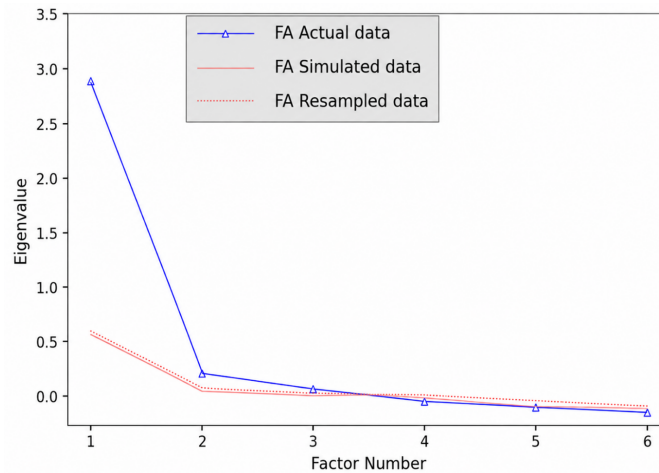


Figure 2. Scree Plot of eigenvalues for six regulatory measures, confirming a two-factor solution

The latent dimensions, labeled as ML1 and ML2 in the factor matrix, categorize the interventions based on their implementation nature:

- Factor 1 (ML1–structural/collective): This factor groups measures that imply a physical or normative modification of the urban environment. It includes road infrastructure improvements (M2), noise-control zones (M6), and restrictions on horn use (M5).

- Factor 2 (ML2–individual/educational): This factor classifies actions centered on personal decision-making and awareness. It encompasses educational campaigns (M4), individual hearing protection (M3), and technical exhaust noise control (M1).

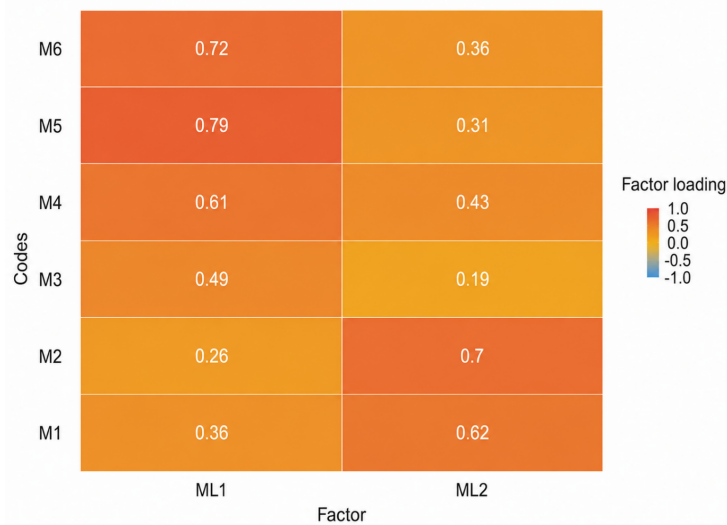


Figure 3. Heatmap of factor loadings from exploratory factor analysis (EFA) of regulatory measures, distinguishing structural/collective (ML1) and individual/educational (ML2) solutions

This structure, visualized in the factor loading heatmap (Figure 3), demonstrates that motorcyclists in Florencia clearly distinguish between solutions that depend on public urban management and those requiring individual behavioral change.

5 Discussion

This study shows that structural strategies (e.g., road infrastructure improvements, noise-control zones) and educational campaigns were perceived as more effective than coercive or individually focused measures. This pattern is consistent with evidence from Latin American and other Global South contexts, where informative and participatory measures achieve higher acceptance than punitive regulations [1, 2]. These findings align with the two-factor solution identified in the EFA, confirming that normative perceptions cluster into structural/collective and individual/educational dimensions.

Legitimacy and coercion are central to understanding regulatory acceptance. As Tyler's procedural justice framework [20] highlights, compliance is shaped less by fear of sanctions than by perceptions of fairness, legitimacy, and respectful treatment by authorities. In Medellín, Cataño and Grisales-Romero [5] showed that high motorcycle crash rates persisted despite coercive rules, illustrating the limits of sanctions without preventive measures. Research in Indonesia found that punishment could deter risky riding among youth [16], while studies in Southeast Asia have also shown that highly punitive approaches may generate resistance when riders perceive regulations as disconnected from their daily mobility realities [15].

In the specific context of Caquetá, this mistrust is rooted in a history of institutional absence and social conflict. When authorities prioritize coercive measures (M1, M5) without providing adequate road infrastructure, riders perceive these actions as primarily revenue-seeking rather than genuine efforts for public welfare. This reinforces the need for procedural justice: involving the motorcycling community in the design of noise-control policies is essential to transform them from perceived impositions into legitimate social norms. Consequently, resistance to regulations in Florencia should be viewed as a rational response to perceived institutional injustice rather than an irrational reaction [10, 23].

In addition to socio-cultural factors, individual elements also influence normative perception. In this study, a significant association was identified between educational level and positive appraisal of regulatory measures. This result is consistent with international literature highlighting the role of formal education in the construction of normative attitudes and prosocial behavior [4, 11].

The positive association between educational level and regulatory appraisal suggests that formal education is associated with a greater sense of collective responsibility. This finding is particularly relevant in the Amazonian context. In contrast, accumulated driving experience did not show statistically significant effects on regulatory perception, leading to the rejection of H2. This result differs from findings in other Latin American contexts, such as Brazil [14], where experience acts as a protective factor against traffic offenses. The evidence suggests that in cities marked by high structural informality like Florencia, a normalization of risk and noise occurs, where both novice and experienced riders appear equally habituated to chaotic traffic patterns and high acoustic levels.

Complementarily, our data revealed that participants perceive a strong coherence between different measures aimed at environmental noise control, such as horn restrictions and low-noise zones. This integrated perception suggests that motorcyclists view regulations as interdependent parts of a cohesive system. Furthermore, the weak correlation between perceived noise and self-reported aggressive driving reveals a cognitive dissonance: while riders identify the city's acoustic environment as stressful and harmful, they tend to externalize its causes.

These findings indicate that combining structural improvements with educational initiatives may be more effective than relying predominantly on coercive regulations in contexts such as Florencia.

6 Conclusions

This study provides empirical evidence on how urban motorcyclists in Florencia perceive the effectiveness of traffic and noise control measures. In a context of high structural informality and weak institutional governance, the results demonstrate a clear preference for educational and structural strategies—such as awareness campaigns and road infrastructure improvements—over coercive measures. This tendency highlights the importance of designing participatory public policies that are perceived as legitimate by the community.

The analysis revealed that educational level has a significant positive effect on the normative appraisal of regulatory measures (H1 confirmed), whereas accumulated driving experience does not (H2 rejected). In informal contexts, formal education emerges as a key factor in promoting voluntary compliance by strengthening pro-social attitudes toward the urban commons. Consequently, traffic education should be treated as a sustained pedagogical process integrated into the social fabric rather than a one-time session.

From a practical perspective, these findings offer specific guidance for urban noise management and mobility policy in intermediate cities:

- Environmental health integration: Noise control should be rebranded as a public health priority. Authorities should implement “Low-Noise Zones” near schools and hospitals, using physical barriers and signage to encourage riders to behave quietly.

- Infrastructure as regulation: Investing in road quality and acoustic-absorbing pavement acts as a non-coercive tool for noise reduction. These structural measures increase spontaneous compliance without the need for constant policing.

- Inclusive governance: To address institutional mistrust, the creation of “Motorcyclist Tables” for policy co-design is essential. This ensures that environmental regulations are viewed as shared efforts toward environmental justice rather than predatory revenue-generating tactics. In a city where motorcycles represent the vast majority of the vehicle fleet, environmental justice is not a theoretical ideal but a practical requirement for social peace. Recognizing riders as active partners in noise reduction—rather than merely as sources of pollution—is the only viable path to sustainable compliance and the protection of the right to a healthy environment in the Amazonian context.

While the use of a convenience sample restricts generalizability, this research provides a critical foundation for territories with high informality. Future studies should bridge the gap between subjective perceptions and objective data by developing a multidimensional noise-exposure index that correlates decibel levels with local socioeconomic strata. Ultimately, combining environmental justice metrics with technical interventions will ensure that urban mobility policies are effective, equitable, and socially legitimized.

Author Contributions

Conceptualization, A.Y.C.-P. and E.J.O.-M.; methodology, A.Y.C.-P. and E.J.O.-M.; software, A.Y.C.-P.; validation, A.Y.C.-P. and E.J.O.-M.; formal analysis, A.Y.C.-P., E.J.O.-M., and S.S.-G.; investigation, A.Y.C.-P., E.J.O.-M., and S.S.-G.; resources, A.Y.C.-P.; data curation, A.Y.C.-P. and E.J.O.-M.; writing—original draft preparation, A.Y.C.-P.; writing—review and editing, A.Y.C.-P., E.J.O.-M., and S.S.-G.; visualization, A.Y.C.-P., E.J.O.-M., and S.S.-G.; supervision, E.J.O.-M. and S.S.-G.; project administration, S.S.-G.; funding acquisition, S.S.-G. All authors have read and agreed to the published version of the manuscript.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Declaration on the Use of Generative AI and AI-assisted Technologies

During the preparation of this work, the authors used DeepL and Grammarly to enhance the fluency and readability of the manuscript. The authors subsequently reviewed and edited the content as needed and take full responsibility for the content of the published article.

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