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Article

Enhancing intersection safety: Testing measures to reduce law violations in Loja (Ecuador)

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Abstract: This study evaluates the effectiveness of measures aimed at reducing traffic violations, specifically focusing on wrong-way driving, at intersections in Loja, Ecuador. The high incidence of accidents at these intersections, often resulting from wrong-way driving and non-compliance with traffic regulations, underscores the critical need for effective strategies to enhance road safety. To address this issue, we adopted a multidisciplinary approach to assess the impact of two specific interventions: the implementation of official warnings and the presence of traffic officers at a selected intersection. Data collection involved recording instances of traffic violations, administering road safety surveys, and monitoring the implementation of these interventions. The post-implementation analysis sought to determine the effect of these measures on driver behavior and overall traffic safety. Our findings indicate that while the interventions succeeded in increasing awareness about traffic violations, they did not produce a significant reduction in undesirable driving behaviors. This suggests that, although the presence of warnings and traffic officers is beneficial in raising awareness, these measures alone may not be sufficient to effect substantial behavioral changes. The research provides valuable insights for the development of more comprehensive road safety strategies and emphasizes the need for further studies to explore and address the underlying causes of traffic violations.

Keywords: intersection safety; law violations; wrong-way driving; control measures; road traffic crashes

1. Introduction

Road traffic injuries represent a severe global public health crisis, with the World Health Organization estimating approximately 1.19 million deaths and up to 50 million injuries annually (WHO, 2023). These incidents not only cause significant human suffering but also impose a substantial economic burden on societies (Mohammed et al., 2019). In response, the United Nations has initiated the Decade of Action for Road Safety 2021–2030, with the goal of reducing road traffic deaths and injuries by 50% by 2030 (United Nations, 2020). In Ecuador, the impact is particularly pronounced, with road traffic accidents emerging as a leading cause of death, evidenced by over 2373 fatalities and more than 18,000 injuries in 2023 alone (ANT, 2023).

Intersections, due to their inherent complexity—including traffic lights, road signs, pedestrian crossings, and turning lanes—are critical points of concern. The intricate nature of these junctions often results in a higher incidence of collisions, making them a focal point for improving road safety (Adli and Naharudin, 2022). Driver behavior, including issues such as inattention, running red lights, and improper turns, is a major factor contributing to intersection accidents (Hussein and Hassan,

2023). Understanding how perception errors impact traffic safety, especially at unsignalized intersections, is crucial (Berkhahn et al., 2022). Advanced statistical analyses and machine learning algorithms are increasingly used to develop predictive models for accident severity, incorporating variables such as time, road surface condition, accident type, and vehicle type (Hsu et al., 2020). These findings highlight the need for enhanced driver education, stricter enforcement of traffic laws, and improved intersection design to mitigate accident risks.

Globally, non-compliance with traffic laws remains a significant issue, contributing to both safety concerns and traffic congestion (Gultom, 2020). Examples include drivers in Indonesia who often ignore traffic flow regulations due to various factors, including lack of awareness and peer influence (Pelanggaran et al., 2024). In South Korea, older drivers have been observed to be less compliant with traffic regulations such as stopping at stop signs (Kim and Kim, 2017), while in Argentina, low compliance rates with seat belt and helmet use have been reported (Beltramino and Carrera, 2007). Nigeria also faces challenges with high non-compliance rates for mobile phone use and seat belt laws (Akinyemi, 2023).

In Ecuador, specific unsafe behaviors, such as not fastening helmets and being distracted by mobile phones while driving, are prevalent among motorcyclists (Febres et al., 2024). Additionally, solo drivers often exhibit riskier behaviors (García-Ramírez et al., 2023), and there is varied agreement among respondents regarding traffic laws, with many expressing dissatisfaction with current regulations (García-Ramírez et al., 2018). These observations underscore the necessity for a more comprehensive approach to road safety, combining stricter enforcement, public education campaigns, and infrastructure improvements. Further research is needed to better understand these behaviors and develop targeted approaches for their prevention.

This study aims to contribute to this broader context by evaluating specific measures to prevent traffic law violations, with a focus on wrong-way driving. The intervention, which included issuing official warnings and the presence of a traffic officer at a selected intersection in Loja, Ecuador, was assessed through collected data and a post-study survey on road safety. By analyzing the effectiveness of these measures, this research seeks to provide evidence-based recommendations for improving road safety strategies and enforcement. The findings could offer valuable insights for enhancing road safety efforts not only within Loja but potentially in other similar contexts, contributing to the broader goal of reducing road traffic injuries and fatalities.

2. Materials and methods

2.1. Selection criteria and study site

To conduct this study, the intersection needed to meet specific criteria: a) The ability to detect contraflow traffic; b) The presence of a structure or building to facilitate interactions with other road users at the intersection. c) Access to a site with electricity and protection against vandalism for installing recording equipment. The intersection of Segundo Cueva Celi and Segundo Puertas streets in Loja, Ecuador, met all these criteria and was selected as the study site, as shown in **Figure 1**.

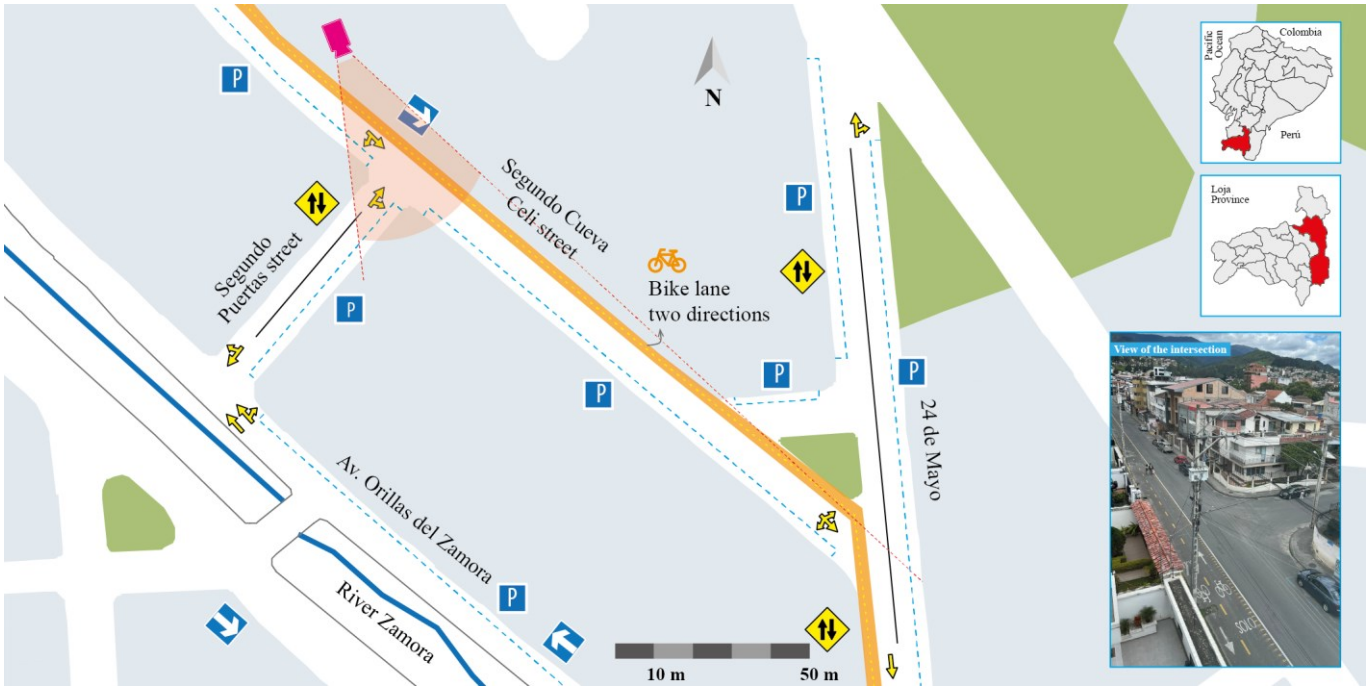


Figure 1. Study site location: Intersection of Segundo Cueva Celi and Segundo Puertas streets, Loja, Ecuador.

2.2. Methodology of data collection

This study was conducted in three distinct stages:

1) Observation Stage: In this initial stage, a surveillance camera was placed at the study intersection to continuously monitor vehicular movement for 2 weeks. The goal was to document the general behavior of road users without affecting their usual traffic decisions.
2) Online Survey: The second stage involved distributing an online survey about road safety. The survey was specifically sent to residents of buildings where at least one person had been observed driving in the wrong direction on the streets being studied. The purpose of this stage was to understand how these individuals perceive road safety.
3) Testing Measures: The final stage included implementing measures to modify driver behavior at the intersection. The traffic control authority issued an official notice stressing the importance of following traffic regulations, particularly regarding bike lanes and contraflow traffic. A traffic officer was also stationed at the intersection to reinforce this notice, but no fines were imposed; only warnings were given. A follow-up assessment was conducted over 4 weeks, on different days and times, to evaluate the effectiveness of these measures in changing driver behavior.

While the use of surveillance cameras and online surveys provided valuable data for this study, future research could enhance the robustness of findings by incorporating additional data collection methods. For example, direct interviews with drivers involved in contraflow incidents could offer deeper insights into behavioral motivations. Additionally, employing manual counts or GPS tracking could provide more comprehensive data on traffic patterns. These methods could help refine intervention strategies and improve road safety outcomes.

2.3. Instrumentation for data collection

The study used the following instruments for data collection throughout its stages:

1) Observation Stage: A surveillance camera was placed at the study intersection to capture vehicular movement continuously over a 2-week period. This camera provided objective data on road users' behavior without interfering with their normal activities.
2) Online Survey: An online survey was developed to gather insights into drivers' perceptions and attitudes toward road safety. The survey was distributed through the building owners, employees, and administrators.
3) Testing Measures: During the implementation stage, an official notice from the traffic control authority was used to promote adherence to traffic regulations. A traffic officer was also stationed at the intersection to support the notice. The officer issued warnings to violators rather than fines, aiming to evaluate how these measures affected driver behavior.

2.4. Data collection

During Stage 1, data collection took place over a period of 2 weeks, including at least two occurrences of each day of the week (e.g., two Mondays, two Tuesdays, etc.). This stage was conducted from 22 April to 5 May 2024. In Stage 2, surveys were collected from 22 April to 6 May 2024. Stage 3 involved applying the measures from 12 June to 28 June 2024. Data collection to evaluate whether the behavior changed as a result of these measures was carried out throughout July 2024, following a similar method to Stage 1.

2.5. Data processing

The data processing was organized into three distinct stages. In the first stage, counts of cyclists and vehicles were taken every 15 min throughout each day of data collection. From these counts, daily averages were computed over a two-week period, and graphs were created to illustrate vehicle and cyclist flow. Additionally, traffic violations, such as contraflow circulation, were documented. The second stage involved analyzing data from surveys completed by residents or business owners in buildings identified in the first stage as being non-compliant with traffic regulations. The final stage involved assessing the impact of the measures implemented by counting infractions on the days surveyed after the measures were applied and comparing these with the counts recorded in the first stage.

2.6. Data analysis

The data analysis was carried out using Minitab 14.2 statistical software (State College, 2005). It started by presenting the vehicular and cyclist flow data, followed by descriptive statistics from the survey results. Next, a statistical analysis of the survey data was conducted, including a t-test to determine the significance of any differences observed between the results before and after the measures were implemented. Finally, a thorough analysis of all the data in the study was completed.

We used t-tests to compare pre- and post-intervention data. While t-tests are suitable for this, they have limitations like assuming equal variances and normality.

Future research could use regression analysis or ANOVA for a more comprehensive understanding of intervention effectiveness. Despite these limitations, t-tests provide valuable insights within our study. Recognizing these constraints helps contextualize our findings and highlights areas for improvement in future analyses.

3. Results

3.1. Stage 1: Observation

Traffic volumes were recorded every 15 min using camera footage and then averaged for the available days, such as Tuesdays and Wednesdays. This was done for three specific traffic directions: vehicles traveling along Segundo Cueva Celi Street, vehicles turning from Segundo Cueva Celi onto Segundo Puertas Street, and vehicles merging from Segundo Puertas Street onto Segundo Cueva Celi. The averages for all days and directions are shown in **Figure 2**.

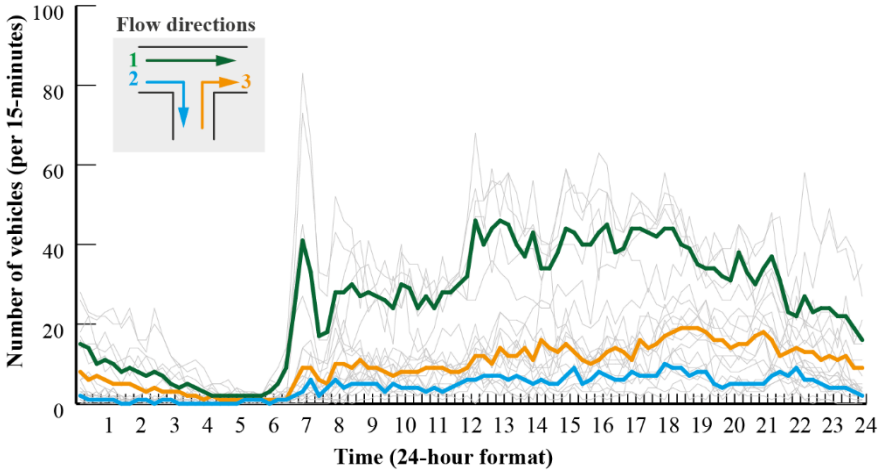


Figure 2. Average traffic volumes by direction and day of the week.

Figure 2 shows that traffic flow is highest starting at 7:00 AM, decreases slightly, and then peaks again between 12:00 and 1:00 PM. It remains steady before declining after 6:00 PM. The busiest traffic is on Segundo Cueva Celi Street, followed by vehicles merging onto Segundo Cueva Celi from Segundo Puertas Street. The lowest traffic flow is from those turning onto Segundo Puertas from Segundo Cueva Celi. Additionally, the average cyclist flow was 145 (with a minimum of 104 and a maximum of 167). Although the cyclist count is not high, it remains consistent throughout the day.

As for wrong-way driving, three main types of violations were identified (see **Figure 3**): 1) vehicles approaching the main road from a side street, either reversing to park on the main road or entering from the side street and driving against traffic on the main road; 2) vehicles exiting a garage, parking on the main road, then reversing along the road before continuing onto the side street; 3) vehicles approaching the main road from a side street, making a U-turn on the main road, and returning to the side street. These maneuvers are dangerous as they can lead to collisions with other vehicles or pedestrians and encourage a disregard for traffic laws. The analysis identified five locations (a bar, bar-café, residence, and two buildings) where these

violations were frequent. These locations were targeted for the survey in the next stage.

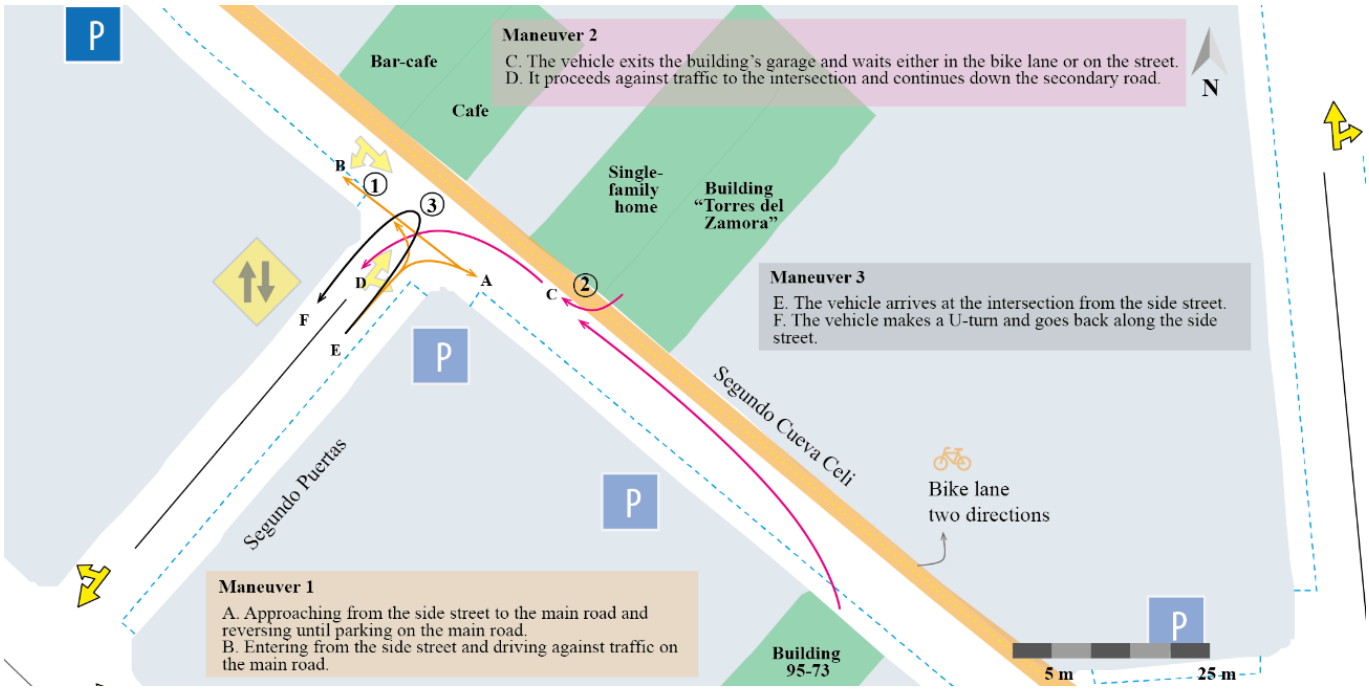


Figure 3. Types of wrong-way driving maneuvers observed at the intersection.

Over the two-week period, 247 wrong-way maneuvers were recorded, averaging about 18 per day. The daily averages were 5.3 on Monday, 19.5 on Tuesday, 20.5 on Wednesday, 22 on Thursday, 25.5 on Friday, 22 on Saturday, and 10 on Sunday, indicating that Friday saw the highest number of these maneuvers.

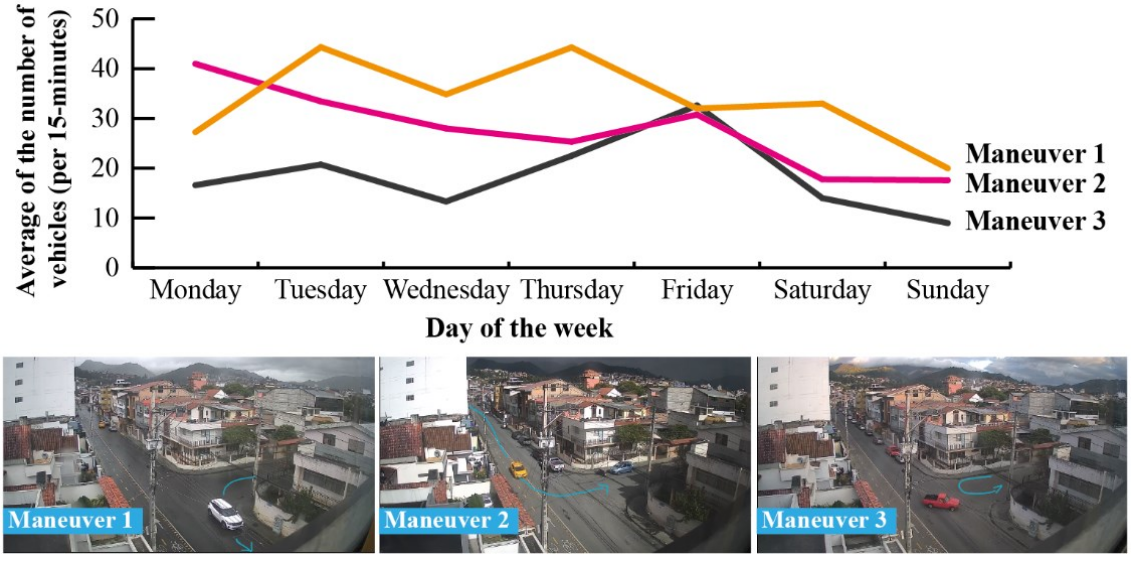


Figure 4. Relationship between traffic volume and frequency of wrong-way maneuvers across different days.

To explore the relationship between the number of wrong-way maneuvers and the volume of vehicles at the intersection, **Figure 4** was created. It shows the average number of vehicles passing through every 15 min when each maneuver occurred on different days. The figure reveals that Maneuver 1 tends to happen during high traffic

volumes on most days, while Maneuver 2 typically occurs during lower traffic volumes. Maneuver 3 falls somewhere in between the other two in terms of traffic volume on most days. Notably, on Fridays, the traffic volumes for all three maneuvers are similar, suggesting that as the weekend approaches, the likelihood of each maneuver is roughly equal. It might be expected that fewer vehicles would lead to an increase in wrong-way maneuvers, but the graph does not support this notion. In some instances, these maneuvers occur during heavy traffic, possibly because the bike lane, which lacks a physical barrier, is perceived as a convenient refuge.

3.2. Stage 2: Online survey

Following the initial observations, an online survey was designed to gauge how much residents of the detected building value sustainable mobility. The survey was created using Microsoft Forms® and shared through the residents' social media channels. While the survey included general questions, there was also a section for participants to specify their vehicle make and type, allowing for a comparison with the infringement data. Unfortunately, only one vehicle frequently involved in wrong-way maneuvers responded, so the analysis was extended to include all other residents of the buildings.

Twenty-two residents responded to the survey. Of these, 54% said they occasionally or never use alternative transportation methods in their daily routines. Fifty percent felt insecure or very insecure when moving around their building and neighborhood, while 36% felt neutral about walking in the area. Additionally, 95% of respondents reported having observed dangerous driving behaviors near their building or neighborhood, such as speeding or distracted driving. Similarly, 95% believe that additional measures are needed to improve road safety in the area. When asked to rate their own behavior as a driver, pedestrian, cyclist, or motorcyclist, 41% considered themselves better than average, while another 41% rated themselves as worse than average. The remaining 18% considered their behavior to be average.

Figure 5 provides further details on these responses. Residents indicated that the neighborhood mainly needs improvements in safety signage, sidewalks, adequate lighting, and speed reduction. This is consistent with the view of the majority (54%) who feel that the current infrastructure does not adequately prioritize pedestrians and cyclists.

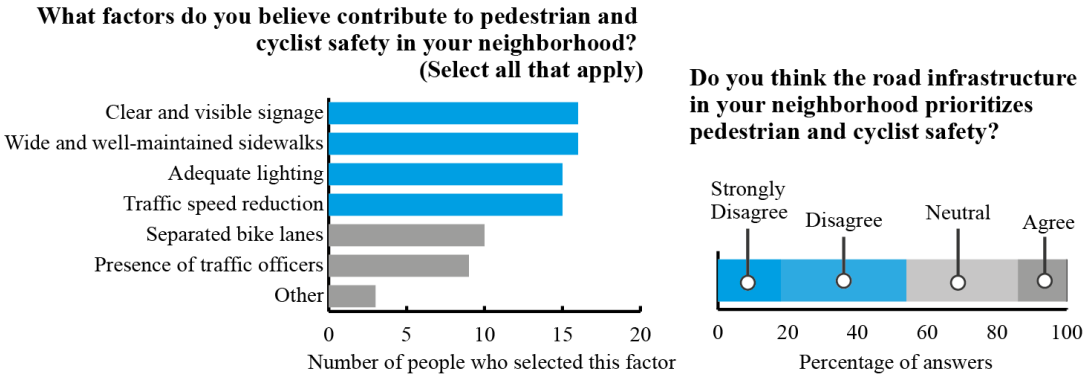
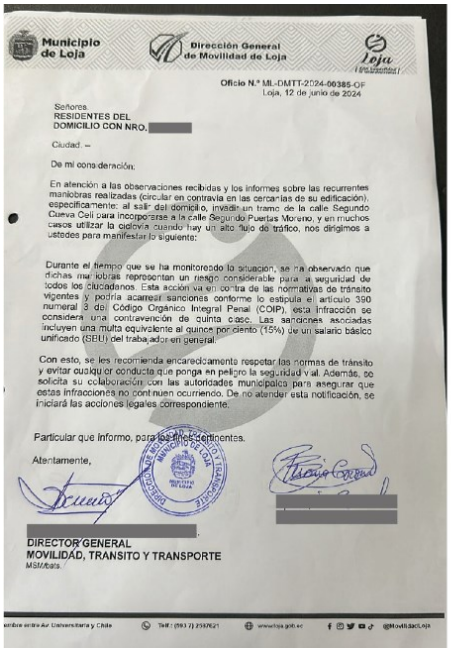


Figure 5. Resident feedback on road safety improvements and perceptions of infrastructure.

3.3. Stage 3: Testing measures

In this stage, traffic control measures were implemented. Notes were sent to property owners or managers to inform them about the recurring traffic violations observed. The notes detailed the specific types of violations recorded and the potential legal consequences. They also requested the residents' cooperation with municipal authorities to prevent these violations from continuing. Each note was customized to include the type of violation, names, and addresses related to the building. These notes were delivered on 12 June 2024. An example of one of these notes, along with its English translation, is shown in **Figure 6**.



Municipio de Loja

Dirección General de Movilidad de Loja

Oficio N.° ML-DMTT-2024-00385-OF
Loja, 12 de junio de 2024

Señores,
RESIDENTES DEL
DOMICILIO CON NRO. [redacted]
Ciudad. –

De mi consideración:

En atención a las observaciones recibidas y los informes sobre las recurrentes maniobras realizadas (circular en contravía en las cercanías de su edificación), específicamente: al salir del domicilio, invadir un tramo de la calle Segundo Cueva Celi para incorporarse a la calle Segundo Puertas Moreno, y en muchos casos utilizar la ciclovía cuando hay un alto flujo de tráfico, nos dirigimos a ustedes para manifestar lo siguiente:

Durante el tiempo que se ha monitoreado la situación, se ha observado que dichas maniobras representan un riesgo considerable para la seguridad de todos los ciudadanos. Esta acción va en contra de las normativas de tránsito vigentes y podría acarrear sanciones conforme lo estipula el artículo 390 numeral 3 del Código Orgánico Integral Penal (COIP), esta infracción se considera una contravención de quinta clase. Las sanciones asociadas incluyen una multa equivalente al quince por ciento (15%) de un salario básico unificado (SBU) del trabajador en general.

Con esto, se les recomienda encarecidamente respetar las normas de tránsito y evitar cualquier conducta que ponga en peligro la seguridad vial. Además, se solicita su colaboración con las autoridades municipales para asegurar que estas infracciones no continúen ocurriendo. De no atender esta notificación, se iniciará las acciones legales correspondiente.

Particular que informo, para los fines pertinentes.

Atentamente,

[redacted]
DIRECTOR GENERAL
MOVILIDAD, TRANSITO Y TRANSPORTE
MSM/[redacted]

Translation to ENGLISH

Official Letter No. ML-DMTT-2024-00385-OF
Loja, June 12, 2024

To the Residents of
Residence No. [redacted]
City –

Dear Sir/Madam,

In response to the observations received and the reports regarding the recurring maneuvers being carried out (driving against traffic near your property), specifically: when exiting the residence, crossing a section of Segundo Cueva Celi Street to merge onto Segundo Puertas Moreno Street, and in many cases using the bike lane when there is heavy traffic, we would like to inform you of the following:

During the time this situation has been monitored, it has been observed that these maneuvers pose a considerable risk to the safety of all citizens. This action violates current traffic regulations and may result in penalties as stipulated in Article 390, Section 3 of the Organic Comprehensive Penal Code (COIP). This infraction is considered a fifth-class misdemeanor. The associated penalties include a fine equivalent to fifteen percent (15%) of a unified basic salary (UBS) of a general worker.

We strongly recommend that you comply with traffic regulations and avoid any conduct that endangers road safety. Furthermore, we request your cooperation with municipal authorities to ensure that this infraction does not continue. Failure to comply with this notification will result in the initiation of corresponding legal actions.

This information is provided for your consideration.

Sincerely,

Signature [redacted]

Figure 6. Example of notice sent to property owners or managers regarding traffic violations.

Figure 7. Photographs of traffic officers on site for deterrence and monitoring.

Additionally, traffic officers were stationed in the area from 24 June to 28 June 2024, starting at 5:00 PM. At times, officers stayed for a little over an hour, which was during the peak time for recorded wrong-way maneuvers. The officers did not issue

fines but were present to deter violations by demonstrating that the municipality was aware of the problem and was acting. Photographs of the traffic officers in the area are shown in **Figure 7**.

After implementing the two measures, data were collected over one month to assess if these actions led to a reduction in the observed maneuvers. **Figure 8** displays the average number of violations for each of the three maneuvers, broken down by day of the week.

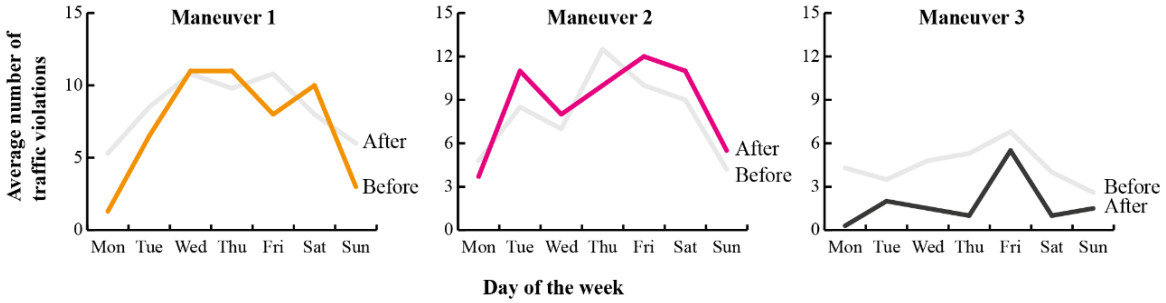


Figure 8. Average number of traffic violations before and after measures by day of the week.

The data collected before and after the measures reveal a similar pattern, with peaks and troughs aligning closely with the days of the week. This suggests that the data collection and processing were consistent. For Maneuver 1 and Maneuver 2, it is noted that Mondays and Sundays generally report fewer violations. For Maneuver 1 specifically, there was an increase in violations on Mondays, Fridays, and Sundays, with a slight decrease on other days. For Maneuver 2, an increase in violations was observed on Mondays and Thursdays after the measures were implemented, while violations decreased on other days. Maneuver 3, although the least frequent of the three, saw an increase in violations across all days after the measures, especially on Fridays, which often marks the beginning of the weekend.

To determine whether there was a significant decrease in violations for the different maneuvers, a t-test was performed. This test compared the number of violations before and after the implemented measures. The t-test was chosen because the sample size for each maneuver did not exceed 30 data points. A significance level of 0.05 was used for the analysis, as detailed in **Table 1**.

Table 1. Statistical comparison of traffic violations before and after measures (*t*-test results).

Maneuver	Day	CI*	*T*–value	*P*–value
1	Mon	−10.0, 2.2	−2.04	0.134
	Tue	−35.6, 31.6	−0.76	0.588
	Wed	−15.6, 16.1	0.07	0.952
	Thu	−15.4, 17.9	0.32	0.778
	Fri	−7.5, 2.0	−1.84	0.163
	Sat	2.7, 10.5	4.72	0.009
	Sun	−30.8, 24.8	−1.37	0.402

Table 1. (*Continued*).

Maneuver	Day	CI*	*T*−value	*P*−value
2	Mon	−3.7, 1.5	−1.32	0.279
	Tue	−25.2, 30.2	1.15	0.456
	Wed	−50.1, 52.1	0.25	0.845
	Thu	−18.1, 15.1	−0.29	0.792
	Fri	−3.6, 7.6	1.55	0.261
	Sat	−48.0, 55.6	0.93	0.523
	Sun	−1.3, 3.9	1.38	0.240
3	Mon	−6.2, −1.6	−4.77	0.009
	Tue	−7.2, 4.2	−1.13	0.374
	Wed	−5.8, −0.7	−4.04	0.027
	Thu	−8.4, −0.1	−3.23	0.048
	Fri	−7.0, 4.5	−0.69	0.542
	Sat	−8.8, 1.9	−2.72	0.113
	Sun	−3.4, 1.2	−1.54	0.221

Note: * means 95% CI for difference.

Overall, the frequency of Maneuver 1 does not show significant differences on most days of the week ($p > 0.05$). This indicates that the measures implemented did not substantially impact the reduction of this maneuver on those days. However, on Saturdays, there is a significant difference ($p = 0.009 < 0.05$), with a confidence interval suggesting an increase in the frequency of this maneuver after the measures were applied. Fridays show a trend toward significance ($p = 0.163$) with a confidence interval that suggests a possible decrease, although this reduction is not statistically significant.

For Maneuver 2, none of the days show significant differences (all p-values > 0.05). This indicates that the measures had no significant effect on the frequency of this maneuver, suggesting that the actions taken were ineffective.

Significant differences for Maneuver 3 were observed on Mondays ($p = 0.009$), Wednesdays ($p = 0.027$), and Thursdays ($p = 0.048$). The negative confidence intervals for these days indicate that the frequency of this maneuver increased after the measures were implemented. This suggests that, despite the efforts, Maneuver 3 significantly increased on these specific days. No significant differences in Maneuver 3 were observed on other days.

The measures had the most notable impact on Maneuver 3, but in a negative way, as there was a significant increase on three days of the week. This implies that the measures were not effective in reducing this maneuver. Maneuver 1 showed a significant increase on Saturdays, indicating that additional measures might be needed for this day. Maneuver 2 was not significantly affected by the measures, suggesting that the actions taken did not impact its frequency.

4. Discussion

This study aimed to evaluate the effectiveness of specific measures—namely

official warnings and the presence of traffic officers—in reducing wrong-way driving at intersections in Loja, Ecuador. The high incidence of accidents due to wrong-way driving underscores the urgent need for effective road safety solutions.

The implementation of official warnings and traffic officer presence did increase drivers' awareness of traffic violations, which aligns with previous studies suggesting that such measures can heighten driver awareness and improve compliance with traffic laws. Research has shown that official warnings and implementation intentions can lead to increased compliance with traffic laws, indicating that these measures can promote learning and behavior change among drivers (Belloc et al., 2011). Additionally, a visible police presence has been found to significantly reduce traffic violations and increase driver vigilance, serving as an effective deterrent (Nakano et al., 2019; Yuliantoro and Sulchan, 2021)

However, despite the increased awareness, this study found no significant reduction in the frequency of wrong-way driving or other traffic violations. While the awareness-raising measures in this study were beneficial, they alone were insufficient for achieving significant behavioral change. This limitation highlights the need for a more integrated approach to road safety. Evidence from existing literature suggests that incorporating stricter law enforcement, targeted public education campaigns, and infrastructural improvements could enhance the effectiveness of individual measures. Effective enforcement strategies should focus on maximizing deterrence and increasing both the perceived and actual probability of apprehension (Bates et al., 2012), infrastructure improvements (Friday, 2012), education (Bovornkijprasert and Rawang, 2016) and the use of intelligent transport systems (ITS) (Young and Regan, 2007) could further support compliance.

Based on the study's findings, the most effective outcome would likely involve making infrastructure changes. For example, this could include adding a physically separated bike lane, converting Segundo Puertas into a one-way street, redesigning the intersection, or implementing a combination of these changes. The current strategies proved insufficient, highlighting the need for such infrastructure improvements.

The study also found a relationship between traffic volume and violations, aligning with existing research that shows a complex interplay between these factors. While higher traffic volumes typically lead to more crashes, they are often associated with lower crash severity (Jiang et al., 2021). For example, during the COVID-19 pandemic, despite reduced traffic volumes, violation rates increased significantly (Sobreira et al., 2022). Moreover, studies have shown that a driver's history of traffic violations can predict their likelihood of future accident involvement (Shawky et al., 2017). The relationship between traffic volume and conflicts appears to be linear in uncongested conditions but becomes non-linear when congested states are included, with significantly higher conflicts observed during congestion (Qu et al., 2015).

Residents are aware of the road safety issues in their neighborhood and recognize the need for infrastructure improvements. They understand that the current infrastructure does not align with the principles of the mobility pyramid, which prioritizes pedestrian and cyclist safety. These results indicate that an integrated approach is needed—one that combines infrastructure upgrades, awareness campaigns, and stricter enforcement to effectively change dangerous driving behaviors.

This study has several limitations. First, focusing on just one intersection in Loja

means the findings might not apply to other places. While this allows for a detailed analysis, future research should study multiple intersections in different cities. Second, the four-week follow-up period might not be long enough to see the full effects of the changes. Longer studies would provide stronger evidence. Third, the study didn't directly ask drivers about their wrong-way driving. While observations and surveys were helpful, interviews would provide more insights into why drivers make this mistake. This would help us create better safety measures. Finally, some measures didn't significantly affect certain types of wrong-way driving. We need to understand why these measures failed. Future studies should consider using a variety of data collection methods, like driver interviews, manual traffic counts, and GPS tracking, to get a better understanding of traffic behaviors and the effectiveness of interventions. Future research should also explore the reasons behind the failures of certain measures, such as problems with implementation or specific characteristics of the maneuvers, to develop more effective solutions.

Despite its limitations, the study provides valuable insights into improving road safety at intersections. By evaluating the effectiveness of control measures like official warnings and the presence of traffic officers, this research offers practical evidence for strategies aimed at reducing traffic violations, particularly wrong-way driving. The study's findings can inform the formulation of traffic policies and the implementation of road safety measures in similar areas. Additionally, the combination of direct observations and surveys provides a comprehensive understanding of driver behaviors and resident perceptions, which can guide future initiatives to enhance intersection safety.

5. Conclusion

This study highlights that while official warnings and the presence of traffic officers at intersections successfully increased awareness of violations like wrong-way driving, these measures alone did not lead to significant reductions in unsafe driving behaviors. This underscores the need for a more comprehensive approach to road safety, suggesting that awareness campaigns are insufficient on their own to drive substantial changes in driver behavior. To effectively address traffic violations, it is essential to adopt a broader strategy that includes stricter law enforcement, extensive public education campaigns, and targeted infrastructure improvements. The findings from this study emphasize the practical applications of combining multiple strategies to enhance road safety. Future research should focus on evaluating the impact of integrated interventions on driver behavior, considering factors such as road design, signage, and local driving culture, as well as exploring long-term effects of various measures. This study contributes to the understanding of road safety interventions and supports the development of more effective policies by advocating for a multifaceted approach that tackles the root causes of traffic violations. By implementing such comprehensive strategies, policymakers and urban planners can work towards creating safer driving environments and improving compliance among road users.

Author contributions: Conceptualization, YGR; methodology, YGR; software, SC; validation, SC and YGR; formal analysis, SC and YGR; investigation, SC and YGR;

data curation, SC and YGR; writing—original draft preparation, SC and YGR; writing—review and editing, YGR; visualization, YGR; supervision, YGR. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest: The authors declare no conflict of interest.

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