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AN ASSESSMENTOF THE EFFECTIVENESS OF TRAFFIC CALMING MEASURES ON ROAD SAFETY IN NYARUGENGE DISTRICT, KIGALI CITY, RWANDA

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ABSTRACT

Traffic congestion and pedestrian safety remain critical challenges in Nyarugenge District, one of Kigali's most densely trafficked areas and home to Rwanda's Central Business District (CBD). This study aims to assess the effectiveness and suitability of traffic calming measures and their impact on road safety in Nyarugenge District, Kigali City, Rwanda. The specific objectives were to: (i) identify and map existing traffic calming devices across the district; (ii) evaluate their geometric compliance with Rwanda Transport Development Agency (RTDA) standards and their influence on driver and pedestrian behavior; and (iii) formulate evidence-based guidelines for improved device installation, spacing, and maintenance. A mixed-methods approach was employed, combining field surveys using GPS and engineering measurement tools, structured traffic behavioral observations during peak and off-peak hours, and questionnaires administered to road users and transport technicians. Data was analyzed using Microsoft Excel and SPSS. Key findings revealed that 39 traffic calming devices were identified across the district, comprising 21 speed humps, 5 rumble strips, 10 warning signs, and 3 pedestrian crossings. Geometric analysis showed that 43% of speed humps exceeded the RTDA maximum height standard of 100 mm, with flat-topped humps in Nyabugogo and Kiyovu reaching heights of up to 153.5 mm. Additionally, 25% of devices showed visible degradation in marking or signage. Behavioral observations indicated higher driver compliance during peak hours (75–82.5%), with compliance declining during off-peak periods when enforcement presence was reduced, and with recurring violations including speeding near schools and failure to yield at pedestrian crossings. These findings are significant because they provide the first systematic, field-based evidence of the geometric compliance and behavioral effectiveness of traffic calming infrastructure in Nyarugenge. The implications for policy and practice are clear: responsible agencies must enforce RTDA design standards, reconstruct non-compliant humps, expand rumble strip coverage to accident-prone zones, and conduct public awareness campaigns. Without targeted intervention, the current infrastructure will continue to fall short of its road safety objectives.

KEYWORDS: Calming devices, road safety, rumble strips, speed humps

INTRODUCTION

Road safety remains a critical challenge worldwide, with over 1.35 million deaths occurring annually due to road traffic accidents (Ehsani, et al. 2023).

Urban areas continue to face major challenges such as traffic congestion, high accident rates, and pedestrian safety concerns.

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To address these issues, many cities have adopted traffic calming measures such as speed humps, pedestrian crossings, rumble strips, and signage. These strategies aim to reduce vehicle speeds and improve safety for all road users. Recent studies have shown that well-planned traffic calming interventions can reduce accidents and enhance pedestrian safety. For instance, such measures led to a reduction in traffic accidents by up to 39%, while many African cities including Nairobi, Johannesburg, and Lagos still struggle with high pedestrian fatality rates, partly due to rapid urbanization, inadequate enforcement, poorly designed and poorly maintained calming devices(Refaat, et al. 2024). Rwanda faces similar challenges, as Kigali City accounts for over 60% of reported road traffic crashes nationwide, according to recent road safety statistics published by the Rwanda National Police (Mulisa 2022).

Nyarugenge District, Home to Kigali central business district (CBD) is one of the most densely trafficked areas in Rwanda. The concentration of commercial activity, public institutions, and informal markets generates sustained vehicle and pedestrian demand, making it a high-risk environment for road accidents. Despite the presence of traffic calming measures, accidents and traffic violations remain frequent, as noted by (Mihigo and Lukenangula 2023), who found that over 60% of drivers in Nyabugogo do not comply with pedestrian crossing rules.

Despite the installation of traffic calming devices across Nyarugenge District, no systematic filed based study has evaluated whether these devices comply with Rwanda Transport Development Agency (RTDA) geometric standards, nor whether they produce measurable changes in driver and pedestrian behavior. Most existing literature on traffic calming in Rwanda focuses on general infrastructure improvements rather than device-specific compliance and behavioral effectiveness (GATERA 2022). This study addresses that gap by providing a comprehensive, evidence-based assessment of existing traffic calming devices in Nyarugenge, combining geometric field measurements, behavioral observation, and public perception data to generate actionable recommendations for improved road safety planning.

Traffic calming encompasses physical, visual, and psychological interventions designed to reduce vehicles speeds and improve safety (Tilahun, e et al. 2023). Physical measures such as speed humps have been shown to reduce vehicle speeds to between 20 and 30 km/h, significantly reducing the severity of accidents (Yeo, et al. 2020). In East Africa, speed humps have achieved varying degrees of effectiveness: Rwanda reports a 62% speed reduction (NYIRAJANA 2023), Kenya 55% (Osoro 2023), and Tanzania 70% (Njanda 2025), though challenges such as poor spacing, aggressive design, and maintenance deficits persist across the region.

Rumble strips serve primarily as an alerting mechanism rather than a physical speed barrier, reducing run-off-road crashes by up to 40%(Khan 2024). In Rwanda, driver compliance with rumble strips stands at approximately 55% (Segerberg and Noriega 2026), indicating potential for improvement. Studies in Kenya and South Africa have found that the effectiveness of both speed humps and rumble strips depends heavily on correct geometric design, advanced signage, and regular maintenance(Monyatsi 2020). In the Rwandan context, limited research has systematically evaluated whether installed devices meet RTDA geometric standards, particularly in Kigali's high-density districts (GATERA 2022). This study addresses that gap.

METHODOLOGY

Study Area Description

This research concentrates on Nyarugenge District, specifically targeting the roads with the highest concentration of speed humps and rumble strips: KN 20 Avenue, KN 2 Avenue, KN 7 Avenue, and KN 98 Street. The surrounding environment includes markets, bus terminals, shops, and public institutions, all of which contribute to high-intensity traffic activity and frequent traffic conflicts. The study was conducted within the Nyarugenge District, as illustrated in Figure 1 below.

LIST OF ABBREVIATION

RTDA: Rwanda Transport Development Agency

GIS: Geographic Information System

GPS: Global Positioning System

SPSS: Statistical Package for Social Sciences

SADC: Southern African Development Community

CBD: Central Business District

RTA: Road Traffic Accident(s)

RS: Rumble Strip

H: Hump (used in Hump IDs such as H1, H2)

km/h: Kilometers per Hour

cm: Centimeter

No.: Number

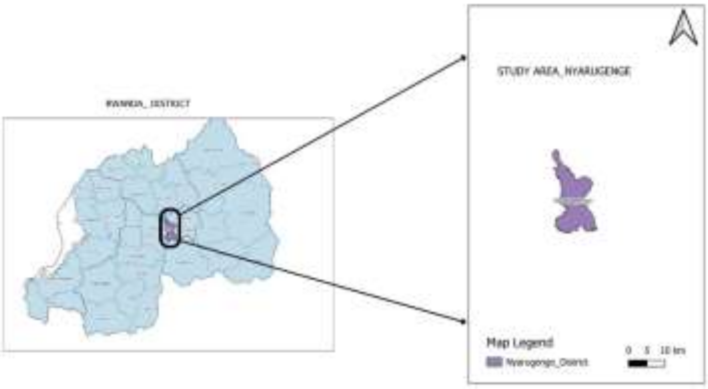

Figure 1: Location Map of the Study Area

Data Collection Methods

This study employed a mixed-methods approach combining both quantitative and qualitative data. Quantitative data included the physical geometric measurements of traffic calming devices specifically the height, width, length, and spacing of speed humps and rumble strips which were recorded numerically in the field and compared against RTDA standards. Speed hump and rumble strip measurements are therefore classified as quantitative data. Qualitative data included structured field observations of device condition, visibility, and placement adequacy, as well as the open-ended responses from questionnaire participants regarding their experiences and perceptions. This distinction guided the subsequent analytical methods applied to each data type.

Sampling Strategy and Questionnaire Design

Before describing the data collection procedures, it is important to outline the sampling approach and instrument design used in this study, as these decisions govern all subsequent data collection activities.

This study targets residents and road users of Nyarugenge District in Kigali City. The total population of Nyarugenge District is 374,319 people (NYIRAJANA 2023). To determine the appropriate sample size, Cochran's formula (1977) was adopted: $N_o = P(1-P)\, Z^2 / e^2$, Where: Z = 1.96 (95% confidence level); P = 0.5 (estimated population proportion); e = 0.07 (margin of error).

Substituting: $\mathbf{N_o = 0.5*(0.5)*(1.96)^2 / (0.07)^2 = 196}$

Applying Cochran's finite population correction: $\mathbf{n = 196 / (1 + (196-1)/374{,}319) \approx 196}$ respondents.

Given the large population size, the finite population correction has a negligible effect on the result. After accounting for potential non-responses and practical field constraints, the final adjusted sample size was set at 193 respondents, distributed proportionally across the four sectors of Nyamirambo, Gitega, Kimisagara, and Nyarugenge.

A stratified random sampling technique was adopted to ensure representation from different areas of the district. The questionnaire included both closed-ended and open-ended questions covering awareness of traffic calming measures; experiences and challenges; perceived effectiveness; and suggestions for improvement. Questionnaires were administered in both English and Kinyarwanda to improve inclusiveness and ensure quality responses.

Field Surveys

The field survey aimed to identify, categorize, and evaluate all physical traffic calming features currently in place across Nyarugenge District. A preliminary reconnaissance visit was undertaken to determine key sections experiencing high vehicular and pedestrian activity. Based on findings from this visit and in alignment with the SADC Road Traffic Signs Manual and local Rwandan road design guidelines, a standardized checklist was developed. The checklist included parameters such as the type of calming device (speed humps, rumble strips, warning signs), their location and spacing, visibility under normal traffic conditions, physical condition, and compliance with recommended geometric design standards. The checklist was developed drawing on methodologies employed in similar urban traffic safety audits, such as the approach used by (Musonda, et al. 2025) in Johannesburg, South Africa, where structured field evaluations were used to examine the spatial distribution and condition of traffic control measures in congestion-prone areas.

The geometric dimensions of speed humps were measured using a standard measuring tape. For each hump, three measurements of height were taken at the left, center, and right of the hump, and the average was used for analysis. The length of each hump was measured from the beginning to the end of the raised section along the direction of traffic. Spacing between consecutive humps was measured along the road centerline. Rumble strip width and spacing were similarly measured using a tape measure. Each device was geotagged using a GPS-enabled mobile phone to support spatial mapping. Photographic documentation was collected for all devices as a record of condition and placement.

Field data were recorded on a standardized checklist and later transferred to Microsoft Excel for analysis.

The actual survey was carried out during daylight hours, between 09:00 and 17:00, to ensure optimal visibility of road markings and signage. The survey team was composed of three members, each assigned specific roles: checklist completion, photographic documentation, and traffic activity observation. Safety precautions were observed throughout, including the use of reflective vests and coordination with local traffic authorities.

Traffic Observation

Traffic observations were conducted over a period of three weeks in March 2025, across five selected locations in Nyarugenge District: Métheo, Gitega, Nyabugogo, Kimisagara, and Kiyovu. These sites were purposely selected based on a preliminary field assessment confirming the presence of diverse traffic calming features and high pedestrian and vehicle volumes. Each observation session lasted approximately two hours, covering morning peak hours (07:00–09:00), midday off-peak hours (11:00–13:00), and evening peak hours (16:30–18:30). In total, 60 vehicles were observed (40 at peak and 20 at off-peak across all locations), and pedestrian behavior was simultaneously recorded. Three team members participated in each session, with roles assigned to vehicle counting, pedestrian observation, and notation on the standardized checklist.

Observations during both peak and off-peak periods were deliberately chosen to capture the full range of driver behavior under varying traffic conditions. Peak hours reflect high-volume, congested environments where enforcement is typically more visible, while off-peak hours allow assessment of driver behavior when traffic is lighter and enforcement presence may be reduced, a context in which non-compliance tends to increase, as confirmed by our own field data.

Observations were documented manually using notebooks and mobile phones for video recording, with each team member taking turns to ensure fairness and consistency. This observational protocol was guided by approaches adapted from (Moyo 2023), who emphasized the importance of real-time behavior monitoring in evaluating the effectiveness of traffic control systems.

It is acknowledged that the observation of 40 vehicles during peak hours and 20 vehicles during off-peak hours represents a limited sample, constrained by the manual, resource-limited nature of this study. These figures are therefore interpreted as indicative of behavioral tendencies at specific locations and time periods, rather than statistically representative of all traffic in Nyarugenge District. The findings are corroborated by questionnaire data from 193 respondents, which provides a broader statistical basis for the study's conclusions. Future research should employ automated counting tools or larger observation windows to achieve greater statistical significance.

Questionnaire Administration

To understand public perception and experiences with traffic calming measures, questionnaires were distributed to various road users including drivers, pedestrians, cyclists, motorcycle riders, and road technicians along key corridors in the study area particularly in Nyabugogo, Métheo, Gitega, Kimisagara, and the surroundings of Stade Nyamirambo. Participants were selected using convenience sampling to ensure representation of different user types and travel behaviors.

Data Analysis and Integration of Results

To ensure that data collected from field surveys, traffic observations, and questionnaires were effectively interpreted, this study adopted a triangulation approach in which findings from the three independent sources were cross-checked to identify convergent and divergent patterns.

Field survey data

Physical measurements were entered into Microsoft Excel, where descriptive statistics including means, frequencies, and percentages, were calculated for device dimensions, compliance rates, and spatial coverage. AutoCAD Civil 3D was used to generate cross-sectional profiles of all 21 speed humps, enabling a direct visual and numerical comparison of measured heights and lengths against RTDA geometric standards (height: 7.5–10 cm; length: 4.0–9.5 m).

Traffic Observation Data

Vehicle behavior was summarized using compliance rate calculations (percentage of compliant versus non-compliant vehicles per location and time period). Pedestrian behavior was analyzed qualitatively.

Questionnaire data

Responses were coded numerically and processed in SPSS. Closed-ended responses were analyzed using frequency distributions and descriptive statistics. Cross-tabulations explored relationships between variables such as road usage frequency, age group, gender, and satisfaction with calming devices. Independent samples of T-tests were applied to compare mean hump heights between compliant and non-compliant groups. Open-ended responses were analyzed thematically, with answers grouped into recurring themes including device visibility, design concerns, user comfort, and enforcement challenges. Results from all three methods were then compared to identify areas of agreement such as widespread perception of height non-compliance confirmed by field measurements and areas of contradiction, which were flagged for further discussion. This integration enabled the identification of underperforming devices and informed the study's final recommendations.

RESEARCH RESULTS AND INTERPRETATION

This chapter presents the results of data collected through field surveys, traffic observations, and questionnaires, as described in point 2. Geometric compliance of speed humps was determined by comparing field-measured heights and lengths against RTDA standards (height: 7.5–10 cm; length: 4.0–9.5 m) using descriptive statistics and cross-sectional profiles generated in AutoCAD Civil 3D. A hump was classified as height-compliant if its measured height fell within the 7.5–10 cm range and as non-compliant if it exceeded 10 cm. Spacing compliance was assessed by comparing the inter-hump distances against the RTDA-recommended minimum of 20 meters and recommended main-road spacing of 100 meters. Driver behavior compliance was calculated as the percentage of observed vehicles that met the defined behavioral criteria. Questionnaire results were analyzed using SPSS frequency distributions and T-tests. The results below are organized to correspond directly with the three research objectives stated in the Introduction.

3.1 Field Survey: Identification and Mapping of Traffic Calming Devices

The field survey identified a total of 36 traffic calming measures installed across the Nyarugenge as indicated in Table 1. District, comprising 21 speed humps, 5 rumble strips, and 10 warning signs. Among the 21 speed humps, 12 (57%) were circular and all located in Gitega, while 9 (43%) were flat-topped, distributed along main roads in Nyabugogo (5 humps) and Kiyovu (4 humps). These devices were distributed primarily near schools, residential areas, and market zones, with approximately 80% strategically placed in high-risk areas. All observed devices were geotagged using GPS to support spatial analysis and future planning.

Table 1: Observed Traffic Calming Devices and Their Characteristics

No.	Type of Calming Measure	Marking Visibility	Painting Color	Nearby Features	Comments
1	Speed humps	Visible	Visible	Schools, markets, churches, stations, curves, residential areas	Most are well designed and clearly visible
2	Rumble strips	Visible	Visible	Curves and residential areas	Only 5 were found in the district
3	Road marking	Visible	Visible	Near speed humps	Present but some faded or not clearly marked
4	Warning signals	Visible	Visible	Parking zones, intersections, road ends	Sufficient and visible to road users
5	Regulatory signs	Visible	Visible	Intersections, pedestrian crossings, speed zones	Well distributed and functioning effectively

In terms of visual clarity, 75% of devices (particularly signs and markings) were considered clearly visible, while 25% showed signs of wear or faded paint, especially at intersections and near speed humps.

Speed Humps

Speed humps were the most prevalent traffic calming measure observed, primarily located in high-risk zones such as near schools, markets, and residential areas. However, the height of many humps exceeded RTDA's standard range of 7.5 to 10 cm, the measured height ranged between 7.55 cm and 15.35 cm. In some sections, humps were spaced too closely or too far apart, reducing their overall effectiveness in controlling vehicle speeds. More details can be seen in Table 2&3.

Table 2: Circular Hump (Gutega)

Hump ID	Shape	Height(cm)	Length(m)
Gitega H1	Circular	8.51	6
Gitega H2	Circular	9.45	6
Gitega H3	Circular	7.7	6
Gitega H4	Circular	8.33	6
Gitega H5	Circular	8.67	6
Gitega H6	Circular	8.785	6
Gitega H7	Circular	8.47	6
Gitega H8	Circular	8.74	6
Gitega H9	Circular	7.549	6
Gitega H10	Circular	9.39	6
Gitega H11	Circular	8.89	6
Gitega H12	Circular	9.36	6

Flat-Topped Humps (Nyabugogo and Kiyovu)

Table 3:Dimensional Compliance of Flat-Topped Speed Humps in Nyabugogo and Kiyovu

Hump ID	Shape	Height (cm)	Length (m)
Nyabugogo Hump 1	Flat-topped	10.47	7
Nyabugogo Hump 2	Flat-topped	10.8	7
Nyabugogo Hump 3	Flat-topped	14.1	7
Nyabugogo Hump 4	Flat-topped	15.35	7
Nyabugogo Hump 5	Flat-topped	14.45	7
Kiyovu Hump1	Flat-topped	12.7	6
Kiyovu Hump2	Flat-topped	12.51	6
Kiyovu Hump3	Flat-topped	12.05	6
Kiyovu Hump4	Flat-topped	13.5	6

Rumble Strips

Five rumble strips were identified along the Metheo–Nyamirambo–Norveji road, refer to Table 3 for more details. Each strip was measured using a tape measure to record its width (perpendicular to traffic flow) and spacing between strips. GPS coordinates were collected for each strip location. The condition of each strip was assessed visually, including pavement texture, marking visibility, and the presence of advance warning signage. These measurements were compared against RTDA guidelines, which specify that rumble strips should be placed 10 to 20 meters ahead of critical areas such as pedestrian crossings or stop signs (Nkubiyaho 2020). As noted by (Zipori 2022), rumble strips are a low-cost yet high-impact traffic calming measure, particularly effective in curved zones where driver inattention is a common cause of crashes.

Table 4:Dimensions of Rumble Strips along Metheo–Nyamirambo–Norveji Route

Location	Width (m)	Length (m)	Spacing Between Strips (m)	Remarks
Norveji RS1	2.65	3.5	0.4	Visible and functional
Norveji RS2	2.65	3.5	0.4	Well positioned on curve
Norveji RS3	2.75	3.5	0.4	Near residential area
Norveji RS4	2.75	3.5	0.4	Moderate condition
Norveji RS5	2.75	3.5	0.4	Clear and effective

RS = Rumble Strip

Despite their correct placement and good visibility, the overall number is low considering the high traffic volume and multiple accident-prone areas, limiting their potential district-wide impact.

Plate 1: Rumble strips

Warning and Regulatory Signs
A total of 10 warning signs were observed across the district. The most common types included Rumble Strips Ahead, School Zone, Children Crossing, and Speed Humps Ahead. These signs were typically placed 20–50 meters before the actual calming devices, generally consistent with RTDA placement guidelines. The visibility of most signs was adequate during the daytime; however, some older signs showed signs of wear and reduced clarity, especially during low-light conditions. Regulatory signs, including STOP, Speed Limit, and Yield signs, were observed at intersections throughout the district, with generally satisfactory visibility and clarity. However, only 62% of Speed Limit signs were clearly visible at night due to faded paint and lack of retroreflective material (Nkubiyaho 2020).

Plate 2: Warning signs and Regulatory Signs

Road Markings
Road markings such as lane separators, speed hump warnings, and pedestrian approach indicators were present across most observed areas. However, a significant portion of them were faded, making them less effective in alerting drivers. According to (Alam, et al. 2024) , poorly maintained markings contribute to unsafe driving behaviors, as drivers are less likely to anticipate changes in road conditions.

Plate3: Road Markings

Geometric Compliance Analysis

Speed Hump Profile Analysis Using AutoCAD Civil 3D

Raised pavement devices were the most prevalent traffic calming measures observed in the study area, primarily located in high-risk zones such as near schools, markets, and residential areas. However, a critical distinction must be drawn between two sub-types identified in the field: speed humps and speed bumps. These terms are not interchangeable; they differ significantly in geometry, design speed, and intended application.

A speed hump is a broad, gently raised pavement section typically 4.0-9.5 m in length and 7.5-10 cm in height, designed to reduce vehicle speeds to approximately 22-35 km/h. Speed humps are appropriate for collector and local roads where moderate speed reduction is required without fully impeding vehicle flow. A speed bump, by contrast, is a shorter, steeper raised section typically less than 1 m in length with heights that can exceed 10 cm, designed to reduce vehicle speeds to 5-18 km/h. Speed bumps are more aggressive in effect and are generally appropriate only for private roads, parking lots, or

pedestrianized zones where very low speeds are mandated.

Applying this classification to the field data collected in this study, the 21 raised pavement devices surveyed can be reclassified as follows:

Speed Humps (Circular Profile -Gitega): The 12 circular-profile devices located in Gitega exhibited heights ranging from 7.55 cm to 9.45 cm and a uniform length of 6 m, placing them squarely within the RTDA-compliant speed hump standard. These devices are correctly designed and positioned to reduce speeds to the 22-35 km/h range and are hereinafter classified as speed humps.

Table 5:Dimensional Compliance of Circular Humps (Gitega)

Hump ID	Shape	Height (cm)	Length (m)	Classification	Height Compliance	Length Compliance
Gitega H1	Circular	8.51	6	Speed Hump	Yes	Yes
Gitega H2	Circular	9.45	6	Speed Hump	Yes	Yes
Gitega H3	Circular	7.70	6	Speed Hump	Yes	Yes
Gitega H4	Circular	8.33	6	Speed Hump	Yes	Yes
Gitega H5	Circular	8.67	6	Speed Hump	Yes	Yes
Gitega H6	Circular	8.79	6	Speed Hump	Yes	Yes
Gitega H7	Circular	8.47	6	Speed Hump	Yes	Yes
Gitega H8	Circular	8.74	6	Speed Hump	Yes	Yes
Gitega H9	Circular	7.55	6	Speed Hump	Yes	Yes
Gitega H10	Circular	9.39	6	Speed Hump	Yes	Yes
Gitega H11	Circular	8.89	6	Speed Hump	Yes	Yes
Gitega H12	Circular	9.36	6	Speed Hump	Yes	Yes

Speed Bumps (Flat-Topped Profile - Nyabugogo and Kiyovu): The 9 flat-topped devices located in Nyabugogo (5 devices) and Kiyovu (4 devices) exhibited heights ranging from 10.47 cm to 15.35 cm all exceeding the RTDA maximum height of 10 cm for speed humps. Their steep vertical profile and significantly elevated height is consistent with the characteristics of speed bumps rather than speed humps. Accordingly, these devices are reclassified as speed bumps, designed to reduce speeds to approximately 5-18 km/h. However, it is important to note that their current heights (up to 15.35 cm) exceed even the upper range typically acceptable for speed bumps, posing risks to vehicle undercarriage, passenger comfort, and emergency vehicle access. These devices require remediation.

Table 6:Dimensional Compliance of Flat-Topped Humps (Nyabugogo and Kiyovu)

Hump ID	Shape	Height (cm)	Length (m)	Classification	Height Compliance	Length Compliance
Nyabugogo H1	Flat-topped	10.47	7	Speed Bump	No	Yes
Nyabugogo H2	Flat-topped	10.80	7	Speed Bump	No	Yes
Nyabugogo H3	Flat-topped	14.10	7	Speed Bump	No	Yes
Nyabugogo H4	Flat-topped	15.35	7	Speed Bump	No	Yes
Nyabugogo H5	Flat-topped	14.45	7	Speed Bump	No	Yes
Kiyovu H1	Flat-topped	12.70	6	Speed Bump	No	Yes
Kiyovu H2	Flat-topped	12.51	6	Speed Bump	No	Yes
Kiyovu H3	Flat-topped	12.05	6	Speed Bump	No	Yes
Kiyovu H4	Flat-topped	13.50	6	Speed Bump	No	Yes

In summary, of the 21 raised pavement devices surveyed, 12 are correctly classified as speed humps (all compliant with RTDA height standards) and 9 should be re-classified as speed bumps (all non-compliant with RTDA height standards and exhibiting steep vertical profiles unsuitable for the road types on which they are installed). The remainder of this paper adopts this corrected classification in all subsequent analysis, discussion, and recommendations.

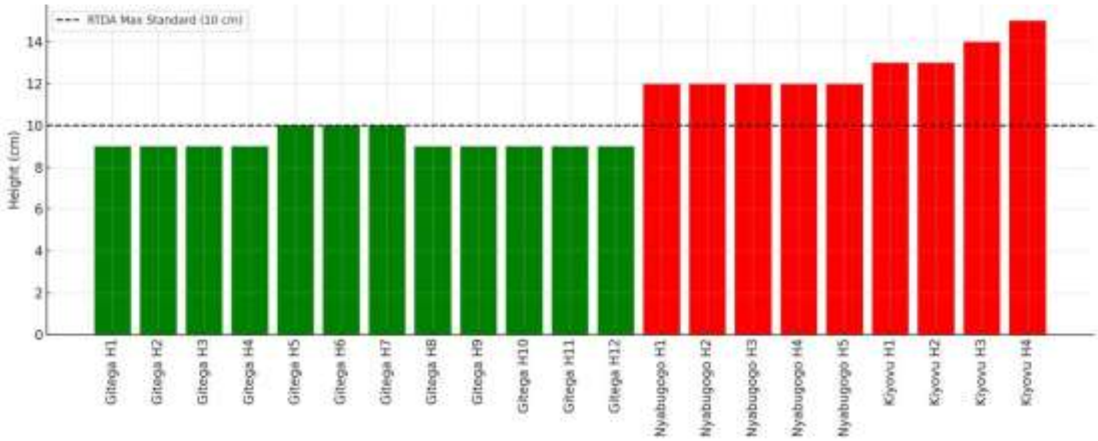

Figure2: Comparison of Measured Hump Heights with RTDA Standards

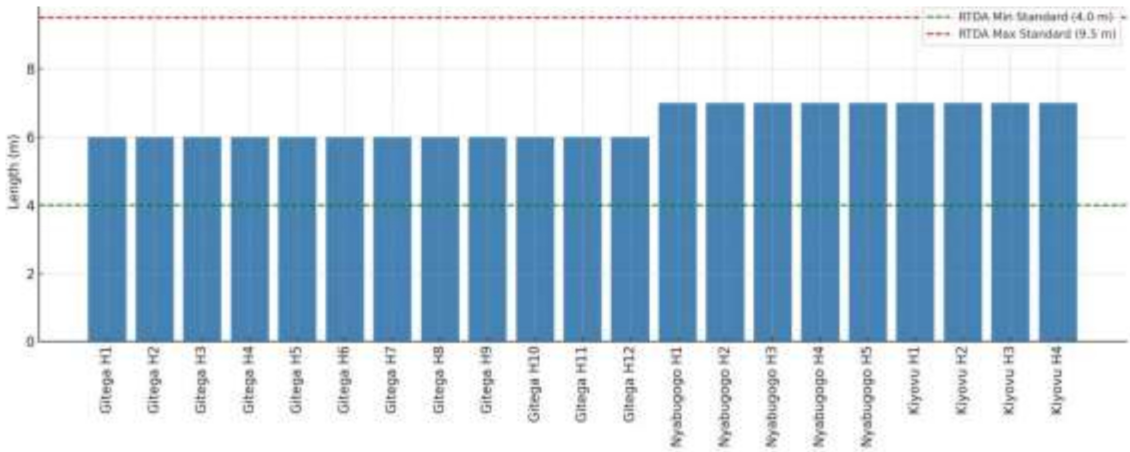

Figure3: Comparison of Measured Hump Lengths with RTDA Standards

Spacing Compliance

Table 7:Assessment of Speed Hump Placement and Spacing Compliance

Area	Number of Humps	Type	No. of Humps Closer Than 100m	Observed Closest Inter-distance (m)	RTDA Required Min Inter-distance (m)	Compliance Status
Nyabugogo	4	Flat-topped	2	50	20–150	Non-Compliant (below 100m ideal for main roads)
Kiyovu	5	Flat-topped	2	50	20–150	Non-Compliant (below 100m ideal for main roads)

In both Nyabugogo and Kiyovu, two flat-topped humps in each area were installed only 50 meters apart. While this falls within the RTDA's minimum of 20 meters, it is significantly below the recommended 100-meter spacing for main roads, which may lead to unnecessary deceleration, increased fuel consumption, and driver frustration (Valentino, Sobio et al. 2021). Humps spaced below the recommended 100-metre minimum compound driver frustration and may encourage dangerous overtaking between devices. Minimum spacing compliance should therefore be made a mandatory prerequisite in all RTDA pre-installation traffic safety assessments.

Spatial Distribution of Traffic Calming Devices

The spatial distribution of traffic calming devices across Nyarugenge District was assessed through systematic field observation across four study zones: Gitega, Nyabugogo, Kiyovu, and Kimisagara. Device locations were recorded relative to named road intersections, sector boundaries, and physical landmarks such as schools, markets, and bus stops, and cross-referenced against publicly available satellite imagery to produce a schematic overview of device distribution. It is acknowledged that this study did not employ formal GPS equipment or spatial analysis software; this represents a methodological limitation, and future research is recommended to apply georeferenced data collection for greater spatial precision.

Field observations revealed a concentration of traffic calming devices in Nyabugogo and Kimisagara, which are among the highest traffic zones in the district. Kiyovu had comparatively fewer devices relative to its observed traffic volumes, and several connecting road stretches between study zones had no speed control measures at all — areas that may be described as "traffic calming deserts" and which warrant prioritization in future planning. Field evidence also indicated instances of non-compliant device placement along roads where RTDA guidelines discourage speed hump installation, suggesting that pre-installation site evaluations were not consistently applied.

Behavioral Response to Traffic Calming Devices

Driver Behavior and Compliance

Table 8:Driver Behavior Observed during Traffic observation

Location	Time Period	Vehicles Observed	Speeding / Violations	Compliant Drivers	% Non-Compliant	% Compliant
Nyabugogo Junction	Peak Hours	40	10 (speeding)	30	25%	75%
Kimisagara	Peak Hours	40	7 (signal violations)	33	17.5%	82.5%
Kiyovu Road	Off-Peak Hours	20	5 (sign ignoring)	15	25%	75%

Compliance Criteria: A vehicle was classified as compliant if it visibly reduced speed before crossing a speed hump or rumble strip, yielded to pedestrians at marked crossings, and respected traffic signal phases. Non-compliance was recorded when a vehicle failed to reduce speed, proceeded through a pedestrian phase without yielding, or disregarded regulatory signs.

The presence of speed humps and pedestrian crossings generally encouraged drivers to reduce their speed, particularly during peak hours. At Métheo and Kimisagara, driver compliance was notably high. However, during off-peak hours, drivers were frequently observed exceeding safe speeds, especially along longer road segments at Gitega and the Stadium zone. Recurring violations included speeding near schools and markets, failure to yield at pedestrian crossings in Nyabugogo and Gitega, and overtaking near rumble strips and speed humps, all of which undermine the intended safety function of these devices. This compliance drop during off-peak hours confirms that physical infrastructure alone is insufficient. Targeted enorcement deployments and speed camera installation especially near schools and pedestrian crossings are essential to sustain safety benefits beyond peak hours.

Pedestrian Behavior and Perception of Safety

Pedestrian behavior correlated strongly with the condition and visibility of traffic calming measures. In areas where crosswalks were freshly painted and signage was clearly visible, such as Gitega, Métheo, and parts of Kimisagara, pedestrians demonstrated greater confidence when using designated crossings. In contrast, in Nyabugogo, where road markings were faded, pedestrians hesitated or chose to cross at undesignated points. These results align with(Distefano and Leonardi 2022), who assert that well-maintained and visible traffic calming infrastructure directly contributes to improved safety perceptions and better compliance by both drivers and pedestrians.

Public Perception: Questionnaire Results

A total of 193 usable questionnaire responses were collected: 51.8% male, 47.2% female, and 1.0% preferred not to disclose. Most respondents (53.9%) were aged 18–30. Road user types included pedestrians (27.5%), public transport users (23.3%), motorcycle riders (19.7%), private car drivers (19.2%), and public transport drivers (10.4%). A total of 97.4% confirmed awareness of traffic calming measures and 95.9% reported having encountered them in the district.

Respondents rated perceived effectiveness of each device type on a three-point scale (slightly, moderately, or very effective). Speed humps received the strongest ratings 61.7% very effective and only 4.1% slightly effective followed by rumble strips (46.6% very effective; 11.4% slightly effective) and warning signs (44.7% very effective; 17.6% slightly effective). On broader perceptions, only 19.8% considered geometric designs appropriate, only 42.2% believed devices comply with standard guidelines, and only 9.9% (n = 19) found the number and placement satisfactory with 77 respondents specifically describing devices as "not well placed."

To determine whether these differences in perceived effectiveness across device types are statistically significant, a Pearson chi-square (χ^2) test of independence was conducted on the observed frequency table below.

Table 9: Perceived Effectiveness by Device Type (n = 193)

Device Type	Slightly Effective	Moderately Effective	Very Effective	Total
Speed Humps	8	66	119	193
Rumble Strips	22	80	90	192
Warning Signs	34	73	86	193
Total	64	219	295	**578**

The test yielded $\chi^2(4) = 23.75$, $p < 0.001$, with an effect size of Cramér's V = 0.143 (small-to-moderate, per Cohen, 1988). The null hypothesis is rejected: perceived effectiveness varies significantly by device type. Speed humps are rated most effective, warning signs least so, with rumble strips in an intermediate position. Particularly the prioritization of speed humps in high-risk zones and the need to review warning sign placement and visibility. The finding that 90.1% of respondents identified issues with device number and placement further underscores the need for localized traffic safety studies and structured stakeholder engagement prior to future installation.

Synthesis of Findings

The combination of Civil 3D profiles, distribution data, field measurements, and questionnaire responses yielded the following key findings:

First, flat-topped humps in Nyabugogo and Kiyovu consistently exceeded RTDA height standards, with values reaching up to 15.35 cm, while circular humps in Gitega showed full compliance in both height and length. Second, the observed interdistance between flat-topped humps (50 meters) falls within the RTDA's acceptable minimum range of 20 meters but is below the recommended 100 meters for main roads. Third, spatial distribution of calming devices is uneven, with some high-risk areas lacking adequate coverage. Fourth, insufficient signage and poor maintenance were observed in multiple locations, leading to driver non-compliance and compromised safety.

Comparison with Literature

The findings of this study are consistent with regional literature. The height no-compliance of flat-topped humps (43% exceeding RTDA limits) mirrors observations from Nairobi and Durban , where improperly constructed humps were found to cause vehicle discomfort and reduce driver compliance (Monyatsi 2020). The strong public support for speed humps (61.7% rating them 'very effective') is consistent with patterns observed in Ghana and South Africa(Sumbo, Wulifan et al. 2025).

In summary, although traffic calming measures are widely implemented, inconsistent application and regulatory gaps continue to limit their effectiveness in enhancing road safety.

CONCLUSION AND RECOMMENDATIONS

This study was motivated by the absence of systematic evidence on whether traffic calming devices in Nyarugenge District meet RTDA design standards and effectively influence road user behavior. By addressing this gap, the study provides a data-driven foundation for improving traffic calming policy and implementation in Rwanda.

This study was conducted to assess the effectiveness and suitability of traffic calming devices in Nyarugenge District, with a focus on speed humps and rumble strips. Using field surveys, traffic observations, and questionnaires, and guided by RTDA standards, the research evaluated the design, placement, and influence of calming devices on driver behavior and pedestrian safety.

This study addressed three objectives. First, 36 traffic calming devices were identified and mapped across Nyarugenge District through comprehensive field surveys, including 21 speed humps, 5 rumble strips, and 10 warning signs. Second, geometric analysis, traffic observations, and questionnaire data revealed that while devices are generally moderately effective, 43% of speed humps are height non-compliant, and driver behavior, particularly during off-peak hours, showed significant non-compliance, including speeding and failure to yield at pedestrian crossings. Third, evidence-based guidelines for device installation, maintenance, and enforcement were formulated based on the study's findings.

The first objective to identify existing traffic calming devices was successfully achieved through comprehensive field surveys. All devices were mapped using GPS and assessed using engineering tools to determine their condition, location, and compliance with RTDA standards.

The second objective to assess effectiveness was addressed using both observational data and public perception. Traffic observations revealed inconsistent driver behavior, especially during off-peak hours, with violations such as speeding and failure to yield at pedestrian crossings. Questionnaire responses indicated that while most road users appreciated the presence of calming devices, their effectiveness was hindered by poor visibility, over-height designs, and inadequate maintenance. Over 43% of speed humps exceeded the RTDA maximum height of 100 mm, creating abrupt transitions that compromised driver comfort and safety.

The third objective, to establish installation guidelines, was fulfilled through the formulation of the following technical and planning recommendations based on data analysis:

- Standardized device dimensions. Responsible agencies should ensure that all speed humps comply with RTDA specifications (height: 7.5–10 cm; length: 4.0–9.5 m; design speed: 22–35 km/h). Speed bumps, which are shorter and steeper (design speed: 5–18 km/h), should only be installed in locations where very low speeds are warranted (e.g., parking lots, private roads). Non-compliant devices should be assessed individually and either reconstructed to appropriate hump or bump standards based on their location and design intent.
- Enforce proper spacing and location. Speed humps on main roads should be spaced no closer than 100 meters apart or no placement. Pre-installation traffic safety assessments should be mandatory before any new device is installed.
- Expand rumble strip coverage. The use of rumble strips should be extended to other accident-prone or curved areas in the district, given their demonstrated effectiveness in alerting drivers at low cost.
- Conduct public awareness campaigns. Road users should be educated on the function and importance of traffic calming devices to improve compliance and safety outcomes.

Limitations and Future Research: This research acknowledges limitations, including reliance on manual speed estimates and limited nighttime observation. Future research should evaluate calming measures during nighttime conditions, assess impacts on emergency response vehicles, explore cost-benefit analyses of different calming types, and employ automated speed detection tools for broader data collection across multiple districts.

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