

# Road-User Perceptions of Rainfall-Related Vehicular Crash Risk in Port Harcourt, Nigeria

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## Abstract

Rainfall can create hazardous road conditions through reduced visibility, wet and slippery road surfaces, surface-water accumulation, flooding, concealed potholes and impaired road-user mobility. In urban areas where drainage and road infrastructure are inadequate, these conditions may increase perceived risks of vehicular crashes. This study assessed road users' perceptions of rainfall-related vehicular crash risk in Port Harcourt, Rivers State, Nigeria. A cross-sectional descriptive survey design was adopted. Data were obtained from 386 road users selected from major traffic corridors and transport activity locations within Port Harcourt. A structured questionnaire was used to assess perceptions of rainfall-related crash risk, perceived environmental, infrastructural and behavioural contributors, and preferred mitigation measures. Data were analysed using frequencies, percentages, weighted mean scores and ranking. The findings indicate that respondents generally perceived rainfall as an important road-safety risk. The highest-rated perception was that extreme rainfall increases the likelihood of road accidents (mean = 2.6), followed by the perception that rainfall reduces drivers' visibility and creates unsafe driving conditions (mean = 2.5). Among perceived determinants of rainfall-related crashes, speeding on wet and slippery roads received the highest rating (mean = 3.0), followed by poor drainage (mean = 2.9), concealed potholes (mean = 2.8), and poor visibility of road signs and markings (mean = 2.7). Improvement of drainage and flood-prone roads received the strongest support as a mitigation measure (mean = 3.0), followed by rainfall-related traffic warnings (mean = 2.7) and driver training on safe driving during rainfall (mean = 2.6). The findings suggest that road users perceive rainfall-related crash risk as an interaction between weather conditions, driver behaviour and deficiencies in road infrastructure rather than rainfall alone. The study recommends improved drainage, maintenance of flood-prone roads, weather-responsive traffic warnings, driver education and stronger enforcement of safe-driving practices during rainfall.

**Keywords:** *Rainfall, road-user perception, vehicular crashes, road safety, drainage, driver behaviour, Port Harcourt*

## 1. Introduction

Road traffic crashes remain a major public-health, transportation and development challenge worldwide. The World Health Organization estimates that approximately 1.19 million people die annually from road traffic crashes, with the burden disproportionately affecting low- and middle-income countries. Road traffic injuries are also among the leading causes of death among children and young people aged 5–29 years (World Health Organization [WHO], 2023). The persistence of road traffic injuries demonstrates that road safety is influenced by interacting human, environmental, infrastructural and institutional factors (Ogboeli et al., 2026).

Weather conditions represent an important environmental component of road safety. Rainfall can alter the driving environment by reducing visibility, increasing stopping distances, reducing tyre–road friction and producing wet or water-covered road surfaces (Ogboeli et al., 2026). Heavy rainfall may also cause temporary flooding, conceal potholes and reduce the visibility of road markings and traffic signs. These changes may make vehicle control and hazard recognition more difficult, particularly where road infrastructure is poorly maintained.

Evidence from previous studies indicates that adverse weather can influence road traffic crashes, although the magnitude and direction of the relationship vary between locations and weather conditions. Qiu and Nixon (2008), in a systematic review and meta-analysis, found that adverse weather conditions were associated with changes in traffic-crash occurrence, with precipitation generally associated with increased crash risk. Andrey et al. (2003) similarly identified weather as an important risk factor in motor-vehicle crashes.

The influence of rainfall on road safety is not necessarily determined by precipitation alone. Rainfall interacts with road conditions, drainage capacity, traffic density, driver behaviour, vehicle condition and road-user decisions. In areas with inadequate drainage, rainfall may result in waterlogging and flooding that reduce road capacity and increase travel hazards. Poor pavement conditions may further intensify these effects by allowing potholes and surface defects to become concealed beneath water (Ogboeli et al., 2026).

Driver behaviour is another important component of rainfall-related road safety. Drivers may respond differently to adverse weather conditions depending on their experience, risk perception and knowledge of safe-driving practices. Excessive speed on wet roads, inadequate following distance, sudden braking and failure to adjust driving behaviour to reduced visibility can increase exposure to road hazards.

Port Harcourt, Rivers State, provides an important setting for examining road users' perceptions of rainfall-related crash risk. The city is a major commercial and transportation centre in the Niger Delta and experiences substantial rainfall during the wet season. Rapid urbanisation, drainage constraints, road-surface deterioration and recurrent surface-water accumulation may create hazardous conditions for road users during periods of heavy rainfall (Osi et al., 2026).

Although objective crash records are important for understanding road safety, road-user perceptions provide complementary information that cannot be obtained from crash statistics alone. Perception data can reveal how drivers, commuters and other road users understand

environmental hazards, identify risky behaviours and evaluate possible interventions. Understanding these perceptions is particularly relevant for designing road-safety education, traffic-management strategies and infrastructure interventions.

The present study therefore focuses exclusively on road users' perceptions of rainfall-related vehicular crash risk in Port Harcourt. Rather than attempting to establish a statistical relationship between rainfall totals and recorded crashes, the study examines how road users perceive the contribution of rainfall, environmental conditions, infrastructure and driver behaviour to road traffic risk.

### **1.1 Aim of the Study**

The study aimed to assess road users' perceptions of rainfall-related vehicular crash risk in Port Harcourt, Rivers State, Nigeria.

### **1.2 Objectives of the Study**

The specific objectives were to:

1. assess road users' perceptions of the influence of rainfall on vehicular crash risk in Port Harcourt;
2. identify environmental, infrastructural and behavioural factors perceived to contribute to rainfall-related vehicular crashes;
3. assess road users' perceptions of appropriate measures for reducing rainfall-related crash risk; and
4. identify priority areas for rainfall-responsive road-safety and traffic-management interventions based on road users' perceptions.

## **2. Materials and Methods**

**Study Area:** The study was conducted in Port Harcourt, the capital of Rivers State, southern Nigeria. Port Harcourt is located within the Niger Delta and has a humid tropical climate characterised by substantial rainfall and a pronounced wet season. The city is an important commercial, administrative and transportation centre, with extensive daily movement of private vehicles, commercial vehicles, motorcycles and other road users. The combination of intensive urban development, substantial rainfall, road congestion, drainage constraints and deterioration of some road infrastructure makes rainfall-related road safety an important concern. During heavy rainfall, surface-water accumulation may occur on some roads, while potholes and other road defects may become difficult for drivers to identify.

**Study Design:** A cross-sectional descriptive survey design was adopted. The design was considered appropriate because the study sought to obtain information on road users' perceptions of rainfall-related vehicular crash risk, perceived causes and preferred mitigation measures at a particular period. The study was strictly perception-based. No attempt was made to establish a causal relationship between rainfall and objectively recorded vehicular crashes.

**Study Population:** The study population comprised road users in Port Harcourt, including drivers, commercial transport operators, motorcyclists and regular commuters. These groups were considered appropriate because they have direct experience of travelling on the city's roads during rainfall.

**Sample Size:** A total of 386 completed questionnaires were used for the analysis. The effective sample size for the perception assessment was therefore  $n = 386$ .

**Sampling Procedure:** A multistage sampling approach was used to select respondents from major traffic corridors and locations characterised by substantial transport activity. Relevant road-use locations were identified first, after which eligible road users were selected for questionnaire administration.

Respondents were included if they were regular road users in Port Harcourt and were willing to participate in the study. Where traffic-management or road-safety personnel were consulted, purposive selection was appropriate because their inclusion was based on their professional involvement in transportation and road-safety activities.

**Instrument for Data Collection:** Data were collected using a structured questionnaire. The questionnaire was divided into sections addressing: respondents' demographic characteristics, perceptions of rainfall and vehicular crash risk, perceived environmental and infrastructural causes of rainfall-related crashes, perceived driver-related factors, personal responses to rainfall and preferred mitigation and traffic-management measures. Items were measured using a four-point Likert-type response scale comprising Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD), scored 4, 3, 2 and 1, respectively.

**Validity and Reliability:** The questionnaire was subjected to expert review to assess its face and content validity. A pilot test was reportedly conducted among respondents outside the final study locations.

**Data Analysis:** Questionnaire data were analysed using descriptive statistics. Frequencies and percentages were used to summarise categorical responses, while weighted mean scores were used to assess the level of agreement with individual perception statements.

For the four-point Likert scale, a criterion mean of 2.50 was used to distinguish agreement from disagreement. Mean scores of 2.50 and above were interpreted as accepted perceptions, while scores below 2.50 were interpreted as rejected perceptions. Items were ranked according to their mean scores, with the highest mean receiving the highest rank.

### 3. Results

#### Road Users' Perceptions of Rainfall and Vehicular Crash Risk

The results show that respondents generally perceived rainfall as an important factor capable of creating hazardous road conditions. The highest-rated perception was that extreme rainfall increases the chances of road accidents, with a mean score of 2.6, which was interpreted as

accepted. This was followed by the perception that rain reduces drivers' visibility and causes unsafe driving conditions, with a mean score of 2.5, also accepted.

The statement that respondents avoid driving during heavy rainfall whenever possible recorded a mean score of 2.4 and was therefore rejected using the 2.50 criterion mean. Similarly, the perception that flooded roads make it difficult to control vehicles recorded a mean score of 2.2, while the statement that there are more road crashes in Port Harcourt when it rains heavily recorded a mean score of 2.3. Both were below the criterion mean.

The findings suggest that respondents recognised rainfall as a potential source of hazardous driving conditions but were less certain that heavy rainfall necessarily resulted in a greater number of crashes or that they personally avoided travelling during rainfall.

**Table 1. Road Users' Perceptions of Rainfall-Related Vehicular Crash Risk**

| Perception statement                                                  | Mean | Decision | Rank |
|-----------------------------------------------------------------------|------|----------|------|
| Extreme rainfall increases the chances of road accidents              | 2.6  | Accepted | 1st  |
| Rain reduces drivers' visibility and causes unsafe driving conditions | 2.5  | Accepted | 2nd  |
| I avoid driving during heavy rainfall whenever possible               | 2.4  | Rejected | 3rd  |
| There are more road crashes in Port Harcourt when it rains heavily    | 2.3  | Rejected | 4th  |
| Flooded roads make it difficult to control vehicles                   | 2.2  | Rejected | 5th  |

### **Perceived Determinants of Rainfall-Related Vehicular Crashes**

Respondents identified a combination of driver behaviour and road-infrastructure deficiencies as important contributors to rainfall-related crash risk. Speeding on wet and slippery roads recorded the highest mean score of 3.0, ranking first. This was followed by poor drainage systems, with a mean of 2.9 and second rank.

The perception that potholes become more dangerous and hidden during rainfall recorded a mean of 2.8, while poor visibility of road signage and markings during heavy rain recorded a mean of 2.7. Both were accepted as perceived contributors.

In contrast, the perception that most vehicles in Port Harcourt are not well maintained for rainy conditions recorded a mean of 2.4 and was rejected.

**Table 2. Perceived Determinants of Rainfall-Related Vehicular Crashes**

| Perceived determinant                                         | Mean | Decision | Rank |
|---------------------------------------------------------------|------|----------|------|
| Many drivers speed even when roads are wet and slippery       | 3.0  | Accepted | 1st  |
| Poor drainage systems increase road accidents during rainfall | 2.9  | Accepted | 2nd  |
| Potholes become more dangerous and hidden during rainfall     | 2.8  | Accepted | 3rd  |
| Road signage and markings are not visible during heavy rain   | 2.7  | Accepted | 4th  |

| Perceived determinant                                      | Mean | Decision | Rank |
|------------------------------------------------------------|------|----------|------|
| Most vehicles are not well maintained for rainy conditions | 2.4  | Rejected | 5th  |

### Perceived Mitigation and Traffic-Management Measures

Respondents showed strong support for infrastructure-based interventions. Improvement of drainage systems and flood-prone roads received the highest mean score of 3.0.

This was followed by provision of traffic warnings during extreme rainfall, with a mean of 2.7, and driver training on safe driving during rainy conditions, with a mean of 2.6.

The respondents' personal precautionary measures received comparatively lower ratings. Reducing speed during rainfall recorded a mean of 2.4, while using weather information to plan travel recorded a mean of 2.3.

These results indicate that respondents placed greater emphasis on institutional and infrastructural interventions than on individual behavioural adaptations.

**Table 3. Perceived Measures for Reducing Rainfall-Related Crash Risk**

| Mitigation measure                               | Mean | Interpretation          |
|--------------------------------------------------|------|-------------------------|
| Improve drainage and flood-prone roads           | 3.0  | Strong support          |
| Provide traffic warnings during extreme rainfall | 2.7  | Supported               |
| Train drivers on safe driving during rainfall    | 2.6  | Supported               |
| Reduce vehicle speed during rainfall             | 2.4  | Relatively weak support |
| Use weather information to plan travel           | 2.3  | Relatively weak support |

## 4. Discussion

The findings demonstrate that road users in Port Harcourt perceive rainfall as an important contributor to hazardous road conditions and potential vehicular crash risk. The strongest perception was that extreme rainfall increases the likelihood of road accidents (mean = 2.6), followed by the perception that rainfall reduces drivers' visibility and creates unsafe driving conditions (mean = 2.5). These findings suggest that road users recognise rainfall primarily as an environmental condition that can compromise safe vehicle operation. This perception is consistent with established evidence that precipitation can affect visibility, pavement conditions, vehicle handling and driver performance, thereby modifying the road-safety environment (Andrey et al., 2003; Qiu & Nixon, 2008).

The finding is particularly relevant in Port Harcourt, where rainfall-related road hazards may interact with existing infrastructure and traffic conditions. Qiu and Nixon (2008), in a systematic review and meta-analysis, reported that precipitation is generally associated with changes in traffic-crash occurrence, although the magnitude of the effect varies according to weather characteristics, road environment and other contextual factors. Similarly, Andrey et al. (2003)

identified weather as an important risk factor in motor-vehicle crashes. The agreement between the present perception findings and previous literature suggests that road users' recognition of rainfall as a safety concern is consistent with the broader understanding of weather-related road risk.

Nevertheless, the findings should not be interpreted as demonstrating that rainfall independently causes vehicular crashes. A perception-based study can establish how road users understand a phenomenon but cannot establish a causal relationship between rainfall and crash occurrence. Rainfall may instead function as a risk modifier, creating conditions under which existing vulnerabilities associated with driver behaviour, road infrastructure, visibility and traffic conditions become more consequential. This interpretation is consistent with the systems perspective of road safety, in which crashes arise from interactions among road users, vehicles, infrastructure and the broader operating environment rather than from a single factor (WHO, 2023).

An important finding was that respondents did not strongly endorse the statement that they avoid driving during heavy rainfall (mean = 2.4). This suggests that adverse weather may not substantially eliminate travel activity among road users in Port Harcourt. Continued travel during rainfall may be associated with commuting requirements, commercial activities and other mobility needs. Consequently, road users may remain exposed to hazardous conditions even when rainfall reduces visibility or deteriorates road-surface conditions. This finding highlights the importance of interventions that improve the safety of necessary journeys rather than relying solely on voluntary travel avoidance.

Respondents also did not strongly agree that flooded roads make vehicle control difficult (mean = 2.2). This result requires cautious interpretation because perceptions of flooding may vary according to respondents' locations, frequency of exposure and individual experiences. It may also reflect differences in the severity and duration of flooding encountered by road users. More importantly, the finding should be considered alongside the strong perception that poor drainage contributes to rainfall-related crashes. The apparent difference between these responses suggests that road users may distinguish between rainfall generally and severe surface-water conditions on specific road segments. Future research should therefore examine rainfall-related road hazards at a finer spatial scale, particularly along flood-prone transportation corridors.

Driver behaviour emerged as the most strongly perceived determinant of rainfall-related crash risk. Respondents identified speeding on wet and slippery roads as the leading contributor (mean = 3.0). This finding underscores the importance of behavioural adaptation during adverse weather. Rainfall can reduce tyre-road friction and impair visibility, meaning that inappropriate speed may reduce the time and distance available for drivers to respond to hazards. From a road-safety perspective, rainfall should therefore prompt drivers to modify their behaviour through speed reduction, increased following distance, smoother braking and greater attention to road conditions. The finding is consistent with the broader road-safety principle that human behaviour interacts with environmental and infrastructural conditions to influence crash risk (WHO, 2023).

Poor drainage was the second-highest perceived contributor to rainfall-related crash risk (mean = 2.9). This finding is particularly important in the context of Port Harcourt because inadequate

drainage can transform rainfall into a more immediate transportation hazard through surface-water accumulation and temporary flooding. Where drainage capacity is inadequate, blocked or poorly maintained, rainfall may reduce usable road space and obscure pavement defects. Thus, respondents' perceptions indicate that the road-safety consequences of rainfall may depend substantially on the capacity of urban infrastructure to accommodate stormwater. This supports the argument that climate resilience and road safety should not be treated as separate infrastructure concerns (Markolf et al., 2019).

The strong perception that potholes become more dangerous and concealed during rainfall (mean = 2.8) further demonstrates the interaction between weather and road condition. Water accumulating within pavement defects can make potholes difficult to detect, potentially increasing the likelihood of sudden braking, swerving or loss of vehicle control. The finding suggests that routine road maintenance has an important road-safety function during the rainy season. Road rehabilitation, pothole repair and maintenance of drainage systems should therefore be integrated into broader traffic-safety planning rather than being considered exclusively as conventional infrastructure-development activities.

Poor visibility of road signs and markings during heavy rainfall was also strongly perceived as a contributor to crash risk (mean = 2.7). Effective signs and road markings provide essential information for speed regulation, lane positioning, intersection navigation and hazard recognition. When rainfall reduces their visibility, drivers may experience greater difficulty interpreting the road environment. Maintaining road markings, signs and other traffic-control devices is therefore particularly important along locations where visibility and decision-making are critical. This finding reinforces the importance of maintaining road infrastructure that remains functional under adverse weather conditions.

In contrast, respondents did not strongly perceive poor vehicle maintenance for rainy conditions as a major contributor to rainfall-related crashes (mean = 2.4). This relatively low rating should not, however, be interpreted as evidence that vehicle condition is unimportant. Tyre condition, braking efficiency, windscreen wipers, headlights and other vehicle components can influence vehicle performance during rainfall. Rather, the finding indicates that respondents perceived driver behaviour and road infrastructure as more prominent contributors to rainfall-related hazards within the context of Port Harcourt. This distinction is important because perception rankings reflect respondents' understanding of risk and should not be equated directly with the objectively measured contribution of each factor.

The strong support for improving drainage and flood-prone roads (mean = 3.0) is particularly noteworthy because it corresponds closely with respondents' identification of poor drainage as a major perceived risk factor. This convergence between perceived problem and preferred intervention provides a strong practical basis for prioritising drainage maintenance and rehabilitation of vulnerable road sections. Such interventions may reduce the accumulation of surface water and improve the functionality and reliability of transportation infrastructure during periods of heavy rainfall. The finding also aligns with broader evidence that transport resilience requires infrastructure capable of withstanding and recovering from extreme weather conditions (Markolf et al., 2019).

Respondents also supported the provision of traffic warnings during extreme rainfall (mean = 2.7). This finding highlights the potential value of weather-responsive traffic management. Weather information is more likely to support road safety when it is converted into actionable information, such as warnings about poor visibility, flooded road segments, hazardous driving conditions and alternative routes. Integration of meteorological information into traffic-management systems could therefore improve the ability of road users and authorities to anticipate and respond to rainfall-related hazards (Osi et al., 2026).

The support for driver training on safe driving during rainfall (mean = 2.6) further demonstrates the perceived importance of behavioural interventions. Rainfall-specific road-safety education should emphasise appropriate speed selection, adequate following distance, careful braking, visibility management, avoidance of flooded sections and appropriate responses to slippery surfaces. Such interventions may be particularly relevant for commercial drivers and other road users whose occupations require frequent travel under variable weather conditions.

An interesting feature of the findings is that respondents placed greater emphasis on institutional and infrastructural measures than on some individual precautionary practices. For example, reducing speed during rainfall received a comparatively lower mean score (2.4), while using weather information to plan travel received 2.3. This may indicate a gap between recognition of rainfall as a road-safety hazard and adoption of appropriate individual protective behaviours. If confirmed by further research, this gap would have important implications for road-safety education because recognising a hazard does not necessarily translate into appropriate behavioural adaptation.

Overall, the findings support a systems-oriented interpretation of rainfall-related road safety in Port Harcourt. Rainfall should not be regarded as an isolated cause of vehicular crashes. Rather, its potential safety implications arise through interactions with driver behaviour, road infrastructure, drainage, pavement condition, visibility and traffic-management practices. This interpretation is consistent with contemporary road-safety approaches that emphasise the interaction of human, vehicle, road and environmental factors (WHO, 2023). Accordingly, effective rainfall-responsive road safety in Port Harcourt requires a combination of infrastructure maintenance, drainage improvement, driver education, traffic warnings and appropriate enforcement rather than reliance on a single intervention.

The findings also demonstrate the value of incorporating road-user perceptions into environmental and transportation research. While perception data cannot substitute for objective crash or meteorological measurements, they provide useful evidence concerning how road users understand hazards, which factors they consider important and which interventions they regard as practical. In the context of Port Harcourt, these perceptions can assist transportation authorities in designing interventions that address both physical road hazards and behavioural responses to rainfall.

## 5. Limitations of the Study

The study has some limitations. First, the findings are based on self-reported perceptions and may not directly reflect objectively measured crash risk. Second, the cross-sectional design limits

causal interpretation and provides information only on respondents' perceptions at the time of the survey. Third, rainfall intensity, duration, flooding depth, traffic volume and crash frequency were not objectively assessed; therefore, the findings do not establish an empirical rainfall–crash relationship. Fourth, respondents were selected from specific road-use locations in Port Harcourt, which may limit the generalisability of the findings across the metropolis. Finally, possible recall and social-desirability biases may have influenced responses. The questionnaire dataset should also be verified to resolve inconsistencies between reported frequencies, weighted scores and the stated sample size before publication.

## **.6. Conclusion**

The study concludes that road users in Port Harcourt perceive rainfall as an important contributor to hazardous road conditions and potential vehicular crash risk, particularly through reduced visibility and unsafe driving conditions. Rainfall-related road safety is therefore perceived as a multifaceted issue rather than an effect of rainfall alone.

Speeding on wet and slippery roads, poor drainage, concealed potholes, and poor visibility of road signs and markings were identified as major perceived contributors to crash risk. Respondents strongly supported improved drainage and flood-prone roads, rainfall-related traffic warnings, and driver training as key measures for reducing rainfall-related road hazards.

Overall, effective rainfall-responsive road-safety management in Port Harcourt should integrate infrastructure improvement, timely weather information, driver education, and enforcement of safe-driving practices. Future research should combine road-user perceptions with objective rainfall, traffic-exposure, road-condition, and crash data to provide stronger evidence of rainfall-related crash risk.

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