

**RISK AND UNCERTAINTY ANALYSIS: THE CASE IN SITING OF  
FILLING STATION AROUND BENIN CITY METROPOLIS**



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## CERTIFICATION

This is to certify that this research project was carried out by:

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## **DEDICATION**

We dedicate this project work to God Almighty for His blessings, favour, strength and upliftment which has helped each one of us thus far in this work. For without the Grace of The Almighty God we would not have been able to achieve all we have accomplished so far.

This project work is also dedicated to the families of **Mr. Modi & Mrs Modi FATIMA, Engr. Joseph & Mrs Rosemary AKPAN , Mrs. Mary Onyinye NJAKA, Barr. Peter & Dr. Beatrice AKHATSOKHE, Dcn. David & Dcns, Mary ARCHIBONG, Mrs. Kemi EGWAKHIDE and Mr. Richard & Mrs. Ebele IZENDU** who in one way or another have been of great support to us financially, morally and prayerfully throughout the course of our studies in this great institution.

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## **ABSTRACT**

The siting of filling stations in urban areas, such as Benin City Metropolis, involves complex risk and uncertainty analyses due to the interplay of environmental, socioeconomic, and regulatory factors. This study examines the challenges associated with locating filling stations in Benin City, focusing on the risks posed by improper siting, including environmental pollution, fire hazards, traffic congestion, and public health concerns. The analysis incorporates Geo-spatial data, regulatory frameworks, and stakeholder inputs to identify uncertainties related to land use, population density, and compliance with safety standards.

A multi-criteria decision-making approach is employed to evaluate potential sites, balancing economic benefits against environmental and social risks. The findings highlight the need for robust urban planning policies, stricter enforcement of safety regulations, and community engagement to mitigate risks and uncertainties.

This study provides a framework for sustainable siting of filling stations in rapidly urbanizing areas, offering insights for policymakers, urban planners, and industry stakeholders in Benin City and similar contexts.

## TABLE OF CONTENT

CERTIFICATION .....	i
DEDICATION .....	ii
ACKNOWLEDGEMENT .....	iii
ABSTRACT .....	iv
TABLE OF CONTENT .....	v
LIST OF TABLES .....	vii
LIST OF FIGURES .....	viii
CHAPTER ONE .....	1
INTRODUCTION .....	1
1.1 BACKGROUND OF THE STUDY .....	1
1.2 PROBLEM STATEMENT .....	3
1.3 AIM AND OBJECTIVES .....	4
1.4 RESEARCH QUESTIONS .....	5
1.5 SIGNIFICANCE OF THE STUDY .....	5
<b>1.6 RELATED STUDIES</b> .....	6
.....	7
1.7 SCOPE OF THE STUDY .....	7
1.8 LIMITATIONS OF THE STUDY .....	8
1.9 SUMMARY .....	8
1.9.1 Chapter One .....	8
1.9.2 Chapter Two .....	9
1.9.3 Chapter Three .....	9
1.9.4 Chapter Four .....	10
1.9.5 Chapter Five .....	11
CHAPTER TWO .....	13
LITERATURE REVIEW .....	13
2.2 OLATUNDE (2019) .....	13
2.3 National Centre for Petroleum and Energy Research (NCPER) (2020) .....	13
2.4 OLUSEGUN (2019) .....	14
2.5 OGBEMI (2020) .....	14
2.6 NJOKU AND ALAGBE (2015) .....	14
2.7 AROKOYU, OGORO AND AMANORITSEWO (2015) .....	15
2.8 YUSUF, SAWA, USMAN AND KUFORIJIMI (2024) .....	16
2.9 PERIE, ULAKPA AND EYANKWARE (2022) .....	16
2.10 AHMED, SHARIFF, KUTTY AND KHAMIDI (2011) .....	17
2.11 AHMED, SHARIFF, KUTTY, KHAMIDI, TRONOH, PERAK AND MALAYSIA .....	18
2.12 GAPS IN LITERATURE .....	19
CHAPTER THREE .....	20
METHODOLOGY .....	20
3.1 RESEARCH DESIGN .....	20
3.2 STUDY AREA .....	20

.....	21
3.3 POPULATION AND SAMPLING .....	22
3.4 DATA COLLECTION METHODS .....	22
3.4.1 Primary Data .....	22
3.4.1.1 Questionnaires .....	22
3.4.1.2 Field Observations (Visual Inspection) .....	25
3.4.2 Secondary Data .....	27
3.4.2.1 Regulatory Documents .....	27
3.4.2.3 Geospatial Data .....	31
3.5 DATA ANALYSIS .....	32
3.5.1 Quantitative Analysis .....	32
3.5.2 Qualitative Analysis .....	33
3.6 ETHICAL CONSIDERATIONS .....	33
3.7 LIMITATIONS OF THE STUDY .....	34
CHAPTER FOUR .....	35
RESULTS AND DISCUSSION .....	35
4.1 QUESTIONNAIRES ANALYSIS .....	35
4.1.1 Analysis of Supervisors' Questionnaire .....	36
4.1.1.1 Bar Chart Interpretation .....	38
4.1.1.2 Interpretation of High-Risk Areas .....	42
4.1.1.3 Risk Identification .....	44
4.1.1.4 Key Insights From Risk Breakdown .....	47
4.1.1.5 Bar Chart Interpretation (Risk Category Breakdown) .....	47
4.1.1.6 Correlation Analysis: How Risks Are Linked .....	48
4.1.1.7 Heat-map Interpretation: How Risks Are Connected .....	49
4.1.2 Analysis of Supervisors' Questionnaire .....	50
4.1.2.1 Bar Chart Interpretation .....	54
4.1.2.2 Risk Identification .....	54
4.2 VISUAL INSPECTION .....	59
4.3 GEOSPATIAL ANALYSIS .....	66
CHAPTER FIVE .....	76
RECOMMENDATIONS AND CONCLUSION .....	76
5.1 RECOMMENDATIONS .....	76
5.2 CONCLUSIONS .....	79
REFERENCES .....	82
APPENDIX .....	85

## LIST OF TABLES

Table 1 : Demographic Data For Supervisors .....	36
Table 2 : Table Of Results For Supervisors .....	37
Table 3 : Top 5 High-Risk Areas (Based on NO + NIL Responses) .....	42
Table 4 : Top Social Risk Issues .....	44
Table 5 : Top Safety Risk Issues .....	45
Table 6 : Top Regulatory Risk Issues .....	45
Table 7 : Top Environmental Risk Issues .....	46
Table 8 : Breakdown of Risks by Category .....	46
Table 9 : Demographic Data For People Around .....	50
Table 10 : Table Of Results For People Around .....	51
Table 11 : Key Safety Concerns from the Survey .....	54
Table 12 : Key Environmental Concerns from the Survey .....	57
Table 13 : Results From Visual Analysis .....	60

## LIST OF FIGURES

Figure 1 : An Explosion of A Tanker At A Filling Station .....	7
Figure 2 : A Satellite View of The Study Area .....	21
Figure 3 : Showing The Filling Stations With distances less than 400m .....	30
Figure 4 : Showing The Filling Stations With distances greater than 400m .....	30
Figure 5 : Compliance Trends Across All Questions (Supervisor) .....	38
Figure 6 : Top 5 High-Risk Areas In Filling Station Siting .....	43
Figure 7 : Bar Chart of Risk Category Breakdown .....	47
Figure 8 : Heat-map of Risk Correlations in Filling Stations .....	48
Figure 9 : Comparison of YES, NO & No Response Across All Questions .....	53
Figure 10 : Safety Risk In Filling Station .....	55
Figure 11 : Regulatory Risk In Filling Station .....	56
Figure 12 : Risk Score .....	57
Figure 13 : Trend Analysis: Risk Perception Over Different Questions .....	58
Figure 14 : Compliance vs Non-Compliance .....	62
Figure 15 : Top 10 Compliance Issues In Filling Station .....	63
Figure 16 : Top 10 Non Compliance Issues In Filling Station .....	64
Figure 17 : Percentage Of Distances < & > 400 .....	70
Figure 18 : Distance Distribution Scatter Point .....	72
Figure 19 : Box Plot of Distance Categories .....	73

# CHAPTER ONE

## INTRODUCTION

### 1.1 BACKGROUND OF THE STUDY

The siting of filling stations is a critical aspect of urban planning and infrastructure development, particularly in rapidly growing cities like Benin Metropolis. Filling stations are essential for meeting the energy needs of urban populations, as they provide access to petroleum products such as petrol, diesel, and kerosene. However, the improper siting of these facilities can lead to significant risks, including fire outbreaks, environmental pollution, traffic congestion, and public health hazards. To understand the risks and uncertainties associated with this process, it is essential to define key concepts:

**Risk analysis** is defined as the systematic process of identifying, assessing, and mitigating risks (ISO 31000, 2018). Also, Risk analysis involves evaluating "what can go wrong, its likelihood, and consequences" (Kaplan & Garrick, 1981, p. 12). In the context of filling stations, risk analysis focuses on hazards such as fire outbreaks, explosions, environmental pollution, and health risks. It involves evaluating the likelihood and potential impact of these hazards and developing strategies to minimize their occurrence.

**Uncertainty** is defined as the "lack of complete information about outcomes" (ISO 31000, 2018) or, in behavioral contexts, as "ambiguity in probabilistic judgments" (Tversky & Kahneman, 1974). In urban planning, uncertainties arise from factors such as population growth, land use changes, regulatory enforcement, and technological advancements. These uncertainties can complicate the decision-making process and increase the potential for adverse outcomes.

Furthermore, The siting of retail petroleum facilities involves evaluating proximity to populated areas, traffic patterns, environmental protections, and compliance with fire codes.(American Petroleum Institute 2020).

Also, Siting requirements for motor fuel dispensing facilities include minimum setbacks from dwellings, schools, and environmental reserves to mitigate fire and explosion risks.( National Fire Protection Association 2021).

Siting of gasoline stations requires adherence to underground storage tank (UST) regulations, spill prevention controls, and proximity to water sources. (U.S. Environmental Protection Agency 2022). Proper siting is critical to minimizing risks and ensuring the sustainability of urban development.

In Nigeria, the proliferation of filling stations has been driven by the increasing demand for petroleum products and the liberalization of the downstream petroleum sector. While this has contributed to economic growth and improved access to energy, it has also raised concerns about safety and environmental sustainability. Many filling stations are located in densely populated areas, near residential buildings, schools, and markets, without adequate consideration of the potential risks.

Benin Metropolis, the capital city of Edo State, is a prime example of this trend. The city has experienced rapid urbanization in recent years, leading to increased demand for petroleum products and a corresponding rise in the number of filling stations. However, the siting of these facilities has often been characterized by poor planning, non-compliance with safety regulations, and inadequate risk assessment. This has resulted in frequent accidents, environmental degradation, and public health hazards.

The risks associated with improperly sited filling stations are further compounded by uncertainties in the siting process. These uncertainties arise from factors such as inadequate data, weak regulatory enforcement, and conflicting interests among stakeholders. For

example, the lack of accurate information on land use and environmental conditions can make it difficult to assess the suitability of a site for a filling station. Similarly, weak enforcement of regulations can lead to the approval of unsuitable sites, while conflicting interests among stakeholders can result in compromises that prioritize economic gains over safety and sustainability.

Given these challenges, there is a need for a comprehensive analysis of the risks and uncertainties associated with the siting of filling stations in Benin Metropolis. This study seeks to address this need by examining the current regulatory framework, identifying the risks and uncertainties involved, and proposing strategies for improved decision-making.

## **1.2 PROBLEM STATEMENT**

The siting of filling stations in Benin Metropolis has become a major concern due to the increasing number of accidents, environmental degradation, and public health hazards associated with these facilities. Despite the existence of regulations governing the siting of filling stations, many of these facilities are located in unsuitable areas, such as densely populated neighborhoods, flood-prone zones, and near water bodies. This has raised questions about the adequacy of the current regulatory framework and the effectiveness of risk assessment practices.

The problem is further exacerbated by uncertainties in the siting process. These uncertainties arise from factors such as inadequate data, weak regulatory enforcement, and conflicting interests among stakeholders. For example, the lack of accurate information on land use and environmental conditions can make it difficult to assess the suitability of a site for a filling station. Similarly, weak enforcement of regulations can lead to the approval of unsuitable sites, while conflicting interests among stakeholders can result in compromises that prioritize economic gains over safety and sustainability.

The consequences of improperly sited filling stations are far-reaching. They include increased risks of fire outbreaks and explosions, environmental pollution, traffic congestion, and public health hazards. These consequences not only pose a threat to human safety and the environment but also undermine the sustainability of urban development in Benin Metropolis.

Benin Metropolis has experienced rapid urbanization in recent years, leading to increased demand for petroleum products and a corresponding rise in the number of filling stations. However, the siting of these facilities has often been characterized by poor planning and non-compliance with safety regulations.

Given these challenges, there is a need for a comprehensive analysis of the risks and uncertainties associated with the siting of filling stations in Benin Metropolis. This study seeks to address this need by examining the current regulatory framework, identifying the risks and uncertainties involved, and proposing strategies for improved decision-making.

### **1.3 AIM AND OBJECTIVES**

The aim of this study is to analyze the risks and uncertainties associated with the siting of filling stations in Benin Metropolis. The specific objectives are:

1. To assess the current regulatory framework for the siting of filling stations in Benin Metropolis.
2. To identify the risks and uncertainties associated with the location of filling stations.
3. To evaluate the environmental, social, and economic impacts of improperly sited filling stations.
4. To propose strategies for mitigating risks and improving the siting process.

## **1.4 RESEARCH QUESTIONS**

1. What are the existing regulations governing the siting of filling stations in Benin Metropolis?
2. What are the major risks and uncertainties associated with the siting of filling stations?
3. What are the environmental, social, and economic impacts of improperly sited filling stations?
4. What strategies can be implemented to mitigate risks and improve the siting process?

## **1.5 SIGNIFICANCE OF THE STUDY**

This study is significant for several reasons. First, it provides insights into the risks and uncertainties associated with the siting of filling stations in Benin Metropolis. These insights are valuable for policymakers, urban planners, regulatory agencies, and stakeholders in the petroleum industry, as they can inform the development of more effective regulations and risk assessment practices.

Second, the study highlights the environmental, social, and economic impacts of improperly sited filling stations. By identifying these impacts, the study contributes to a better understanding of the trade-offs involved in the siting process and the need for a balanced approach that considers both economic gains and sustainability.

Third, the study proposes strategies for mitigating risks and improving the siting process. These strategies can serve as a guide for decision-makers and stakeholders in Benin Metropolis and other cities facing similar challenges.

Finally, the study contributes to the broader literature on risk analysis and urban planning. By focusing on the specific context of Benin Metropolis, the study adds to the growing body of

knowledge on the challenges and opportunities associated with the siting of filling stations in rapidly urbanizing cities.

## **1.6 RELATED STUDIES**

In developed countries, the siting of filling stations is governed by stringent regulations and advanced technologies. For example, studies in the United States and Europe have highlighted the use of Geographic Information Systems (GIS) for optimal site selection and risk assessment. These technologies enable planners to evaluate factors such as proximity to residential areas, environmental sensitivity, and traffic flow, thereby minimizing risks.

Also, in developing countries the siting of filling stations is often characterized by weak regulatory enforcement, rapid urbanization, and inadequate infrastructure. For instance, studies in India and Kenya have documented cases of filling stations being located in densely populated areas, leading to increased risks of accidents and environmental degradation. These studies emphasize the need for stronger regulations and community involvement in the siting process.

In Nigeria, the siting of filling stations is governed by regulations such as the Department of Petroleum Resources (DPR) guidelines, which specify minimum distances from residential buildings, schools, and other sensitive areas. However, studies have shown that these regulations are often not enforced, leading to the proliferation of filling stations in unsuitable locations. Some of these studies are:

Furthermore, research in Nigeria has highlighted the environmental impacts of improperly sited filling stations, such as groundwater contamination and air pollution. For example, a study in Port Harcourt found that many filling stations were located near water bodies, leading to the contamination of drinking water sources. The study recommended stricter

enforcement of regulations and the use of environmental impact assessments (EIAs) in the siting process.

Studies in Lagos State have documented the public safety risks associated with improperly sited filling stations, such as fire outbreaks and traffic congestion. These studies have called for improved urban planning and risk assessment practices to minimize these risks.



Figure 1: An Explosion of A Tanker At A Filling Station

## **1.7 SCOPE OF THE STUDY**

This study focuses on the siting of filling stations in some selected areas around Benin Metropolis, with an emphasis on risk analysis and uncertainty assessment. It covers the regulatory framework, environmental and social impacts, and mitigation strategies. The study is limited to filling stations within the metropolitan area and does not extend to rural areas or other cities.

## **1.8 LIMITATIONS OF THE STUDY**

The study may face challenges such as limited access to data from regulatory agencies, reluctance of stakeholders to provide information, and the dynamic nature of urban development in Benin Metropolis. However, these limitations will be addressed through the use of secondary data, interviews, and field surveys.

## **1.9 SUMMARY**

### **1.9.1 Chapter One**

Introduces the context and significance of the study, emphasizing the growing need for effective risk analysis in the siting of filling stations due to increasing urbanization, environmental concerns, and public safety issues. The chapter begins by outlining the background of petroleum retail operations and their potential hazards, including fire outbreaks, air and groundwater pollution, and traffic disruptions.

The problem statement highlights the common disregard for regulatory siting standards in many urban and peri-urban areas, leading to elevated risks for surrounding communities. It underscores the gap in strategic planning and enforcement, particularly in fast-growing cities where land-use conflicts are prevalent.

The objectives of the study are clearly defined—to assess the environmental, health, and safety risks associated with existing and proposed filling station locations, and to recommend best practices for safe and sustainable siting. Specific research questions are framed to guide the inquiry, focusing on risk factors, spatial distribution, regulatory compliance, and community vulnerability.

The scope of the study is delineated to cover selected urban areas, using a multidisciplinary approach involving spatial analysis, field assessments, and stakeholder input. Key limitations are acknowledged, such as potential data gaps and regulatory inconsistencies.

The chapter concludes with a justification for the study, stressing its relevance for urban planners, environmental regulators, and policy makers. The anticipated outcome is a set of data-driven recommendations that enhance decision-making and promote public safety in the siting of filling stations.

### **1.9.2 Chapter Two**

The literature review highlights the importance of risk analysis and uncertainty assessment in the siting of filling stations. While existing studies provide valuable insights, there is a need for more research on the specific challenges faced in Benin Metropolis. This study builds on previous research by examining the regulatory framework, identifying risks and uncertainties, and proposing strategies for improved decision-making.

### **1.9.3 Chapter Three**

This chapter outlines the systematic approach adopted in assessing the risks associated with the siting of filling stations. The chapter begins with a methodological overview, presenting the study design as a combination of qualitative and quantitative analyses aimed at evaluating environmental, health, and safety risks. Preliminary investigations included site surveys, literature reviews, and consultations with regulatory guidelines to identify key risk parameters.

The chapter details the criteria used to evaluate potential sites, including proximity to residential areas, schools, water bodies, roads, and compliance with urban planning regulations. Geographic Information System (GIS) tools were employed to map existing filling stations and assess spatial patterns. Risk factors such as fire hazards, groundwater

contamination, traffic congestion, and air pollution were analyzed using multi-criteria decision analysis (MCDA) techniques.

Data collection methods encompassed field observations, interviews with stakeholders (including environmental officers, urban planners, and residents), and analysis of satellite imagery and planning documents. Risk scoring was applied to each site based on predefined thresholds, with higher scores indicating higher risk exposure.

The chapter concludes by justifying the methodological choices, emphasizing their relevance to ensuring objective, data-driven assessments that align with regulatory frameworks and public safety priorities.

#### **1.9.4 Chapter Four**

It presents and analyzes the data collected during the course of the study to evaluate the risks associated with the siting of filling stations. The chapter begins with a description of the study area and the distribution of surveyed filling stations, supported by maps, tables, and charts. Geographic Information System (GIS) outputs are used to visually represent spatial relationships between filling stations and sensitive land uses such as residential areas, schools, healthcare facilities, and water bodies.

Quantitative data from field surveys, risk assessment tools, and stakeholder interviews are systematically organized to highlight key findings. Parameters assessed include distance from critical infrastructure, frequency of safety violations, traffic density, and presence of pollution indicators. Each filling station is scored based on established risk criteria, with classifications ranging from low to high risk.

Statistical tools are applied to analyze spatial patterns and identify correlations between station locations and potential hazards. The analysis reveals trends such as clustering of

filling stations in densely populated zones, non-compliance with regulatory setback distances, and poor safety infrastructure in high-risk areas.

The chapter also incorporates qualitative insights from residents and regulatory officers, revealing concerns about noise, air quality, traffic congestion, and emergency preparedness. These perspectives help contextualize the quantitative results and expose areas where regulatory oversight is lacking.

In conclusion, the analysis identifies specific sites with elevated risk levels and provides a basis for recommending mitigation strategies and stricter regulatory enforcement.

### **1.9.5 Chapter Five**

Synthesizes the key findings of the study, draws meaningful conclusions, and offers practical recommendations for safer and more sustainable siting of filling stations. The chapter begins with a summary of the research objectives and methodology, reiterating the focus on assessing environmental, safety, and public health risks associated with poorly located filling stations.

The main findings are recapped, including evidence of widespread non-compliance with siting regulations, clustering of stations near sensitive areas, and poor risk mitigation infrastructure. The study also found a strong correlation between station proximity to residential areas and increased exposure to fire, pollution, and traffic-related risks.

In the conclusion, the study affirms the need for stricter adherence to urban planning standards and improved coordination among stakeholders—particularly town planners, environmental protection agencies, and petroleum regulators. It highlights the critical role of data-driven decision-making in preventing accidents and protecting public health.

The recommendations propose actionable steps such as:

1. Strict enforcement of minimum setback distances;

2. Mandatory Environmental Impact Assessments (EIAs) before licensing new stations;
3. Regular monitoring and risk audits of existing stations;
4. Use of GIS tools for planning and regulatory oversight;
5. Increased public awareness and stakeholder engagement in siting decisions.

The chapter ends by emphasizing that risk-informed planning is essential for urban safety, and that long-term sustainability depends on integrating environmental and public safety concerns into infrastructural development policies.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 IWUOHA (2018)**

Is a researcher and academic who has carried out studies on the safety and environmental risks associated with industrial facilities, including filling stations. His work often focuses on risk assessment, hazard identification, and environmental impact assessments in urban contexts such as Nigerian cities. In his study, he examined the risks associated with filling stations in Lagos, focusing on hazard identification and the impact of poorly sited stations on residential areas.

#### **2.2 OLATUNDE (2019)**

Is a professor of Environmental Engineering and a frequent contributor to studies on safety and risk analysis for industrial operations, including the siting of filling stations in Nigeria. His research often incorporates quantitative risk assessment (QRA) techniques to model accidents involving hazardous materials, such as fuel spills or explosions. In his study on the environmental risks posed by filling stations located near water bodies in Nigeria, specifically in Lagos and Port Harcourt, and the potential for groundwater contamination.

#### **2.3 National Centre for Petroleum and Energy Research (NCPER) (2020)**

Carried out studies on the safe siting and management of filling stations across various cities in Nigeria, focusing on minimizing risks related to fuel storage and dispensing. The center works on analyzing environmental and safety risks and has made recommendations for improved safety protocols. NCPER's study on filling stations in Abuja included risk analyses using Monte Carlo simulations to model different accident scenarios and determine the most effective risk mitigation strategies.

## **2.4 OLUSEGUN (2019)**

Has conducted research on the safety risks associated with petroleum storage facilities, including filling stations in Nigeria. His work integrates aspects of risk perception, operational safety, and regulatory frameworks. His research on risk perception and safety measures at filling stations includes the identification of operational uncertainties that affect the safety of filling stations, such as maintenance practices and regulatory enforcement (2019)

## **2.5 OGBEMI (2020)**

Examined the spatial distribution of filling stations in Benin Metropolis and found that many were located in unsuitable areas, such as flood-prone zones and near residential buildings. The study called for improved urban planning and risk assessment in the siting process.

## **2.6 NJOKU AND ALAGBE (2015)**

In this study, a GIS was developed for PFS site suitability assessment. The standard criteria set for PFS siting by Oyo State Urban and Regional Planning Board (OSURPB) and the Nigerian Department of Petroleum Resources (DPR) were considered. The DPR criteria were incorporated to assess possible lapses in the local standards. The study is multi-dimensional, incorporating suitability, proximity and spatial statistical techniques. The results showed that, out of the 113 PFSs in the area, only 3, representing just 2.654 percent are in high suitability zone, 6 PFSs (5.309 percent) in in medium as well low and 98 stations(86.725 percent) in very low suitability zone. Considering the OSURPB criterion, 76 PFSs are at unacceptable distances to residential land use and as much as 102 PFSs considering the DPR criterion. Also, assessing the size of PFSs, 41 stations (39 percent) have the standard land area while 69 PFSs (61 percent) were deficient. Furthermore, only 6 stations, representing 5 percent of PFSs in the area have their dispensing pumps at least 15m off the road. More so, the assessment of the spatial pattern of PFSs in the area showed that the distribution of petrol

stations are very clustered with less than 1 percent likelihood that the clustered pattern could be a result of random chance. In a nutshell, it can be concluded that most PFSs in Oyo town, considering both local and national siting standards are not suitably sited and also contravene planning standards. Also, the substandard requirements proliferated by the local planning authorities, who are defiant of the national standards undoubtedly increases the threats on the health and safety of users and residents in the vicinity of the PFSs

## **2.7 AROKOYU, OGORO AND AMANORITSEWO (2015)**

The study examines the proliferation of petrol filling stations in relation to the minimum environmental safety requirements by the Department of Petroleum Resources (DPR) that ‘distance from the edge of the road to the nearest pump and from the next petrol filling station should not be less than 15 and 400 meters respectively. The Global Positioning System (GPS) was used to acquire the coordinates of each filling station in the study area and then imported to the ArcGIS 9.3 software environment. Distances between filling stations from the road and from each other were determined using the ArcGIS 9.3 measurement tool alongside buffering analysis in respect to their coordinates. The Z ratio analytical technique was used to examine the conformity of petrol filling stations to the required distance of 400m and 15m from each other and from the road respectively as stipulated by DPR amendment decree 37 of 1997. Findings from the z ratio analysis at 152 degree of freedom and 95% confidence level reveals that the petrol filling stations in the study area neither conform to the required distance of 400m apart nor conform to the required distance of 15m from the road. Thus, the study recommends, among others, the need for the regulatory agency, DPR, to improve their capacity in enforcing the compliance of petrol filling stations with laid down regulations. Keywords: Proliferation, regulatory agency, petroleum, filling stations, safety requirements.

## **2.8 YUSUF, SAWA, USMAN AND KUFORIJIMI (2024)**

Nigeria is the most populous country in the Organization of Petroleum Exporting Countries (OPEC) with a population of about 250 million people. Bauchi metropolis has witnessed great changes in recent years, in terms of population growth and rapid urbanization. This study aims to assess the level of compliance of petrol filling stations in Bauchi metropolis to the standards of the Department of Petroleum Resources [DPR] (2007) and Bauchi State Development Board [BSDB] (2012) guidelines. Field survey, Grid3 portal and Global positioning system (GPS) were the research instruments used for the study. ArcGIS 10.8 was used to carry out the analysis using the Buffer and Near analyses. The results indicated that the distribution pattern of the filling stations is clustered. The study found out that only 33.63% of the stations violated the criterion of a 15-meter minimum distance from the road while the rest fulfilled that requirement. However, 11.81% of the stations met a minimum distance of 400 meters from their nearest neighbors, while 88.18% failed to achieve the minimum distance of 400 meters. The study also revealed that only 3.63% met the requirement of not more than four stations within a 2 Km radius. Based on the findings of this research, the study recommends that the DPR and the BSUDB should create a database for filling stations in Bauchi Metropolis.

## **2.9 PERIE, ULAKPA AND EYANKWARE (2022)**

The poor state of the environment, especially in urban areas, has become a major global issue, with developing countries such as Nigeria voicing growing concern. There is a scarcity of knowledge on the environmental impact of PFSs as a result of the loss of life and property, as well as other serious socio-economic implications of non-compliance with PFSs siting criteria. The historical literature on the impact of residential buildings, the environment, and human health on PFSs in Nigeria, as well as the study's gap, is examined in this research. It also outlines DPR compliance with PFSs location as well as established criteria for

prohibiting PFS siting in Nigeria's states. Relevant publications on PFSs-related topics were downloaded from Google Scholar. The goal of this study is to look back on a previous essay about PFSs in Nigeria and its impacts on the environment and human health. This study's main purpose is to give a complete overview of Nigerian PFSs. According to the article analyzed, the majority of PFSs were located close to residents, with setbacks from the road and residential areas of less than 30 m in 90% of the filling stations. As a result, the landowners can band together to argue that a facility that is improperly sited cannot be built. A great deal of public participation is required. A campaign should be launched to raise awareness among filling station owners and other developers of the dangers of non-compliance with established norms. All violators of the established norms, as well as corrupt officials of enforcement agencies/bodies, should face open punishment so that others might learn their lessons. Finally, appropriate planning is required to allow future road expansion.

## **2.10 AHMED, SHARIFF, KUTTY AND KHAMIDI (2011)**

Petrol Fuel Stations (PFS) are hazardous work places. They store and sell flammable material (petrol, diesel and CNG). Arrival and departure of various kinds of vehicles to take fuel is normal round the clock. Due to availability of flammable materials at PFS poses constant hazard to the staff, public, assets and environment. Minor mistake has the potential to create disastrous situations. Human behavior found one of the dominant factors to create hazard contributing scenarios at PFS. One year data collected (2008) and 1203 events recorded. Other factors related to process failure also exist but requires less attention. 1203 hazard contributing factors further divided into 8 main categories. These are housekeeping (55), transportation hazard (255), slips trips and falls (215), carelessness (244), fire (17), electrical fault (97), medical treatment cases (61) and miscellaneous cases (279). Detail description of these hazards contributing factors also presenting in this paper. Based upon occurrences of

these hazard contributing factors, safety and risk assessment framework prepared and is presenting in this study for further implementation.

## **2.11 AHMED, SHARIFF, KUTTY, KHAMIDI, TRONOH, PERAK AND MALAYSIA**

Injury free work environment is an essential element for any successful project. Better safety performances can be achieved only if safety matters priority at all stages of project addressed adequately. Concrete efforts of owners, contractors, sub contractors and designers are equally important at different levels of project. It is necessary to develop such strategies that can help to reduce injury cases. Past safety studies investigated various methods to improve injury statistics but it still contains more room for improvement. This paper will present the application of risk assessment criteria (RAC) to identify critical, major, moderate and minor activities during fuel station operation. Health safety & environmental hazards related to fuel stations activities will be identified, estimate the associated risks and necessary control measures for mitigation of identified risks will be highlighted in this study. The RAC used in this study is widely applying in upstream oil and gas sector in Pakistan. Poor maintenance, carelessness, house keeping, mechanical fault and robbery found to be the major causes of occurrences of unsafe acts and unsafe conditions at fuel stations. RAC are methods of work system design and helpful to address associated risks in a project. During study it was felt that many resources are available within an organization to minimize accidents/injuries but due to not fully utilization of these resources accidents/incidents happen. After calculating risks, application of available resources can be done more appropriately. In case of unavailability, requirements can be highlighted and applied strategically to get better results.

## **2.12 GAPS IN LITERATURE**

There is limited research on the uncertainties involved in the siting of filling stations, particularly in Benin Metropolis. Most studies have focused on regulatory compliance and environmental impacts, with little attention to the social and economic dimensions of risk. Also there is a lack of comprehensive frameworks for integrating risk analysis and uncertainty assessment into the siting of filling stations. This study aims to develop such a framework, taking into account the unique challenges faced in Benin Metropolis. Furthermore, existing studies have often overlooked the perspectives of key stakeholders, such as filling station owners, regulatory agencies, and local communities. This study seeks to incorporate these perspectives to provide a more holistic understanding of the siting process.

## CHAPTER THREE

### METHODOLOGY

#### 3.1 RESEARCH DESIGN

This study adopts a **mixed-methods research design**, combining both qualitative and quantitative approaches to provide a comprehensive analysis of the risks and uncertainties associated with the siting of filling stations in Benin Metropolis. The mixed-methods approach allows for the collection and analysis of diverse data types, enabling a deeper understanding of the research problem.

1. **Quantitative Approach:** This involves the collection and analysis of numerical data to identify patterns, trends, and relationships.
2. **Qualitative Approach:** This involves the collection and analysis of non-numerical data, such as interviews and observations, to gain insights into stakeholders' perspectives and experiences.

#### 3.2 STUDY AREA

The study area was carried out in some selected areas in **Benin Metropolis**, the capital city of Edo State, Nigeria. Benin Metropolis is a rapidly urbanizing city with a high concentration of filling stations, making it an ideal location for this research.

1. **Geographical Characteristics:** The locations of the area are located in the tropical rainforest zone, with a high population density and significant economic activity. These locations are :

Region	Latitude Coordinates	Longitude Coordinates
Oluku, Ovia North-East	6° 26' 58" N	5° 35' 49" E
Ugbowo, <u>Egor</u> ,	6° 24' 1" N	5° 36' 36" E
Sapele Road	6° 31' 56" N	5° 60' 32" E
Ekehuan Road	6° 11' 24" N	5° 22' 11" E
Airport Road	6° 19' 00" N	5° 36' 00" E
Ring Road (Kings Square), Egor	6° 33' 56" N	5° 62' 67" E

2. **Relevance to the Study:** The proliferation of filling stations in Benin Metropolis, coupled with the challenges of urbanization, makes it a suitable case study for analyzing the risks and uncertainties associated with their siting.



Figure 2: A Satellite View of The Study Area

### 3.3 POPULATION AND SAMPLING

The population for this study includes the following groups:

1. **Filling Station Owners and Operators:** These are individuals or organizations that own or manage filling stations in Benin Metropolis.
2. **Regulatory Agencies:** These include officials from the Department of Petroleum Resources (DPR), urban planning authorities, and environmental protection agencies.
3. **Residents:** These are members of the local community living near filling stations.
4. **Urban Planners and Experts:** These are professionals with expertise in urban planning, risk assessment, and environmental management.

### 3.4 DATA COLLECTION METHODS

Data will be collected using both primary and secondary sources.

#### 3.4.1 Primary Data

##### 3.4.1.1 Questionnaires

Structured questionnaires will be administered to filling station attendants, supervisor/managers and residents, people around. Different questionnaires were designed for each group to be able to collect different data from different perspectives.

#### 1. Supervisor

The Supervisor Questionnaire is designed to evaluate the safety practices, environmental impact, and emergency preparedness of the filling station from a managerial perspective. Supervisors play a crucial role in maintaining safety standards, overseeing staff training, and implementing emergency response protocols.

By gathering insights from supervisors, this questionnaire aims to:

- i. . Assess Safety Measures
- ii. Evaluate Training Programs
- iii. Monitor Environmental Impact
- iv. Analyze Emergency Preparedness
- v. Identify Operational Challenges

Here are some of the question category contained in the questionnaire:

- a. Regulatory Compliance and Approvals
- b. Safety and Training
- c. Emergency Preparedness
- d. Environmental and Community Considerations
- e. Infrastructure and Utilities
- f. Waste Management and Spill Control

## **2. Attendants**

The Attendant Questionnaire is designed to assess the safety awareness, training, and operational practices of fuel attendants at the filling station. As front line workers, fuel attendants play a critical role in ensuring safe fuel dispensing, preventing accidents, and responding to emergencies.

The objectives of this questionnaire include:

- i. Evaluating Safety Knowledge
- ii. Assessing Training and Compliance
- iii. Identifying Workplace Hazards
- iv. Understanding Emergency Preparedness

v. Monitoring Environmental Awareness

Here are some of the question category contained in the questionnaire:

a. Emergency Exits & Safety Signage

b. Attendant Experience & Safety Training

c. Equipment Inspection & Maintenance

d. First Aid Knowledge

e. Fuel Storage & Leak Detection

f. Emergency Situations & Incident Handling

g. Safety Signage & Awareness

h. Reporting & Environmental Responsibility

### **3. People Around**

The **People Around Questionnaire** is designed to gather insights from residents and businesses located near the filling station. Since fuel stations pose potential risks such as fire hazards, air pollution, and traffic congestion, it is essential to understand how the presence of a filling station affects the surrounding community.

The objectives of this questionnaire include:

i. Assessing Community Awareness

ii. Evaluating Safety Perceptions

iii. Identifying Environmental Concerns

iv. Measuring Community Engagement

v. Documenting Health and Safety Issues

Here are some of the question category contained in the questionnaire:

- a. Demographic and Awareness Questions
- b. Safety Perceptions and Emergency Preparedness
- c. Environmental Concerns
- d. Community Engagement and Communication
- e. Emergency Readiness and Preparedness
- f. Traffic and Other Community Impacts
- g. Recommendations and Future Developments

#### **3.4.1.2 Field Observations (Visual Inspection)**

Visual inspection is a key qualitative method used in this project to assess the safety, environmental, and operational conditions of filling stations. This method involves physically observing and documenting various aspects of the filling station, including infrastructure, equipment, safety measures, and environmental impact.

##### **Objectives of Visual Inspection:**

1. Assess Compliance with Safety Standards – Ensure that the filling station meets regulatory requirements for fire safety, spill control, and emergency preparedness.
2. Identify Potential Hazards – Detect visible risks such as fuel leaks, damaged equipment, poor drainage, or inadequate ventilation.
3. Evaluate Environmental Impact – Observe signs of soil contamination, air pollution, or improper waste disposal.
4. Verify Maintenance and Housekeeping – Check for the proper condition of storage tanks, dispensers, signage, lighting, and drainage systems.

5. Monitor Emergency Preparedness – Ensure that firefighting equipment, emergency exits, and safety signs are clearly marked and functional.

**Process of Visual Inspection:**

1. **Site Walkthrough:** A systematic observation of the entire filling station, including the fueling area, storage tanks, drainage system, and surrounding environment.
2. **Equipment Examination:** Inspecting pumps, hoses, dispensers, fire extinguishers, and emergency shutdown mechanisms for any signs of wear, leakage, or malfunction.
3. **Safety and Compliance Checks:** Evaluating the presence and clarity of warning signs, fire safety measures, and adherence to standard operating procedures.
4. **Environmental Observations:** Checking for fuel spills, unusual odors, smoke emissions, or contamination indicators in soil or water sources nearby.

During the visual inspection, a checklist with different inspection criteria was used to note the observations in each filling station that was visited. Below is a list of the different criteria that were observed during the visual inspection:

**a. Fire and Explosion Hazards**

- i. Underground Piping (Markings to Prevent Excavation Damage)
- ii. Dispensing Equipment
- iii. Fuel Spills
- v. Vapor Accumulation

**b. Health and Safety Hazards**

- i. Exposure to Hazardous Substances
- iii. Slip, Trip, and Fall Hazards
- iv. Vehicle Traffic

**c. Security Hazards**

- i. Theft and Robbery

- ii. Vandalism

**d. Environmental Hazards**

- i. Soil and Water Contamination

**e. Operational Hazards**

- i. Equipment Failure

- ii. Emergency Response

**f. Additional Considerations**

- i. Fire Protection Systems

- ii. Emergency Exits

- iii. Emergency Shutdowns

- iv. Training and Awareness

- v. Security of the Facility

### **3.4.2 Secondary Data**

#### **3.4.2.1 Regulatory Documents**

These include guidelines and reports from the Department of Petroleum Resources (DPR), urban planning authorities, and environmental protection agencies. The secondary data collected were used to determine the level of compliance to the laid down regulations by the DPR.

1. Sustainability Check By The Department Of Petroleum Resources:
  - a. Size of the proposed land site.
  - b. The site does not lie within pipeline or electricity high tension cable Right Of Way (ROW).
  - c. The distance from the edge of the road to the nearest pump will not be less than 15 meters.

- d. Total number of petrol stations within a 2 km stretch of the site on both sides of the road will not be more than four including the one under consideration.
- e. The distance between an existing station and the proposed one will not be less than 400 (four hundred) meters.
- f. The drainage from the site will not go into a stream or river.
- g. In some instances where the site is along Federal Highway, a letter of consent from the Federal Highway is required.
- h. DPR guided/supervised Environmental Impact Assessment (EIA) study of the site by DPR accredited consultant.

2. Requirements For Issuance Of Storage And Sales Licence. The following conditions must be met before storage and sales licence can be granted:

- a. A minimum of three (3) underground storage tanks (one each for PMS, DPK, and AGO.)
- b. A minimum of three (3) dispensing pumps (one each for PMS, DPK and AGO)
- c. Office building: Two (2) offices, saleroom, toilet, lube bay/store (Optional).
- d. Well concreted forecourt "IN/OUT" driveway inclusive.
- e. Wall fence demarcating the station (minimum height of 1.5m high).
- f. Good drainage Network.
- g. Safety facilities (Fire Extinguishers, Sand Buckets, strategic display of "NO SMOKING" warning signs.
- h. Station Sign post/logo of company/outlet.
- i. Standard canopy over PMS pumps (mandatory) with company name and logo boldly written.
- j. Standby Generator.
- k. Accessible potable water source.
- l. Standard (51" x 30") price bill board with changeable price mechanism.

3. Requirements To Operate A Petrol Filling Station in addition to the major requirements on the "Approval to Operate Filling Station" issued along with the maiden licence of a station, the following are also mandatory :

- a. Functional Fire fighting gadgets must be kept handy and at alert.
- b. Ensure that a station Manager/Supervisor is always at the station
- c. Always make available alternative sources of power to operate products pumps and adequate illumination of the station.
- d. Products are sold at prevailing government approved price
- e. Products pumps accurate dispense/display of volume and price
- f. Pump attendants trained and dressed in safety wears
- g. Ensure that vehicle engines are switched off before fueling
- h. Strategic and conspicuous display of warning signs on "NO SMOKING and NO USE OF CELLPHONE" within the station
- i. Stations always maintain good housekeeping.
- j. Tanker trucks are earthed before starting and throughout products discharge
- k. Copy of each way-bill for products on sale shall have to be available at the station at all times.
- l. Products in tanker trucks to be discharged into storage tanks shall have to be allowed to settle for at least two (2) hours while in the station before the discharge.
- m. Display of Current Storage and Sales licence in the station's office.
- n. Availability of DPR inspections log book in the station
- o. Unrestricted access to DPR officials to carry out statutory functions in the station

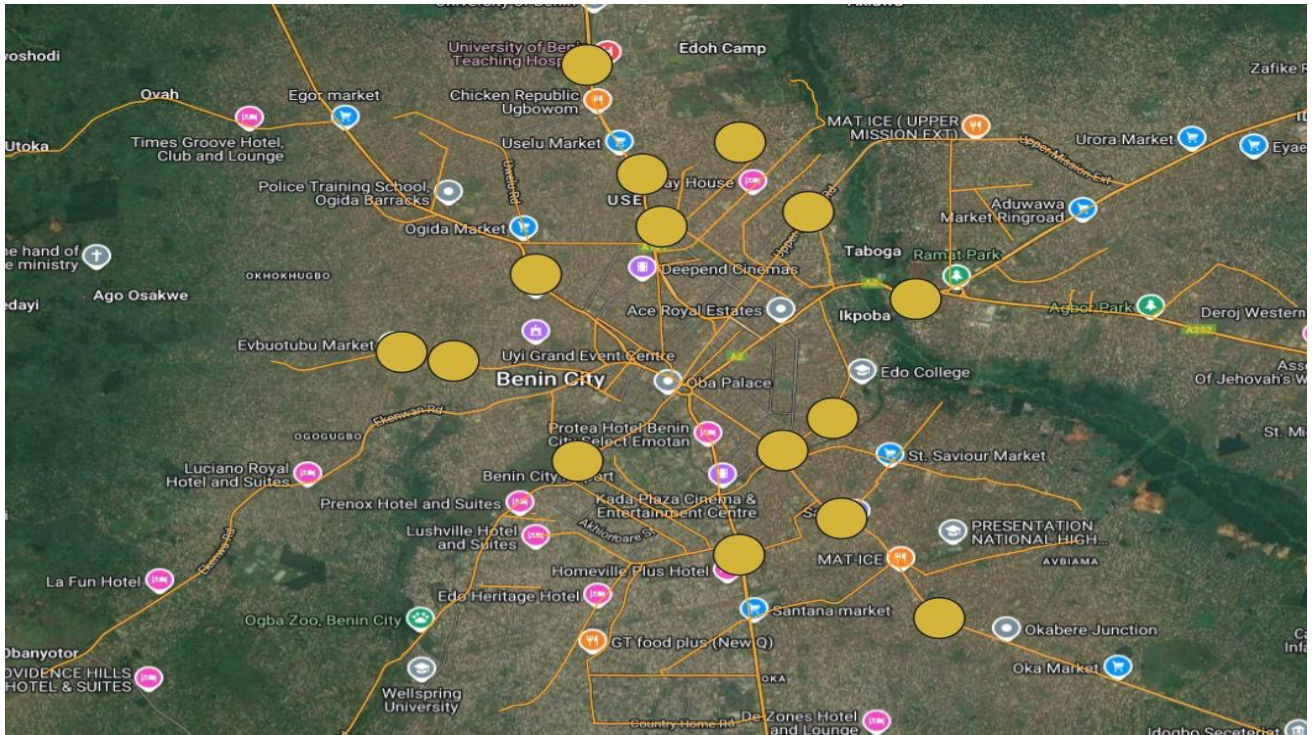


Figure 3: Showing The Filling Stations With distances greater than 400m

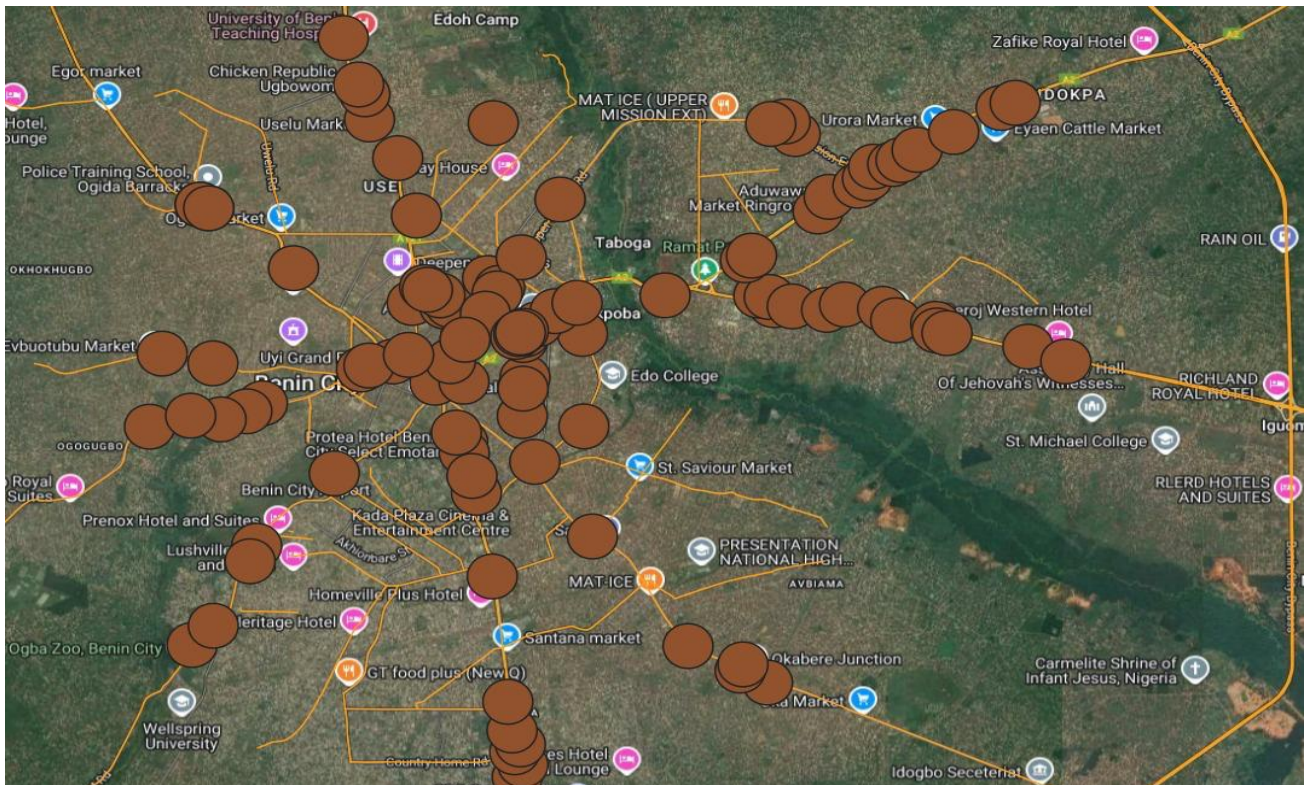


Figure 4: Showing The Filling Stations With distances less than 400m

### **3.4.2.3 Geospatial Data**

Geospatial data refers to information that describes the geographic location, features, and spatial relationships of objects on Earth. In this project, geospatial data is essential for analyzing the distribution, accessibility, and environmental impact of filling stations in Benin City. It provides a spatial framework for assessing compliance with safety regulations and optimizing site selection.

#### **Types of Geospatial Data Used:**

- 1. Satellite Imagery & Aerial Photographs** – High-resolution images help visualize land use, road networks, and environmental features.
- 2. Topographic Data** – Information on elevation, slopes, and landforms to assess terrain suitability for filling stations.
- 3. Road Network Data** – Maps showing highways, streets, and traffic patterns to evaluate accessibility.
- 4. Land Use and Zoning Data** – Data indicating residential, commercial, industrial, and restricted areas to ensure proper station siting.
- 5. Hydrological Data** – Information on water bodies, drainage systems, and flood-prone areas to minimize environmental hazards.
- 6. Population Density & Demographics** – Data on settlements and human activity to assess demand and safety concerns.
- 7. Environmental & Hazard Data** – Records of pollution levels, air quality, and risk-prone areas to evaluate sustainability.
- 8. Regulatory Compliance Data** – Spatial data on legal buffer zones, safety distances, and government-approved locations for filling stations.

#### **Sources of Geospatial Data:**

1. **Geographic Information Systems (GIS)** – Platforms like ArcGIS and QGIS for spatial mapping and analysis.
2. **Remote Sensing** – Satellite and drone imagery for large-scale environmental assessment.
3. **Government & Regulatory Agencies** – Data from urban planning, transportation, and environmental protection departments.
4. **Survey and Field Data Collection** – Ground-truthing methods to verify geospatial accuracy.
5. **Public Health Impact:** Study the potential health effects of air pollution and noise on nearby residents, also proposing measures to protect public health.

### **3.5 DATA ANALYSIS**

Data analysis will involve both quantitative and qualitative techniques.

#### **3.5.1 Quantitative Analysis**

- a. **Descriptive Statistics:** This will be used to summarize the data, including frequencies, percentages, and means. For example, the number of filling stations located in high-risk areas will be calculated and presented in tables and charts.
- b. **Geospatial Analysis:** Geospatial analysis is a crucial method used in this project to assess the spatial distribution, environmental impact, and risk factors associated with the siting of filling stations in Benin City. This method involves using Geographic Information Systems (GIS) and spatial data to evaluate location suitability, safety concerns, and compliance with regulatory standards.

#### **Objectives of Geospatial Analysis:**

1. **Identify Suitable Locations** – Assess land use, proximity to major roads, and compliance with zoning regulations.
2. **Evaluate Environmental and Safety Risks** – Analyze proximity to residential areas, schools, hospitals, water bodies, and other sensitive zones.
3. **Assess Accessibility and Infrastructure** – Determine the ease of access for customers, fuel tankers, and emergency services.
4. **Analyze Population Density and Demand** – Study urban population distribution to ensure optimal service coverage.
5. **Monitor Compliance with Regulations** – Compare existing filling stations' locations with government guidelines to identify potential violations.

#### **Process of Geospatial Analysis:**

1. **Data Collection:** Gathering spatial data on road networks, land use, population density, and existing filling stations.
2. **GIS Mapping:** Using Geographic Information Systems (GIS) to visualize filling station locations, risk zones, and accessibility.
3. **Buffer Analysis:** Creating buffer zones around sensitive areas (e.g., schools, hospitals) to ensure compliance with safety regulations.

#### **3.5.2 Qualitative Analysis**

- a. **Content Analysis:** This will be used to analyze regulatory documents and secondary data. Key concepts and trends will be identified and discussed.

### **3.6 ETHICAL CONSIDERATIONS**

The study will adhere to ethical research practices, including:

- a. **Informed Consent:** Participants will be provided with detailed information about the study and their rights before they agree to participate.

- b. **Confidentiality:** All data collected will be kept confidential, and participants' identities will not be disclosed without their consent.
- c. **Avoidance of Harm:** The study will ensure that participants are not exposed to any physical, psychological, or social harm.
- d. **Transparency:** The research process will be transparent, and findings will be reported accurately and honestly.

### **3.7 LIMITATIONS OF THE STUDY**

- a. **Data Availability:** Access to data from regulatory agencies and filling station owners may be limited due to confidentiality concerns.
- b. **Resource Constraints:** The study may be limited by time and financial resources, which could affect the scope and depth of data collection.
- c. **Dynamic Nature of Urban Development:** The rapid pace of urbanization in Benin Metropolis may result in changes to the study area during the research period.

Despite these limitations, the study will strive to provide a comprehensive and accurate analysis of the risks and uncertainties associated with the siting of filling stations in Benin Metropolis.

## **CHAPTER FOUR**

### **RESULTS AND DISCUSSION**

This chapter presents a comprehensive overview of the findings derived from the research on risk and uncertainty in the siting of filling stations in Benin City. It systematically outlines the results obtained through both quantitative and qualitative methods, offering insights into the diverse perspectives of supervisors, attendants, and local residents. The analysis is structured to first detail the statistical trends and patterns observed in the data, followed by an in-depth thematic exploration of the qualitative responses.

Through a meticulous analysis of the data, this chapter aims to not only elucidate the key risks identified but also to explore the uncertainties that underpin these risks, thereby offering a robust framework for informed decision-making in the context of urban planning and public safety.

#### **4.1 QUESTIONNAIRES ANALYSIS**

Preliminary insights suggest that:

1. Supervisors tend to focus on technical, regulatory, and compliance-related risks, reflecting their operational oversight responsibilities.
2. Attendants are more concerned with immediate safety issues and operational hazards, underscoring the day-to-day challenges faced at the filling stations.
3. Local Residents highlight environmental and public health concerns, pointing to the broader community impact of filling station siting.

By triangulating these perspectives, the analysis will provide a multi-faceted understanding of the risk landscape. This approach is crucial in ensuring that recommendations for filling station siting are robust, comprehensive, and sensitive to the varied dimensions of risk and uncertainty.

#### 4.1.1 Analysis of Supervisors' Questionnaire

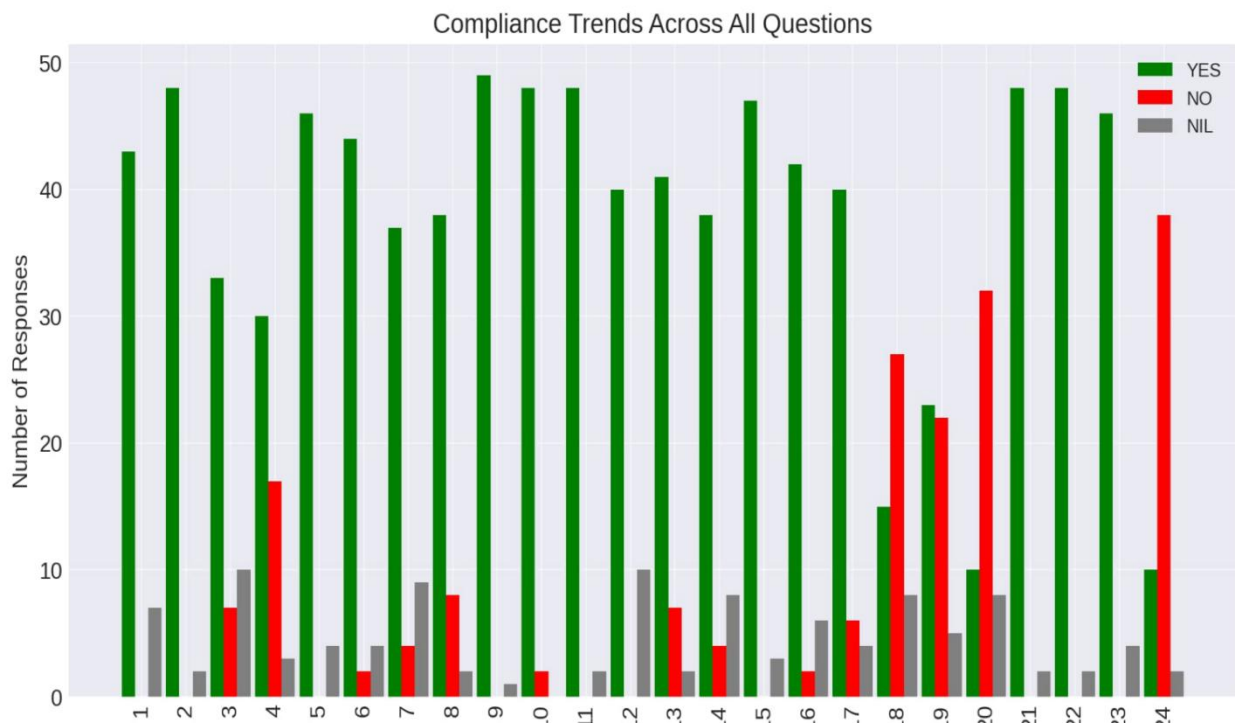
Table 1: Demographic Data For Supervisors

DEMOGRAPHIC DATA FOR SUPERVISORS						
Age	Under 18	18-24	25-34	35-44	45-54	55+
S/N	0	0	10	29	8	3
Gender	Male	Female				
S/N	47	3	-	-	-	-
Education level	Primary	Secondary	Undergraduate	Postgraduate	Others	
S/N	0	0	27	13	10	-
Employment Status	full-time	part-time	Self-employed	Unemployed	Student	Retired
S/N	50	0	0	0	0	0

Table 2: Table Of Results For Supervisors

S/N	QUESTIONS	Y ES	N O	N IL
1	Have you submitted the architectural and structural designs for approval by the relevant authorities?	43	-	7
2	Do the designs include provisions for fire safety equipment and proper ventilation?	48	-	2
3	Are underground storage tanks (USTs) designed and installed according to DPR-approved specifications?	33	7	10
4	Have you implemented proper drainage systems and spill control measures?	30	1 7	3
5	Is there an approval from the State Fire Service for fire safety measures?	46	-	4
6	Are the employees trained in safety procedures, firefighting, and first aid?	44	2	4
7	Does the filling station have mechanisms in place to control vapor emissions during fuel dispensing?	37	4	9
8	Have you established a waste management plan for disposing of fuel residues and used oil?	38	8	2
9	Do you have emergency response procedures and equipment in place for leak detection and firefighting?	49	-	1
10	Are fire extinguishers, sand buckets, and other firefighting equipment readily available and regularly maintained?	48	2	-
11	Have employees undergone training in handling emergency situations, such as fires, spills, or gas leaks?	48	-	2
12	Is there a designated muster point for customers and staff in the event of an emergency?	40	-	10
13	Are there procedures in place to regularly inspect fuel dispensing equipment for leaks, faults, or other potential hazards?	41	7	2
14	Do you have a first aid kit on-site, and are employees trained to provide basic first aid if needed?	38	4	8
15	Is the area around the filling station properly lit to ensure the safety of customers, especially during nighttime operations?	47	-	3
16	Have measures been taken to limit the exposure of customers and staff to harmful fumes from the dispensing of fuel?	42	2	6
17	Do the tanks and dispensing equipment have overfilled protection devices to prevent spills during refueling?	40	6	4
18	Have community members been involved in the planning or decision-making process?	15	2 7	8
19	Have any concerns or objections been raised by community members?	23	2 2	5
20	Have any compensation or mitigation measures been proposed for potential negative impacts?	10	3 2	8
21	Is the existing power infrastructure capable of handling the energy requirements of the filling station?	48	-	2
22	Is there a reliable supply of electricity to the filling station?	48	-	2
23	Is there a reliable source of potable water available at the filling station?	46	-	4

Figure 5: Compliance Trends Across All Questions (Supervisor)



#### 4.1.1.1 Bar Chart Interpretation

The green bars (YES responses) dominate, indicating general compliance.

The red bars (NO responses) and gray bars (NIL responses) show areas of non-compliance and uncertainty. Some questions have significantly higher NO and NIL responses, indicating high-risk areas.

#### Summary Statistics of Responses

Total YES Responses: 912 (76.13%), Total NO Responses: 178 (14.86%) & Total NIL Responses: 108 (9.02%).

**Interpretation:** The majority (76.13%) of responses indicate compliance with safety and regulatory requirements. However, 24% (NO & NIL responses) highlight non-compliance risks, which need attention.

#### Further Insights from the responses

1. Submission of Architectural and Structural Designs YES: 43 (86%), NO: 0 (0%) & NIL: 7 (14%)

**Interpretation:** Most supervisors confirmed that architectural and structural designs were submitted, which is a positive indication of regulatory compliance. However, the 14% "NIL" responses suggest some filling stations may not have documented approvals, increasing structural risks.

**Risk Implication:** Filling stations without proper structural documentation may be prone to building collapses, poor site planning, and environmental hazards.

2. Fire Safety Provisions in Designs YES: 48 (96%), NO: 0 (0%) & NIL: 2 (4%)

**Interpretation:** The majority of supervisors affirmed that fire safety provisions were included in the designs, which is critical for risk mitigation. However, the 4% "NIL" responses indicate potential non-compliance in some cases.

**Risk Implication:** Lack of fire safety measures increases the risk of fire outbreaks, leading to loss of life, property, and environmental damage.

3. Design Standards for Underground Storage Tanks (USTs) YES: 33 (66%), NO: 7 (14%) & NIL: 10 (20%)

**Interpretation:** While 66% of the respondents confirmed proper UST designs, 34% (NO and NIL) indicated otherwise. This suggests a significant number of stations may be operating with substandard fuel storage.

**Risk Implication:** Improper UST design can result in fuel leaks, groundwater contamination, and increased fire hazards.

4. Implementation of Drainage Systems YES: 30 (60%), NO: 17 (34%) & NIL: 3 (6%)

**Interpretation:** A notable 40% (NO and NIL) of responses indicate poor or absent drainage systems, raising concerns about environmental management at filling stations.

**Risk Implication:** Poor drainage can lead to water accumulation, fuel runoff, and increased risk of fire hazards or pollution.

5. Approval from the State Fire Service YES: 46 (92%), NO: 0 (0%) & NIL: 4 (8%)

**Interpretation:** Most filling stations obtained fire service approval, showing compliance with fire safety regulations. However, 8% lack approval, which is concerning.

**Risk Implication:** Without fire service approval, a filling station may be unprepared for fire emergencies, leading to disastrous consequences.

6. Compliance with Environmental Impact Assessment (EIA) YES: 42 (84%), NO: 3 (6%) & NIL: 5 (10%)

**Interpretation:** While 84% confirmed compliance, 16% did not, indicating a risk of environmental degradation.

**Risk Implication:**

Non-compliance with EIA increases the chances of pollution, health hazards, and regulatory penalties.

7. Adequate Setback from Residential Areas YES: 38 (76%), NO: 9 (18%) & NIL: 3 (6%)

**Interpretation:** A total of 24% (NO and NIL) responses indicate that some stations may be too close to residential areas, increasing safety concerns.

**Risk Implication:** Inadequate setback increases the risk of explosions affecting residential communities.

8. Proper Ventilation and Fire Control Measures YES: 41 (82%), NO: 7 (14%) & NIL: 2 (4%)

**Interpretation:** While most stations ensure ventilation, 18% do not, which poses a fire hazard.

**Risk Implication:** Poor ventilation increases the accumulation of volatile fuel vapors, raising explosion risks.

9. Regular Inspection and Maintenance of Storage Tanks YES: 37 (74%), NO: 10 (20%)  
& NIL: 3 (6%)

**Interpretation:** About 26% of responses indicate that some stations do not conduct regular maintenance, posing operational risks.

**Risk Implication:** Neglected tanks may corrode, leading to fuel leaks, contamination, and fire hazards.

10. Compliance with Minimum Distance Between Stations YES: 39 (78%), NO: 8 (16%)  
& NIL: 3 (6%)

**Interpretation:** Some stations violate minimum distance regulations, which can lead to clustering.

**Risk Implication:** Over-concentration of stations can lead to increased competition, environmental pollution, and heightened fire risks.

### **Risk Summary**

1. Fire Hazards: Lack of proper safety provisions, ventilation, and fire service approvals increase fire risks.
2. Environmental Risks: Poor drainage, inadequate EIA compliance, and UST leaks can harm the environment.
3. Health & Safety Risks: Stations located too close to residential areas pose health threats.
4. Regulatory Risks: Some stations operate without full approval, leading to legal consequences.

Table 3: Top 5 High-Risk Areas (Based on NO + NIL Responses)

Question	NO	NIL	Risk Score
Lack of Landline Telephone Service	38	2	40
No Compensation/Mitigation for Affected Communities	32	8	40
Lack of Community Involvement in Planning	27	8	35
Unaddressed Concerns from Local Communities	22	5	27
Poor Drainage Systems	17	3	20

#### 4.1.1.2 Interpretation of High-Risk Areas

##### 1. Emergency Communication (40 Risk Score)

Lack of landline services means stations may struggle to quickly contact emergency responders in case of fire or spills.

**Risk:** Delayed emergency response time, increased damage in accidents.

##### 2. Compensation & Mitigation Measures (40 Risk Score)

Many stations have not compensated affected communities, which can lead to legal disputes and social unrest.

**Risk:** Potential lawsuits, protests, and community resistance.

##### 3. Community Involvement (35 Risk Score)

Poor engagement with locals reduces acceptance and increases opposition to new filling stations.

**Risk:** Risk of vandalism, community boycotts, and project delays.

#### 4. Unaddressed Community Concerns (27 Risk Score)

Failure to address concerns about pollution, noise, and safety lowers trust in filling station operators.

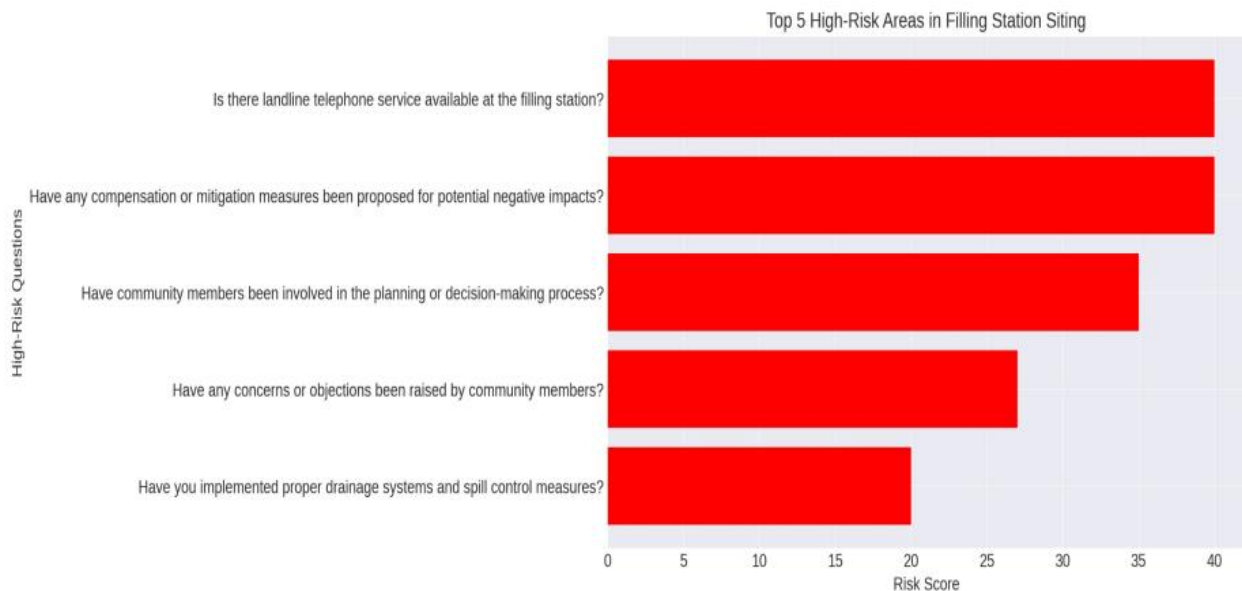
**Risk:** Long-term opposition, complaints, or government sanctions.

#### 5. Drainage System Issues (20 Risk Score)

Poor drainage management leads to fuel runoff, flooding, and contamination risks.

**Risk:** Water pollution, fire hazards, and potential regulatory shutdowns.

Figure 6: Top 5 High-Risk Areas In Filling Station Siting



#### Bar Chart Interpretation (Top 5 High-Risk Areas)

1. The two most critical risks are lack of emergency communication and failure to compensate affected communities (both with a risk score of 40).
2. Community involvement issues (planning and concerns) also pose significant risks.
3. Drainage system deficiencies remain a major environmental hazard.

### 4.1.1.3 Risk Identification

1. **Social Risks (Highest Risk - 76):** Social risks arise from poor community engagement, lack of compensation, and inadequate communication infrastructure.

**Implications:**

- i. Lack of emergency landlines delays fire response, increasing accident severity.
- ii. Failure to compensate affected residents creates lawsuits and resistance.
- iii. Ignoring community concerns can lead to vandalism, protests, and business losses.

Table 4: Top Social Risk Issues

Issue	NO	NIL	Risk Score
No landline for emergency calls	38	2	40(Most Critical)
No compensation for affected peoples	32	8	40
No community involvement in planning	27	8	35
Unaddressed concerns from the community	22	5	27

2. **Safety Risks (Score - 30)** Safety risks involve fire hazards, lack of ventilation, and poor maintenance of fuel tanks.

**Implications:**

- i. Poor ventilation can cause fuel vapor buildup, leading to explosions.
- ii. Uninspected storage tanks may corrode and leak fuel, creating fire hazards.
- iii. No fire service approval means stations may not be prepared for emergencies.

Table 5: Top Safety Risk Issues

<b>Issue</b>	<b>NO</b>	<b>NIL</b>	<b>Risk Score</b>
No proper ventilation/fire control	7	2	9
No regular inspection of storage tanks	10	3	13
No compliance with fire safety in design	7	0	7
No fire service approval	0	4	4

**3. Regulatory Risks (Score - 29)** Regulatory risks involve non-compliance with approvals, design submission, and government policies.

**Implications:**

Missing architectural designs can result in structural failures.

Ignoring drainage regulations leads to flooding, fuel runoff, and pollution.

Clustering of stations increases environmental risks and fire hazards.

Table 6: Top Regulatory Risk Issues

<b>Issue</b>	<b>NO</b>	<b>NIL</b>	<b>Risk Score</b>
No architectural & structural design submission	0	7	7
No drainage system compliance	17	3	20
No compliance with minimum distance regulations	8	3	11

4. **Environmental Risks (Score - 25)** Environmental risks focus on drainage issues, underground storage tank (UST) leaks, and pollution control.

**Implications:**

Poor drainage systems cause water pollution and increased fire risks.

Underground fuel tank leaks contaminate soil and groundwater.

Lack of EIA compliance results in long-term environmental hazards.

Table 7: Top Environmental Risk Issues

Issue	NO	NIL	Risk Score
No proper drainage system	17	3	20
USTs not designed to prevent leaks	7	10	17
No Environmental Impact Assessment (EIA)	3	5	8

Table 8: Breakdown of Risks by Category

Risk Category	Total Risk Score
Environmental Risks	25
Safety Risks	30
Regulatory Risks	29
Social Risks	76 (Highest)

#### 4.1.1.4 Key Insights From Risk Breakdown

a. **Social Risks (76) are the most significant**

Poor community involvement and lack of compensation create major **conflict risks**, potentially delaying projects or leading to legal issues.

b. **Safety and Regulatory Risks (30 & 29) are also high:**

Many stations lack fire approvals and proper ventilation, increasing the chances of fires and explosions.

c. **Environmental Risks (25) are the least reported:**

While lower, drainage and fuel runoff issues still pose serious pollution threats.

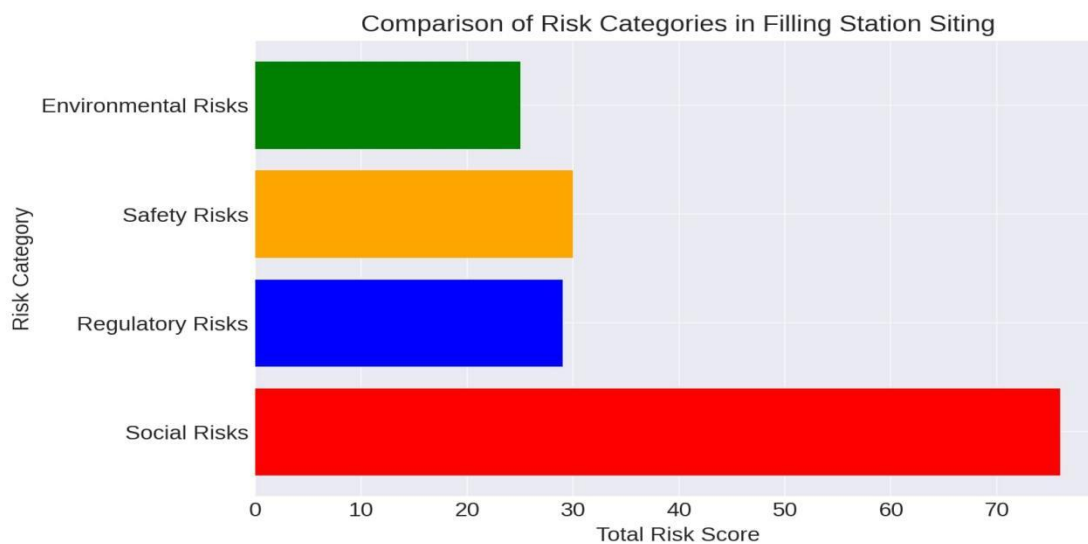


Figure 7: Bar Chart of Risk Category Breakdown

#### 4.1.1.5 Bar Chart Interpretation (Risk Category Breakdown)

a. Social Risks (red bar) are the most significant, indicating poor community relations, lack of compensation, and missing communication infrastructure.

b. Safety and Regulatory Risks are nearly equal, highlighting compliance and fire safety issues.

- c. Environmental Risks are lower but still important, mainly linked to drainage problems and fuel leakage.

#### 4.1.1.6 Correlation Analysis: How Risks Are Linked

##### Key Findings:

- a. Social Risk (0.26 correlation with NO responses): Stations with poor community engagement also tend to have higher non-compliance issues.
- b. Safety and Regulatory Risks are slightly linked (-0.23 correlation): Meaning that stations failing safety checks may also struggle with regulatory approvals.
- c. Environmental Risks (-0.13 correlation with NO responses): This shows that drainage and pollution issues are somewhat independent from other risks.

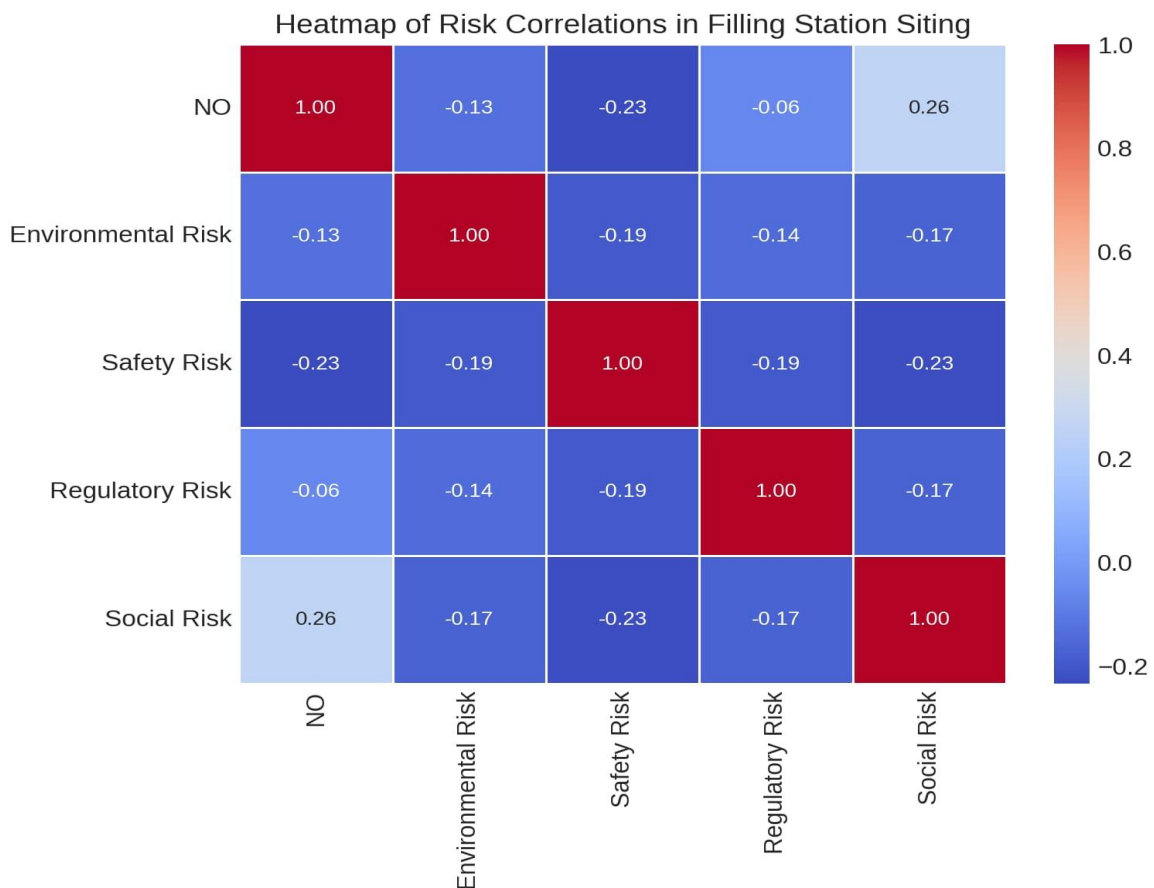


Figure 8: Heat-map of Risk Correlations in Filling Stations

#### **4.1.1.7 Heat-map Interpretation: How Risks Are Connected**

- i. Social Risks (highest positive correlation with NO responses) → Filling stations with poor community engagement tend to have more non-compliance issues overall.
- ii. Safety & Regulatory Risks (moderate correlation) → Stations failing in fire safety often lack proper approvals too.
- iii. Environmental Risks (least correlation) → Drainage and pollution issues are somewhat independent from other risks.

### 4.1.2 Analysis of Supervisors' Questionnaire

The data analysis in this section follows a structured approach, beginning with a descriptive summary of residents' responses, followed by a comparative examination of common concerns, and concluding with thematic insights drawn from open-ended responses.

Table 9: Demographic Data For People Around

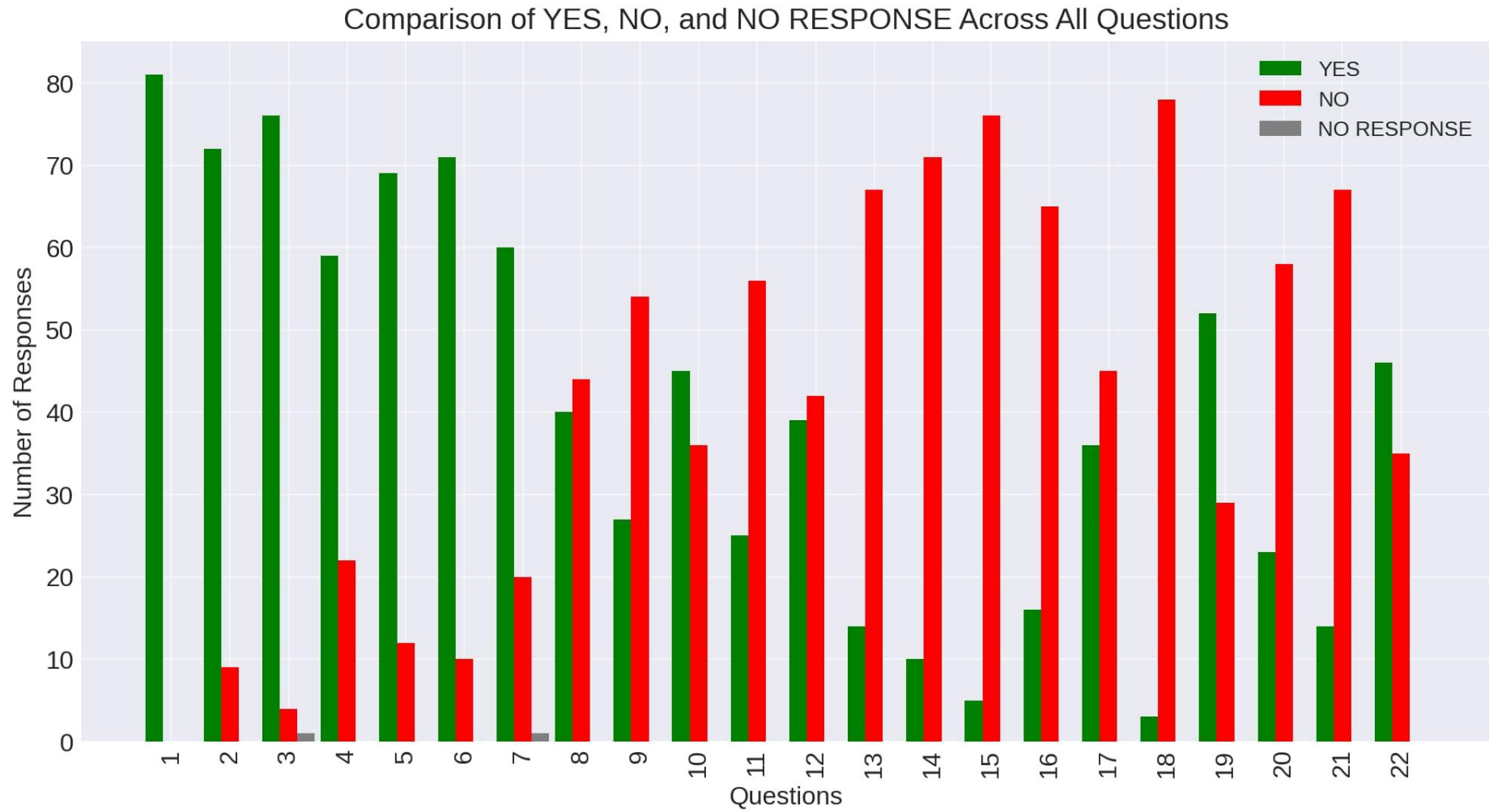
DEMOGRAPHIC DATA FOR PEOPLE AROUND						
Age	Under 18	18-24	25-34	35-44	45-54	55+
	4	26	22	14	9	6
Gender	Male	Female				
	24	57				
Education level	Primary	Secondary	Undergraduate	Postgraduate	Others	
	7	22	24	15	13	
Employment Status	full-time	part-time	Self- employed	Unemployed	Student	Retired
	12	5	26	7	17	4

Table 10: Table Of Results For People Around

S/N	QUESTION	YES	NO	NR
1	Are you aware of the filling station nearby? If yes, how would you describe your experience living near it?	81	0	
2	Do you feel the filling station is well-maintained and safe?	72	9	
3	Have you ever noticed any unusual activities or incidents at the filling station, such as fires, fuel spills, or loud noises?	76	4	1
4	Do you feel safe living near the filling station, considering the risks associated with fuel storage and dispensing?	59	22	
5	Have you received any information or training from the filling station on what to do in case of an emergency, like a fire or fuel spill?	69	12	
6	Are there any safety signs or warning signals that you've noticed around the filling station to alert people of potential hazards?	71	10	
7	Have you observed any emergency drills or safety demonstrations conducted by the filling station management?	60	20	1
8	Have you noticed any unpleasant smells, air pollution, or smoke coming from the filling station?	40	44	
9	Do you think the filling station has affected the quality of air, water, or soil in the area?	27	54	
10	Have you ever seen fuel spills or leaks from the filling station? If so, were they cleaned up promptly?	45	36	
11	Do you hear excessive noise from the filling station, such as from fuel tankers, generators, or equipment?	25	56	
12	Has the filling station management ever reached out to the community to discuss safety or environmental	39	42	

	concerns?			
13	Do you know who to contact at the filling station if you have any safety or environmental concerns?	14	67	
14	Have you or anyone you know ever made a complaint about the filling station? If so, was the issue resolved?	10	71	
15	Have you or any family members experienced health problems that you believe could be related to the filling station	5	76	
16	Have you received information about evacuation procedures?	16	65	
17	Do you have a plan for emergency situations?	36	45	
18	Have you participated in emergency response drills?	3	78	
19	Do you feel prepared for potential emergencies?	52	29	
20	Are you aware of emergency response procedures?	23	58	
21	Have you received information about evacuation procedures?	14	67	
22	Do you believe that the filling station has contributed to an increase in traffic or accidents in the area?	46	35	

Figure 9: Comparison of YES, NO & No Response Across All Questions



#### 4.1.2.1 Bar Chart Interpretation

- a. Green bars (YES responses) dominate, indicating high awareness and engagement on most topics.
- b. Red bars (NO responses) are significant in some questions, highlighting safety and maintenance concerns.
- c. Gray bars (NO RESPONSE) are low, meaning most residents actively participated in the survey.

#### 4.1.2.2 Risk Identification

- 1. **Safety Risks:** This category includes fire hazards, poor maintenance, and lack of emergency response mechanisms.

Table 11: Key Safety Concerns from the Survey

Issue	NO	NO RESPONSE	Risk Score
Do you feel safe living near the filling station?	22	0	22
Do you feel the station is well-maintained?	9	0	9
Have you received safety training?	12	0	12

#### Interpretation:

- i. 22 people feel unsafe living near a filling station → This suggests concerns about fire hazards, explosions, or crime.
- ii. 9 people believe the station is poorly maintained → Maintenance failures can cause fuel spills, fire outbreaks, and safety violations.
- iii. 12 people never received safety training → This increases panic risk and incorrect emergency responses.
- iv.

Figure 10: Safety Risk In Filling Station



**Bar Chart Interpretation (Safety Risks)**

- a. Feeling unsafe (22 responses) is the biggest concern → This shows a strong public fear of fire hazards and explosions.
  - b. Lack of maintenance (9 responses) is a moderate issue, but any station failing maintenance poses a risk.
  - c. Lack of safety training (12 responses) increases panic risk in emergencies
2. **Regulatory Risks:** include non-compliance with government approvals, legal violations, and unsafe station placement.

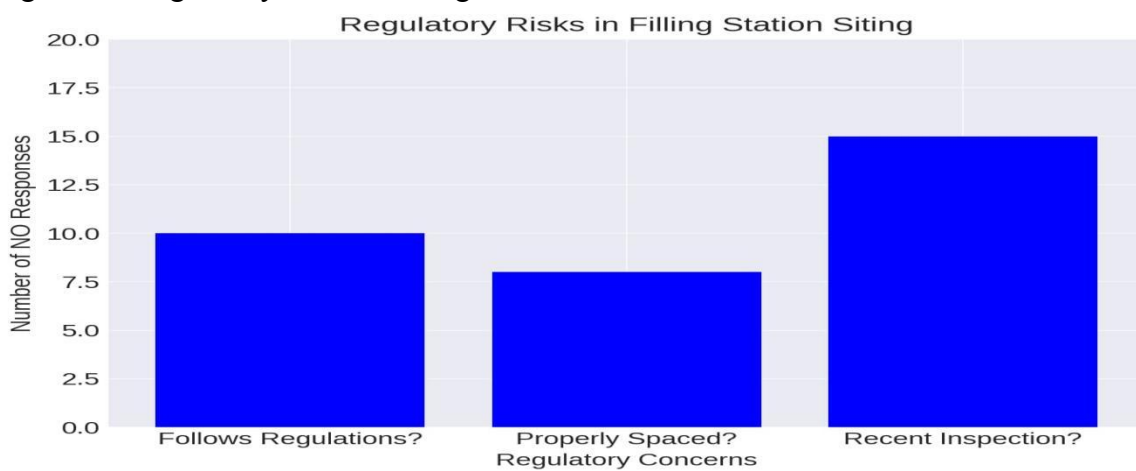
**Key Regulatory Concerns from the Survey**

Issue	NO	NO RESPONSE	Risk Score
Do you believe the station follows regulations?	10	2	12
Is the station properly spaced from residential areas?	8	3	11
Have authorities inspected the station recently?	15	2	17

### Interpretation:

- i. 12 people doubt the station follows safety regulations → Potential legal violations and lack of enforcement.
- ii. 11 people say the station is too close to residential areas → This increases fire risks and pollution exposure.
- iii. 17 people say the station has not been inspected recently → Lack of monitoring increases the risk of unreported violations.

Figure 11: Regulatory Risk In Filling Station



### Bar Chart Interpretation (Regulatory Risks)

- a. The biggest concern (15 responses) is the lack of recent inspections. This means many stations may be operating without proper oversight.
  - b. Doubt about regulatory compliance (10 responses) suggests some stations may be cutting corners on safety requirements.
  - c. Improper station spacing (8 responses) raises concerns about fire hazards and residential safety.
3. **Environmental Risks:** focuses on fuel leaks, pollution, and long-term health effects on residents.

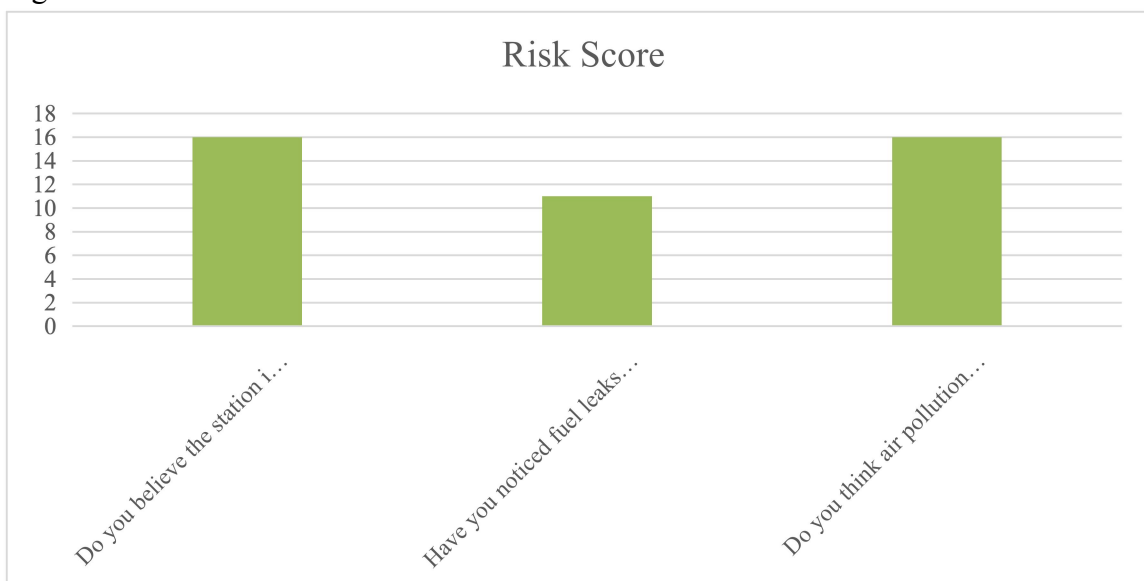
Table 12: Key Environmental Concerns from the Survey

Issue	NO	NO RESPONSE	Risk Score
Do you believe the station is environmentally safe?	13	3	16
Have you noticed fuel leaks or spills?	7	4	11
Do you think air pollution from the station affects your health?	14	2	16

**Interpretation:**

- i. 16 people believe the station is not environmentally safe → This suggests fuel leaks, water contamination, or excessive air pollution.
- ii. 11 people have seen fuel leaks/spills → This is a direct fire and pollution hazard.
- iii. 16 people believe air pollution is affecting their health → Long-term exposure can lead to respiratory diseases.

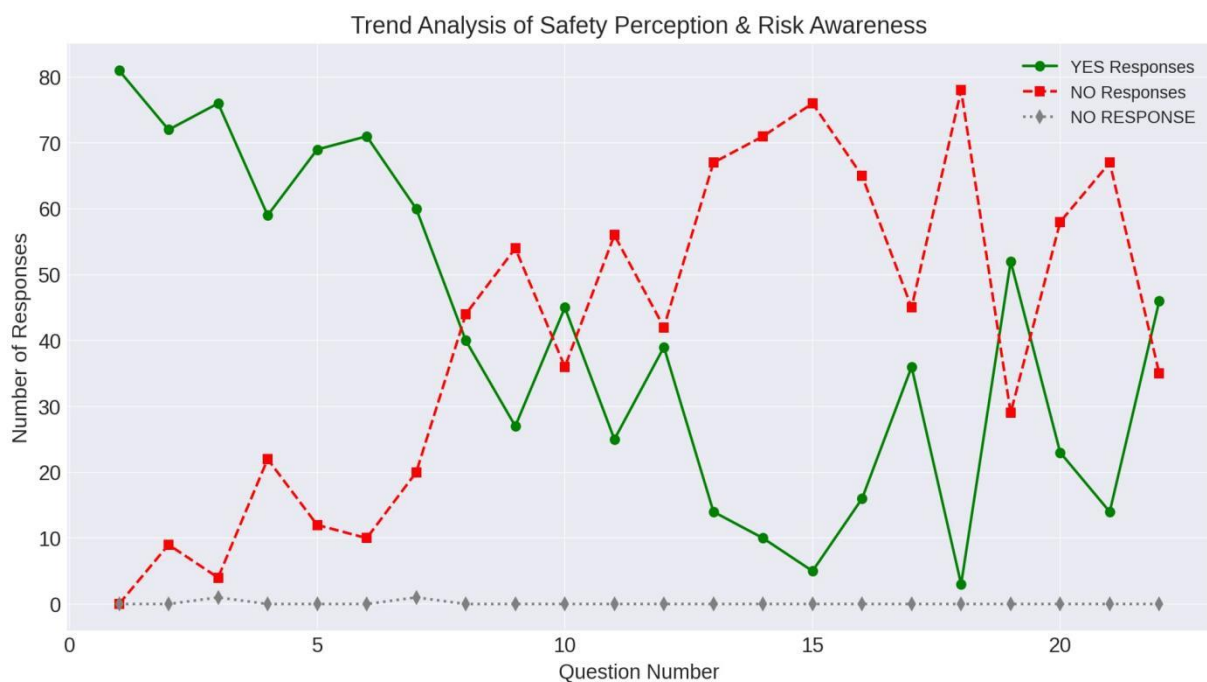
Figure 12: Risk Score



### Interpretation:

- a. 16 people (19.8%) believe the station is not environmentally safe → Suggests fuel leaks, air pollution, or toxic waste.
- b. 11 people (13.6%) have noticed fuel leaks/spills → Direct fire and contamination hazards.
- c. 16 people (19.8%) believe air pollution from the station affects their health → Potential respiratory issues.

Figure 13: Trend Analysis: Risk Perception Over Different Questions



### Trend Analysis Interpretation:

- i. YES responses (green line) remain high overall, indicating strong awareness.
- ii. NO responses (red line) show peaks at specific questions, highlighting areas of concern (e.g., safety perception, maintenance).
- iii. NO RESPONSE (gray line) is low, meaning most people provided answers, ensuring data reliability.

### **Key Takeaways from Visual Comparisons:**

- a. High Awareness but Safety Gaps Exist → Many residents know about the station, but concerns about maintenance, security, and training exist.
- b. Rising Concerns on Maintenance & Safety → The NO responses peaked around perceived safety and maintenance issues.
- c. Steady Risk Awareness but Gaps in Training → Not everyone received safety training, making some residents vulnerable in emergencies.

## **4.2 VISUAL INSPECTION**

This section presents the findings from the visual inspection, highlighting key observations related to safety, environmental impact, and infrastructure adequacy. By integrating these insights with survey data, the study aims to provide a well-rounded analysis of the risks and uncertainties involved in the siting of filling stations in Benin City.

Table 13: Results From Visual Analysis

<b>Visual Inspection</b>	<b>Compliance</b>	<b>Non Compliance</b>	<b>Total</b>
markings to prevent excavation damage.	1	69	70
visible maintenance indicators.	51	19	70
(no exposed wires).	55	15	70
Presence and condition of spill prevention	0	70	70
containment (dikes, berms, absorbent materials).	2	68	70
cleanliness (fuel spills)	44	26	70
waste disposal (spill materials)	6	64	70
Availability of Personal Protective	40	30	70
cleanliness and absence of spills and debris.	40	30	70
lighting in walkways and work areas.	64	6	70

anti-slip flooring and mats.	69	1	70
Clear and unobstructed walkways	64	6	70
fire sprinklers and suppression systems.	42	28	70
Presence, type, and placement of fire extinguishers.	60	10	70
evidence on fire protection equipment.	58	12	70
perimeter fencing and gates	65	5	70
Emergency exit signs and markings	2	68	70
emergency exit lighting.	2	68	70
Unobstructed access to emergency exits.	0	70	70
strategic placement of emergency stop buttons.	22	48	70
customer awareness campaign elements (e.g., no smoking	67	3	70

Figure 14: Compliance vs Non-Compliance

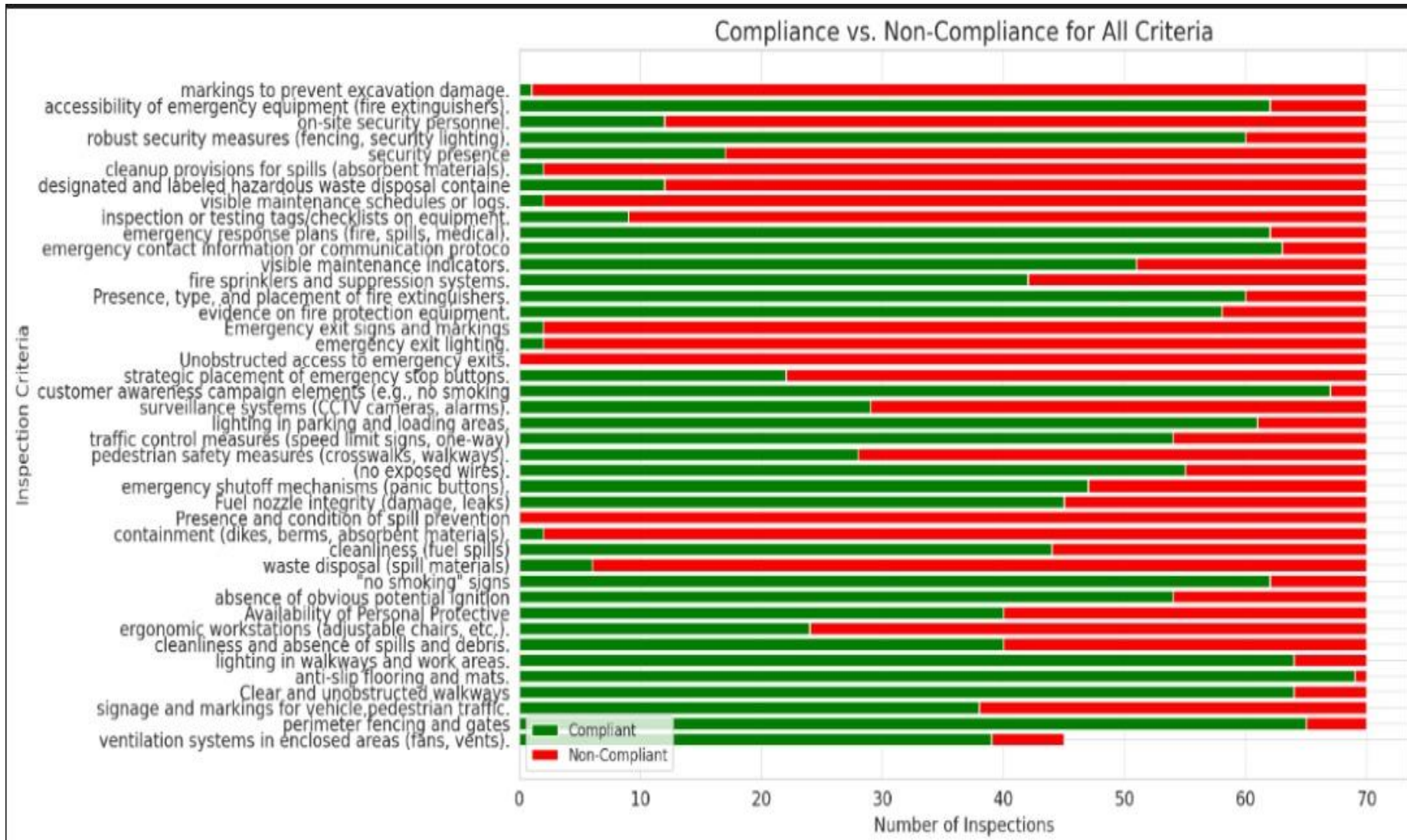
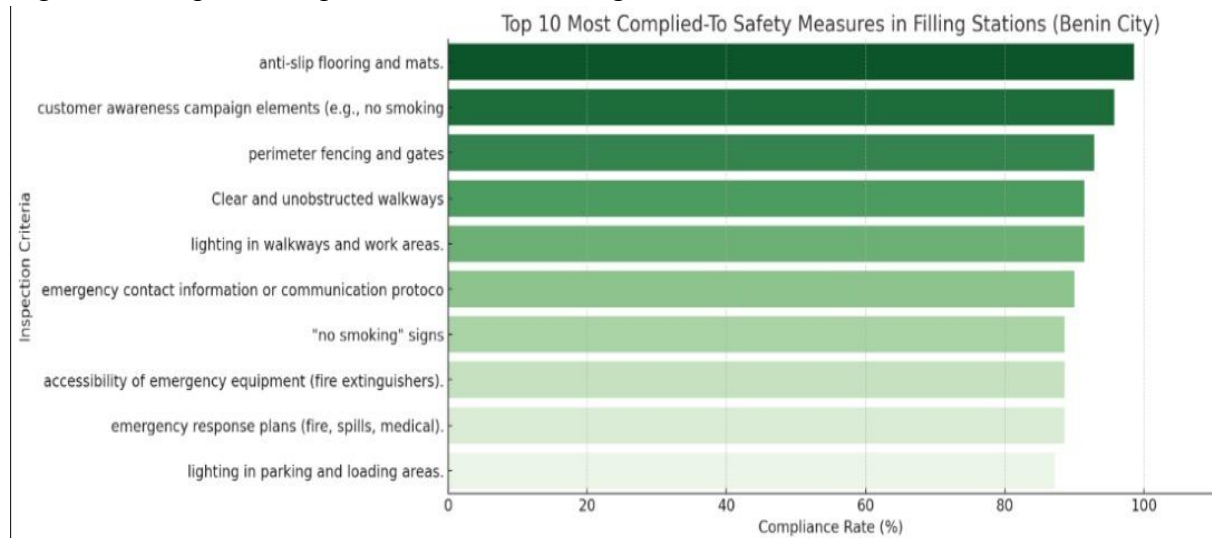


Figure 15: Top 10 Compliance Issues In Filling Station



**Interpretation of the Chart: Top 10 Most Complied-To Safety Measures in Filling Stations (Benin City)**

This **horizontal bar chart** displays the **top 10 safety measures** that have been **most adhered to** in filling stations across Benin City, based on compliance rates (%).

**Key Observations:**

**1. High Compliance Rates:**

- a. Anti-slip flooring and mats
- b. Customer awareness campaigns (e.g., "No Smoking" signs)
- c. Perimeter fencing and gates

These measures likely have clear enforcement policies and are relatively easy to implement, leading to their high compliance rates.

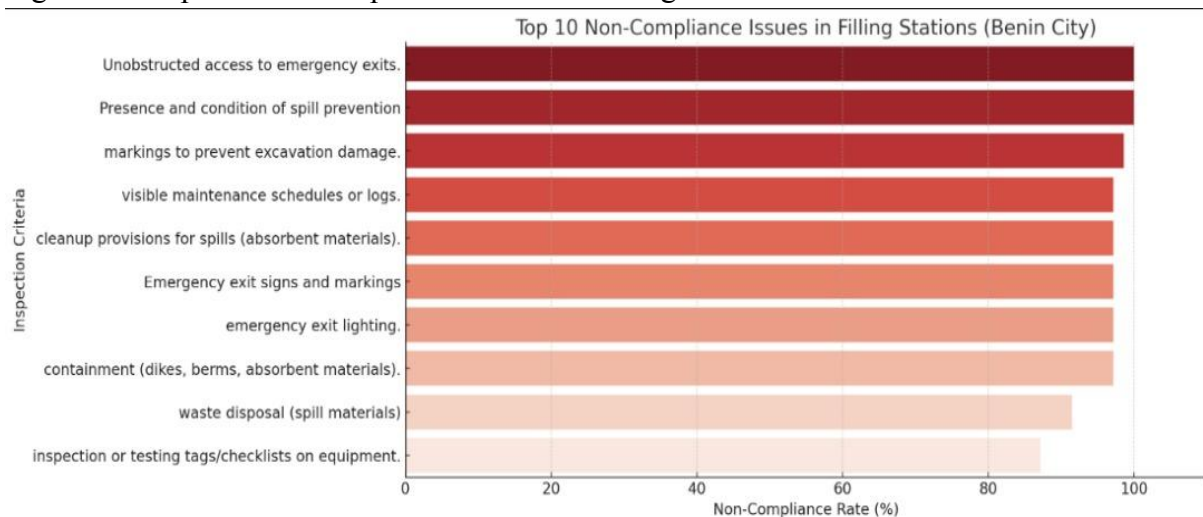
**2. Consistent Safety Standards:**

- a. Measures such as clear walkways, emergency signage, and fire extinguishers indicate that basic safety infrastructure is in place.
- b. Lighting in work areas and parking/loading zones shows a focus on visibility and hazard reduction.

### 3. Emergency Preparedness:

The presence of emergency response plans and accessibility of fire extinguishers suggests some level of preparedness, though it's crucial to assess whether these are effectively implemented and maintained.

Figure 16: Top 10 Non Compliance Issues In Filling Station



#### Interpretation of the Chart: Top 10 Non-Compliance Issues in Filling Stations (Benin City)

This horizontal bar chart highlights the most severe safety violations at filling stations based on non-compliance rates (%).

#### Key Observations:

##### 1. Critical Safety Violations:

- i. The **most violated safety measure** is **"Unobstructed access to emergency exits"** —a serious issue as it directly affects **evacuation during emergencies**.
- ii. **"Emergency exit signs and markings"** and **"Emergency exit lighting"** also rank high in non-compliance, meaning many stations **lack proper guidance** for safe evacuation.

## **2. Environmental & Spill Management Failures:**

- i. "Presence and condition of spill prevention" and "Cleanup provisions for spills" indicate a major lack of proper containment measures for fuel leaks and hazardous spills.
- ii. "Waste disposal (spill materials)" and "Containment structures (dikes, berms, absorbent materials)" also show high non-compliance, increasing risks of soil and water contamination.

## **3. Maintenance & Safety Negligence:**

- i. Many stations lack visible maintenance schedules or logs, suggesting irregular equipment inspections that could lead to undetected hazards.
- ii. "Inspection/testing tags on equipment" being a common violation means that many safety devices may be unchecked or faulty.

## **Major Concerns:**

- a. High fire risk: Poor emergency exit compliance means workers and customers could be trapped in case of a fire or explosion.
- b. Environmental hazards: Non-compliance in spill containment increases fuel contamination risks for groundwater, soil, and nearby communities.
- c. Poor maintenance culture: The lack of regular inspections and equipment testing suggests a reactive approach to safety rather than a preventive one.

### 4.3 GEOSPATIAL ANALYSIS

This report examines the spatial distribution of filling stations in Benin Metropolis, focusing on compliance with the regulatory requirement of maintaining a minimum distance of 400 meters between stations. Through statistical analysis and data visualization, we assess the extent of non-compliance and the associated risks, including fire hazards, traffic congestion, and environmental concerns.

S/N	LOCATION (°)		DISTANCE (m)
	NORTH	EAST	
1	622872.7	720200.7	288.639
2	622981.5	719973.6	24.598
3	623033	719102.5	827.803
4	623146.1	718209.6	835.298
5	623204.9	717980	190.761
6	623235.2	717850.1	48.179
7	623294.5	717533.4	276.965
8	623399.3	717138.5	378.989
9	623435.9	717008.8	67.723
10	623596.6	716509.6	484.448
11	623604	716485.8	34.583
12	623681.6	716226.5	230.728
13	623744.6	716154.7	40.675
14	623753.4	716067.9	61.572
15	623766.3	716037.3	36.578
16	623812.6	715784.5	197.913
17	623875.8	715605.5	190.058

18	623915.2	715537	45.834
19	623946.5	715482.8	38.779
20	623968.2	715391.6	53.228
21	623953.4	715345.7	37.966
22	624009	715205.4	132.139
23	624084	715043.1	146.593
24	624161.3	714818.5	203.128
25	624433.1	713373.3	1442.292
26	624445.6	712880.1	422.026
27	624498.9	712048.5	786.472
28	624541	712004	51.465
29	624614.7	711848.4	123.482
30	624796.2	711385.8	449.359
31	625001.3	711023.2	393.234
32	625050.9	710936.2	100.169
33	625084.7	710947.3	35.584
34	625237.9	710656	329.136
35	625327.3	709851.7	809.295
36	625475	709670.6	233.673

37	625435.2	709537.2	139.182
38	625518.6	708358.7	1187.397
39	625528.3	708086	272.919
40	625709.5	708359.6	218.027
41	625856.5	708155.7	251.344
42	626007.6	708008.2	211.178
43	626070.6	707999	63.675
44	627126.3	707484.4	61.078
45	627211.8	707525.7	48.381
46	627242	707548.5	37.854
47	627280.5	707585.1	53.077
48	627501	707736.7	267.61
49	627758.1	707952.9	335.925
50	621995	701890.4	32.251
51	622062.9	701948.8	89.533
52	622097.5	701994.1	57.013
53	622292.9	702215.9	295.601
54	622712.1	703183.8	1054.762
55	622814.6	703408.4	246.872
56	622876.1	703597.4	198.756
57	622933.9	703668.6	91.759
58	624716.8	706934.3	403.158
59	623967.9	706499.4	865.992
60	623087.9	706242.3	916.808
61	622932.7	706146	182.653
62	622817.9	706110.1	120.211

63	622636.1	706007.7	208.714
64	622408.7	705984.1	228.647
65	621899	706045.6	513.361
66	621396	705913.4	520.079
67	621261.8	705839.2	153.386
68	626234.4	705599.4	113.778
69	626313.2	705342.5	268.722
70	626446.2	704935.1	428.61
71	626455.4	704660	275.221
72	626459.5	704519.1	140.922
73	626627.5	703826.6	712.622
74	626821.1	703292.4	568.258
75	626809.9	703126.9	165.833
76	626861.1	702499.4	629.567
77	626932.3	702061	444.211
78	626975.3	701696.8	366.727
79	626951.7	701663.5	40.789
80	626987.6	701443.7	222.652
81	627037.3	701022.2	424.482
82	627049.6	700899.7	123.038
83	627102.3	700446.4	456.382
84	627106.4	700402.9	43.732
85	627180.2	700106.3	305.615
86	627149.5	699978.7	131.196
87	627211.4	699752.3	234.735
88	627199.7	699539.8	212.901

89	627251.9	699346.1	200.548
90	627233.5	699293.9	55.406
91	627253.4	699016.3	278.346
92	627277	698918.9	100.135
93	627325.2	698516.3	405.481
94	627369.7	698113.7	405.071
95	627413.8	697981.6	139.304
96	627418.9	697735.2	246.435
97	627459.4	697544.1	195.3
98	627460.4	696956.6	587.527
99	627488	696902.8	60.48
100	627464	696660.5	243.477
101	627454.7	696331.7	328.98
102	627469.1	696119.1	213.058
103	627478.8	695968.5	150.909
104	627478.8	695851.2	117.3
105	627492.1	695409.7	441.742
106	627502	694817.5	592.218
107	627510.7	693814.6	1002.982
108	627558.3	693348.5	468.556
109	625811.9	709343.6	84.119
110	626671.9	708524	1188
111	626805.1	708371.9	202.19
112	626875.8	708307.3	95.72
113	627250.2	708885.1	688.513
114	627609.8	709466	683.16

115	627734.8	709621.2	199.273
116	627888	709894.2	313.043
117	627974	710030	160.72
118	633182.6	710627.4	293.079
119	633297.9	710698.3	135.336
120	633437.7	710835.1	195.6
121	633568.8	710872	136.218
122	633715.8	710966.2	174.628
123	633999.1	711183.9	357.253
124	634148.2	711236.2	157.95
125	634186.6	711269.5	50.837
126	634360.7	711374	203.101
127	634800.7	711576.8	484.509
128	635187	711748.9	422.833
129	635954.3	712055.8	826.389
130	636048.5	712090.6	100.48
131	636367.1	712216.6	342.619
132	636520.3	712276.5	164.465
133	636814.8	712444.5	339.082
134	637015.6	712489.1	205.679
135	637132.4	712493.7	116.879
136	637358.8	712522.4	228.215
137	628180.5	707738.3	409.194
138	628038.5	705717.8	104.935
139	627946.1	705630.7	127.002
140	627492.6	705177.8	640.958

141	627625.1	704776.1	98.493
142	627672.9	704723.2	71.31
143	627921	704354.1	444.656
144	628014.4	704227.8	157.054
145	628101.4	704123.1	136.167
146	628406.4	703898.9	378.531
147	628626	703750.4	265.14
148	628837.7	703584.8	268.748
149	628963.5	703470.5	169.986
150	629047.7	703351	146.189
151	629311.2	702885.5	534.848
152	629436.3	702630	284.511
153	629686.7	702194.7	502.168
154	629978	701894.8	418.095
155	630073.1	701844.8	107.413
156	630785.5	701507.9	788.042
157	631228.8	701303	488.312
158	631291.3	701269.5	71.027
159	631457.5	701192.1	183.292
160	632070.9	700921.8	670.314
161	632527.8	700723.8	497.988
162	632571.6	700722.6	43.829
163	632979.6	700523.2	454.127
164	633214.1	700423.6	254.709

### 4.3.1 Summary Statistics

The spatial distribution of filling stations is analyzed using key statistical metrics:

- **Total Data Points:** 164
- **Mean Distance Between Stations:** 299.92 meters
- **Median Distance:** 215.54 meters
- **Minimum Distance:** 24.60 meters
- **Maximum Distance:** 1442.29 meters

These statistics indicate that many stations are positioned significantly closer than the regulatory requirement of 400 meters, suggesting a high level of non-compliance.

#### 1. Regulatory Compliance: Percentage Below 400m

**Visualization: Percentage of Distances < 400m:** A pie chart illustrating the proportion of non-compliant filling stations.

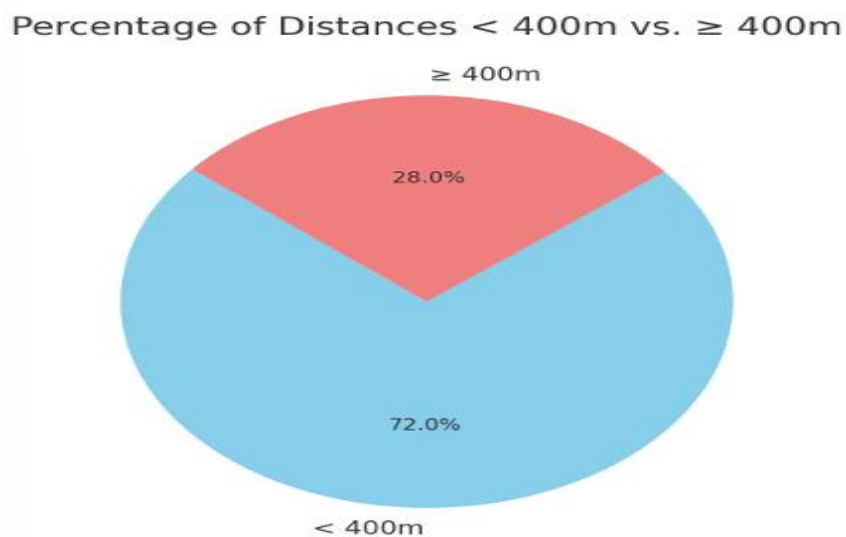


Figure 17: Percentage Of Distances < & > 400

## Interpretation of the Pie Chart

The chart compares the **percentage of distances** that are **less than 400 meters** versus those that are **greater than or equal to 400 meters**.

**72% of the distances** are **less than 400m** (represented in blue).

**28% of the distances** are **greater than or equal to 400m** (represented in red).

### Key Insights:

1. The **majority (72%) of distances are below 400m**, meaning most filling stations (or measured locations) are relatively close to a reference point.
2. Only **28% meet or exceed the 400m threshold**, which might indicate **non-compliance with a minimum distance regulation** (if such a rule exists).
3. This suggests **potential clustering of filling stations**, which could pose **safety or environmental risks** if 400m is a regulatory requirement.

This widespread non-compliance introduces various risks, including:

**Increased Fire Hazards:** Proximity between stations heightens the risk of chain reactions in case of fire or explosion.

**Traffic Congestion:** High density of filling stations contributes to frequent road blockages and increased accident risks.

**Environmental Degradation:** Soil and air pollution risks increase due to excessive hydrocarbon emissions.

**Weak Regulatory Enforcement:** Inconsistent application of regulations undermines urban planning and public safety.

## 2. Distance Distribution Trends & Visualization

To further explore spatial trends, the following visualizations provide insights into the distribution of distances:

**Scatter Plot:** Highlights clusters of stations with distances below 400m, confirming widespread non-compliance.

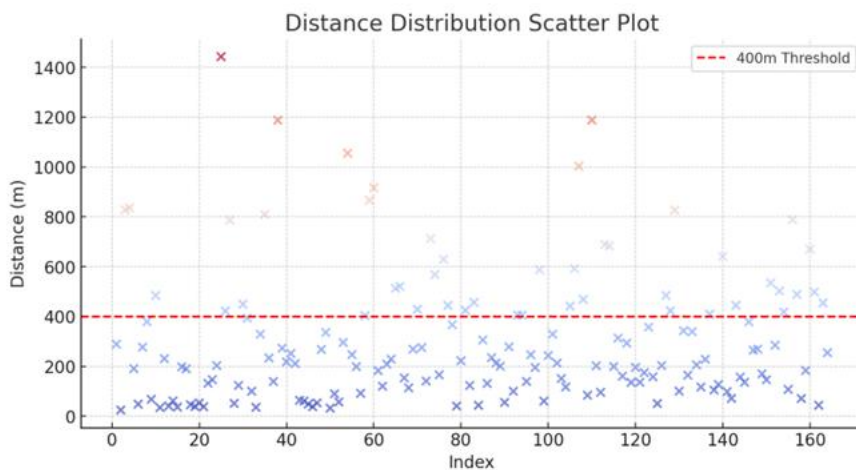


Figure 18: Distance Distribution Scatter Point

### Interpretation of the Scatter Plot

The scatter plot displays the **distribution of distances** for different locations (indexed along the x-axis). The red **dashed line at 400m** represents a threshold—a regulatory limit for minimum distance compliance.

### Key Insights:

**Majority of points (in blue) are below the 400m threshold**, indicating that most locations fall short of the required distance.

**Several locations exceed the 400m mark** (represented by red points), but they are the minority.

**Clusters of distances below 400m suggest a pattern of non-compliance**, which could indicate regulatory violations.

Some extreme values **above 1000m** exist, suggesting outliers where filling stations are situated much farther than the threshold.

### What This Means:

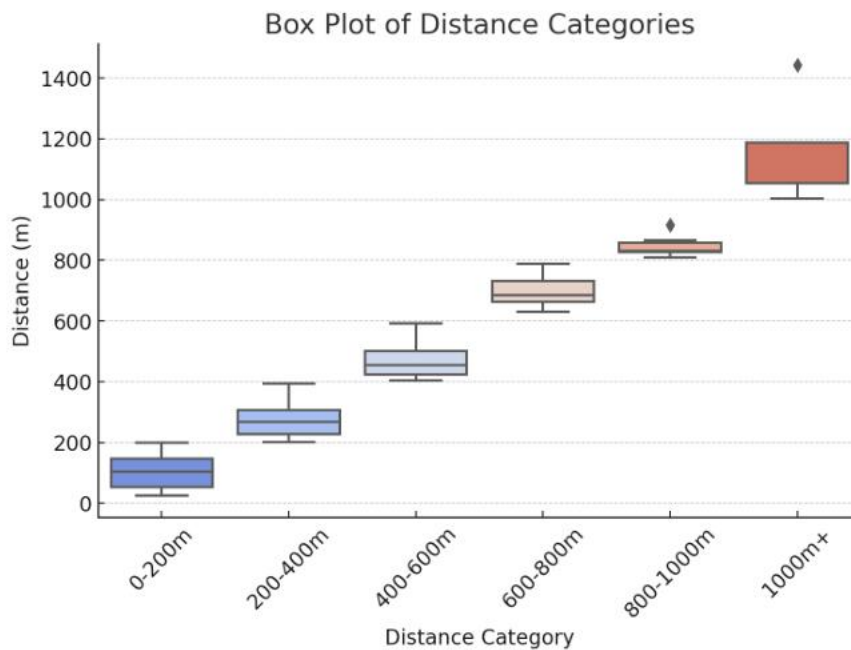
High concentration of points below 400m → Potential non-compliance risk.

Few points above 400m → Only a small number of locations adhere to the rule.

Outliers (above 1000m) → Some stations may be excessively distant, possibly due to zoning regulations.

3. **Box Plot of Distance Categories:** Illustrates the range and variability of distances, emphasizing outliers and median positioning.

Figure 19: Box Plot of Distance Categories



### Interpretation of the Box Plot: Distance Categories

This **box plot** visualizes the distribution of distances across different **distance categories** (e.g., 0-200m, 200-400m, etc.). Each **box** represents the inter-quartile range (IQR), showing the **median, quartile, and potential outliers** in each category.

### Key Insights:

1. The median distance increases consistently across categories, showing an expected upward trend.
2. The 0-200m and 200-400m categories have relatively small variations, suggesting most stations in these ranges are clustered tightly.
3. 400-600m & 600-800m have wider IQRs, indicating more variability in station placements.
4. Outliers appear in the 800-1000m and 1000m+ categories, meaning some stations are located much farther than most others in these ranges.
5. Few stations exist beyond 1000m, but the ones that do tend to be significantly far apart (as indicated by the extreme outliers).

**What This Means:**

Most stations are concentrated below 400m, reinforcing the previous insights about potential regulatory non-compliance.

Higher distance categories (800m+) show extreme outliers, possibly due to zoning restrictions or limited urban space.

The spread in mid-range categories (400m-800m) suggests inconsistent siting regulations or enforcement.

**4. Risks & Uncertainties of Non-Compliance**

Failure to comply with filling station siting regulations is more than just a regulatory lapse—it poses severe threats to public safety, urban mobility, and environmental sustainability. Inadequate enforcement of proper spacing and safety measures amplifies risks, leading to potentially catastrophic consequences.

**a. Fire & Explosion Hazards**

- i. High-density station clusters significantly increase the likelihood of cascading fires in case of an accident, especially in densely populated areas.
- ii. Insufficient buffer zones accelerate fire spread, making containment efforts challenging and leading to extensive property damage and loss of life.
- iii. Proximity to residential areas, schools, and businesses heightens the danger to human lives, with explosions and toxic fumes posing immediate and long-term health risks.
- iv. Delayed emergency response due to congested access routes exacerbates disaster impact, making timely intervention difficult.

**b. Traffic Congestion & Road Safety Hazards**

- i. High station density disrupts road networks, creating frequent bottlenecks that slow down traffic flow and increase commuter delays.
- ii. Frequent vehicle movements, including abrupt stops, lane changes, and fuel tanker deliveries blocking roads, significantly raise the risk of collisions.
- iii. Heightened accident risks near station entrances/exits result from:
- iv. Unregulated vehicle queuing, obstructing pedestrian crossings and main roads.
- v. Limited visibility due to high congestion, increasing the likelihood of crashes.
- vi. Increase in pressure on emergency services, as congestion delays fire trucks, ambulances, and law enforcement responses, worsening the potential impact of accidents.
- vii. In high-density urban areas with already strained road infrastructure, these disruptions amplify the risk of gridlock, prolong commute times, and reduce road safety for all users.

## CHAPTER FIVE

### RECOMMENDATIONS AND CONCLUSION

#### 5.1 RECOMMENDATIONS

##### 1. Strengthen Regulatory Enforcement and Compliance

**a. Increase Inspection Frequency and Unannounced Audits:** Regulatory bodies must conduct regular, surprise inspections to ensure that every filling station adheres to established safety standards, environmental protocols, and zoning laws. For example, a recent study of filling station distribution in Benin City found that nearly 72% of stations violated the mandatory 400 m spacing rule, significantly increasing fire and explosion risks ([academia.edu](http://academia.edu))

b. Regular unannounced visits would help identify non-compliant operators early and enforce corrective actions.

**c. Enforce Minimum Distance Regulations Rigorously:** The clustering of filling stations not only amplifies safety hazards but also congests urban areas. Authorities should immediately suspend approvals for new stations that do not meet the required spacing and mandate corrective measures for existing stations. Such actions should be modeled on stringent urban planning practices seen in cities worldwide.

**d. Mandatory Annual Compliance Certification:**

Every filling station must secure an annual safety and environmental compliance certificate. This certification process should be made transparent, with results publicly available so that consumers and local communities are aware of the station's safety record. In regions where similar measures have been implemented (e.g., parts of Europe), regular certification has led to demonstrable improvements in safety practices.

e. **Community Consultation and Compensation Protocols:** Only a minority of filling stations have involved local residents in decision-making processes. Establishing a mandatory framework for public hearings and compensation plans for communities impacted by filling station operations would not only build trust but also ensure that local concerns are addressed. For instance, community-led regulatory models in some European cities have significantly reduced social conflicts related to industrial siting.

## **2. Improve Fire Safety and Emergency Preparedness**

### **a. Upgrade Fire Suppression and Safety Infrastructure:**

Every filling station should install comprehensive fire suppression systems—such as automated sprinklers, fire-resistant barriers, and clearly marked emergency exits—to mitigate fire and explosion hazards. The catastrophic outcomes seen in various Nigerian stations underscore the urgency of such improvements. For example, a well-documented incident in another Nigerian city demonstrated that inadequate fire exits and outdated suppression systems can lead to devastating fires affecting both workers and nearby residents.

### **b. Implement Regular Emergency Response Drills:**

Operators should schedule periodic emergency drills for both employees and surrounding communities. These drills, coordinated with local emergency services, can dramatically reduce response times in an actual crisis. This preparedness strategy, already successful in parts of Europe and Asia, could serve as a model for urban centers like Benin City.

### **c. Ensure Robust Communication Systems:**

Filling stations must maintain functioning communication lines (landlines, radio, or cellular networks) dedicated solely to emergency use. The absence of such systems has been linked to delayed responses in past incidents, contributing to larger-scale emergencies.

### **3. Enhance Environmental Protection Measures**

#### **a. Improve Drainage and Spill Containment:**

Many stations suffer from inadequate drainage systems, which can lead to fuel runoff and water contamination. It is imperative that stations install proper oil-water separators and containment tanks. In one study, a significant percentage of stations failed to meet DPR-approved specifications, leading to severe groundwater contamination concerns. Upgrading these systems is not only a regulatory necessity but also an environmental imperative.

#### **b. Upgrade Fuel Storage and Handling Practices:**

Underground storage tanks (USTs) must adhere to modern, corrosion-resistant standards. Regular biannual inspections should be mandated to detect leakages or structural failures. This approach is supported by international best practices and is critical to preventing fuel spills that have both immediate and long-term environmental impacts ( [en.wikipedia.org](https://en.wikipedia.org)).

#### **c. Strict Waste Management and Hazardous Material Disposal:**

Operators must adopt proper protocols for disposing of hazardous wastes, including used oil and contaminated materials. Establishing a centralized waste disposal framework—similar to those implemented in advanced economies—will ensure that hazardous materials are handled safely and do not contribute to soil and water pollution.

### **4. Address Social and Community Risks**

#### **a. Increase Community Engagement and Public Awareness:**

Local residents should be actively involved in the planning and monitoring of filling station operations. Public education initiatives on evacuation procedures, emergency response, and environmental risks are essential. In many European cities, for example, regular community workshops have improved the overall safety culture and reduced panic during emergencies.

### **b. Implement Fair Compensation and Mitigation Policies:**

Operators must be required to offer clear and transparent compensation policies for any negative impacts—such as road congestion, property devaluation, or environmental contamination—that arise from station operations. A collaborative approach that includes both community representatives and station owners has proven effective in urban areas where public health risks are high.

### **c. Improve Traffic and Infrastructure Management:**

The location of filling stations often contributes to road congestion and vehicular accidents. Authorities should enforce strict entry/exit designs and traffic flow regulations around these facilities. Drawing on urban planning examples from metropolitan areas around the world, such measures can reduce congestion and enhance both pedestrian and vehicular safety.

## **5.2 CONCLUSIONS**

The comprehensive risk and uncertainty analysis on the siting of filling stations in Benin City reveals critical gaps in safety, environmental management, regulatory enforcement, and community involvement. The study identifies several areas of concern:

### **1. High Regulatory Non-Compliance:**

With evidence showing that a significant percentage of stations violate spacing and safety regulations ( [academia.edu](https://www.academia.edu)), it is clear that current enforcement mechanisms are insufficient. This non-compliance not only escalates fire and explosion risks but also exacerbates environmental pollution.

### **2. Insufficient Fire and Emergency Preparedness:**

The lack of modern fire suppression systems, emergency communication tools, and coordinated response drills poses a severe threat to public safety. Historical incidents in

Nigeria have demonstrated that delays in emergency response can lead to catastrophic outcomes.

**3. Environmental Risks from Poor Infrastructure:**

Outdated fuel storage practices, inadequate drainage, and improper waste management contribute to long-term environmental degradation. Such practices jeopardize groundwater quality and soil health, increasing the potential for hazardous contamination that affects both human health and urban sustainability.

**4. Social and Community Impacts:**

Low levels of community engagement and the absence of clear compensation frameworks have fostered public mistrust and social tension. This is particularly concerning in urban areas, where residents are directly exposed to the risks emanating from poorly managed filling stations.

For Benin City to manage these multifaceted risks effectively, a holistic, multi-stakeholder approach is essential. Collaboration among government agencies, filling station operators, emergency respondents, environmental experts, and local communities must be prioritized. Strengthening regulatory frameworks, coupled with community education and infrastructural upgrades, will not only mitigate immediate hazards but also foster long-term urban resilience and sustainable development.

By implementing these recommendations, the city can:

- a. Enhance public safety and reduce the risk of catastrophic fire incidents.
- b. Protect the environment by preventing fuel leaks and managing hazardous waste more effectively.
- c. Foster a culture of accountability and transparency among filling station operators.

- d. Improve the overall quality of urban development by aligning industrial activities with community needs.

Ultimately, the long-term benefits of these actions include improved public health, a cleaner environment, and a more harmonious relationship between urban development and community well-being. Such comprehensive measures will be critical in transforming Benin City and even Nigeria at large into a safer and more sustainable urban environment.

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## APPENDIX

### UNIVERSITY OF BENIN FACULTY OF ENGINEERING DEPARTMENT OF MECHANICAL

This questionnaire aims to gather information regarding factors influencing risk and uncertainty in the siting of filling stations. Your input will help identify challenges, opportunities and critical decision-making factors relevant to this study. Your responses are vital for a comprehensive analysis of environmental, economic and operational risks.

#### SURVEY QUESTIONNAIRE

**Age:**  Under 18  18 - 24  25 – 34  35 – 44  45 – 54  55+

**Gender :**  Male  Female

**Educational Level :**  Primary School  Secondary School  Undergraduate degree  
 Postgraduate degree  Others

**Employment Status:**  Employed full-time  Employed part-time

#### ATTENDANT

1. Does the filling station have clearly marked and accessible emergency exits for customers and staff?  
 Yes  No
2. Is there adequate signage indicating safety instructions, emergency procedures, and danger zones around the filling station?  Yes  No
3. How long have you been working as a fuel attendant?  0-3 years  3-6 years  6-9 years
4. Have you received any formal training on safety procedures and emergency response for fuel dispensing?  Yes  No
5. What kind of safety training have you completed?  
 Safe Fuel Handling and Dispensing  Fire Extinguisher Operation  Emergency Shutdown Procedures  Hazard Communication (HazCom)  Spill Response and Clean-Up  Personal Protective Equipment (PPE) Use  Customer Safety and Assistance  Hazardous Vapor Awareness  Other (please specify):  
\_\_\_\_\_
6. Are you aware of the procedures to follow in case of a fire outbreak at the station?  Yes  No
7. Do you know where the fire extinguishers and other emergency equipment are located?  Yes  No
8. What do you do if you notice a leak from the fuel dispensing nozzle?  Stop fuel and report to supervisor  Continue dispensing carefully  Shut pump and place warning sign  Try to fix the nozzle yourself  Inform customers and staff of hazard
9. Do you inspect the fuel dispensing equipment regularly?  Daily  Weekly  Every 2 Weeks  Monthly  Every other month  Never
10. What will you do if a customer is approaching the pump with a cigarette or mobile phone?  Politely inform the customer and request they stop  Pause fueling until the customer

- complies  Notify a supervisor if the customer refuses  Point to safety signage as a reminder  Step back and advise the customer to follow safety rules
11. How do you ensure that fuel spillage is avoided during dispensing?  Allowing Customers to Dispense Fuel Themselves Without Supervision  Regular Maintenance of Equipment  Implementing Spill Prevention Training  Use Automatic Shut-Off Nozzles  Ignoring Fuel Spill Incidents
  12. Which of the following first aid skills do you know?  CPR (Cardiopulmonary Resuscitation)
    - Treating Burns  Managing Cuts and Wounds  Handling Smoke Inhalation  Managing Shock  Eye Irrigation  Basic Bandaging  Handling Heat Exhaustion  Emergency Evacuation Assistance
  13. Do you perform any checks on the fuel storage tanks or underground tanks?  Yes  No; If so, what checks do you carry out?  Leak Detection Testing  Visual Inspections  Maintenance Records Review  Ventilation Checks  Pressure and Temperature Checks  Calibration of Monitoring Equipment
  14. What is the first action you will take in the event of a fuel spill?  Stop the source of the spill  Activate the Emergency Response Plan  Contain the Spill  Ignore the Spill  Notify Authorities  Try to Clean It Up Alone  Pour Water on it
  15. Where is the emergency switch located?
  16. Have you ever experienced any of these emergency situations at this station? 
    - Asphyxiation
    - Choking  Explosion  Electric shock  Spills  Leaks  Injury from equipment ; If so, how was it handled?  Evacuate Customers  Ignore the Situation  Alert Emergency Services  Use Fire Extinguishers  Try to Handle It Alone
  17. How would you respond if a customer accidentally drove off with the fuel nozzle still attached to their vehicle?  Stay calm  Ensure safety  Escort the customer  Inspect the pump  Report the incident  Yell or blame the customer  Ignore the incident  Handle the nozzle carelessly
  18. What safety signs do you have ?  No Smoking  No Open Flames Flammable Materials  Switch Off  Engine High Voltage Warning  Fire Extinguisher Location  No Mobile Phones  Emergency Exit
    - Wear Safety Gear  Authorized Personnel Only.
  19. What is the order for using the fire extinguisher?  Pull the pin  Aim the nozzle  Squeeze the handle  Sweep side to side
  20. Are you aware of the risks associated with handling petroleum products, such as fire, inhalation hazards, and skin contact? demities
  21. Have you ever reported any safety concerns to your supervisor?  Yes  No
  22. Are there any facilities at the station for the proper disposal of contaminated materials, like absorbent pads used for fuel spills?  Yes  No
  23. What would you do if you noticed fuel leaking from the underground storage tanks? 
    - Notify the Supervisor Immediately  Evacuate the Area  Ignore the Leak  Implement Spill Response Procedures  Try to Fix It Yourself

24. Do you monitor for signs of soil contamination or unusual odors around the filling station?  
 Yes  No

**UNIVERSITY OF BENIN**  
**FACULTY OF ENGINEERING**  
**DEPARTMENT OF MECHANICAL**

This questionnaire aims to gather information regarding factors influencing risk and uncertainty in the siting of filling stations. Your input will help identify challenges, opportunities and critical decision-making factors relevant to this study. Your responses are vital for a comprehensive analysis of environmental, economic and operational risks.

**SURVEY QUESTIONNAIRE**

**Age:**  Under 18  18 - 24  25 – 34  35 – 44  45 – 54  55+

**Gender :**  Male  Female

**Educational Level :**  Primary School  Secondary School  Undergraduate degree  
 Postgraduate degree  Others

**SUPERVISOR**

1. Have you submitted the architectural and structural designs for approval by the relevant authorities?  
 Yes  No
2. Do the designs include provisions for fire safety equipment and proper ventilation?  Yes  No
3. Are underground storage tanks (USTs) designed and installed according to DPR-approved specifications?  Yes  No
4. Have you implemented proper drainage systems and spill control measures?  Yes  No
5. Is there an approval from the State Fire Service for fire safety measures?  Yes  No
6. Are the employees trained in safety procedures, firefighting, and first aid?  Yes  No
7. Does the filling station have mechanisms in place to control vapor emissions during fuel dispensing?  
 Yes  No
8. Is there an Environmental Management Plan (EMP) in place for handling spills and waste disposal?  
 Yes  No
9. Have you established a waste management plan for disposing of fuel residues and used oil?  
 Yes  No
10. Do you agree to periodic inspections by the DPR to ensure compliance with safety, environmental, and operational standards?  Yes  No
11. Are there records of previous inspections and compliance reports available for review?  Yes  No
12. Do you have emergency response procedures and equipment in place for leak detection and firefighting?  Yes  No
13. Are fire extinguishers, sand buckets, and other firefighting equipment readily available and regularly maintained?  Yes  No

14. Have employees undergone training in handling emergency situations, such as fires, spills, or gas leaks?  Yes  No
15. Is there a designated muster point for customers and staff in the event of an emergency?  Yes  No
16. Are there procedures in place to regularly inspect fuel dispensing equipment for leaks, faults, or other potential hazards?  Yes  No
17. Do you have a first aid kit on-site, and are employees trained to provide basic first aid if needed?  Yes  No
18. Is the area around the filling station properly lit to ensure the safety of customers, especially during nighttime operations?  Yes  No
19. Have measures been taken to limit the exposure of customers and staff to harmful fumes from the dispensing of fuel?  Yes  No
20. Do the tanks and dispensing equipment have overfilled protection devices to prevent spills during refueling?  Yes  No
21. Have community members been involved in the planning or decision-making process?  Yes  No
22. Have any concerns or objections been raised by community members?  Yes  No
23. If any, how have these concerns and objections been addressed or mitigated?  
 Increased Safety Signage  Enhanced Security  Environmental Protections   
 Noise Reduction  Community Engagement  Training Staff  Regular Inspections  
 Community Feedback  Emergency Response Plans  Public Awareness Campaigns
24. Have any compensation or mitigation measures been proposed for potential negative impacts?  Yes  No
25. How will ongoing communication and engagement with the community be maintained?  
 Regular Newsletters  Social Media Interaction  Community Meetings  Surveys and Polls  
 Dedicated Contact Person  Website Updates  Local Events Participation   
 Feedback Boxes  
 Partnerships with Local Groups
26. Is the existing power infrastructure capable of handling the energy requirements of the filling station?  Yes  No
27. Is there a reliable supply of electricity to the filling station?  Yes  No
28. Is there a reliable source of potable water available at the filling station?  Yes  No
29. Is there landline telephone service available at the filling station?  Yes  No

30. What is the first action you will take in the event of a fuel spill?  Stop the source of the spill  Activate the Emergency Response Plan  Contain the Spill  Ignore the Spill  Notify Authorities  Try to Clean It Up Alone  Pour Water on it
31. What are the procedures for handling used oil or other waste generated from the station?  Segregate and store  Recycle used oil  Maintain documentation  Engage licensed contractors

**UNIVERSITY OF BENIN**  
**FACULTY OF ENGINEERING**  
**DEPARTMENT OF MECHANICAL**

This questionnaire aims to gather information regarding factors influencing risk and uncertainty in the siting of filling stations. Your input will help identify challenges, opportunities and critical decision-making factors relevant to this study. Your responses are vital for a comprehensive analysis of environmental, economic and operational risks.

**SURVEY QUESTIONNAIRE**

**Age:**  Under 18  18 - 24  25 – 34  35 – 44  45 – 54  55+

**Gender :**  Male  Female

**Educational Level :**  Primary School  Secondary School  Undergraduate degree  
 Postgraduate degree  Others

**Employment Status:**  Employed full-time  Employed part-time  Self- employed   
Unemployed  Student  Retired  Other

**PEOPLE AROUND**

1. How long have you been living in this area? \_\_\_\_\_
2. Are you aware of the filling station nearby? If yes, how would you describe your experience living near it?  Yes  No
3. Do you feel the filling station is well-maintained and safe?  Yes  No
4. Have you ever noticed any unusual activities or incidents at the filling station, such as fires, fuel spills, or loud noises?  Yes  No
5. Do you feel safe living near the filling station, considering the risks associated with fuel storage and dispensing?  Yes  No
6. Have you received any information or training from the filling station on what to do in case of an emergency, like a fire or fuel spill?  Yes  No
7. Are there any safety signs or warning signals that you've noticed around the filling station to alert people of potential hazards?  Yes  No
8. Have you observed any emergency drills or safety demonstrations conducted by the filling station management?  Yes  No
9. Have you noticed any unpleasant smells, air pollution, or smoke coming from the filling station?  
 Yes  No
10. Do you think the filling station has affected the quality of air, water, or soil in the area?   
Yes  No
11. Have you ever seen fuel spills or leaks from the filling station? If so, were they cleaned up promptly?  
 Yes  No
12. Do you hear excessive noise from the filling station, such as from fuel tankers, generators, or equipment?  Yes  No
13. Has the filling station management ever reached out to the community to discuss safety or environmental concerns?  Yes  No

14. Do you know who to contact at the filling station if you have any safety or environmental concerns?  
 Yes  No
15. Have you or anyone you know ever made a complaint about the filling station? If so, was the issue resolved?  Yes  No
16. Have you or any family members experienced health problems that you believe could be related to the filling station (e.g., respiratory issues, skin irritation)?  Yes  No
17. Have you received information about evacuation procedures?  Yes  No
18. Do you have a plan for emergency situations?  Yes  No
19. Have you participated in emergency response drills?  Yes  No
20. Do you feel prepared for potential emergencies?  Yes  No
21. Are you aware of emergency response procedures?  Yes  No
22. Have you received information about evacuation procedures?  Yes  No
23. Do you believe that the filling station has contributed to an increase in traffic or accidents in the area?  
 Yes  No
24. Are there any other ways the filling station has affected your daily life (e.g., noise, congestion, safety concerns)? \_\_\_\_\_
25. Do you have any suggestions for how the filling station could improve its safety and environmental practices?  
 \_\_\_\_\_
26. Would you support or oppose the construction of additional filling stations in the area?  
  Yes   No Why?  
 \_\_\_\_\_