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SPATIAL DISTRUBUTION AND IMPACT OF FUEL STATION ON TRAFFIC FLOW IN ADDIS ABABA

BY

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November, 2023

Addis Ababa

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University, Ethiopian Institute of Architecture, Building Construction and City Development (EiABC), in Partial Fulfillment for Master's Degree in Urban Planning.

Advisor:

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Addis Ababa, Ethiopia

DECLARATION

I, Natnael Habtemaryam, do hereby declare that this research work entitled "SPATIAL DISTRUBUTION AND IMPACT OF FUEL STATION ON TRAFFIC FLOW IN ADDIS ABABA" is my own original work, and it has not been submitted to any other university/ institutions for any degree/ diploma & for other purposes. Materials and information used in this study other than my own are dually acknowledged and cited.

Name: Natnael Habtemaryam

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Signature

APPROVAL

As a member of the Examiners board of the final Master's thesis open defense of Natnael Habtemaryam, we have read and evaluated the Thesis prepared by Natnael Habtemaryam entitled "SPATIAL DISTRUBUTION AND IMPACT OF FUEL STATION ON TRAFFIC FLOW IN ADDIS ABABA" and recommended to Ethiopian Institute of Architecture, Building Construction and City Development, Addis Ababa University to accept the Thesis for the Fulfillment of Requirements for the award of Degree of Master 's of Science in Urban Planning.

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DEDICATION

This thesis manuscript is dedicated to my mother Worknesh Habtemaryam for nursing the author with affection and love and for her dedicated partnership in the success of her life.

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ABSTRACT

As cities grow and expand traffic flow also increases in cities this phenomenon may results in traffic congestion which is a major problem for urban mobility. This research study investigated the spatial distribution and impact of fuel stations on traffic flow in Addis Ababa city. The study used both qualitative and quantitative approaches and other forms of data collection techniques. Names and street addresses of the filling stations were obtained from government bodies. Global positioning System (with in a mobile phone device) was used to capture the location of the filling station. Arrival rate of Vehicles, service rate and number of servers were acquired on field by keeping track of when cars arrived at Fuel Stations and the amount of time it took to serve each car. The geographical data were imported to Arc Map environment of ArcGIS 10.5 and analyses for spatial distribution were performed in the Arc Map environment using spatial statistics, spatial analyst and proximity tools available in the software. For the traffic impact analysis M/M/s queuing theory method is used. The findings revealed that there are 131 Fuel Stations in Addis Ababa and 75 Fuel Stations are found on PAS (Principal arterial street) road type, 40 Fuel Stations are found on SAS (Sub arterial street) road type and 16 Fuel Stations are found on CS (Collector street) road type Furthermore, utilizing the M/M/S Queuing System, the study reveals that traffic intensity in sampled Fuel Stations in the CS road type, SAS (Sub arterial street), and PAS (Principal arterial street) road types is significantly higher than one, indicating high demand. However, in CS (Collector Street) road type none of the stations have traffic intensity below 1. In contrast, 19 of the sampled 22 Fuel Stations in the SAS (Sub Arterial Street) road type have traffic intensity greater than one. The majority of Fuel Stations in the PAS (Principal Arterial Street) road type have traffic intensity less than one. Analysis from arc gis software showed that fuel stations along the city road are not evenly distributed, rather they are more concentrated together at different centers. In conclusion this Fuel Stations have a significant impact on the flow of traffic during rush hours. In light of these findings, the study recommends the development of urban planning standards, zoning regulations, and traffic impact assessments to optimize fuel station distribution. Operational Efficiency and Traffic Management Strategies are essential components of sustainable urban mobility in Addis Ababa City.

Key Words: Fuel Station, Traffic Impacts, Spatial Distribution, Traffic Intensity, Queuing Model, ArcGIS.

Table of Contents

List of figures

List of tables

1 CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The majority of Ethiopia's cities have seen fast expansion, which has accelerated the rise of the country's vehicle traffic and, as a result, raised the demand for gasoline stations along highways, city streets, and settlements. These developments must be carefully monitored and managed. The number of gasoline stations in Addis Ababa city has increased, and as a result, less thought has been given to the placement and operation of Fuel Stations.

Land for socioeconomic services is in great demand in most regions of Addis Ababa. Because of the great demand for land, there has frequently been land scrambling and unlawful change of land uses, resulting in chaotic construction and the purposeful placement of fuel filling stations in inappropriate sites that are particularly sensitive to dangers.

The petroleum industry has been significantly impacted by technological development in the automotive sector, and this has led to the construction of gasoline stations in key places to meet the demand for vehicular operations.(Abdul et al., 2009)

The majority of Fuel Station s sell gasoline, diesel, natural gas, and kerosene, while the remainder some also operates shops. It is assumed that Fuel Stations will be situated in an orderly and sustainable way because they have spatial dimensions. However, the majority of fuel stations are still positioned in a way that is chaotic and potentially dangerous, despite Addis Ababa city having no guidelines governing the positioning of gasoline filling stations.

The spatial distribution criteria for Fuel Stations are influenced by things like closeness to population centers, separation from nearby stations, permissions to use existing utilities, and levels of environmental pollution. (Alesheikh & Golestani, 2011) Customers, transportation, the neighborhood, finances, and the longer-term future are additional factors to take into account when choosing the location of a business enterprise such as a Fuel Station. These are variables that should not be wished away when choosing the location of investments such as filling stations. Considering how crucial the operations of places like Fuel Stations are to the sustainability and safety of the environment. (Sesulihatien, 2012)

Fuel demand is one of several demands that are created by the rise of the urban population and the number of cars and other vehicles. Long urban streets and pointless trips waste a significant amount of gasoline for vehicles. (Harrison, 1999) Since engines are built to use petroleum products and filling stations are where fuel is sold, an increase in automobiles has resulted in an increase in demand for fuel and, by extension, fuel stations. In light of this development, many developers take advantage of this necessity and construct Fuel Stations carelessly without taking into account any possible consequences of their location. Nowadays, it is well acknowledged that economic expansion can significantly contribute to expanding impacts, especially when such advancements are not sustainable.

The growing number of fuel stations in the Addis, together with issues with their distribution and location within the study area, are what motivated this study. This is mostly because some Fuel Stations are poorly situated, which causes traffic jams, accidents, pollution, fire risks, and other problems. Therefore, it is crucial to evaluate the distribution pattern of Fuel Stations and their effects on traffic in Addis Ababa City. This research project intends to analyze the spatial distribution and effects of Fuel Stations on traffic flow in across Addis Ababa City.

1.2 Statement of the Problem

Fuel stations have a key role in a variety of traffic-related problems in urban areas, such as congested roadways, air pollution, accidents, and the risk of fire and explosions. Many of these issues are brought on by some fuel stations' disregard for specified physical planning standards. The impact of these problems depends on a number of variables, including their location, size, and closeness to highways.(Kuby & Lim, 2007)

The research area's backdrop, Addis Ababa, has seen an increase in fuel stations, some of which have been built without proper consideration for. In light of these issues, it is important to point out that Addis Ababa currently lacks comprehensive standards for the construction of fuel stations. The complexity of the impact of Fuel Stations on traffic flow and urban dynamics is further exacerbated by the lack of guiding standards.

Remarkably, despite the evident ramifications of unregulated fuel station placement, a comprehensive research study addressing the precise influence of fuel stations on traffic flow within Addis Ababa remains noticeably absent. This research endeavors to address this void by rigorously investigating the nexus between fuel station distributions, by assessing the adherence of fuel stations to potential planning standards and analyzing their effects on traffic flow, this study strives to unearth critical insights.

Additionally, this study hopes to act as a catalyst for change because Addis Ababa lacks formal planning guidelines for where to locate Fuel Stations. This study aims to outline the issues with fuel station distribution while also suggesting workable solutions to the problems that have been identified. These measures, which are supported by thorough analysis and recommendations that are pertinent to the context, may serve as the foundation for future planning standards.

Furthermore, this research sees itself not only as an exploration of difficulties, but also as a useful resource for urban planning organizations and institutions. This study intends to contribute to the development of successful Fuel Station rules and policies by providing data-driven insights and evidence-based recommendations. It aims to provide urban planning and regulatory authorities with the knowledge they need to establish a healthy link between fuel station infrastructure and traffic management in Addis Ababa.

In conclusion, this study takes a multifaceted approach to illuminating the intricate interplay between fuel station distribution, traffic dynamics, and urban planning. It seeks to shed light on existing issues while imagining a future in which informed decisions and coordinated efforts can mitigate the negative effects of fuel stations on traffic flow and contribute to Addis Ababa's long-term development.

1.3 OBJECTIVES OF THE STUDY

1.3.1 General Objective

The primary aim of this study is to examine how the spatial distribution of fuel stations in Addis Ababa and its impact on traffic flow.

1.3.2 Specific Objectives

1. To identify and map the existing fuel station
2. To analyze the spatial distribution of fuel stations
3. To examine the impacts of spatial distribution of fuel stations on traffic flow in Addis Ababa.

1.4 RESEARCH QUESTIONS

1. How many Fuel Stations are Present in Addis Ababa
2. What is the spatial distribution of Fuel Stations in Addis Ababa city?
3. What are the effects of spatial distribution of fuel stations on traffic flow?

1.5 SCOPE OF THE STUDY

1.5.1 Conceptual scope

The study aims to investigate not only the physical locations of fuel stations but also their broader implications on the transportation system. By conducting a comprehensive analysis, I seek to gain insights into how fuel stations are strategically positioned within the urban landscape, understand their impact on traffic dynamics, and propose actionable measures to mitigate potential negative consequences.

The spatial distribution of fuel stations plays a critical role in shaping the accessibility and convenience of fueling services for motorists across the city. By examining the specific locations of fuel stations, patterns, clusters, or disparities in their distribution can be identify. This analysis will shed light on the factors that influence the decision-making process behind the placement of fuel stations, such as proximity to major roads, commercial areas, or densely populated neighborhoods. I aim to uncover potential relationships between the presence and density of fuel stations and traffic conditions. This analysis will provide valuable insights into how fuel stations contribute to traffic congestion, potential bottlenecks, and delays experienced by commuters and road users.

Furthermore, this research aims to go beyond a mere assessment of the current situation by suggesting actionable measures to address any negative impacts identified.

In achieving our objectives, the study will objectively identify and classify fuel stations based on various criteria, including ownership, on which road type they are found, sub city, nearest to each other size, and facilities. This classification will provide a comprehensive understanding of the fuel station landscape in Addis Ababa and enable a more nuanced analysis of their impacts on traffic flow.

By undertaking this comprehensive research, the aim is to contribute valuable insights to any institution and government body that are responsible on this matter or person in Addis Ababa. The findings of this study will serve as a basis for informed decision-making, policy development, and strategic interventions aimed at improving the spatial distribution of fuel stations and enhancing the overall efficiency of the transportation system.

1.5.2 Geographical Scope

The dynamic Ethiopian metropolis of Addis Ababa is included in the study's geographic scope. The capital and largest city of Ethiopia is Addis Ababa, which is situated in the center of the nation. The study concentrated on examining the spatial distribution of Fuel Stations and their effects on traffic flow within this urban environment.

The study examined all of Addis Ababa, including its many neighborhoods, significant road systems, and vital transportation routes. The research tries to capture the varied features and dynamics of gasoline station distribution and their influence on traffic patterns across different sections of Addis Ababa by looking at the city as a whole.

Within this geographic range, the study takes into consideration both the city's center districts and its periphery, accounting for any changes in land use, population density, and transit facilities. This extensive geographic coverage guarantees a thorough comprehension of the spatial link between fuel stations and traffic flow inside the Addis Ababa metropolitan area.

The study's conclusions and suggestions are particularly useful to transportation planning and development projects taking place within Addis Ababa’s city limits, offering information that may guide policy decisions and municipal actions.

1.6 SIGNIFANCE OF THE STUDY

The findings of the study will be of great benefit to project approving agencies in Addis Ababa also for the whole Ethiopia, Agencies like Ministry of Mines, Petroleum and Energy Authority, Physical planners, the communities and other actors in making decisions about how to locate Fuel Stations geographically during the development process.

The result of this study will be a good resource for planning body or any organization that has the authority to formulate Standards for Spatial Distribution of Fuel Stations in Addis Ababa.

Other academics working in the subject of physical planning can use the study's findings to build a foundation by doing a literature review.

The study's findings will also highlight how poorly distributed gasoline stations affect traffic flow and offer solutions that the planning authority and other development stakeholders may use to remedy the issue.

1.7 Research Limitation

While the study aims to provide valuable insights into the spatial distribution and impacts of fuel stations on traffic flow in Addis Ababa City, it's essential to acknowledge certain limitations inherent in the research design and scope.

Data Collection Challenges: Weather conditions, varying traffic patterns, and access to specific locations may all pose challenges to the collection of primary data, particularly observational data related to traffic flow. These variables may have an impact on the data's accuracy and representativeness.

Dynamic Urban Context: Urban environments are inherently dynamic, with regulations, infrastructure, and urban development changing over time. The findings may not fully account for future changes in fuel station distribution and the evolving effects on traffic flow.

Budget Constraints: Budget constraints may limit the scope of data collection methods, sample size and data analysis tools used in the study. The available budget may limit the scope of field surveys or access to specific data sources.

Time Constraints: The study is limited in time, which may affect the depth and breadth of data collection, analysis, and interpretation. Time constraints may necessitate a trade-off between research thoroughness and timeline constraints.

Despite these limitations, the study aims to provide a thorough examination of the relationship between fuel stations and traffic flow in Addis Ababa. Recognizing these constraints promotes a more balanced understanding of the research findings and encourages future studies to expand on these findings.

1.8 Description of the study area

Addis Ababa, Ethiopia's capital and largest city, is a vibrant city as well as a vital transportation hub within the country. Addis Ababa is located in the central part of Ethiopia, at approximately latitude 9.005401 and longitude 38.763611, with an elevation of 2355m. It is surrounded by beautiful scenery and shares borders with the newly established Sheger city in all directions.

Addis Ababa, with its rapidly growing population, is home to a diverse community comprised of various cultural groups and languages spoken. The city's urban features and architectural styles reflect a distinct blend of traditional and modern influences.

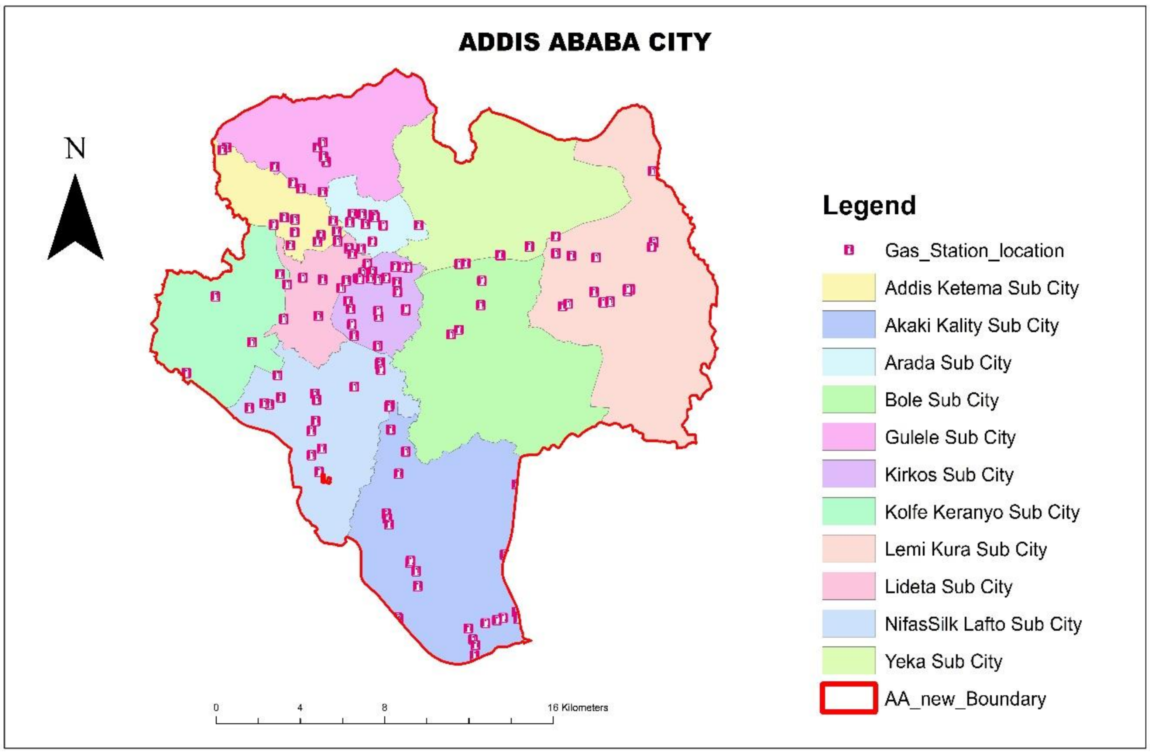


Figure 1-1 Addis Ababa City (Source: Organized by the author, using Arc GIS 10.5 Analysis, (2023))

Addis Ababa's thriving urban life is supported by an advanced transportation system. The city's transportation system includes major thoroughfares and arterial roads. Additionally, the city has public transportation options, such as buses and the recently installed light rail system, to make it easier to get around Addis Ababa and the surrounding areas.

Fuel stations are critical to meeting the transportation needs of Addis Ababa residents and visitors. The city has a network of Fuel Stations strategically placed along major thoroughfares and in different neighborhoods. These Fuel Stations sell various types of gasoline and are frequently operated by small business owners as well as large fuel station chains.

Traffic flow in Addis Ababa has varying patterns and levels of congestion. The city is congested, especially during rush hour. Understanding the transportation dynamics of Addis Ababa necessitates a thorough understanding of traffic patterns, congested areas, and the effects of fuel station placement on traffic flow.

The analysis of the geographic distribution and effects of Fuel Stations on traffic flow in Addis Ababa is quite pertinent. This research can help with educated urban planning decisions, sustainable transportation management, and the general development of Addis Ababa as a vibrant and effective city by looking at the link between the placement of gasoline stations and traffic dynamics.

1.9 Organization of the document

There are 5 chapters in the following work.

Chapter One includes the Introduction section, Background of the Study, Problem Statement, Objectives of the study, and the Importance of the Study are all included in this chapter.

Chapter Two Provides a general introduction, a review of literature on fuel station spatial distribution, factors influencing fuel station spatial distribution, standards for fuel station spatial distribution, traffic flow, traffic flow types, and fuel station impacts.

Chapter Three focuses on general introduction, research design, sampling techniques and procedures, study area, target population, and sample size are all presented, Techniques for gathering data (reconnaissance survey and mapping, observation, GPS, GIS, and photography). Secondary data collection, data processing, editing, and analysis, as well as ethical considerations, are all part of the process.

Chapter Four Presents a general introduction and research findings covering the study's four objectives, which are to identify, map, and classify existing fuel stations, to investigate the spatial distribution of Fuel Stations, to investigate the effects of fuel station spatial distribution on traffic flow in Addis Abeba, and to propose measures that can be implemented to mitigate the effects of fuel stations on traffic flow.

Chapter Five is about summary of the research findings, conclusions, study recommendations, future study recommendations, references, and appendices are presented.

2 CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

An overview of the literature on the spatial distribution and effects of Fuel Stations on traffic flow is included in this section. Under this chapter, a critical evaluation of papers and documents was conducted regarding the topics that have been researched and studied in the literature on the spatial distribution and effects of fuel stations on traffic flow, both theoretically and experimentally. It was crucial to take into account the literature already present in the works of academics who have written about the subject of study. The literature was comparative in the sense that it was relevant to the study's specific goals in order to help the researcher recognize the contributions of other researchers and spot any gaps. In conclusion, this chapter contains literature on the following subsections: traffic flow, types of traffic flow, impacts of fuel stations, variables influencing the spatial distribution of fuel stations, standards for the spatial distribution of fuel stations.

2.2 Spatial Distribution of Fuel Stations

According to(Jakle, 1978), a graphical representation of such an arrangement is a key tool for assessing the possible effects that could result from inadequate spatial distribution of these facilities. Jackle defines spatial distribution as the layout of fuel stations over the space. For the explication of fundamental issues in many fields of knowledge, understanding the geographical distribution of events that occur in space today presents a significant difficulty. Due to the availability of inexpensive Geographic Information Systems (GIS) with user-friendly interfaces, studies about urban planning and spatial distribution are becoming more and more popular.

According to (Keeble, 1969), a fuel station is a location that offers gasoline and lubricants for cars. Petrol, diesel, and kerosene are the most popular fuels sold. Fuel stations should be placed in areas that are both physically accessible and where outsiders may find them easily. They should also be placed with as little hazard and congestion as is physically practicable. Many also provide additional minor repair services including motor tuning and tire alignment.

Fuel stations could be arranged logically in accordance with the size, spacing, or distance, and population to be supplied, claims the central location theory (Getis & Getis, 1966). This implies that a system of service points at the central locations would be able to meet the demand for the goods sold at filling stations. As a result, the visible manifestation of any urban activity in the environment should be divided among service locations that can meet a variety of needs. However,(Lösch et al., 1954) claimed that there might be an unequal distribution of service centers (i.e., core locations) throughout the metropolis, resulting in a city wealthy and city poor sector. A dilemma for an urban planner is where to put infrastructure and services, which exposes the urban population to various risks.

The spatial distribution of filling stations is supposed to be governed by a set standard, notwithstanding the fact that filling station operators may have locational preferences and that this is important for the economy(Journals et al., 2015). Every site on earth has analyzable benefits and drawbacks, according to (Bolen, 1988), and according to (Journals et al., 2015), conducting an environmental impact assessment is necessary before granting planning permission to build a Fuel Station (EIA). EIA, according to (Lawrence, 1997), is a tool for decision-making that offers a thorough analysis of the environmental effects of a proposed action and its alternatives before a choice is made.

According to (Bolen, 1988), there are both analyzable advantages and disadvantages to the spatial distribution of Fuel Stations. He claims that the contributing variables can be divided into two physical conditions. These are actual and analytical physicals. Real physical refers to an area's observable conditions, such as the state of the land, the width, and the distance from the highway. On the other side, analysis physical refers to the physical state as determined by physical analysis, including competitor analysis, neighborhood factor analysis, and population factor analysis. Both of these considerations are crucial when choosing a location for a Fuel Station because, although physical conditions can have an impact on the nature and type of business to be done, physical analyses can also have an impact on how well the business performs. For instance, if two stations are too close to one another that will result in fewer turnovers at each station (Sesulihatien, 2012)

According to (Iman et al., 2009), the spatial distribution of Fuel Stations is typically influenced by the type and volume of traffic that passes the location, proximity to a major thoroughfare, visibility from the road, the amount of time that drivers must slow down to enter the Fuel Station , the ability to draw customers in general, the direction or movement of the road, the types of arteries, and the distance between catchment areas and residential neighborhoods. Such physical characteristics of a site location can mean the difference between a service station's success, mediocrity, or failure. Site proximity to the neighboring residential neighborhoods can be anticipated to have a substantial impact on a Fuel Station business, depending on the distance of catchment regions from those neighborhoods.

For the explication of fundamental issues in many fields of knowledge, understanding the geographical distribution of events that occur in space today presents a significant difficulty. Due to the availability of inexpensive Geographic Information Systems (GIS) with user-friendly interfaces, studies are becoming more and more popular. A database and geographic foundation (such as a map of the municipalities) are sufficient for achieving this and the GIS are capable of displaying a colored map that enables the depiction of the spatial pattern of the occurrence (Ahmed, 2013).

2.3 Factors Influencing the Spatial Distribution of Fuel Stations

Location variables are features of an outlet that, at least temporarily, cannot be easily changed. They have an impact on the potential market size and actual sales of the station, which may be viewed as the total of a transient and local demand component. Unfortunately, necessary information is lacked to distinguish between these two sales sources. Therefore, it is supposed that these two components were actually expressed by the vehicle traffic that crossed a station over a certain period of time. The retained spatial variables are now covered (Nelson, 1958).

Site Location: For a long time, it has been maintained that the site location is the primary component in determining a station's performance, with all other aspects contributing just slightly (Nelson, 1958). For this reason, it is believed that a good proxy for potential sales due to a location is the density of the motor traffic flow passing each station.

Local competition (Competition, number of competing stations): Local competition obviously affects a station's performance. Intensity is measure by the number of other stations within a two-kilometer radius surrounding a station in a market area sharing the same vehicular traffic flows, it is assumed that the higher the degree of competition, the lower the average sales per station in that area because of demand saturation effect.

Market area: According to (Elzinga & Hogarty, 1978), a market area or market zone is the geographic area where at least 90% of indigenous sellers' sales take place and at least 90% of indigenous buyers' purchases come from those merchants. Even though the product offerings of various stations in the urban gasoline market are nearly comparable, it is very difficult to adopt the aforementioned criteria. Indeed, drivers are constantly on the move. In contrast to earlier spatial models, whether linear (Hotelling, 1929) or circular (Salop, 1979), which assumed that each station only had two direct competitors—one on each side—because of drivers' constant movement and price sensitivity, each station has more than two direct rivals.

Traffic Flow: One of the most crucial elements taken into account while developing a station is this. Due to the likelihood that these main routes will draw more customers, marketers choose to locate their stations along them. In other words, the demand for gasoline increases as traffic volume increases (Png & Reitman, 1994).

Exit Roads: The majority of filling stations are located along the exit roads that connect cities and villages; these roads also have the most stations. Anyone traveling out of town must fill up his tank because petroleum had been compared to food (with fuel). According to the research, most Fuel Stations are built on the side of the exit where customers would find it easiest to enter the station and fill up their vehicle (Png & Reitman, 1994).

Convenience: This is another aspect that marketers take into account when deciding where to locate their company. Despite the fact that marketers are drawn to areas with high traffic volumes, they want to build their stations in areas where drivers will find it convenient to park and refuel. As a result, Fuel Stations are constructed with ample room for consumers to move their vehicles when entering or leaving after filling up (Png & Reitman, 1994).

The level of outlet attraction is decided by marketing tools called non-locational (or non-spatial) variables. They are typically created to make a customer feel comfortable and increase their likelihood of making a purchase. The underlying premise is that, despite the product's lack of differentiation, shops may still compete on factors like pricing, service quality, and others to draw clients and fulfill their needs. In the part below.

Servicing ability (Capacity): The number of felling stations, bays, pumps, and attendants (a proxy for station size) a station has to accommodate drivers who want to buy fuel is known as service capacity. An intuitive assumption that is supported by the findings of (Png & Reitman, 1994)Reitman, is that the projected service time will decrease as the station's service capacity increases.

The number of hours the station is open and staffed by an attendant during the course of a year is the operating hours. Stations are under pressure to work longer hours to accommodate an increase in consumer demand in order to recoup their increased investment in fixed assets, such as land, pumps, bays, and storage tanks.

2.4 Standards for Spatial Distribution of Fuel Stations

Even though there are no standards for fuel station in Addis Ababa. Construction of fuel stations are guided by the private sector which have different guidelines of their own. Thoughtful consideration must be given to the control that must be exercised, the legal means that may be necessary to impose such control, and the ideal conditions that should be produced from the point of view of service to the general public when deciding where and how to sit gasoline stations. One of the main sources of traffic dangers, a reduction in aesthetic value, and probable fire causal agents have been recognized as Fuel Stations (Sur & Sokhi, 2006).

2.5 Traffic Flow

According to (Journals et al., 2015), traffic flow is the movement of cars. The theory of traffic flow was created based on how motorcyclists, cars, and pedestrians move through lanes. They combine to make the most intricate component of the transportation system. Numerous variables, including design speed, the proportion of heavy vehicles, the number of lanes, and the presence of intersections, have an impact on the flow of traffic. The number of cars, motorbikes, and pedestrians using a certain road in a given hour is known as the traffic flow on that particular road. It is calculated using traffic counts that were made for a specific amount of time at one location along the lane segment.

There will be variation in the counts made at various times on a given day. Peak hour traffic must be considered for any traffic flow analysis. It is necessary to evaluate traffic flow on the road in order to identify congested areas, determine whether a junction needs a traffic light, determine whether the road's capacity can accommodate the current flow, and perform other tasks.

Speeds of traffic and vehicle density are two factors that affect how well traffic moves. Vehicle density shouldn't exceed 30 vehicles per mile of travel for movement to remain unimpeded. 75 mph should be the free flow speed on a freeway to improve the level of service on a specific road. According to(Journals et al., 2015), the free flow speed on an urban road should be kept at roughly 50 mph.

2.5.1 Types of Traffic Flow

Five main categories can be used to categorize traffic flow. You can choose the analysis techniques and descriptions that are most appropriate for a specific situation by first determining the type of flow that is there. (Journals et al., 2015).

Completely Free Flowing Traffic: When other traffic is not a hindrance, cars can move at a maximum speed of (free speed). This speed depends on the design speed of a speed, flow rate, and density will be close to zero, among other factors.

Saturated Traffic: Speed and flow rate are zero on overloaded roadways. There is a maximum gridlock density and the vehicles are lining up.

Capacity Traffic: A road's capacity is equal to its maximum flow rate, qc. With respect to the maximum flow rate of qc, and are the capacity speed and density, respectively.

Uninterrupted Flow: Vehicle-vehicle interactions and interactions between vehicles and the roadway control the flow. For instance, there is a continuous flow of vehicles on an interstate highway.

Interrupted flow: Here, the flow is controlled by an outside factor, like a traffic signal. Vehicle-vehicle interactions and vehicle-roadway interactions are less important in determining traffic flow when there is interrupted flow.

2.6 Impacts Fuel Stations

According to (Ayodele, 2011), filling stations have a substantial impact on traffic issues such congestion, pollution, accidents, longer travel times, and fire explosions in heavily populated regions. The severity of these issues is determined by factors or criteria including location, size, and setback from the road, among others. Unplanned development can lead to hazards like traffic congestion, pollution, and a host of other issues. In addition to these risks, communities must deal with other issues like accidents, fire, and explosions. Urban Fuel Stations have been the focus of studies.

Increased cost of travel (Dachis, 2015) He mentioned a number of costs related to poor location of Fuel Stations, traffic slowing down speed, which is a visible cost, and people skipping trips out of fear of traffic, which becomes a hidden cost of traffic. He also mentioned that when traffic congestion causes people to leave their cities, they miss out on better jobs and amenities. He reiterated that these additional, hidden costs of congestion, which are in addition to the expense of slower travel, vary from $500 million to $1.2 billion annually.

Research has shown that travel behaviors of consumer choice models can influence the valve of time spent in travel for both work and other activities, despite the inability to predict travel time and delay movements(Hensher, 1997).Choice of mode or route using the LOGIT model. The models show that the decisions made by a sample of massage therapists are related to the variations these people encounter in terms of in-vehicle and out-of-vehicle travel times as well as in terms of the financial expenditures connected with each method or alternative route.

The time saving is then given a monetary value using the ratio parameter valve that is ascribed to the travel time relative to travel cost. The studies on the deviation of traveler cost function (Black & Towriss, 1993; Jackson & Jucker, 1982; Polak, 1987) demonstrate that under the correct conditions, travel during crowded peak period travel can reduce variability and uncertainty and provide a large advantage to travelers. This empirical research looked at how frequently traffic incidents occur, including serious collisions that temporarily close lanes of traffic as well as numerous minor collisions such vehicle breakdowns and other causes (Lindley, 1987). (Giuliano, 1986) This model described the mean and variance in the time lost due to such traffic incidents along freeways.

Fire outbreak: According to (Rodrigue, 2009), improper handling of fuel leakage from gasoline storage could result in fire outbreak. Numerous lives would be lost and priceless assets would be destroyed during the flames. Risks could also arise from leaks through dispenser pumps and storage tanks.

Congestion: As observed by (Ayodele, 2011), According to (Ayodele, 2011), filling stations are a key source of traffic issues such congestion, pollution, fire, and explosion in heavily populated regions. The criteria or variable, such as location, size, setback from traffic, etc., affects how severe these issues are. Unplanned development can lead to risks including pollution, traffic jams, and many other issues. In addition to these risks, communities must deal with other issues including accidents, fire, and explosions. A regression and Geographic Information System (GIS) based spatial system were used in another study by (Hamid, 2009) to explore the site potentiality for a Fuel Station company based on traffic volume counts. The authors emphasized that site potentiality is a crucial element that affects the commercial viability of a Fuel Station that depends on customer traffic. On this point, (Kemp, 2008) stated that site location was experimentally discovered to be the key determinant for drivers when choosing a Fuel Station in the United States of America. (see also (Hamid, 2009), p.11).

3 CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The primary goal of this research is to thoroughly investigate two critical aspects in Addis Ababa City: where fuel stations are located and how they affect traffic flow. It is best to know if specific locations where fuel stations are located are contributing to traffic congestion. It is best to know if having fuel stations in certain areas causes more traffic congestion, and other traffic-related issues.

The research tools and methodologies that was employed in the study to examine the spatial distribution and effects of Fuel Stations on traffic flow in Addis Ababa City are presented in this chapter. The research design, sampling procedures (simple random sampling and clustered sampling), study area, target population, sample size, data collection techniques (observation and photography, reconnaissance survey and mapping, GPS data collection technique), secondary data sourcing, data processing and analysis, ethical considerations, and challenges faced by the researcher were all covered in this chapter.

The investigation was carried out primarily on all Fuel Stations for spatial distribution analysis and on sampled Fuel Stations in Addis Ababa City for traffic impact analysis, and Global Positioning System (GPS) gadget was used to locate each one and record its specific geographic coordinates.

3.2 Research Design

A descriptive analytical research design using both quantitative and qualitative methods was used for the study. The sample and the sample components was chosen for the study using simple random sampling and clustered methods that was purposeful. Both quantitative and qualitative data gathering procedures was used. According to (Breweton & Millward, 2001), a case study offers a thorough analysis of the issue in a condensed amount of time. He goes on to say that the idea of mixing qualitative and quantitative data in case study research holds up the potential of getting closer to the entirety of a case than could be accomplished by a study using only one method.

3.3 Data Types

3.3.1 Primary Data:

Geographical coordinates: The precise geographic coordinates (latitude and longitude) of Fuel stations in Addis Ababa were gathered using a GPS device as primary data. The mapping and geographical analysis of the location of gasoline stations across the city were made possible by the GPS data.

Observational Data: Primary data was gathered by directly watching the flow of vehicles at numerous points throughout Addis Ababa. In order to determine how fuel stations, affect traffic flow, it was necessary to visually observe traffic patterns, vehicle movements, and levels of congestion.

Arrival of Vehicles and Service Rate: data was acquired by keeping track of when cars arrived at Fuel Stations and monitoring the service rate, or the amount of time it took to serve each car. The operational effectiveness of Fuel Stations and its possible influence on traffic flow are revealed by this data.

3.3.2 Secondary Data:

Maps (Road map and City Map): This includes road maps and administrative maps of Addis Ababa city. These maps provide a crucial visual understanding of the city's layout and the distribution of various areas. Utilizing these secondary data sources help to enhance the accuracy and context of my research findings.

Spatial plans and related documents: that provides information on the designated areas and regulations for the establishment of gasoline stations within the city.

List of Fuel Station in Addis Ababa: Secondary data was sourced from these departments, specifically the list of registered gasoline stations in Addis Ababa. This data serves as a comprehensive inventory of the existing fuel stations within the city.

3.4 Source of data

GPS device: As primary data, the precise geographic coordinates (latitude and longitude) of Fuel stations in Addis Ababa were collected using a GPS device. The GPS data enabled the mapping and geographical analysis of the locations of gasoline stations throughout the city.

Observational: Primary data was collected by directly observing the movement of automobiles at various sites in Addis Ababa. It was important to visually study traffic patterns, vehicle movements, and levels of congestion in order to determine how fuel stations affect traffic flow.

Planning Offices: Secondary data was obtained from the planning offices like spatial plans and related documents that provide information on the designated areas and regulations for the establishment of gasoline stations within the city.

Addis Ababa City Environmental Protection Department of Oil and Oil Facility Competency Certification Team and Addis Ababa Trade bureau: Secondary data was sourced from these departments, specifically the list of registered gasoline stations in Addis Ababa. This data serves as a comprehensive inventory of the existing fuel stations within the city.

Table 3-1 Data Types and Source of Data

NO	Data Types		Source of Data
	Primary Data	Secondary Data	
2	Geographical coordinates	Maps (Road map and City Map)	GPS device
3	Observational Data	Spatial plans and related documents	Observational
4	Arrival of Vehicles and Service Rate		Planning Offices

3.5 Sampling design

Sample size is calculated for the purpose of objective number three which is "To examine the impacts of spatial distribution of fuel stations on traffic flow in Addis Ababa" so out of the 131 Fuel Stations found in Addis Ababa a sample is calculated.

According to (Kothari, 2004), sample size is the number of items chosen from the universe to constitute a sample, and (Amin, 2005) defines a target population as the population to which the researcher ultimately wants to generalize the results. The study had a target sample population size of 70 Fuel Station, estimated levels of precision and reliability, costs, and operational constraints were all taken into account. Both clustered and Stratified sampling techniques were used in the study. Cochran's formula was used in this study to calculate an appropriate sample size.

The sample size of Fuel Station (n) is calculated according to the formula: n = [z2 * p * (1 - p) / e2] / [1 + (z2 * p * (1 - p) / (e2 * N))]

$$n_0 = \frac{z^2 p(1-p)}{e^2}$$

Equation 3-1 Cochran's formula

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Equation 3-2 Cochran's formula correction factor

Where: z = 1.96 for a confidence level (α) of 95%, p = proportion (expressed as a decimal), N = population size, e = margin of error.

z = 1.96, p = 0.5, N = 131, e = 0.08

n = [1.962 * 0.5 * (1 - 0.5) / 0.082] / [1 + (1.962 * 0.5 * (1 - 0.5) / (0.082 * 131))]

n = 150.0625 / 2.1455 = 69.942

n ≈ 70

The number of sampled Fuel Stations for Traffic intensity calculations are (with finite population correction) is equal to **70**

After the sample size is determined the sample is clustered in to group based on the road type they are found and calculated by the percentage of their total share using stratified sampling method.

Table 3-2 Sample size calculation using cluster method `

Number	Road Type	percentage of Fuel Station found	Number of samples	Distance from traffic intersection	Percentage of Fuel Station found	Number of samples
1	PAS	57%	=0.57*70 **=40**	Within 150m traffic intersection	13.33%	=0.1333*40 **=5**
				Not within 150m traffic intersection	86.33%	=0.8633*40 **=35**
2	SAS	31%	=0.31*70 **=22**	Within 150m traffic intersection	22.5%	=0.225*22 **=5**
				Not within 150m traffic intersection	77.5%	=0.775*22 **=17**
3	CS	12%	=0.12*70 **=8**	Within 150m traffic intersection	18.75%	=0.1875*8 **=2**
				Not within 150m traffic intersection	81.25%	=0.8125*8 **=6**

(Source: Source: Organized by the author, (2023))

From the above table it can be seen that 40-Fuel Stations which are found in PAS (Principal Arterial Road) road type was selected. Out of the 40 Fuel Stations 5 Fuel Stations will be from those that have less than 150-meter distance from traffic intersection and 35 that have above 150 meters from traffic intersection.

22 Fuel Stations which are found in SAS (Sub Arterial Road) road type were selected. Out of the 22 Fuel Stations 5 Fuel Stations are from those that have less than 150-meter distance from traffic intersection and 17 that have above 150-meter from traffic intersection.

8 Fuel Stations which are found on CS (Collector Road) road type were selected. Out of the 8 Fuel Stations 2 Fuel Stations are from those that have less than 150-meter distance from traffic intersection and 6 that have above 150-meter from traffic intersection.

From the above clustered sample simple random selection method is used to identify the samples.

3.6 Methods Data Collection

Information was gathered from both primary and secondary sources. While primary data were gathered using GPS device and field survey, secondary data were obtained from already published publications, journals, and magazines and institution.

3.6.1 Reconnaissance Survey and Mapping

In essence, this required completing a preliminary survey to locate, map out, categorize, and record the local Fuel Stations. Geographic coordinates, the names of Fuel Stations, and quick satellite images with a resolution of 0.5 meters are among the types of information obtained. The creation of additional maps illustrating the research area's location as well as the spatial distribution of the gasoline stops are another step in this method. ArcGIS are primarily utilized for this (10.5 version). This has given the researcher knowledge of the region and the several fuel stations under investigation, as well as instruction on where to find the data, what kinds of data were required, and how to get ready for fieldwork.

3.6.2 Global Positioning System (GPS)

According to (Kothari, 2004), a global positioning system is a satellite navigation system used to pinpoint an object's location on the ground. Because of this, the researcher in this instance used a GPS to record the locations of the Fuel Stations in the study area. These coordinates were transferred to ArcGIS 10.5 to enable the creation of a map showing the spatial distribution of fuel stations.

3.6.3 Observation and Photography

It is feasible to gather information directly and instantly related to the topic under study through personal observation. To gather primary data, site visits and wandering around were conducted at particular fuel station sites. Interesting observations for purposes of comparison resulted from this. This were made easier by surveys and improved by taking images and documenting the pertinent data. As a result, the researcher were able to study the spatial distribution of fuel stations, and some of their effects on traffic flow, particularly during rush hour.

3.7 Methods of Data analysis

Data analysis is the process of looking over information that has been gathered during an experiment or survey and drawing conclusions from it. in 2002 (Orodho & Kombo, 2002). Information from the field survey and GIS were included in the quantitative data. Everything is crucial to organize and structure it in order to extract meaning and information from it. Excel is used to enter data. In order to describe the key variables connected to the study objectives, descriptive analysis was used. Following that, the data is displayed as tables, frequencies, and percentages.

3.7.1 ARC GIS 10.5 and Microsoft Excel

A preliminary investigation was carried out to discover and document surrounding fueling stations. This acquainted the researcher with the location and provided direction on how to source data, the types of data needed, and field work preparation. The AA City Administrative Boundary & Structural Plan First Term Amendment (Sep, 2022) of Addis Ababa city was obtained from the Addis Ababa city Government plan and Development Commission, from which the researcher obtained information such as road maps. The list of Fuel stations was obtained from the Fuel and Fuel Products Facilities Competency Certification team (an Addis Ababa Environmental Protection Authority department responsible for registering and regulating filling stations) and the Addis Ababa Trade Bureau. The name, type, and street location of the Fuel Station were identified. This served as a guide for verification and data collection using the Global Positioning System (GPS). The retail Fuel stations' coordinates were determined primarily using a handheld Global Positioning System (GPS) device and online research using Google Earth Pro and maps.

The data from the GIS device was first entered into Microsoft Excel applications to create a simple database. Columns were used as fields to store filling station information. The data were saved in the project folder (created on the C drive) and exported to the ArcGIS 10.5 ArcMap environment. The data was converted to a shape file, which was then used to perform all of the analysis. To map out the filling stations, various symbols were used. The number of Fuel Stations on each road was determined. Tables and charts created in Microsoft Excel were also used to present the data collected. These contribute to the first goal of the work, which is to identify, map, and classify the existing fuel stations.

Arc Map was used to compare the location of the filling stations with the standards buffer and proximity analysis. To identify stations that are found in 150-meter distance from the roundabout and traffic intersection, a buffer of 150 meters was created on the roundabout and traffic intersection. Query by location was performed using the selection menu in the ArcMap environment. Furthermore, the data was queried to return all locations that are within a 150m buffer. The selected stations were highlighted, the shape file (which contained the station) was right-clicked, and the software was told to create a layer from the selected features. The stations identified are found with in the distance of 150m from the roundabout and traffic intersection.

Another query operation was performed using the selection menu; the query is to return stations that are within 400 meters of another station. The chosen stations are those that are within 400 meters between each other. A shape file for these stations was also created, saved, and used to compute the proportion of stations within each other.

The spatial pattern of Fuel stations in the study area was identified using Nearest Neighbor Analysis (NNA). To determine the spatial distribution of Fuel stations, the Average Nearest Neighbor Analysis (ANNA) and Manhattan distance method were also used. In the nearest neighbor analysis, the point layer shape file was used as input.

3.7.2 M/M/S Queuing System

Queues or wait times are the most common occurrence in our daily lives. A queuing system is a key component of Operations Research. It is a scientific and systematic process for analyzing and solving complex problems, as well as making better judgments(Cooper, 1981). Queuing theory is used to solve traffic congestion problems in bank counters, ration shops, railway reservation counters, toll plazas, doctor's clinics, and automobile services, among other places. Its main purpose is to predict congestion situations in a specific urban transportation network and suggest improvements in traffic areas(Newell, 1965). In this work, Markova processes is introduced, which are important to the analysis of all basic queuing systems so that the third objective is analyzed. I.e., To examine the impacts of spatial distribution of fuel stations on traffic flow in Addis Ababa.

The concept of multi-channel queuing is relevant when there are several servers at the service facility to deliver the service. The servers are connected in parallel, and any of the servers can supply any unit in the waiting queue(Cohen, 2008; Kendalld, 1953).

In a system with several servers, where arrivals are generated by a Poisson process and service times follow an exponential distribution, the M/M/S model describes the queue length. According to this model, the service and arrival rate both depend on how long the queue is. First come, first served (FCFS) is the basis on which arrivals are managed, and clients are served in accordance with FCFS guidelines. Arrivals form a single line, while the service facility has numerous servers.

Due to the exponential process's Markovian characteristics, the Poisson and exponential distributions are related to one another and are both represented by the letter "M".

Due to the exponential process's Markovian characteristics, the Poisson and exponential distributions are related to one another and are both represented by the letter "M".

When there are multiple servers in the service facility to deliver the service, the multichannel queuing model is applicable. Each customer in the waiting line can be served by any one of the servers, and the service rate is the same for all of them due to the parallel arrangement of the servers.

To demonstrate the close relationship between the exponential and Poisson distributions, the inter arrival time in the pure birth model, where arrivals are only permitted, and the inter departure time in the pure death model, where departures are only permitted, are described using the exponential distribution.

The mean service rate is higher than the mean arrival rate (i.e., $\mu>\lambda$). When $\mu>\lambda$, no queue will be formed and the arriving customers will not have to wait. when $\mu=\lambda$, in this case, if the initial queue length was zero then new arrival will not have to wait, and in case the initial queue length was not zero, then every person arriving in the system will have to join the queue i.e., the length of the queue would remain constant. When $\mu<\lambda$, in this case, the length will increase indefinitely and this will not be a steady system. The average arrival rate is less than the combined average service rate of all servers i.e., $\lambda<S.\mu$ where s is the number of servers. The ratio λ/μ is known as the utilization factor.

Equation 3-3 The average number of customers in queue (i.e., queue length)

$$Lq = \frac{\left(\lambda.\mu\left(\lambda/\mu\right) \wedge s\right)}{(s-1)!\,(s.\mu-\lambda)^2} * P_o + \frac{\lambda}{\mu}$$

Equation 3-4 The average number of customers in the system

$$Ls = \frac{\left(\lambda.\mu\left({}^{\lambda}/_{\mu}\right) \wedge s\right)}{(s-1)!\,(s.\mu-\lambda)^2} * P_o$$

This is the number of customers in the queue plus the number of Customers being served.

Equation 3-5 Average waiting time in the queue system

$$Ws = \frac{Ls}{\lambda}$$

It is the time that a customer spends waiting in queue plus the time it takes for servicing the customer.

Equation 3-6 The average waiting time in the queue.

$$Wq = \frac{Lq}{\lambda}$$

Traffic intensity ρ= (mean arrival rate) λ / (mean service rate) S.μ. 'S' is the number of sever

Equation 3-7 Traffic intensity ρ

$$\rho = \frac{\lambda}{S * \mu}$$

All the above calculation is done using an excel template obtained from an online source (https://ericjjesse.wordpress.com/course-introduction/queues/).

Queue Template M/M/s

Input Data		
Arrival rate (l)	1	hour
Service rate (m)	2	hour
Number of servers (s)	3	for queue
Cost of Service	0	hour
Cost of Waiting	0	hour

**Arrival and service rate must use the same units of time as must cost of service and w aiting

Queue Performance/Operating Characteristics		
Average server utilization (r)	16.7%	busy
Average number of customers in the queue (L_q)	0.0030	in queue
Average number of customers in the system (L)	0.503	in system
Average waiting time in the queue (W_q)	0.0030	hour
Average time in the system (W)	0.073	hour
Probability (% of time) system is empty (P_0)	0.606	empty

Color Key
Model Input (change)
Model Output (read)
Decision Metric (act on)

Probabilities		
Number in System	**Prob**	**Cum. Prob**
0	0.6061	0.6061
1	0.3030	0.9091
2	0.0758	0.9848
3	0.0126	0.9975
4	0.0021	0.9996
5	0.0004	0.9999
6	0.0001	1.0000
7	0.0000	1.0000
8	0.0000	1.0000
9	0.0000	1.0000
10	0.0000	1.0000
11	0.0000	1.0000
12	0.0000	1.0000
13	0.0000	1.0000
14	0.0000	1.0000
15	0.0000	1.0000
16	0.0000	1.0000
17	0.0000	1.0000
18	0.0000	1.0000
19	0.0000	1.0000
20	0.0000	1.0000

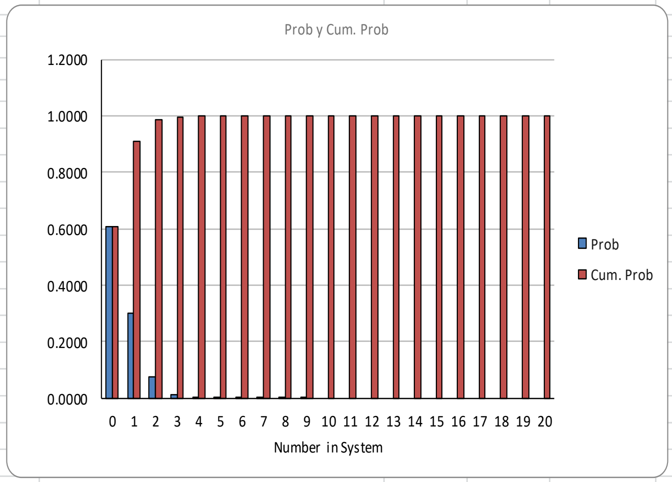


Figure 3-1 Excel Template used for computation of MMS queuing (https://ericjjesse.wordpress.com/course-introduction/queues/)

3.8 Methods of data presentation

The techniques utilized to present and illustrate the data gathered for the investigation on the spatial distribution and effects of Fuel Stations on traffic flow in Addis Ababa are described in this part. A comprehensive comprehension of the links and patterns discovered is made possible by an effective data presentation, which is essential for communicating the research's conclusions. The following techniques were used to present the data:

- **Maps and Geographic Information System (GIS):** Maps are effective representational tools for spatial data. To produce precise maps that show the geographic distribution of filling stations in Addis Ababa, GIS software was used. The locations and clustering patterns of Fuel Stations in relation to significant roadways, junctions, and other key characteristics are depicted visually on these maps. For a thorough study and interpretation of the results, GIS technology enables the overlaying of several layers of data.

- **Graphs and Charts:** Numerical data and trends are best presented via graphical representations. To show how various factors relate to one another, a variety of graphs and charts were used. For instance, bar charts were used to compare the number of Fuel Stations in various Addis Ababa neighborhoods or districts. To show temporal fluctuations in traffic flow metrics, such as traffic volume or congestion levels, line graphs were used. The correlation between the vicinity of Fuel Stations and traffic congestion was depicted using scatter plots. These graphical depictions make it easier to spot trends, patterns, and possible relationships in the data.
- **Tables and Statistical Summaries:** To provide exact numerical data and statistical summaries, tables were used. Pertinent data is categorized, such as the quantity of Fuel Stations in various administrative zones, the typical traffic volumes on particular road segments, or the typical wait times at Fuel Stations during peak hours. Tables make it simple for readers to compare results, spot outliers, and view statistical measurements that aid in comprehending the research findings.
- **Photographs and Visual Documentation:** To offer a visual backdrop and explain certain elements of the research region, images and visual documentation in addition to maps, graphs, and tables were also included. These illustrations aid readers in visualizing the physical surroundings, transportation systems, and gasoline station features, which improves understanding and interest in the research as a whole.

The data gathered in a thorough and understandable way by combining maps, graphs, charts, tables, and visual documentation were displayed. These techniques make it easier to comprehend the geographic distribution of Fuel Stations, how they relate to traffic flow, and how this affects Addis Ababa’s transportation dynamics.

3.9 Validation and Reliability

The following precautions are used to assure the legitimacy of the methods, materials, and outcome of the thesis result. The results gained through the simultaneous application of quantitative and qualitative methodologies boost the value of the conclusion.

Referring other researchers work done on spatial distribution of Fuel Stations and their impact on traffic flow and discussion with advisors and experts on issues that require expertise advice and also crosschecking information's and data's gathered from the concerned offices of the city through field survey, also different composed Addis Ababa city town road maps profiles, prepared and published materials on the subject matter. Almost all of office data collected are very reliable. So, this helps the researcher for the reliability and validity of information generated.

4 CHAPTER 4: RESULTS AND DISCUSSION

4.1 Existing Fuel Stations Characteristics

4.1.1 Spatial Distribution of Fuel Stations in the Study Area

This data reveals valuable insights into the spatial distribution and ownership structure of Fuel Stations in Addis Ababa. The city is home to a total of 131 Fuel Stations, with the highest concentration found in Akaky Kaliti Sub City (25), and followed by Kirkos Sub City (23) and Nifas Silk-Lafto Sub City (17).

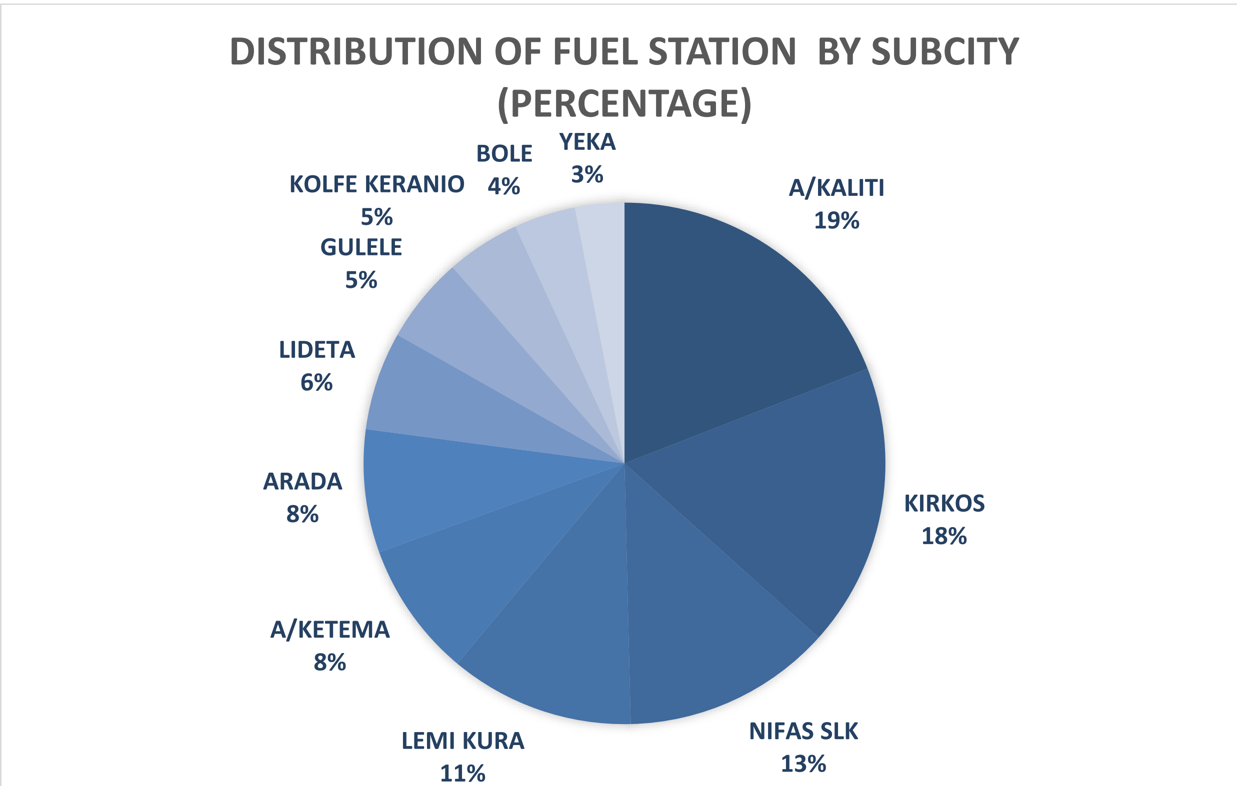


Figure 4-1 Distribution of Fuel Station by Sub city (Source: Organized by the author, (2023))

Table 4-1 Distribution of Fuel Station to sub city

SUBCITY	Number of Fuel Stations
A/KALITI	25
KIRKOS	23
NIFAS SLK	17
LEMI KURA	15
A/KETEMA	11
ARADA	10
LIDETA	8
GULELE	7
KOLFE KERANIO	6
BOLE	5
YEKA	4
Grand Total	131

(Source: Organized by the author, (2023))

Among the Fuel Station owners, Total Energies has the largest presence with 37 stations, followed closely by Ola Energy with 31 stations. The National Oil Company (NOC) operates 23 Fuel Stations, while Yetebaberut Beherawi Petroleum (YBP) operates 9 stations. Other Fuel Station owners include TAF Oil (6), KOBIL (5), Nile (3) and Habesha, Petrol Ethiopia, Sky petroleum, and Delta with 2 stations each. Additionally, Africa Oil, Alpha Petroleum, Baro, Dalol, Gomeju, JR PETROL, Tera, Yegha, Zemen, and Zobel each operate 1 Fuel Station in Addis Ababa.

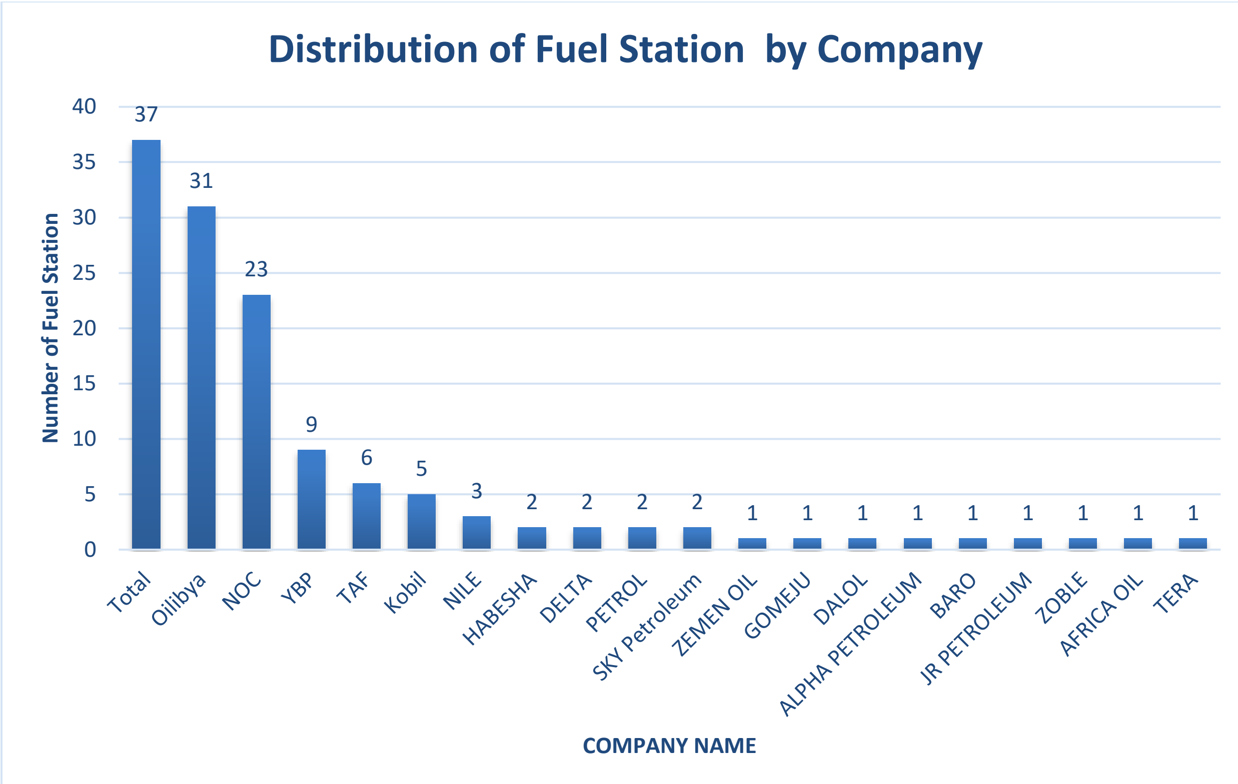


Figure 4-2Distribution of Fuel Station by company (Source: Organized by the author, (2023))

This detailed information on Fuel Station distribution and ownership across the city provides a foundation for further analysis of their spatial impact on traffic flow and the development of targeted strategies to address any potential traffic-related challenges. By understanding the geographic concentration of Fuel Stations and the diverse ownership landscape, stakeholders can implement effective measures to optimize traffic management and ensure smooth transportation within Addis Ababa.

4.1.2 Inventory of Filling Stations by Road type

The placement of Fuel Stations creates a striking pattern of accessibility and convenience for both locals and visitors within the busy city landscape of Addis Ababa City. 75 of the city's 131 Fuel Stations are situated along the Principal Arterial Streets (PAS) road type. These are the main thoroughfares of the city, with wide road widths of at least 40 meters. The availability of Fuel Stations throughout PAS not only meets the high demand for refueling services but also emphasizes the crucial role that these wide boulevards play in promoting efficient transportation around the city.

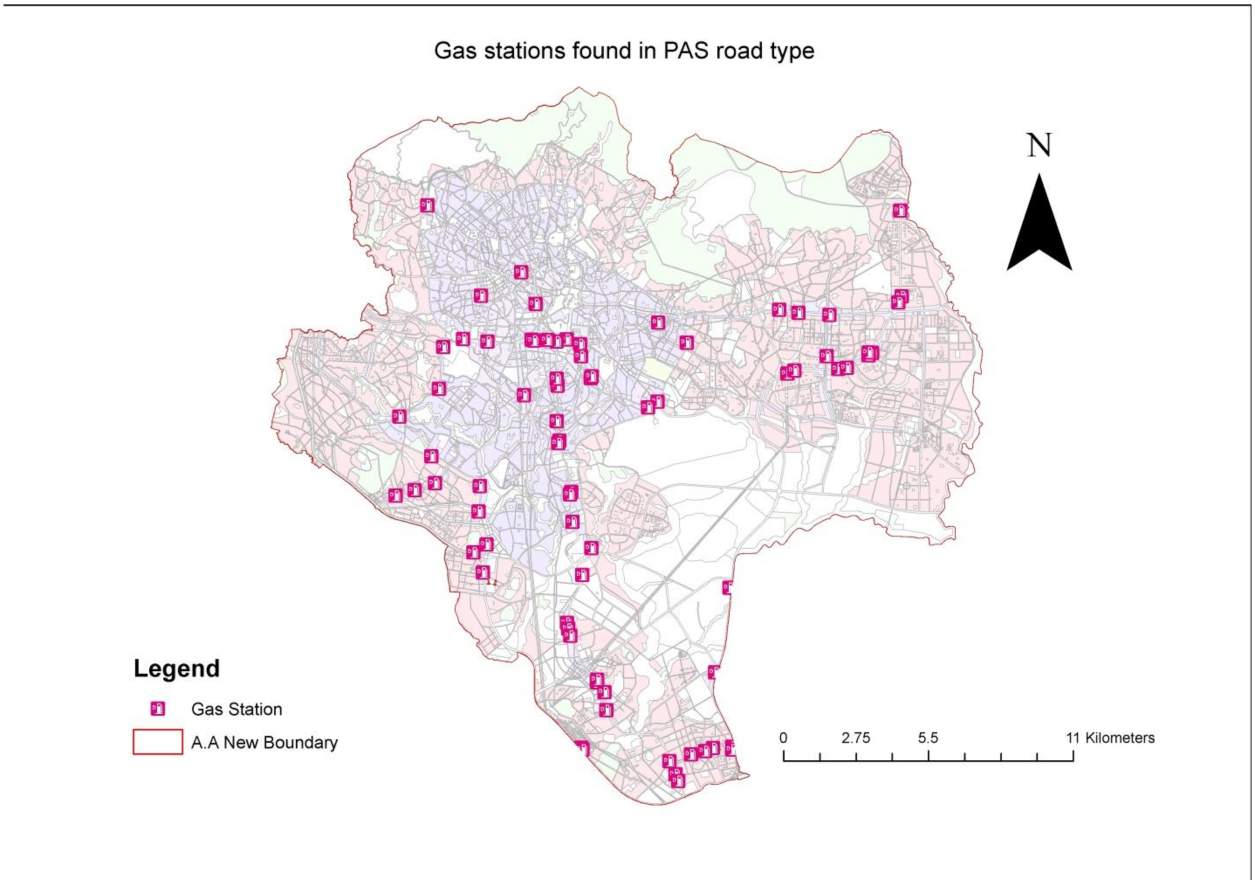


Figure 4-3 Fuel Stations found in PAS road Type (Source: Organized by the author, (2023))

The research come upon another aspect of the placement of Fuel Stations as gone farther into the city's road system. The Sub Arterial Streets (SAS) in Addis Abeba are now home to a total of 40 Fuel stations. These roads, which range in width from 25 meters to just under 40 meters, serve as crucial thoroughfares for both intra-city and inter-city transit. Fuel Stations are strategically positioned along SAS as a tribute to their essential role in meeting the diversified mobility demands of a global population and enhancing the accessibility of refueling services inside the city's network of thoroughfares.

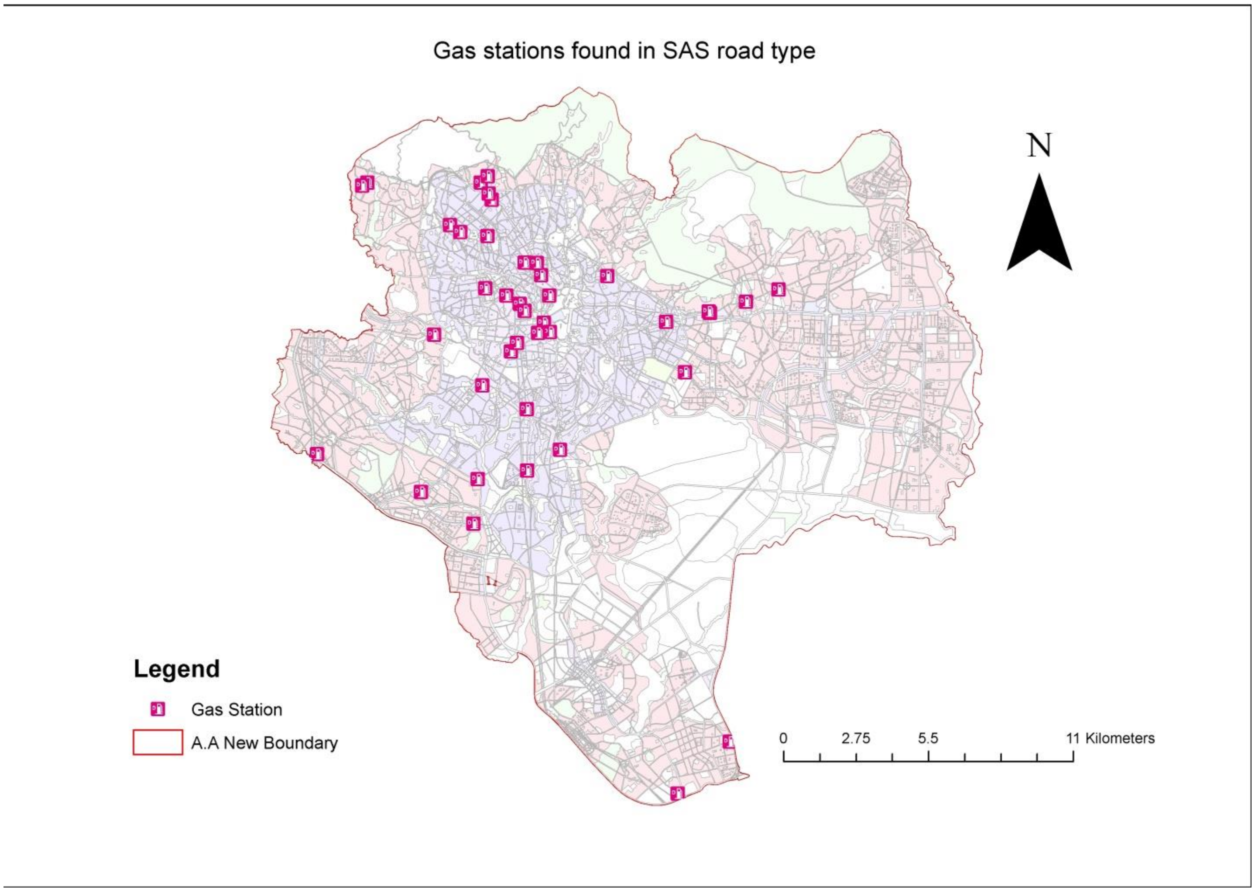


Figure 4-4 Fuel Stations found in SAS road Type (Source: Organized by the author, (2023))

Furthermore, an interesting discovery is made by our thorough analysis: the city's Collector Roads (CS), where road widths narrow to less than 25 meters, are home to 16 Fuel stations almost all of the Fuel Stations found on the CS road type are found in the inner city. These roads play a crucial part in the dynamics of local traffic and are frequently differentiated by their closeness to residential areas and business centers. Fuel Stations are essential to supplying localized communities and ensuring that fuel resources are always within easy reach of neighborhoods, which adds to the ease and functioning of these places. Their presence along these smaller collector routes denotes this.

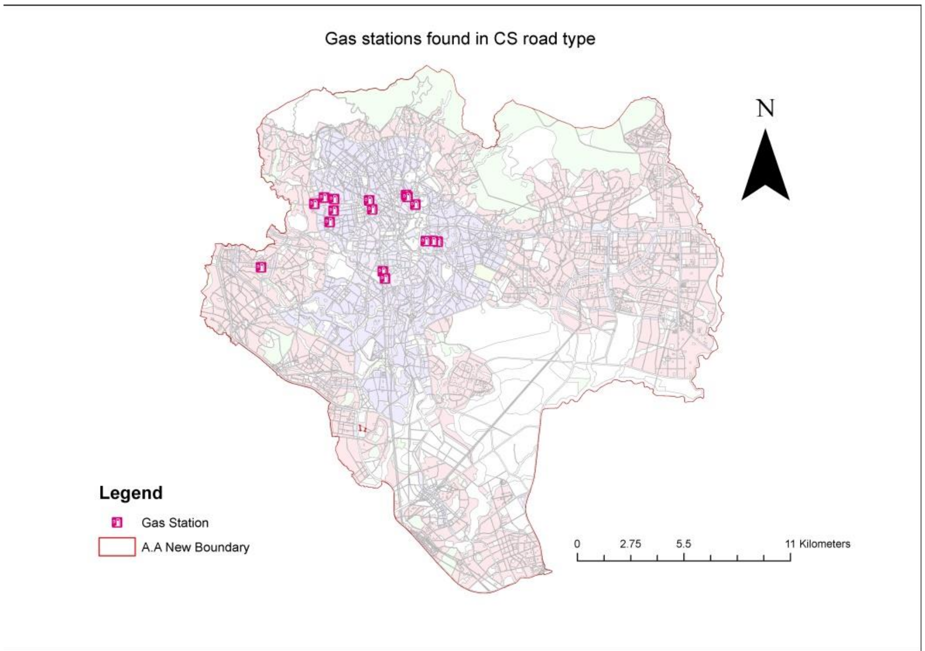


Figure 4-5 Fuel Stations found in CS road Type (Source: Organized by the author, (2023))

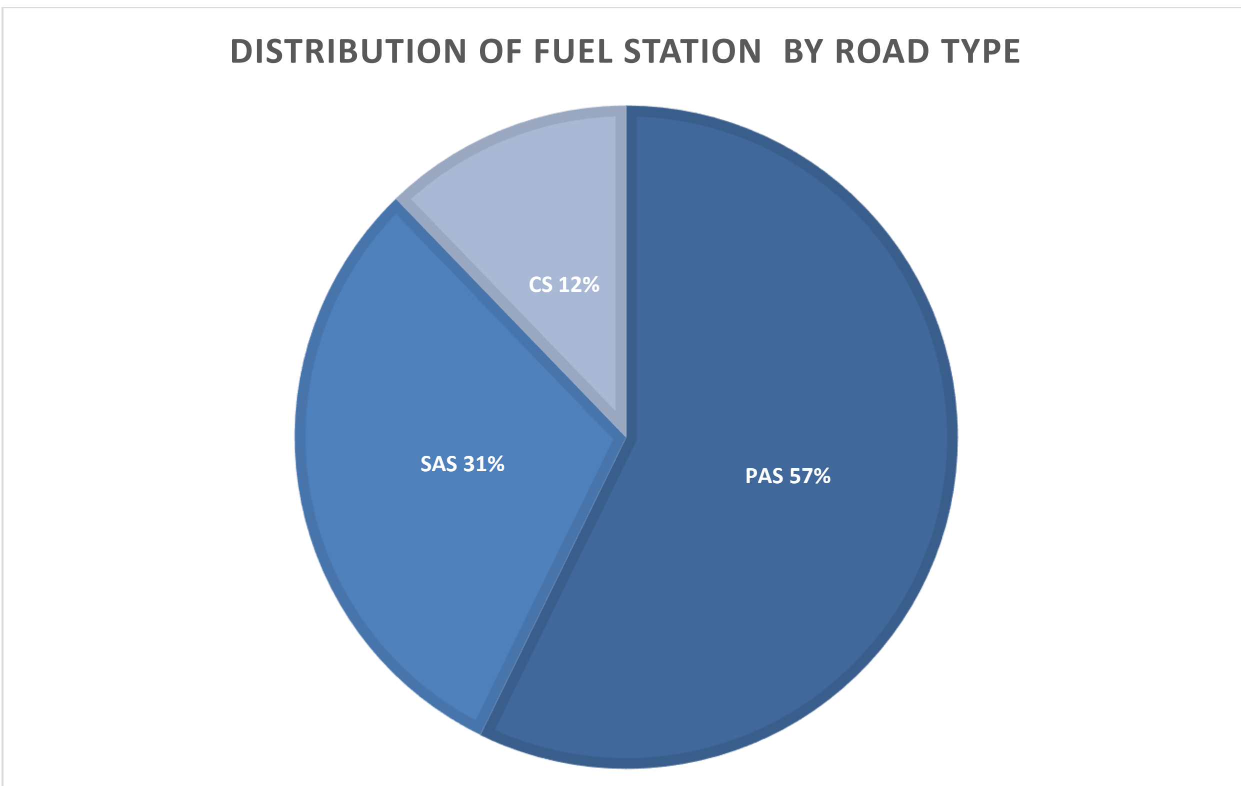


Figure 4-6 Distribution of Fuel Stations on road type (Source: Organized by the author, (2023))

4.1.3 Distance between the Location of Filling Stations

Using the proximity function of the analysis tool, distances between stations in the area were calculated in the ArcMap environment. The research found that the largest distance between nearby Fuel Stations was approximately 3,250 meters. This was discovered between Yegha Petroleum (found in Akaki Kality sub city, woreda 13, Around Koye Feche Square) and Africa Oil (found in Akaki Kality, woreda 10, around Hachalu Hundessa Square). The average distance between nearby fueling stations, was approximately 565 meters. The closest separation, less than 83 meters, was seen where two nearby stations were located side by side in Akaki Kality sub city woreda 4 locally known as Gelan Condominium between TAF OIL and JR Petroleum. Additionally, the outcome reveals that half of the Fuel Stations were located within 400 meters apart from their neighbor's. However, only 11.2% of the stations were found within 100-meter separation from their neighbors'.

Figure 4-7 closest Fuel Stations (Source: Google Earth (2023))

Figure 4-8 second nearest Fuel Station (Source: Google Earth (2023))

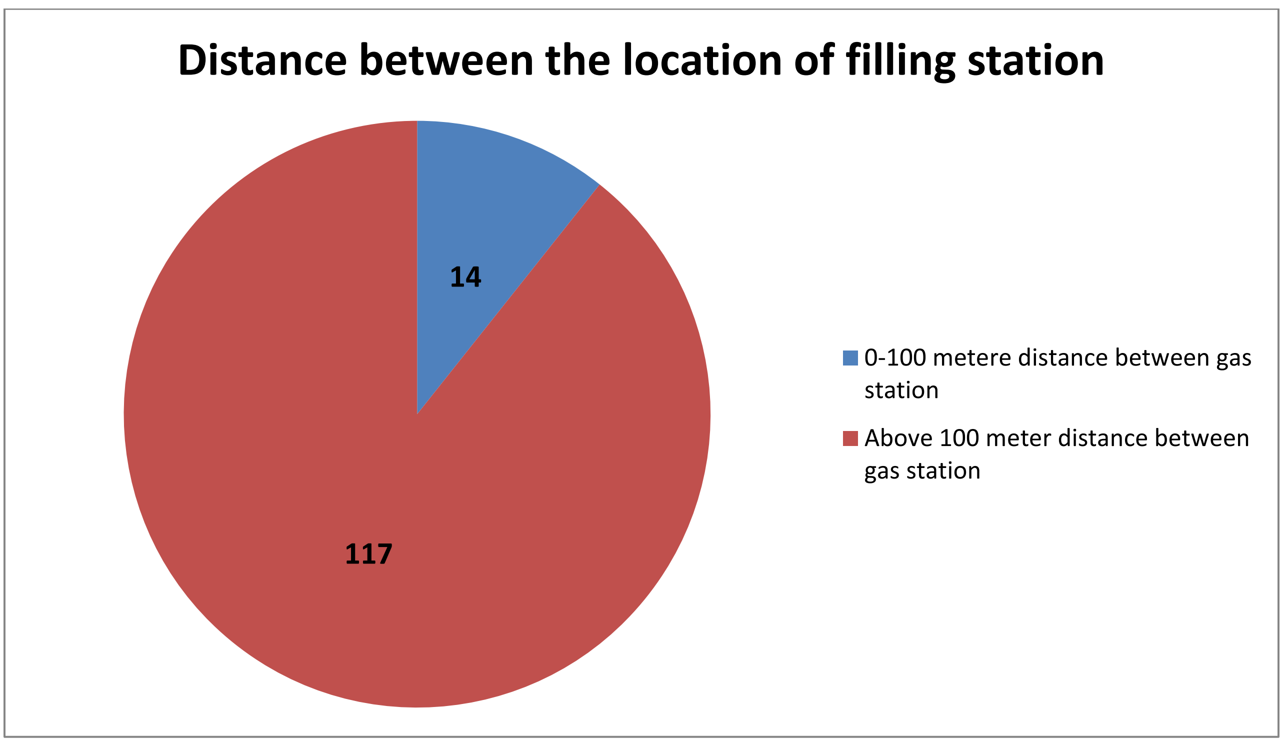


Figure 4-9 Distance of Fuel Station between each other (Source: Organized by the author, (2023))

4.1.4 Distance of the Fuel Stations from the traffic intersection

According to (Neufert & Neufert, 2012) Fuel Station should not be located in in the queuing area in front of traffic lights. Fuel Stations shouldn't often be placed near traffic signals since it is generally not a good idea for urban planning and traffic management. The region of the road just before a traffic signal known as the queue area is where cars halt when the light turns red. This region is crucial for making sure that traffic moves through junctions safely and effectively.

After selecting the location of every road intersection (including roundabouts, traffic lights, and crossroads), a buffer of 150 meters was created in arc GIS 10.5 from the selected road intersection. The Fuel Stations located within 150 meters of the selected road intersection were then identified using the geoprocessing tool intersects between all the Fuel Stations and the selected road intersection.

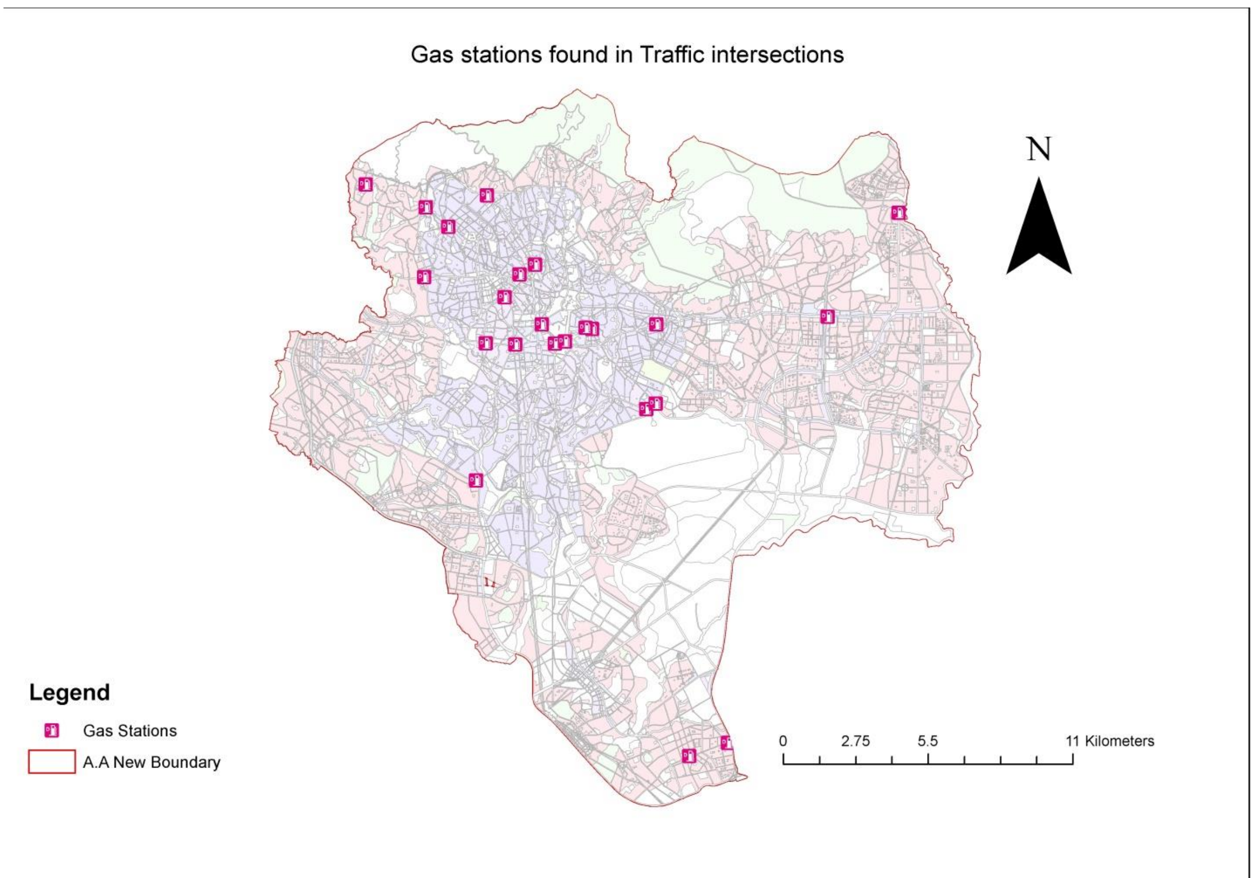


Figure 4-10 Fuel Station Found in traffic intersection (Source: Organized by the author, using Arc GIS 10.5 Analysis, (2023))

ArcGIS 10.5 analysis findings provide a few interesting facts about the Fuel stations in Addis Abeba. 22 of the 131 Fuel stations examined are within 150 meters or less of significant traffic centers, such as intersections of roads. The importance of these locations for city traffic flow makes it significant that Fuel stations are close by.

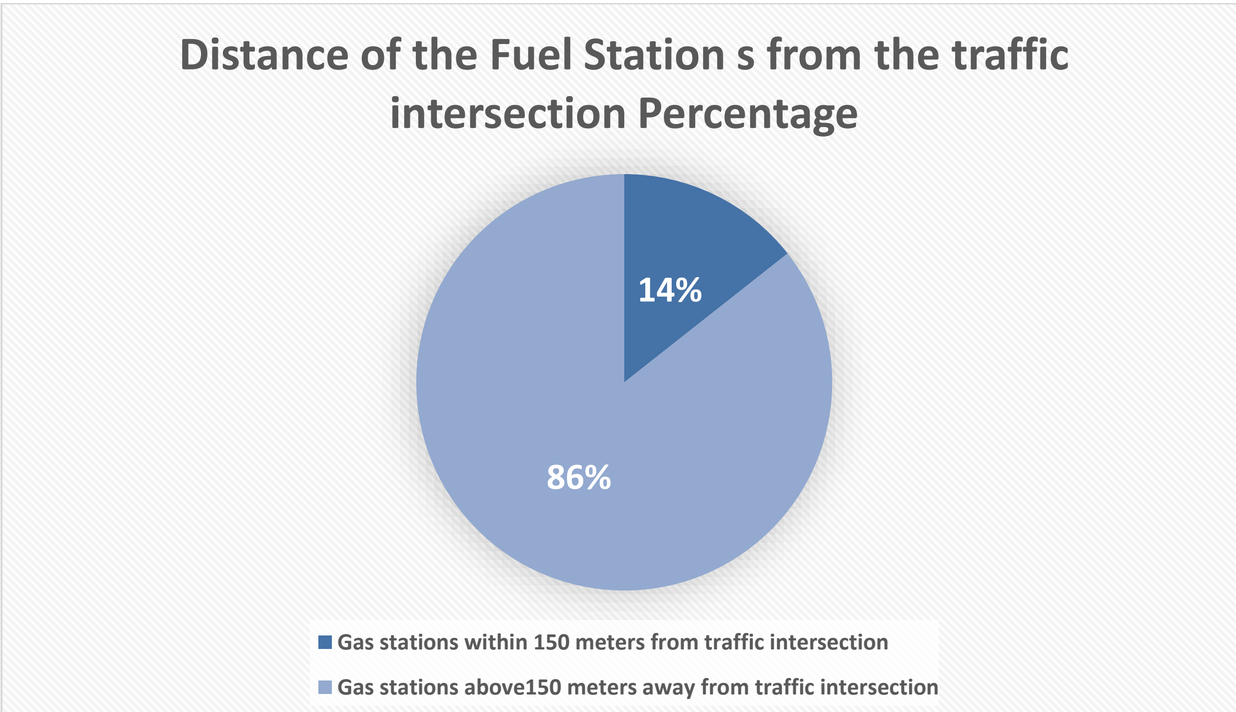


Figure 4-11 percentage of Fuel Stations found on traffic intersection (Source: Organized by the author, (2023))

The above 22 Fuel Stations near road intersections may be split into three groups when taken a closer look at them. There are five of them at junctions with no traffic signals and five of them at intersections with traffic lights. Furthermore, 12 are near to roundabouts. This breakdown provides a clearer idea of the location of these Fuel Stations in relation to major traffic intersections.

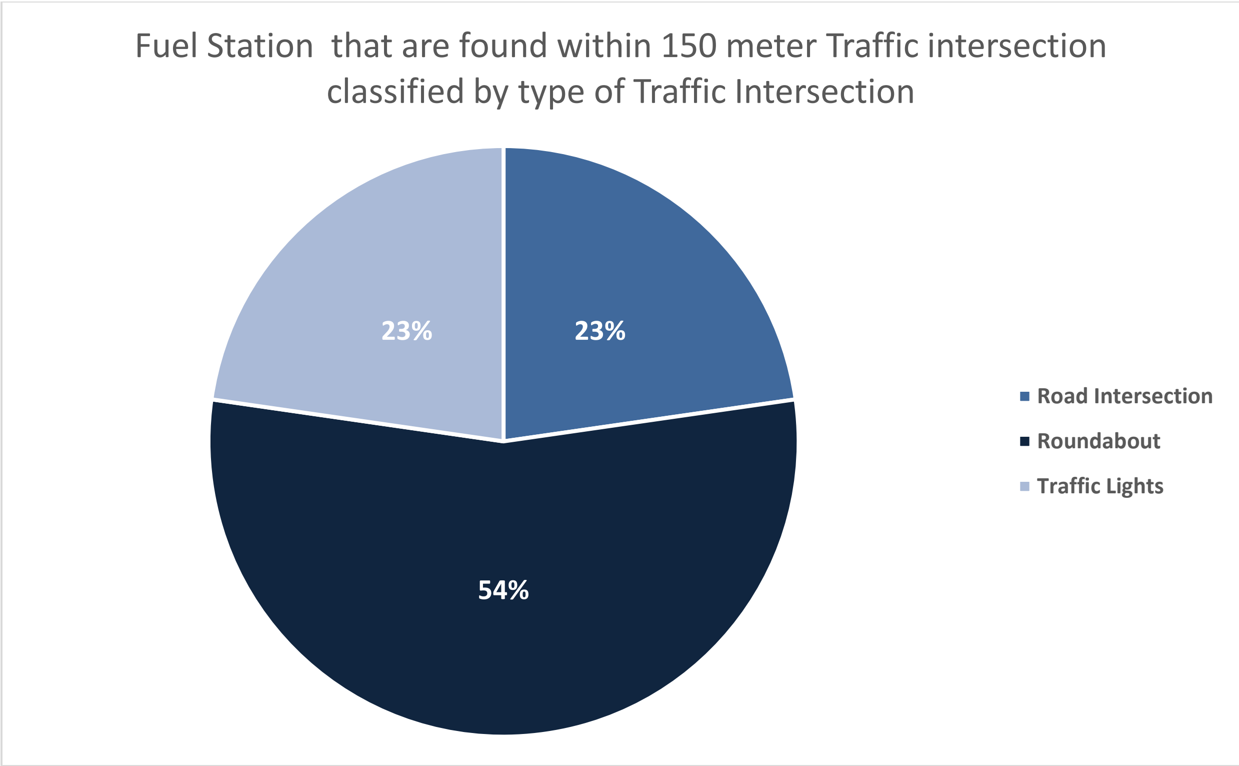


Figure 4-12 Fuel Station that are found within 150-meter Traffic intersection classified by type of Traffic Intersection (Source: Organized by the author, (2023))

Figure 4-13 example of Fuel Station found on roundabout (Source: Google Earth (2023))

Figure 4-14 example of Fuel Station found on traffic lights (Source: Google Earth (2023))

Figure 4-15 example of Fuel Station found on road intersection (Source: Google Earth (2023))

4.2 Analysis of Spatial Distribution of Fuel Station Using Nearest Neighbor Analysis

The spatial layout of Fuel stations in the study area was identified using Nearest Neighbor Analysis (NNA). To determine the spatial distribution of Fuel stations, the Average Nearest Neighbor Analysis (ANNA) and Manhattan distance approach were also used. The coordinates of Fuel stations were entered into an excel spreadsheet. The excel sheet was imported into a GIS system and converted to a point layer. The nearest neighbor analysis uses this point layer shape file as input. The square kilometer area occupied by all of the Fuel stations was also used as an input in the criteria required for running the nearest neighbor analysis (NNA) for the spatial pattern of Fuel stations in the city.

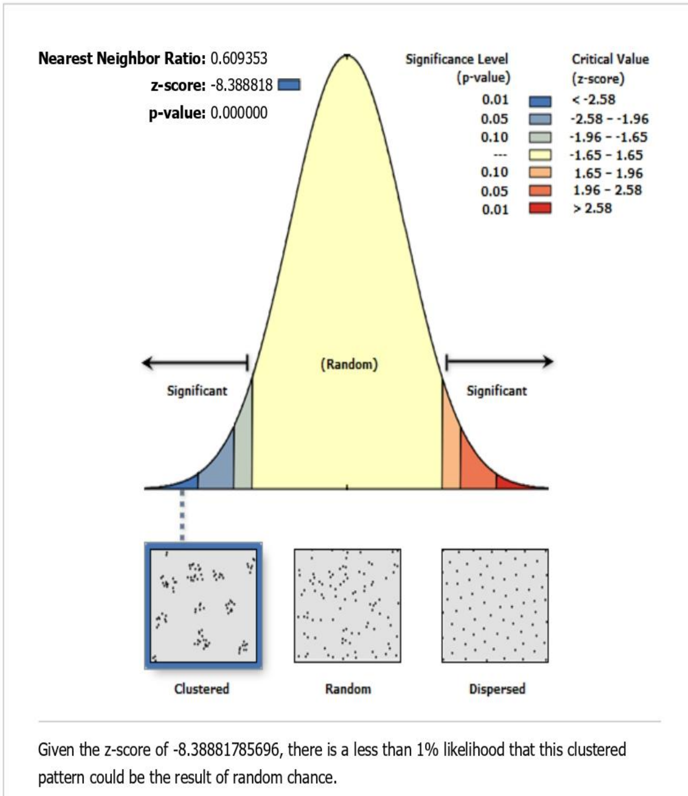
This investigation uncovered significant spatial distributions. Addis Ababa's spatial layout revealed a nearest neighbor ratio of 0.609353. This indicates that the distribution is clustered.

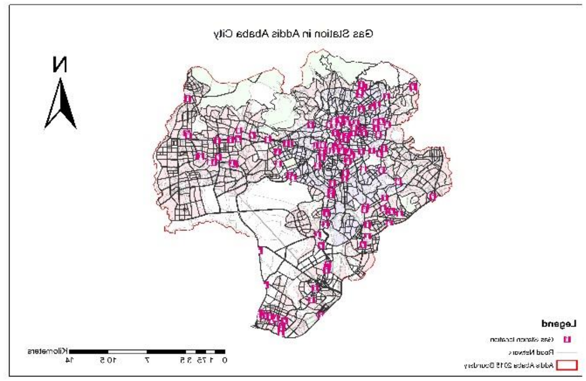
A number of factors influenced the location and distribution pattern of Fuel stations in a given area. High power tension, commercial/industries, motor garage, public facility, residential area, highway, and services, all of which are rotated around the metropolitan region, are considered the cardinal guides in seating Fuel station in geographic space.

According to (Getis & Getis, 1966), he stated that Fuel stations (points) must be positioned logically based on the size, 50-meter distance (near residential areas, public facilities, commercial/industries), and people to be supplied. However, this is not the case in the research area.

This ratio shows a tendency for Fuel Stations to cluster together in close proximity, which may have an effect on accessibility, traffic flow, and other urban dynamics. The spatial clustering of Fuel Stations raises significant planning and management issues for urban areas. It is essential to comprehend the causes of this clustering and how it affects safety, pollution, and traffic congestion in order to develop efficient distribution strategies for these vital services in urban areas. In order to achieve both the more general objectives of sustainable urban development and the convenience of fuel accessibility, careful planning and policy measures are required.

Average Nearest Neighbor Summary





Average Nearest Neighbor Summary

Observed Mean Distance:	569.5152 Meters
Expected Mean Distance:	934.6229 Meters
Nearest Neighbor Ratio:	0.609353
z-score:	-8.388818
p-value:	0.000000

Dataset Information

Input Feature Class:	Gas_Station_location
Distance Method:	EUCLIDEAN
Study Area:	440254055.290209
Selection Set:	False

Figure 4-16 Average nearest Summary of Fuel Stations in Addis Ababa (Source: Organized by the author, using Arc GIS 10.5 Analysis, (2023)

4.3 Analysis of impact of fuel station on traffic flow Using Queuing System

This study assumes the First Come, First Served (FCFS) system, in which cars are queued and served according to their turn. "An examination of data collected at 70 Fuel Stations, sampled during both the morning and evening peak hours, over a one-hour period, revealed certain findings. The study calculates critical characteristics such as traffic intensity for systems with many servers, mean queue length, total number of customers in the system, and average wait times for consumers in both queues and the overall system.

Appendix 1 specifically presents these findings for clarity and reference. It is worth noting that the results indicate the presence of traffic congestion during peak hours, throwing light on the issues encountered during these periods of increased demand and vehicle activity.

Out of the 70 Fuel Stations sampled for traffic intensity, only 26 showed traffic intensity less than 1. Out of these, 23 are found on PAS road types, and 3 are found on SAS road types. The other 44 Fuel Stations have a traffic intensity greater than 1. Out of these 8 Fuel Stations found on CS road type (almost all sampled Fuel Stations from CS road type category), 19 are found on SAS road type, and 17 of them are found on PAS road type.

In conclusion, the majority of Fuel Stations surveyed have a traffic intensity greater than 1, with only a small percentage showing a lower intensity. Interestingly, the SAS road type appears to have the highest number of Fuel Stations with low traffic intensity, while the PAS road type has the highest number of Fuel Stations overall. Additionally, the CS road type seems to have a lower proportion of Fuel Stations with high traffic intensity compared to the other road types. These findings suggest that road type may play a role in determining the traffic intensity at Fuel Stations.

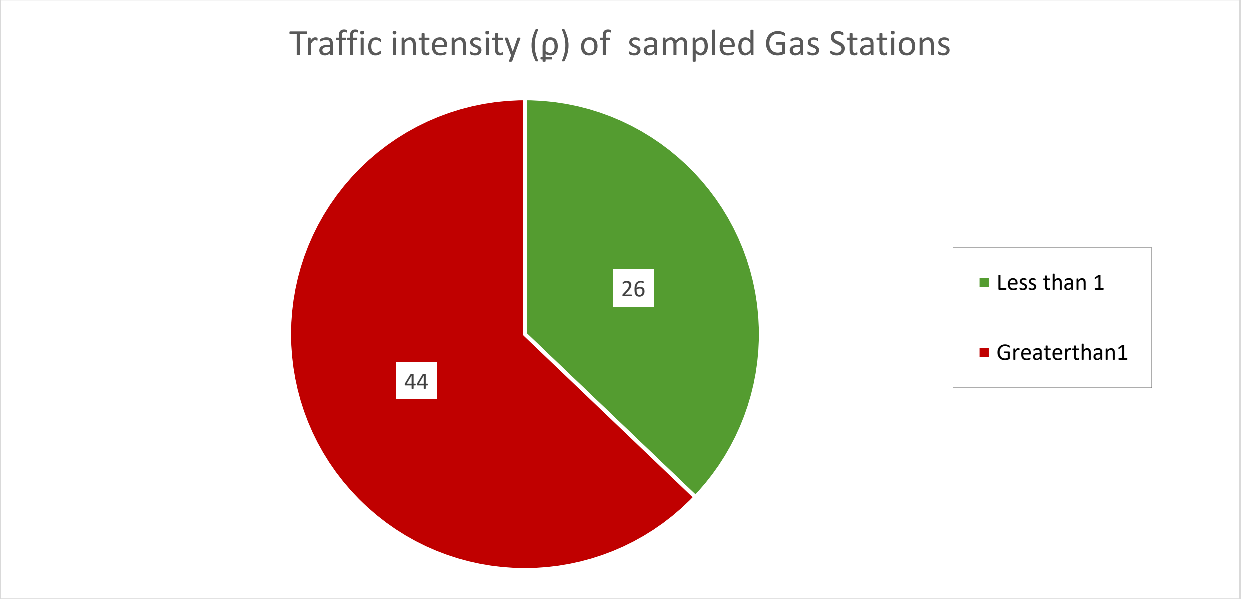


Figure 4-17 Traffic Intensity of Sampled Fuel Stations (Source: Organized by the author)

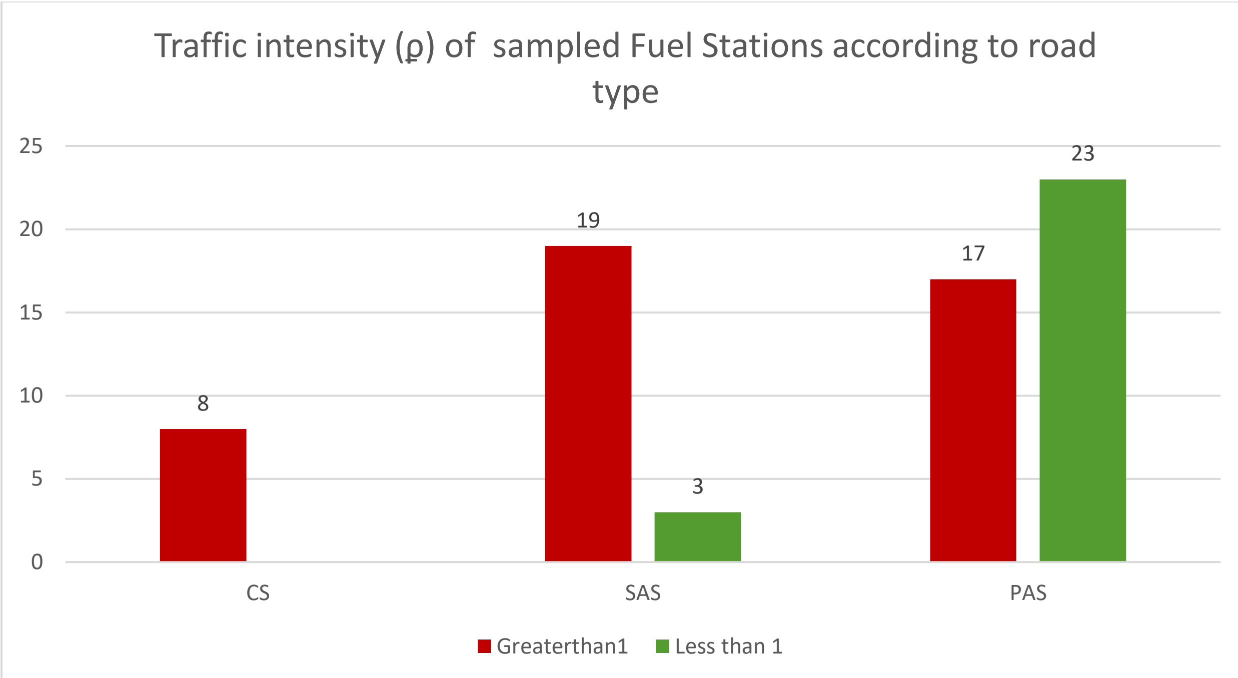


Figure 4-18 Traffic intensity results from sampled Fuel Station respect to road type (Source: Organized by the author, (2023))

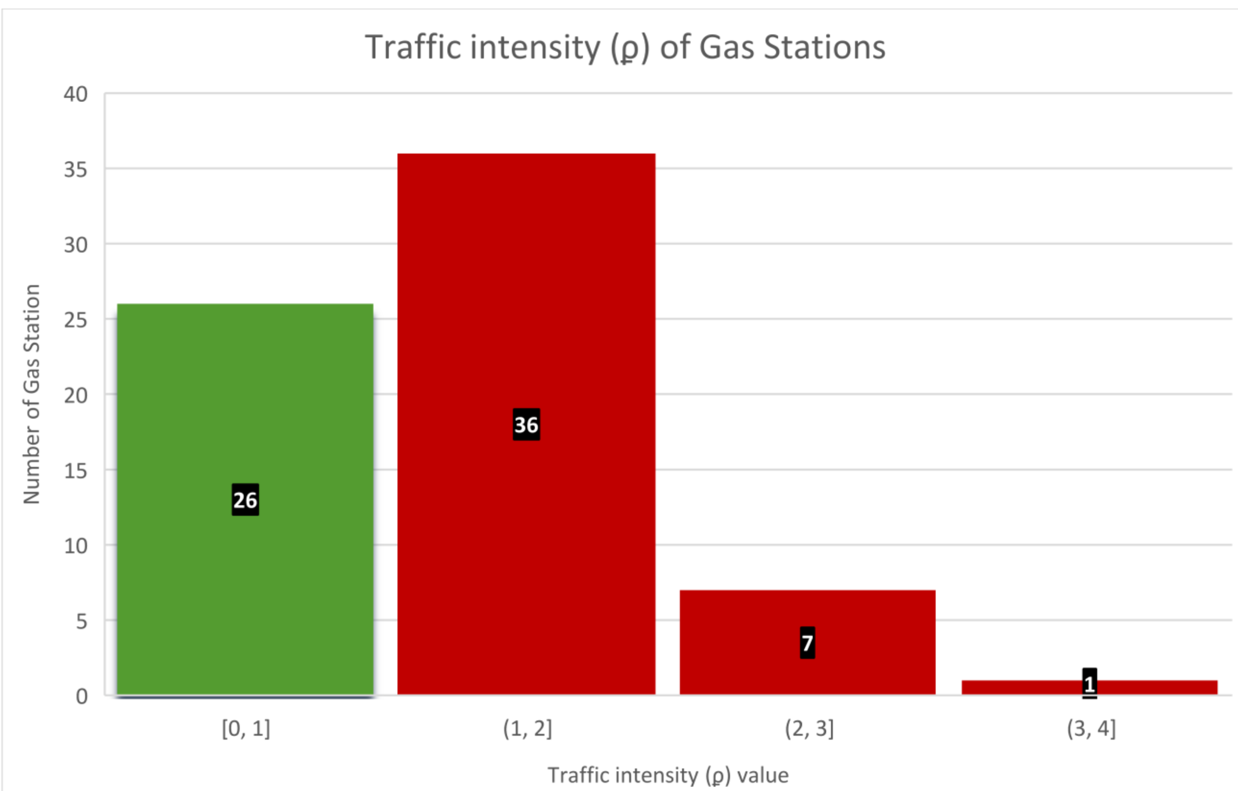


Figure 4-19 Traffic intensity of Fuel Station (Source: Organized by the author, (2023))

As seen in the figures below when queues of vehicles form, especially in the context of Fuel Stations or any other points of interest along a road, these queues typically occupy one lane of the road. This means that a portion of the road's width, typically equivalent to the width of one lane, becomes dedicated to the vehicles waiting in the queue.

Figure 4-20 Google image showing cars in queue at a Fuel Station (Source: Google Earth (2023))

Figure 4-21 sampled Fuel Station (Source: Photo taken by author on site, (2023))

This situation has several implications for traffic and road dynamics. One is reduced Road Capacity, by allocating a lane to the queue, the effective width available for moving traffic is reduced. This reduction in road capacity means that fewer vehicles can pass through the affected section of the road within a given time frame. It effectively narrows the road, limiting the flow of vehicles.

Congestion**,** the reduction in road capacity due to queues often leads to traffic congestion. As vehicles accumulate in the remaining lanes, they may slow down or even come to a standstill. This congestion can extend beyond the immediate vicinity of the queue, affecting the overall traffic flow in the area. This will result in traffic Delays: Vehicles in the queue experience delays as they wait for their turn, which can further contribute to congestion and disrupt the smooth flow of traffic. Delays can be particularly significant during peak hours when traffic volumes are already high.

Other concern is Safety Queuing on the road can pose safety risks. Vehicles waiting in the queue may partially obstruct adjacent lanes, increasing the likelihood of accidents or collisions, especially if drivers attempt lane changes to bypass the queue. Congestion caused by queues can lead to increased idling of vehicles, which in turn contributes to higher levels of air pollution and greenhouse gas emissions.

Queues from Fuel Stations or other points of interest can extend to nearby intersections, affecting the operation of traffic signals and potentially causing gridlock and will have Impact on Nearby Intersections. In summary, when queues form and occupy a lane of the road, it not only reduces the road's capacity but also has a cascading effect on traffic flow, safety, and environmental factors.

4.3.1 Traffic intensity on CS road type

It is clear from the sample of 8 Fuel Stations that are part of the CS road type that demand exceeds their operational capacity in all 8 of them. This traffic intensity or utilization factor is greater than 1, none of these stations have traffic intensity below 1, indicating that they are always operating in high demand.

Figure 4-22 sampled Fuel Station on CS road type (Source: Google Earth (2023))

Figure 4-23 photo showing queues formed (Source: Photo taken by author on site, (2023))

Table 4-2 Traffic data of Fuel Filling Station found on CS road type

No	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	ELIYAS ALI	Total	KIRKOS	/6/	AU/BULGARYA TOTAL	Above 150 meters	3	55	8	2.291
2	SADYA HUSSIEN	Kobil	ARADA	/2/	70 DEREJA	Above 150 meters	1	15	8	1.875
3	ZERTIHUN MARKOS	Oilibya	A/KETEMA	/4/	EHIL BERENDA	Above 150 meters	4	34	7	1.214
4	DAWIT MOKENEN	Oilibya	KIRKOS	/8/	KASANCHIS SUPER	Above 150 meters	4	36	7	1.285
5	HAYMANOT SHENKUTE	Oilibya	ARADA	/6/	RAS MEKONEN	Above 150 meters	6	90	7	2.142
6	ABATE BEKELE	Total	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	15	7	1.071
7	TEFERI MENGSTE	Oilibya	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	19	7	1.357
9	BIZUWORK DEBEBE	Total	ARADA	/9/	B/S MATEMIYA	Above 150 meters	3	45	8	2.812

(Source: Organized by the author, (2023))

4.3.2 Traffic intensity on SAS road type

Of the 22 Fuel Stations in the SAS road type sample, 19 have traffic intensity or utilization factor greater than one, indicating that demand exceeds capacity." In contrast, three of these stations have traffic intensities less than one, indicating that demand exceeds capacity.

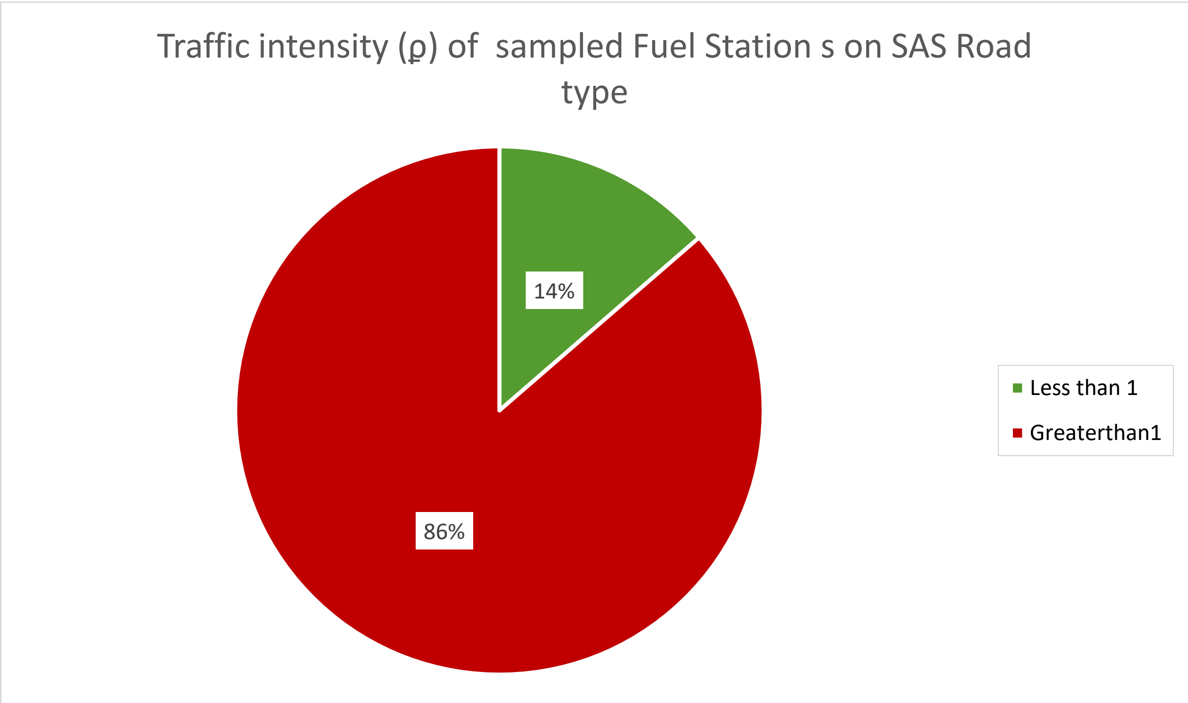


Figure 4-24 Traffic intensity (ρ) of sampled Fuel Stations on SAS Road type (Source: Organized by the author, (2023))

Table 4-3 Traffic data of Fuel Filling Station found on SAS road type

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	QUEENS SUPERMARKET PLC	NOC	GULELE	/9/	PASTOR	Above 150 meters	8	70	8	1.093
2	MR x	NOC	NIFAS SLK	/06/	Gofa NOC	Above 150 meters	5	52	7	1.485
3	BAHIRU NEGASH	NILE	NIFAS SLK	/1/	JEMO 1	Above 150 meters	6	63	9	1.166
4	MEKBIB WERKU	Oilibya	KIRKOS	/7/	RAS HOTEL	Above 150 meters	1	25	8	3.125
5	TIGIST BIRUK	Total	A/KETEMA	/8/	MERKATO	Above 150 meters	4	82	7	1.107
6	HAYAT BIRHANU	Total	YEKA	/9/	LAMBERET	Above 150 meters	6	63	8	1.312
7	TAMIRAT BELAY	Oilibya	A/KETEMA	/5/	PASTOR	Above 150 meters	4	58	9	1.611
8	ZELALEM AYSHESHIM	Oilibya	KIRKOS	/7/	Gihon hotel	Above 150 meters	4	40	7	1.111
9	MELESE TADESSE	Oilibya	YEKA	/9/	LAMBERET	Above 150 meters	2	38	8	2.375
10	HIWOT BIRHANU	NOC	BOLE	/7/	GERJI ST. MARY	Above 150 meters	3	34	9	1.259
11	FISEHA KEBEDE	Total	ARADA	/1/	KULSEN TOTAL	Above 150 meters	2	30		2.142
12	KENEA DABA	Oilibya	LIDETA	/10/	AFRICAN UNION	Above 150 meters	8	60	7	1.071
13	FASIL BAYE YILMA	Total	BOLE	/4/	MEGENAGNA	Above 150 meters	6	60	9	1.111
14	W/GIYORGIS ATRESO	Oilibya	LIDETA	/7/	TIKUR ANBESA	Above 150 meters	2	30	8	1.875
15	KASSAYE TEGEGN AND LIJOCHU	NOC	LEMI KURA	/13/	WESEN	Above 150 meters	6	62	8	1.291
16	YIGEREM WOLDE	YBP	YEKA	/9/	ETHIO CHINA	Above 150 meters	7	51	7	1.040
17	ABIY SHIFERAW EJIGU	Oilibya	LIDETA	/3/	TEKLEHAYMANOT	Below 150 meters	7	65	8	1.160
18	ALEM TADESSE	NOC	A/KALITI	/13/	TULU DIMTU	Below 150 meters	10	60	8	0.75
19	NESRO GIRAG OBSE	TOTAL	NIFAS SLK	/3/	GERMAN SQUARE	Below 150 meters	15	52	7	0.495
20	AZENEW MUHAMMED	Kobil	GULELE	/7/	ADDISU GEBEYA	Below 150 meters	5	39	8	0.975
21	WUDENESH BEFEKADU SEMU	Total	ARADA	/5/	PIYASA	Below 150 meters	4	54	7	1.928
22	ALEMAYEHU TESFAYE	Oilibya	ARADA	/7/	KEBENA	Above 150 meters	3	62	8	2.583

(Source: Organized by the author, (2023))

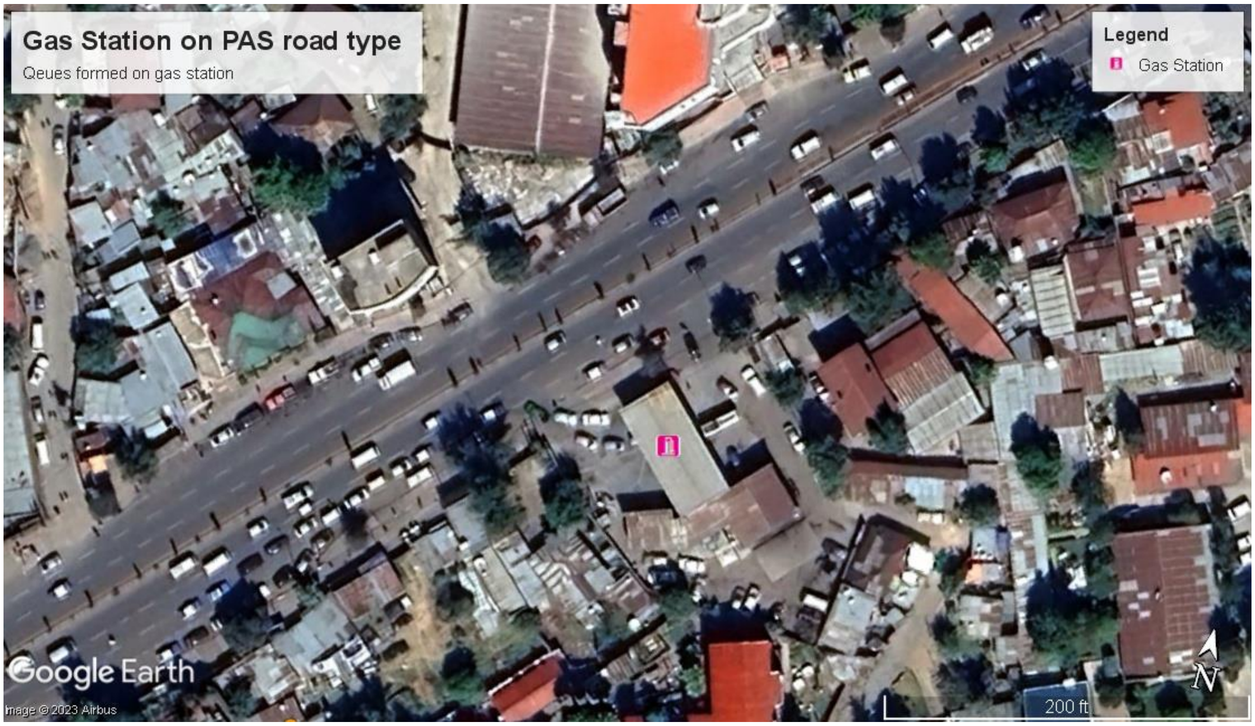


Figure 4-25 sampled Fuel Station on PAS road type (Source: Google Earth (2023))

Figure 4-26 photo showing queues formed (Source: Photo taken by author on site, (2023))

4.3.3 Traffic intensity on PAS road type

Among the 40 Fuel Stations sampled from the PAS road type, 19 have traffic intensity or utilization factor more than one, indicating that demand exceeds capacity. In contrast, a large majority of 21 of these 40 stations have traffic intensity less than one, indicating that they are running at or below capacity.

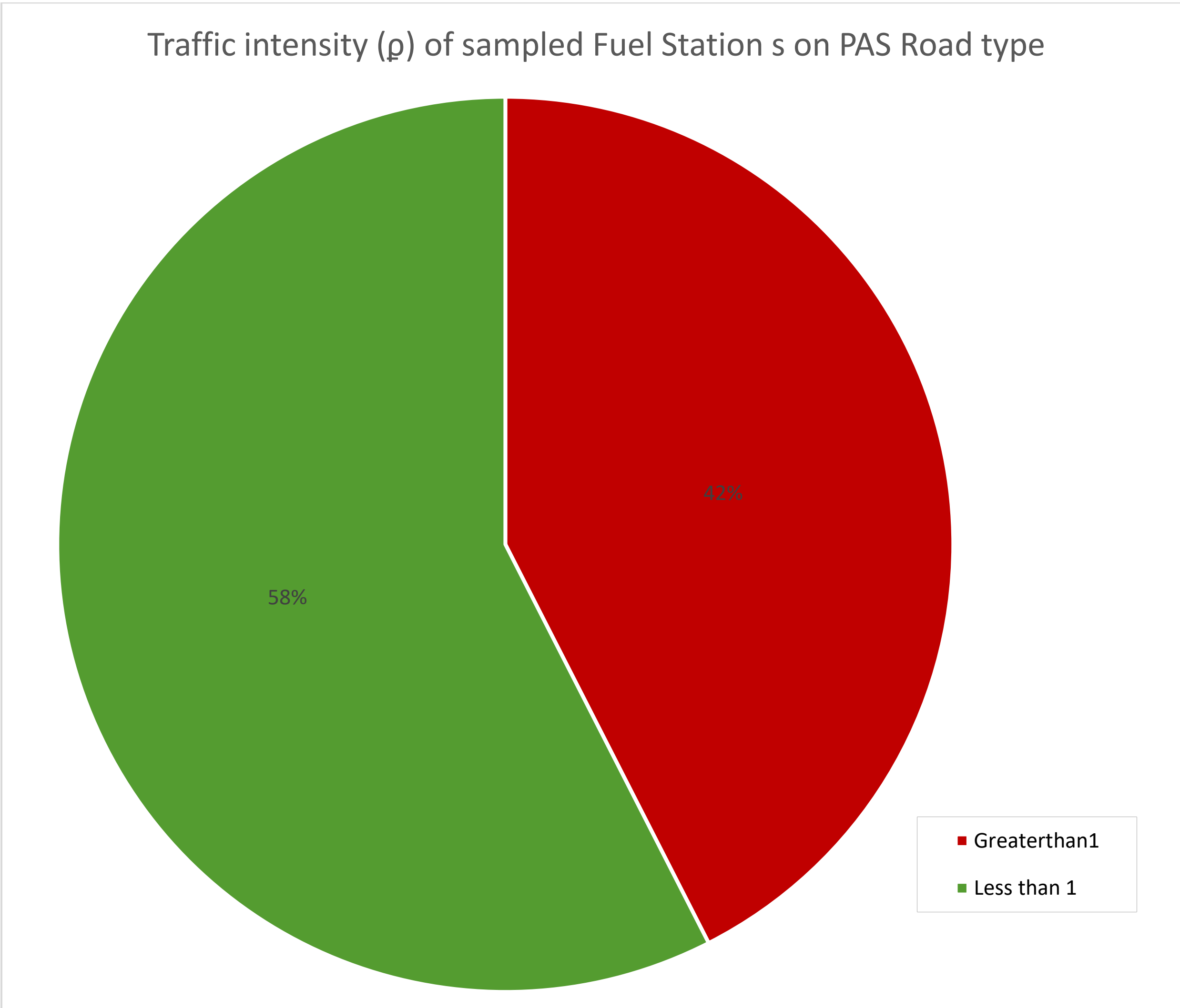


Figure 4-27 Traffic intensity (ρ) of sampled Fuel Stations on PAS Road type (Source: Organized by the author, (2023))

Table 4-4 Traffic data of Fuel Filling Station found on PAS road type

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	SAMSON BEDASA	Total	BOLE	/3/	BOLE BRASS	Below 150 meters	6	47	7	1.119
2	ELENI TAFESSE	Oilibya	KIRKOS	/9/	ESTIFANOS	Below 150 meters	6	108	8	2.25
3	EFREM GIZACHEW	NOC	BOLE	/3/	INFRONT OF SKY LIGHT	Below 150 meters	6	59	9	1.092
4	DILARGACHEW BELAY	Oilibya	LIDETA	/1/	LIDETA	Below 150 meters	4	45	8	1.406
5	ADEM BEDRE	Total	A/KETEMA	/2/	SEBATEGHA TOTAL	Above 150 meters	4	33	9	0.916
6	HABTAMU AKLILU	Total	LEMI KURA	/2/	AYAT	Above 150 meters	2	36	9	2
7	MERIF PETROLEUM	DALOL	LEMI KURA	/10/	SUMIT 72	Above 150 meters	4	45	8	1.406
8	DAGACHEW ABRAHA	Oilibya	NIFAS SLK	/7/	GOTERA	Above 150 meters	4	37	9	1.027
9	TSEGA ASAMERE & FAMILY P.L.C	YBP	A/KALITI	/7/	KALITI MAREMIYA	Above 150 meters	10	45	8	0.562
10	FIKREMARIYAM BELAY	NOC	LEMI KURA	/10/	SEMIT PEPSI	Above 150 meters	7	65	9	1.031
11	ABAYNEHE DENQU	Total	A/KALITI	/6/	ADDEY ABEBA	Above 150 meters	6	49	7	1.166
12	TILIKSEW GEDAMU	SKY Petroleum	LEMI KURA	/9/	SEMIT MEDHANIYALEM	Above 150 meters	2	17	9	0.944
13	MIKIYAS AKLILU	TAF	NIFAS SLK	/2/	JEMO	Above 150 meters	8	62	8	0.968
14	TERECHE GETACHWE	TERA	A/KALITI	/1/	ALEM BANK	Above 150 meters	8	52	8	0.812
15	MR c	TOTAL	A/KALITI	/08/	AKAKI STADIUM	Above 150 meters	8	45	7	0.803
16	KAFDM TRADING P.L.C	Oilibya	A/KALITI	/12/	KALITI MENAHARIYA	Above 150 meters	4	30	7	1.071
17	MELAKU W/MEDIHIN	TAF	A/KALITI	/4/	GELAN CONDOMINIUM	Above 150 meters	8	29	6	0.604
18	FATUMA KELIFA	Oilibya	NIFAS SLK	/6/	GOTERA	Above 150 meters	8	64	9	0.888
19	MULAW WERASH	Total	A/KALITI	/7/	KALITI CROWN	Above 150 meters	4	35	8	1.093
20	BELETE G/SIELASSE WOLDEYOHANNES	Total	A/KALITI	/8/	kality total	Above 150 meters	4	30	8	0.937
21	MARKOS LAKEW	PETROL	LEMI KURA	/3/	SUMIT 72	Above 150 meters	6	46	8	0.958
22	ESAYAS BERHE	NOC	LEMI KURA	/13/	CIVIL SERVICE	Above 150 meters	7	71	9	1.126
23	HABTAMU TAFERA BEYENE	PETROL	NIFAS SLK	/1/	JEMO/LEBU	Above 150 meters	8	62	9	0.861
24	SADYA BESHIR	YBP	NIFAS SLK	/2/	JEMO	Above 150 meters	6	53	9	0.981
25	NETSANET BIRHANU	NOC	KIRKOS	/7/	DEBREWORK TOWER	Above 150 meters	3	25	8	1.562
26	JEMAL ALI	Total	A/KALITI	/9/	TULU DIMTU	Above 150 meters	5	40	9	0.888

Table 4-4 (continued).

27	ESKEDAR ALEMAYEHU	NOC	LEMI KURA	/10/	SUMMIT NOC FIYEL BET	Above 150 meters	7	57	9	0.904
28	MEKONEN MENGISTE	JR PETROL EUM	A/KALITI	/4/	GELAN CONDOMINIUM	Above 150 meters	4	21	7	0.75
29	Goldmark P.L.C	NOC	LEMI KURA	/5/	SUMIT 72	Above 150 meters	4	47	8	1.468
30	HAILE T/KIROS	Total	NIFAS SLK	/2/	HAILE GARMENT	Above 150 meters	14	79	9	0.626
31	EMEBET ABEBE	Oilibya	LIDETA	/3/	3 KUTIR MAZORIYA	Above 150 meters	6	42	8	0.875
32	MR z	TOTAL	KIRKOS	/02/	BEKELO BET TOTAL	Above 150 meters				
33	LICHEYA MEHARI	AFRICA OIL	A/KALITI	/10/	KOYE FECHE	Above 150 meters	10	62	7	0.885714
34	TEFERA TESEMA	Oilibya	KIRKOS	/7/	LEGEHAR	Above 150 meters	2	21	8	1.315
35	ABAC TRADING	ALPHA PETROL EUM	A/KALITI	/9/	TULU DIMTU SQUARE	Above 150 meters	5	37	8	0.925
36	ABEBE ALEMU	DELTA	A/KALITI	/5/	kality maseltgna	Above 150 meters	5	43	8	1.075
37	DEGNEW NEGASH	YBP	A/KALITI	/1/	AQAQI YETEBABRUT/A LEM BANK	Above 150 meters	7	42	7	0.857
38	TEWEDROS ERIKE	HABESH A	LEMI KURA	/5/	SUMIT PEPSI	Above 150 meters	3	36	8	1.5
39	MEKETAYE GIRMA	Total	KIRKOS	/1/	BOLE MENGED	Above 150 meters	4	35	4	1.093
40	SELOME TADESSE	NOC	YEKA	/10/	LEM HOTEL	Below 150 meters	5	52	7	1.485

(Source: Organized by the author, (2023))

Figure 4-28 sampled Fuel Station on PAS road type (Source: Google Earth (2023))

Figure 4-29 photo showing how queues formed (Source: Photo taken by author on site, (2023))

4.3.4 Traffic intensity of Fuel Stations that are within 150 meters of traffic intersection

It is interesting that 9 of the sample's 12 Fuel Stations, which are all located within 150 meters of traffic junctions, show traffic intensity or utilization factors that are higher than 1. This implies that a sizeable fraction of these stations experiences high demand, which could cause congestion and service issues. The next three stations, in contrast, have traffic intensities below 1, even if they are still close to crossings, indicating a considerably lesser demand compared to their operational capacity. This difference in traffic volume highlights the wide range in service demand across Fuel Stations located close to traffic crossings, which is an important consideration when evaluating their influence on traffic flow.

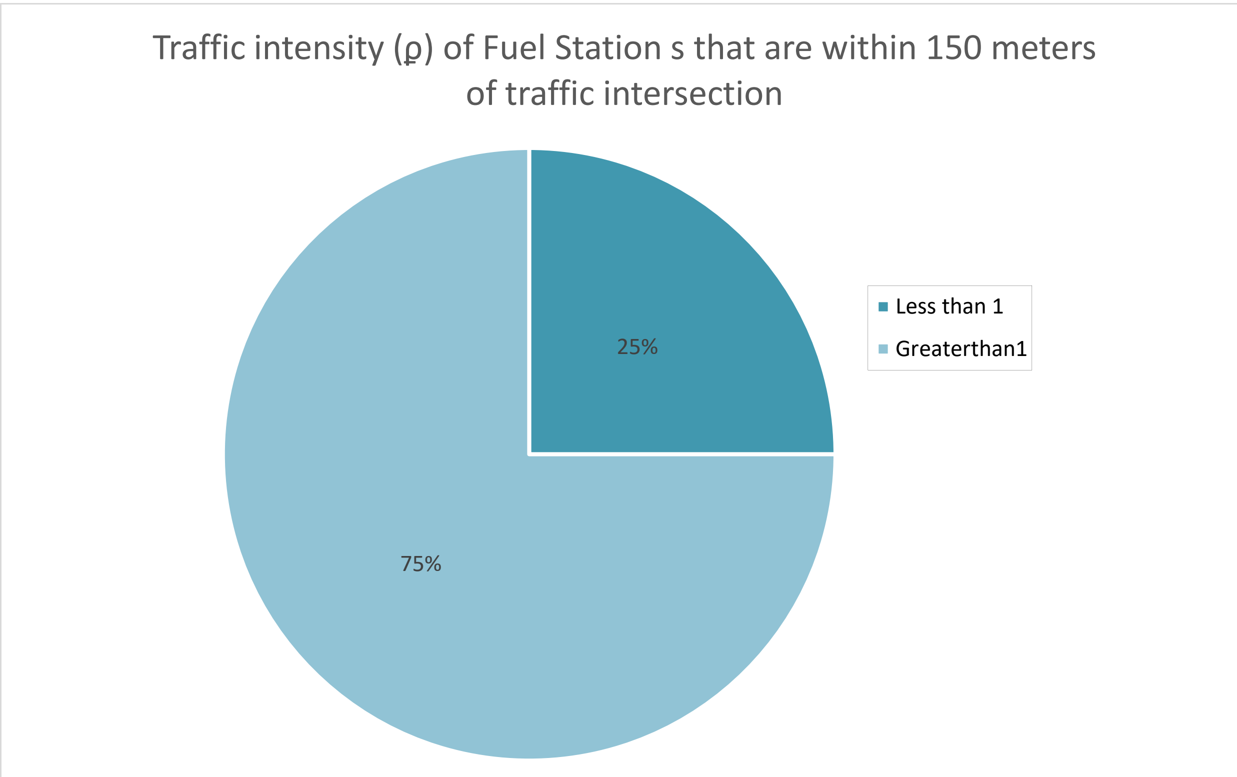


Figure 4-30 Traffic intensity (ρ) of Fuel Stations that are within 150 meters of traffic intersection, (Source: Organized by the author, (2023))

Table 4-5 Traffic intensity (ρ) of Fuel Stations that are within 150 meters of traffic intersection data

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	SAMSON BEDASA	Total	BOLE	/3/	BOLE BRASS	Below 150 meters	6	47	7	1.119
2	ELENI TAFESSE	Oilibya	KIRKOS	/9/	ESTIFANOS	Below 150 meters	6	108	8	2.25
3	EFREM GIZACHEW	NOC	BOLE	/3/	INFRONT OF SKY LIGHT	Below 150 meters	6	59	9	1.092
4	DILARGACHEW BELAY	Oilibya	LIDETA	/1/	LIDETA	Below 150 meters	4	45	8	1.406
5	ABIY SHIFERAW EJIGU	Oilibya	LIDETA	/3/	TEKLEHAYMANOT	Below 150 meters	7	65	8	1.160
6	ALEM TADESSE	NOC	A/KALITI	/13/	TULU DIMTU	Below 150 meters	10	60	8	0.75
7	NESRO GIRAG OBSE	TOTAL	NIFAS SLK	/3/	GERMAN SQUARE	Below 150 meters	15	52	7	0.495
8	AZENEW MUHAMMED	Kobil	GULELE	/7/	ADDISU GEBEYA	Below 150 meters	5	39	8	0.975
9	WUDENESH BEFEKADU SEMU	Total	ARADA	/5/	PIYASA	Below 150 meters	4	54	7	1.928
10	ABATE BEKELE	Total	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	15	7	1.071
11	TEFERI MENGSTE	Oilibya	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	19	7	1.357
12	SELOME TADESSE	NOC	YEKA	/10/	LEM HOTEL	Below 150 meters	5	52	7	1.485

(Source: Organized by the author, (2023))

5 CHAPTER 5፡ CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the spatial distribution of fuel stations and their effects on traffic flow in Addis Ababa City were investigated. Through meticulous data collection, analysis, and evaluation, a thorough understanding of the complex relationship between fuel station placement and its effects on urban traffic dynamics was sought.

The spatial distribution analysis showed a varied landscape with 131 Fuel Stations placed strategically throughout the different metropolis sub cities. Notably, it was discovered that a significant number of these stations were located in specific sub-cities, including Akaky Kaliti and Nifas Silk-Lafto, demonstrating the need to serve densely populated areas.

The Nearest Neighborhood Analysis for spatial distribution and the M/M/S Queuing System for traffic impact were both used in the analysis, which produced important results. A significant number of Fuel Stations, especially those found along SAS and CS road type, were found to have traffic volumes that were higher than their operational limits. This suggests that there are significant congestion problems during rush hour, which could have an effect on traffic flow, air quality, and road safety.

When comparing data for various road types, an intriguing trend became apparent. Compared to Collector Streets (CS), stations along Sub Arterial Streets (SAS) had a higher prevalence of stations with traffic intensity greater than 1. Additionally, out of 40 stations, 22 of them were SAS stations, which showed the highest frequency of congestion.

Beyond these numerical results, the study emphasizes the significance of thorough urban planning standards. There are currently no specific planning guidelines for where to locate Fuel Stations in Addis Ababa City. The results show that adhering to such standards can lessen traffic congestion, lessen pollution, improve road safety, and guarantee effective urban mobility.

The study has revealed the intricate interactions between traffic flow and fuel station distribution in Addis Ababa City. Urban planners, policymakers, and other stakeholders in the field can learn a lot from the challenges and opportunities that have been identified. With the help of this research, future initiatives in this vibrant city's urban planning, traffic control and environmental sustainability can be guided.

A service station may increase traffic volume and the nature and intensity of the traffic created may distinguish this use from other types of drive-in businesses. The traffic generated by a service station can have several consequences. A station increases the number of roadway access points. This, in turn, impairs vehicle movements and can affect the capacity of the street to carry the volume of traffic for which it was designed. The concentration of service stations along a traffic artery may compound the problem and multiply these effects.

A service station located at an intersection increases the number of points of conflict between vehicle and pedestrian. This effect is much more marked when there is a concentration of service stations, as they can significantly impact traffic flow. However, the utilization factors of these stations vary significantly, with most stations experiencing high traffic intensity, causing congestion and service issues, while some have lower traffic intensities.

All interested parties will need to work together to find solutions to these problems, with an emphasis on striking a balance between the accessibility of fuel and the demands for effective traffic management and sustainable urban development. The vision for Addis Ababa City's future is informed urban planning, and this study makes a contribution to that vision.

5.2 Recommendations

Service stations located in the Central Business Core shall be considered integral with adjacent development if they are designed as part of a building complex with obvious pedestrian and vehicular circulation provided to surrounding activities.

- **Service Rate Evaluation:** Conduct a thorough examination of the service rates of Fuel Stations, particularly those situated in inner cities, with a keen focus on Collector Streets (CS). This assessment should take into account factors such as the number of service points, staff efficiency, and technological advancements that can speed up the refueling process.
- **Urban Planning Standards:** Develop and implement specific urban planning standards and regulations governing the location and distribution of fuel stations within Addis Ababa City. These standards should consider factors such as road type, traffic intensity, size, minimum area and proximity to intersections to ensure an optimal and efficient distribution of fuel stations.
- **Investment in Infrastructure:** Encourage Fuel Station operators to invest in infrastructure upgrades in collaboration with relevant authorities. This could include adding more fuel dispensers, improving traffic flow within the station, and implementing modern refueling technologies to reduce service time.
- **Operational Efficiency:** Increase operational efficiency by training Fuel Station employees to provide quick and efficient service. Implement customer service protocols that prioritize quick refueling while adhering to safety standards.
- **Zoning and Land Use Policies**: Incorporate zoning and land use policies that consider the spatial distribution of fuel stations. Encourage station clustering in appropriate areas while limiting station concentration in densely populated inner-city areas. This can be accomplished by enacting zoning ordinances that designate appropriate zones for fuel station establishments.
- **Traffic Impact Assessments:** Detailed traffic impact analyses should be required before approving any new fuel station construction permits. These analyses ought to consider how a new station might affect safety, traffic flow, and congestion. Where necessary, mitigation strategies should be recommended.

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- **Traffic Management Strategies**: Utilize traffic management techniques during peak times, particularly in areas with a lot of Fuel Stations. These tactics might involve optimizing traffic flow through the use of intelligent transportation systems, lane management, and dynamic traffic signal adjustments.
- **Monitoring and Compliance:** Establish mechanisms for regular monitoring and compliance checks of existing fuel stations to ensure they adhere to planning standards. Non-compliant stations should be required to implement necessary adjustments or face penalties.
- **Data Collection and Analysis:** Continuously collect and analyze data related to traffic flow, fuel station usage, and road congestion. This data-driven approach can provide valuable insights for ongoing urban planning and policy adjustments.
- **Interagency Collaboration:** Encourage cooperation between important government organizations, such as those in charge of transportation, environmental protection, and city planning. Decision-making and policy implementation can be streamlined through interagency coordination...

By implementing these recommendations, Addis Ababa City can work toward a more balanced and sustainable distribution of fuel stations, mitigating the impact on traffic flow and enhancing overall urban livability. These measures will contribute to a more efficient transportation network and a healthier urban environment for its residents.

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7 ANNEX

Annex 1 Publishable Article

SPATIAL DISTRUBUTION AND IMPACT OF FUEL STATION ON TRAFFIC FLOW IN ADDIS ABABA

Natnael Habtemaryam Rade

Abstract

This research study investigated the spatial distribution and impact of fuel stations on traffic flow in Addis Ababa city. The study objectively sought to identify, map and classify fuel stations throughout the city, to study the spatial distribution of fuel station in the city, to examine the impacts of spatial distribution of fuel stations on traffic flow and to suggest measures that can be undertaken to reduce on the impacts associated with fuel stations on traffic flow. The study used both qualitative and quantitative approaches and other forms of data collection techniques. Names and street addresses of the filling stations were obtained from government bodies. Global positioning System (with in a mobile phone device) was used to capture the location of the filling station. Arrival rate of Vehicles, service rate and number of servers were acquired on field by keeping track of when cars arrived at Fuel Stations and the amount of time it took to serve each car. The geographical data were imported to Arc Map environment of ArcGIS 10.5 and analyses for spatial distribution were performed in the Arc Map environment using spatial statistics, spatial analyst and proximity tools available in the software. For the traffic impact analysis an Excel template of M/M/s queuing model is used obtained from online resource. The findings revealed that there are 131 Fuel Stations in Addis Ababa and 75 Fuel Stations are found on PAS road type, 40 Fuel Stations are found on SAS road type and 16 Fuel Stations are found on CS road type Furthermore, utilizing the M/M/S Queuing System, the study reveals that traffic intensity in sampled Fuel Stations in the CS road type, SAS, and PAS road types is significantly higher than one, indicating high demand. However, in CS road type none of the stations have traffic intensity below 1. In contrast, 19 of the sampled 22 Fuel Stations in the SAS road type have traffic intensity greater than one. The majority of Fuel Stations in the PAS road type have traffic intensity less than one. The research concluded that fuel stations along the city road are not evenly distributed, rather they are more concentrated together at different centers which have a significant impact on the flow of traffic especially during rush hours. In light of these findings, the study recommends the development of urban planning standards, zoning regulations, and traffic impact assessments to optimize fuel station distribution. Public transportation promotion, environmental considerations, and community engagement are essential components of sustainable urban mobility in Addis Ababa City.

Keywords: Fuel Stations, Traffic Impacts, Spatial Distribution 3

1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The majority of Ethiopia's cities have seen fast expansion, which has accelerated the rise of the country's vehicle traffic and, as a result, raised the demand for gasoline stations along highways, city streets, and settlements. These developments must be carefully monitored and managed. The number of gasoline stations in Addis Ababa city has increased, and as a result, less thought has been given to the placement and operation of Fuel Stations. This research project intends to analyze the spatial distribution and effects of Fuel Stations on traffic flow in across Addis Ababa City.

Fuel demand is one of several demands that are created by the rise of the urban population and the number of cars and other vehicles. Long urban streets and pointless trips waste a significant amount of gasoline for vehicles. (Harrison, 1999) Since engines are built to use petroleum products and filling stations are where fuel is sold, an increase in automobiles has resulted in an increase in demand for fuel and, by extension, fuel stations. In light of this development, many developers take advantage of this necessity and construct Fuel Stations carelessly without taking into account any possible consequences of their location. Nowadays, it is well acknowledged that economic expansion can significantly contribute to expanding impacts, especially when such advancements are not sustainable.

The growing number of fuel stations in the Addis, together with issues with their distribution and location within the study area, are what motivated this study. This is mostly because some Fuel Stations are poorly situated, which causes traffic jams, accidents, pollution, fire risks, and other problems. Therefore, it is crucial to evaluate the distribution pattern of Fuel Stations and their effects on traffic in Addis Ababa City.

1.2 Description of the study area

Addis Ababa, Ethiopia's largest city is surrounded by beautiful scenery and shares borders with Sheger city, making it a vital transportation hub.

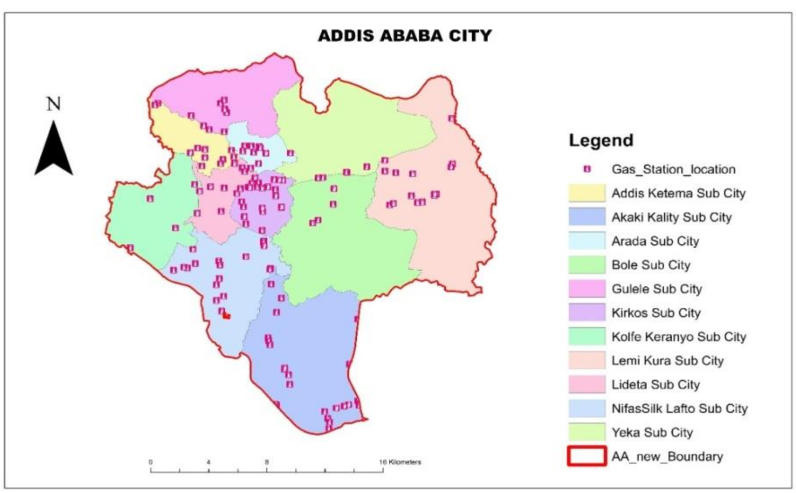

Figure 1-1 Addis Ababa City (Source: Organized by the author, using Arc GIS 10.5 Analysis, (2023))

Fuel stations are critical to meeting the transportation needs of Addis Ababa residents and visitors. The city has a network of Fuel Stations strategically placed along major thoroughfares and in different neighborhoods. These Fuel Stations sell various types of gasoline and are frequently operated by small business owners as well as large fuel station chains.

2 RESEARCH METHODOLOGY

2.1 Sampling design

Sample size is calculated for the purpose examining the impacts of spatial distribution of fuel stations on traffic flow in Addis Ababa" so out of the 131 Fuel Stations found in Addis Ababa a sample is calculated.

The sample size (n) is calculated according to the formula: n = [z2 * p * (1 - p) / e2] / [1 + (z2 * p * (1 - p) / (e2 * N))]

$$n_0 = \frac{z^2 p(1-p)}{e^2}$$

Equation 1-1 Cochran's formula

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Equation 1-2 Cochran's formula correction factor

Where: z = 1.96 for a confidence level (α) of 95%, p = proportion (expressed as a decimal), N = population size, e = margin of error.

z = 1.96, p = 0.5, N = 131, e = 0.08

n = [1.962 * 0.5 * (1 - 0.5) / 0.082] / [1 + (1.962 * 0.5 * (1 - 0.5) / (0.082 * 131))]

n = 150.0625 / 2.1455 = 69.942

n ≈ 70

The sample size (with finite population correction) is equal to **70**

After the sample size is determined the sample is clustered in to group and calculated by the percentage of their total share using stratified sampling method.

Table 1-1 Sample size calculation using cluster method `

Number	Road Type	percentage of Fuel Station found	Number of samples	Distance from traffic intersection	Percentage of Fuel Station found	Number of samples
1	PAS	57%	=0.57*70 =40	Within 150m traffic intersection	13.33%	=0.1333*40 =5
				Not within 150m traffic intersection	86.33%	=0.8633*40 =35
2	SAS	31%	=0.31*70 =22	Within 150m traffic intersection	22.5%	=0.225*22 =5
				Not within 150m traffic intersection	77.5%	=0.775*22 =17
3	CS	12%	=0.12*70 =8	Within 150m traffic intersection	18.75%	=0.1875*8 =2
				Not within 150m	81.25%	=0.8125*8

traffic intersection	=6

(Source: Source: Organized by the author, (2023))

2.2 Methods Data Collection

Information was gathered from both primary and secondary sources. While primary data was gathered using GPS device and field survey, secondary data was obtained from already published publications, journals, and magazines and institution.

2.3 Methods of Data analysis

2.3.1 ARC GIS 10.5 and Microsoft Excel

A preliminary investigation was carried out to discover and document surrounding fueling stations. This acquainted the researcher with the location and provided direction on how to source data, the types of data needed, and field work preparation. The AA City Administrative Boundary & Structural Plan First Term Amendment (Sep, 2022) of Addis Ababa city was obtained from the Addis Ababa city Government plan and Development Commission, from which the researcher obtained information such as road maps. The list of filling stations was obtained from the Fuel and Fuel Products Facilities Competency Certification team (an Addis Ababa Environmental Protection Authority department responsible for registering and regulating filling stations) and the Addis Ababa Trade Bureau. The name, type, and street location of the Fuel Station were identified. This served as a guide for verification and data collection using the Global Positioning System (GPS). The retail Fuel stations' coordinates were determined primarily using a handheld Global Positioning System (GPS) device and online research using Google Earth Pro and maps.

The data from the GIS device was first entered into Microsoft Excel applications to create a simple database. Columns were used as fields to store filling station information. The data were saved in the project folder (created on the C drive) and exported to the ArcGIS 10.5 ArcMap environment. The data was converted to a shape file, which was then used to perform all of the analysis. To map out the filling stations, various symbols were used. The number of Fuel Stations on each road was determined. Tables and charts created in Microsoft Excel were also used to present the data collected. These contribute to the first goal of the work, which is to identify, map, and classify the existing fuel stations.

Arc Map was used to compare the location of the filling stations with the standards buffer and proximity analysis. To identify stations that are found in 150-meter distance from the roundabout and traffic intersection, a buffer of 150 meters was created on the roundabout and traffic intersection. Query by location was performed using the selection menu in the ArcMap environment. Furthermore, the data was queried to return all locations that are within a 150m buffer. The selected stations were highlighted, the shape file (which contained the station) was right-clicked, and the software was told to create a layer from the selected features. The stations identified are found with in the distance of 150m from the roundabout and traffic intersection.

Another query operation was performed using the selection menu; the query is to return stations that are within 400 meters of another station. The chosen stations are those that are within 400 meters between each other. A shape file for these stations was also created, saved, and used to compute the proportion of stations within each other.

The spatial pattern of Fuel stations in the study area was identified using Nearest Neighbor Analysis (NNA). To determine the spatial distribution of Fuel stations, the Average Nearest Neighbor Analysis (ANNA) and Manhattan distance method were also used. In the nearest neighbor analysis, the point layer shape file was used as input.

2.3.2 M/M/S Queuing System

Queues or wait times are the most common occurrence in our daily lives. A queuing system is a key component of Operations Research. It is a scientific and systematic process for analyzing and solving complex problems, as well as making better judgments(Cooper, 1981). Queuing theory is used to solve traffic congestion problems in bank counters, ration shops, railway reservation counters, toll plazas, doctor's clinics, and automobile services, among other places. Its main purpose is to predict congestion situations in a specific urban transportation network and suggest improvements in traffic areas(Newell, 1965). In this work, Markova processes was introduce, which are important to the analysis of all basic queuing systems so that the third objective is analyzed. I.e., To examine the impacts of spatial distribution of fuel stations on traffic flow in Addis Ababa.

The concept of multi-channel queuing is relevant when there are several servers at the service facility to deliver the service. The servers are connected in parallel, and any of the servers can supply any unit in the waiting queue(Cohen, 2008; Kendalld, 1953).

When there are multiple servers in the service facility to deliver the service, the multichannel queuing model is applicable. Each customer in the waiting line can be served by any one of the servers, and the service rate is the same for all of them due to the parallel arrangement of the servers.

The mean service rate is higher than the mean arrival rate (i.e., $\mu>\lambda$). When $\mu>\lambda$, no queue will be formed and the arriving customers will not have to wait. when $\mu=\lambda$, in this case, if the initial queue length was zero then new arrival will not have to wait, and in case the initial queue length was not zero, then every person arriving in the system will have to join the queue i.e., the length of the queue would remain constant. When $\mu<\lambda$, in this case, the length will increase indefinitely and this will not be a steady system. The average arrival rate is less than the combined average service rate of all servers i.e., $\lambda<S.\mu$ wheres is the number of servers. The ratio λ/μ is known as the utilization factor.

Traffic intensity ρ= (mean arrival rate) λ / (mean service rate) $S.\mu$. 'S' is the number of sever

Equation 1-3 Traffic intensity ρ

$$\rho = \frac{\lambda}{S * \mu}$$

All the above calculation is done using an excel template obtained from an online source (https://ericjjesse.wordpress.com/course-introduction/queues/).

3 Results and Discussion

3.1 Spatial Distribution of Fuel Stations in the Study Area

This data reveals valuable insights into the spatial distribution and ownership structure of Fuel Stations in Addis Ababa. The city is home to a total of 131 Fuel Stations, with the highest concentration found in Akaky Kaliti Sub City (25), and followed by Kirkos Sub City (23) and Nifas Silk-Lafto Sub City (17).

Table 1-2 Distribution of Fuel Station to sub city

SUBCITY	Number of Fuel Stations
A/KALITI	25
KIRKOS	23
NIFAS SLK	17
LEMI KURA	15
A/KETEMA	11
ARADA	10
LIDETA	8
GULELE	7
KOLFE KERANIO	6
BOLE	5
YEKA	4
Grand Total	131

(Source: Organized by the author, (2023))

Among the Fuel Station owners, Total Energies has the largest presence with 37 stations, followed closely by Ola Energy with 31 stations. The National Oil Company (NOC) operates 23 Fuel Stations, while Yetebaberut Beherawi Petroleum (YBP) operates 9 stations. Other Fuel Station owners include TAF Oil (6), KOBIL (5), Nile (3) and Habesha, Petrol Ethiopia, Sky petroleum, and Delta with 2 stations each. Additionally, Africa Oil, Alpha Petroleum, Baro, Dalol, Gomeju, JR PETROL, Tera, Yegha, Zemen, and Zobel each operate 1 Fuel Station in Addis Ababa.

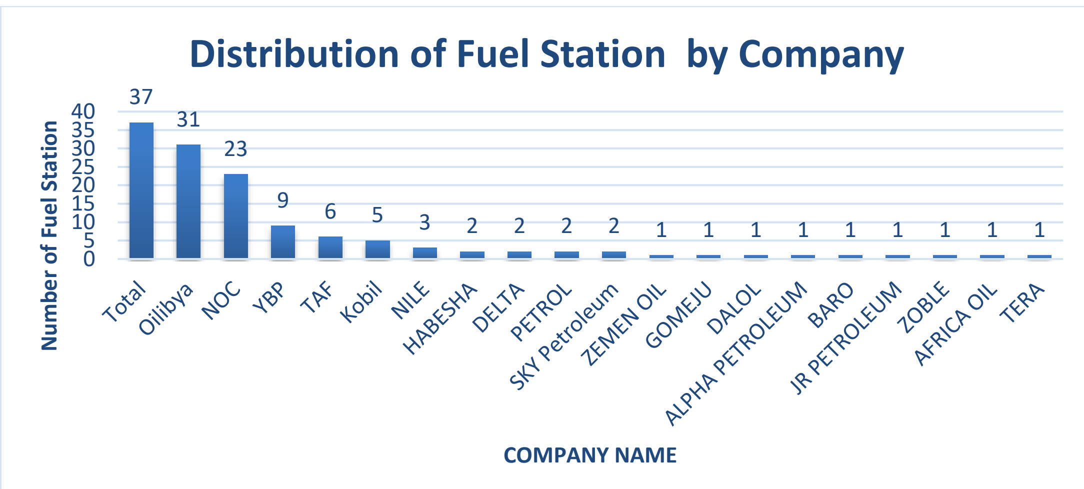

Figure 1-2Distribution of Fuel Station by company (Source: Organized by the author, (2023))

This detailed information on Fuel Station distribution and ownership across the city provides a foundation for further analysis of their spatial impact on traffic flow and the development of targeted strategies to address any potential traffic-related challenges. By understanding the geographic concentration of Fuel Stations and the diverse ownership landscape, stakeholders can implement effective measures to optimize traffic management and ensure smooth transportation within Addis Ababa.

3.1.1 Inventory of Filling Stations by Road type

The placement of Fuel Stations creates a striking pattern of accessibility and convenience for both locals and visitors within the busy city landscape of Addis Ababa City. 75 of the city's 131 Fuel Stations are situated along the Principal Arterial Streets (PAS) road type. These are the main thoroughfares of the city, with wide road widths of at least 40 meters. The availability of Fuel Stations throughout PAS not only meets the high demand for refueling services but also emphasizes the crucial role that these wide boulevards play in promoting efficient transportation around the city.

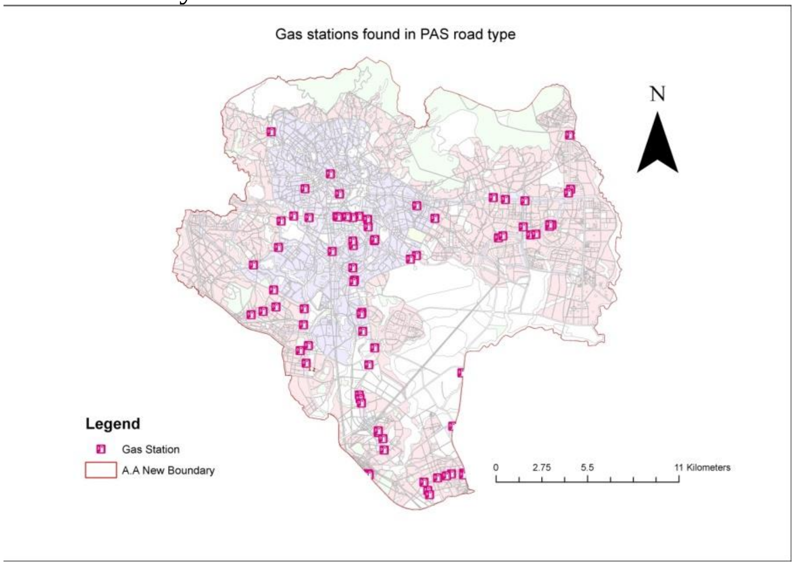

Figure 1-3 Fuel Stations found in PAS road Type (Source: Organized by the author, (2023))

Another aspect of the placement of Fuel Stations when gone farther into the city's road system. The Sub Arterial Streets (SAS) in Addis Abeba are now home to a total of 40 Fuel stations. These roads, which range in width from 25 meters to just under 40 meters, serve as crucial thoroughfares for both intra-city and inter-city transit. Fuel Stations are strategically positioned along SAS as a tribute to their essential role in meeting the diversified mobility demands of a global population and enhancing the accessibility of refueling services inside the city's network of thoroughfares.

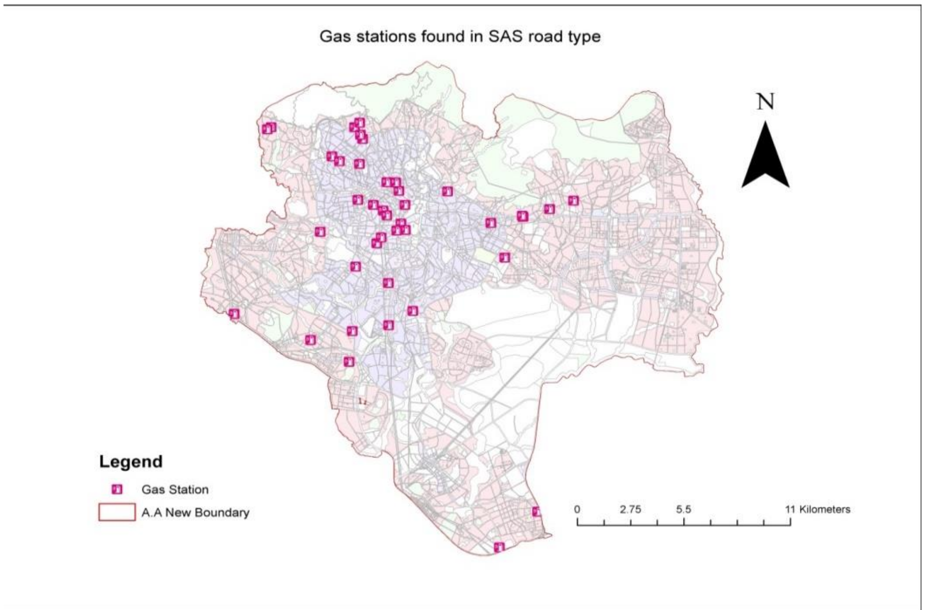

Figure 1-4 Fuel Stations found in SAS road Type (Source: Organized by the author, (2023))

Furthermore, an interesting discovery is made by our thorough analysis: the city's Collector Roads (CS), where road widths narrow to less than 25 meters, are home to 16 Fuel stations almost all of the Fuel Stations found on the CS road type are found in the inner city. These roads play a crucial part in the dynamics of local traffic and are frequently differentiated by their closeness to residential areas and business centers. Fuel Stations are essential to supplying localized communities and ensuring that fuel resources are always within easy reach of neighborhoods, which adds to the ease and functioning of these places. Their presence along these smaller collector routes denotes this.

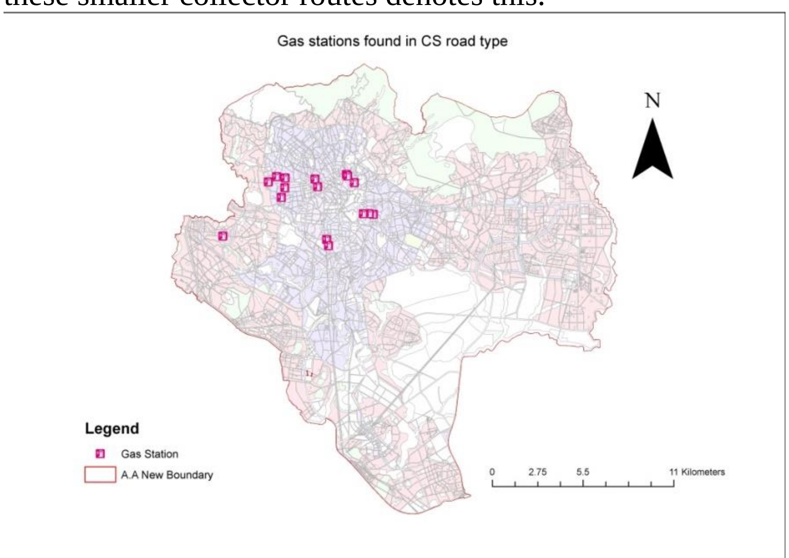

Figure 1-5 Fuel Stations found in CS road Type (Source: Organized by the author, (2023))

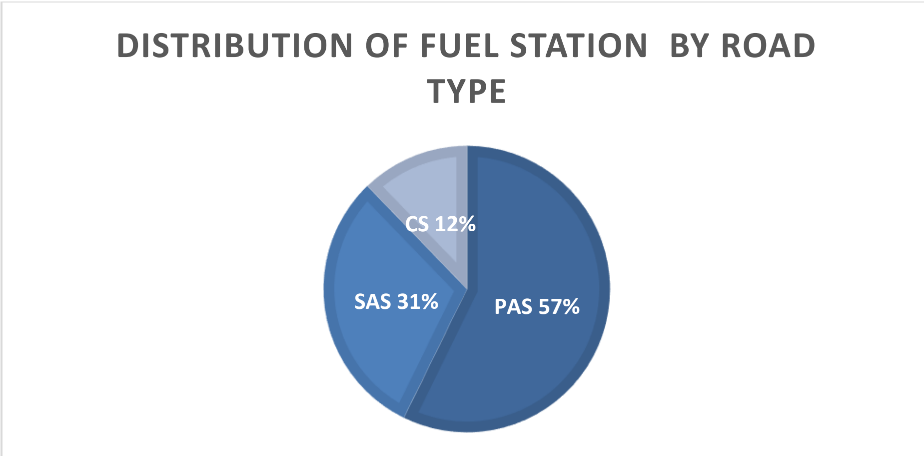

Figure 1-6 Distribution of Fuel Stations on road type (Source: Organized by the author, (2023))

3.1.2 Distance between the Location of Filling Stations

Using the proximity function of the analysis tool, distances between stations in the area were calculated in the ArcMap environment. The research found that the largest distance between nearby Fuel Stations was approximately 3,250 meters. This was discovered between Yegha Petroleum (found in Akaki Kality sub city, woreda 13, Around Koye Feche Square) and Africa Oil (found in Akaki Kality, woreda 10, around Hachalu Hundessa Square). The average distance between nearby fueling stations, was approximately 565 meters. The closest separation, less than 83 meters, was seen where two nearby stations were located side by side in Akaki Kality sub city woreda 4 locally known as Gelan Condominium between TAF OIL and JR Petroleum. Additionally, the outcome reveals that half of the Fuel Stations were located within 400 meters apart from their neighbor's. However, only 11.2% of the stations were found within 100-meter separation from their neighbors'.

Figure 1-7 closest Fuel Stations (Source: Google Earth (2023))

Figure 1-8 second nearest Fuel Station (Source: Google Earth (2023))

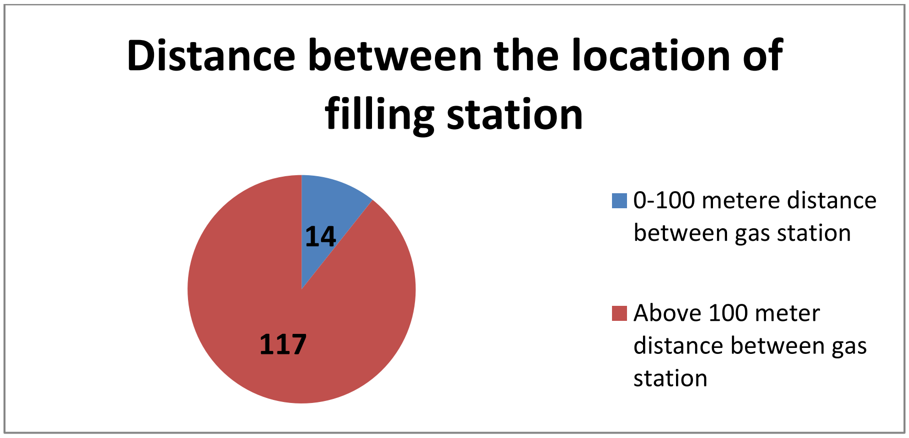

Figure 1-9 Distance of Fuel Station between each other (Source: Organized by the author, (2023))

3.1.3 Distance of the Fuel Stations from the traffic intersection

According to (Neufert & Neufert, 2012) Fuel Station should not be located in in the queuing area in front of traffic lights. Fuel Stations shouldn't often be placed near traffic signals since it is generally not a good idea for urban planning and traffic management. The region of the road just before a traffic signal known as the queue area is where cars halt when the light turns red. This region is crucial for making sure that traffic moves through junctions safely and effectively.

After selecting the location of every road intersection (including roundabouts, traffic lights, and crossroads), a buffer of 150 meters was created in arc GIS 10.5 from the selected road intersection. The Fuel Stations located within 150 meters of the selected road intersection were then identified using the geoprocessing tool intersects between all the Fuel Stations and the selected road intersection.

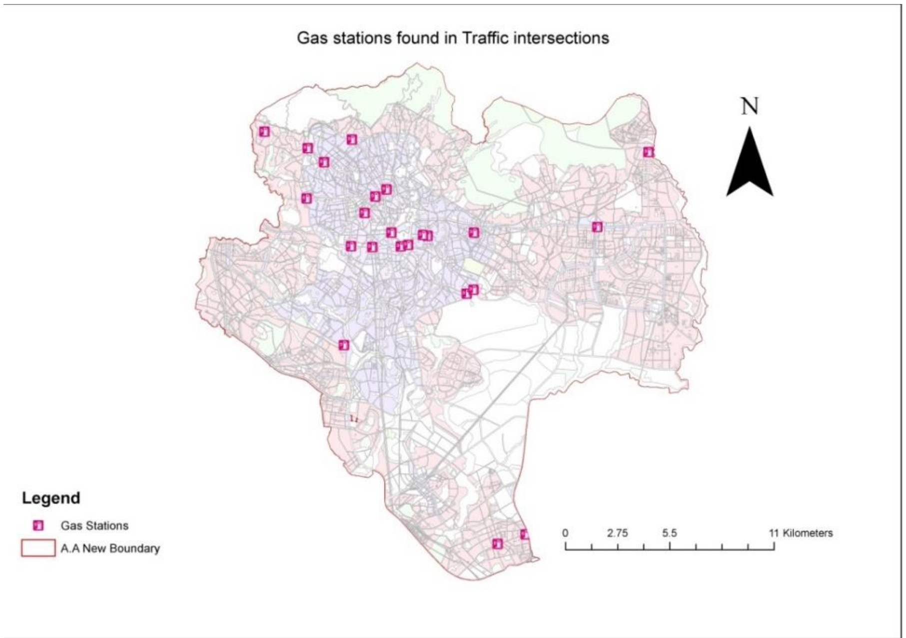

Figure 1-10 Fuel Station Found in traffic intersection (Source: Organized by the author, using Arc GIS 10.5 Analysis, (2023))

ArcGIS 10.5 analysis findings provide a few interesting facts about the Fuel stations in Addis Abeba. 22 of the 131 Fuel stations examined are within 150 meters or less of significant traffic centers, such as intersections of roads. The importance of these locations for city traffic flow makes it significant that Fuel stations are close by.

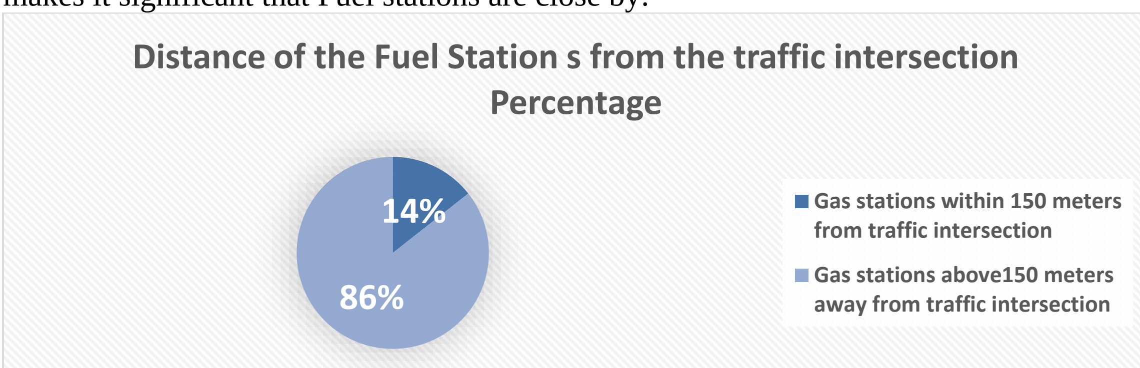

Figure 1-11 percentage of Fuel Stations found on traffic intersection (Source: Organized by the author, (2023))

The above 22 Fuel Stations near road intersections may be split into three groups when taken a closer look at them. There are five of them at junctions with no traffic signals and five of them at intersections with traffic lights. Furthermore, 12 are near to roundabouts. This breakdown provides a clearer idea of the location of these Fuel Stations in relation to major traffic intersections.

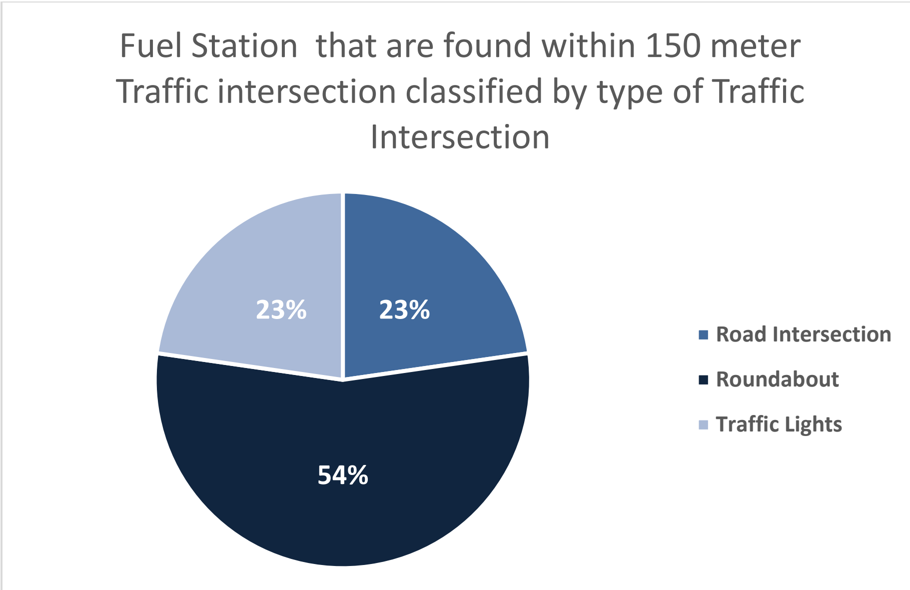

Figure 1-12 Fuel Station that are found within 150 meter Traffic intersection classified by type of Traffic Intersection (Source: Organized by the author, (2023))

Figure 1-13 example of Fuel Station found on roundabout (Source: Google Earth (2023))

Figure 1-14 example of Fuel Station found on traffic lights (Source: Google Earth (2023))

Figure 1-15 example of Fuel Station found on road intersection (Source: Google Earth (2023))

3.1.4 Analysis of Spatial Distribution of Fuel Station Using Nearest Neighbor Analysis

The spatial layout of Fuel stations in the study area was identified using Nearest Neighbor Analysis (NNA). To determine the spatial distribution of Fuel stations, the Average Nearest Neighbor Analysis (ANNA) and Manhattan distance approach were also used. The coordinates of Fuel stations were entered into an excel spreadsheet. The excel sheet was imported into a GIS system and converted to a point layer. The nearest neighbor analysis uses this point layer shape file as input. The square kilometer area occupied by all of the Fuel stations was also used as an input in the criteria required for running the nearest neighbor analysis (NNA) for the spatial pattern of Fuel stations in the city.

This investigation uncovered significant spatial distributions. Addis Ababa's spatial layout revealed a nearest neighbor ratio of 0.609353. This indicates that the distribution is clustered.

A number of factors influenced the location and distribution pattern of Fuel stations in a given area. High power tension, commercial/industries, motor garage, public facility, residential area, highway, and services, all of which are rotated around the metropolitan region, are considered the cardinal guides in seating Fuel station in geographic space.

According to (Getis & Getis, 1966), he stated that Fuel stations (points) must be positioned logically based on the size, 50-meter distance (near residential areas, public facilities, commercial/industries), and people to be supplied. However, this is not the case in the research area.

This ratio shows a tendency for Fuel Stations to cluster together in close proximity, which may have an effect on accessibility, traffic flow, and other urban dynamics. The spatial clustering of Fuel Stations raises significant planning and management issues for urban areas. It is essential to comprehend the causes of this clustering and how it affects safety, pollution, and traffic congestion in order to develop efficient distribution strategies for these vital services in urban areas. In order to achieve both the more general objectives of sustainable urban development and the convenience of fuel accessibility, careful planning and policy measures are required.

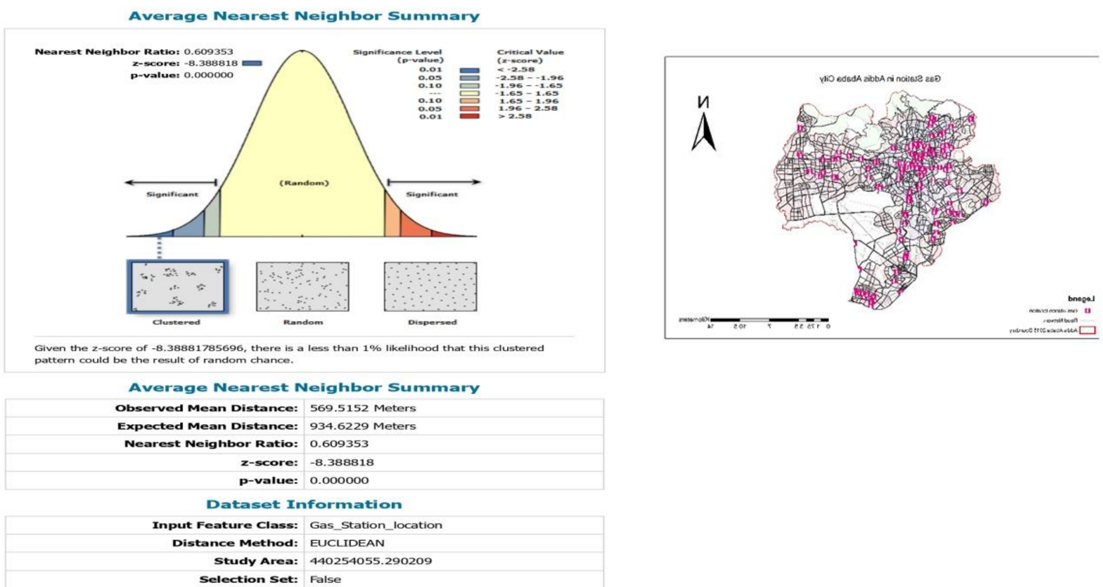

Figure 1-16 Average nearest Summary of Fuel Stations in Addis Ababa (Source: Organized by the author, using Arc GIS 10.5 Analysis, (2023)

3.2 Analysis of impact of fuel station on traffic flow Using Queuing System

This study assumes the First Come, First Served (FCFS) system, in which cars are queued and served according to their turn. "An examination of data collected at 70 Fuel Stations, sampled during both the morning and evening peak hours, over a one-hour period, revealed certain findings. The study calculates critical characteristics such as traffic intensity for systems with many servers, mean queue length, total number of customers in the system, and average wait times for consumers in both queues and the overall system.

Appendix 1 specifically presents these findings for clarity and reference. It is worth noting that the results indicate the presence of traffic congestion during peak hours, throwing light on the issues encountered during these periods of increased demand and vehicle activity.

Out of the 70 Fuel Stations sampled for traffic intensity, only 26 showed traffic intensity less than 1. Out of these, 23 are found on PAS road types, and 3 are found on SAS road types. The other 44 Fuel Stations have a traffic intensity greater than 1. Out of these 8 Fuel Stations found on CS road type (almost all sampled Fuel Stations from CS road type category), 19 are found on SAS road type, and 17 of them are found on PAS road type.

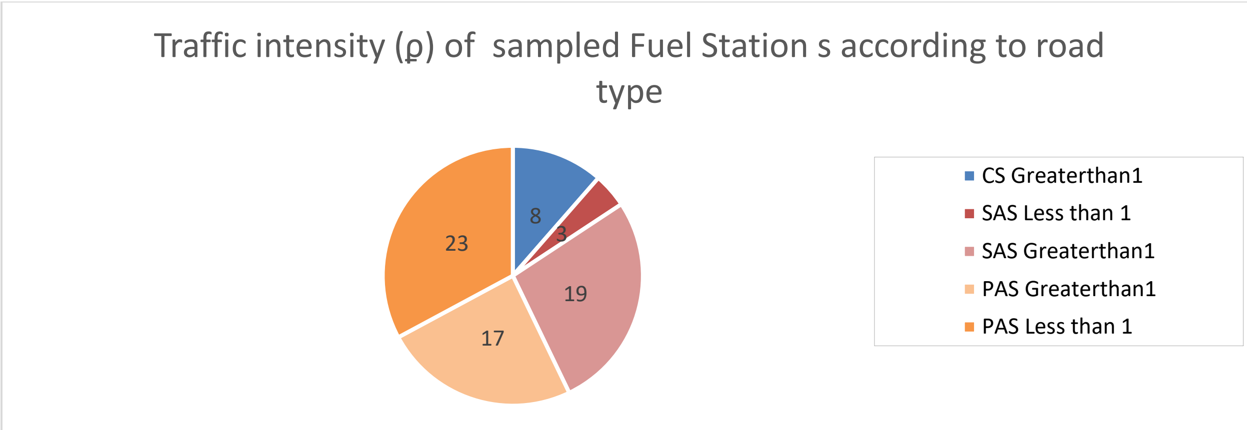

Figure 1-17 Traffic intensity results from sampled Fuel Station respect to road type (Source: Organized by the author, (2023))

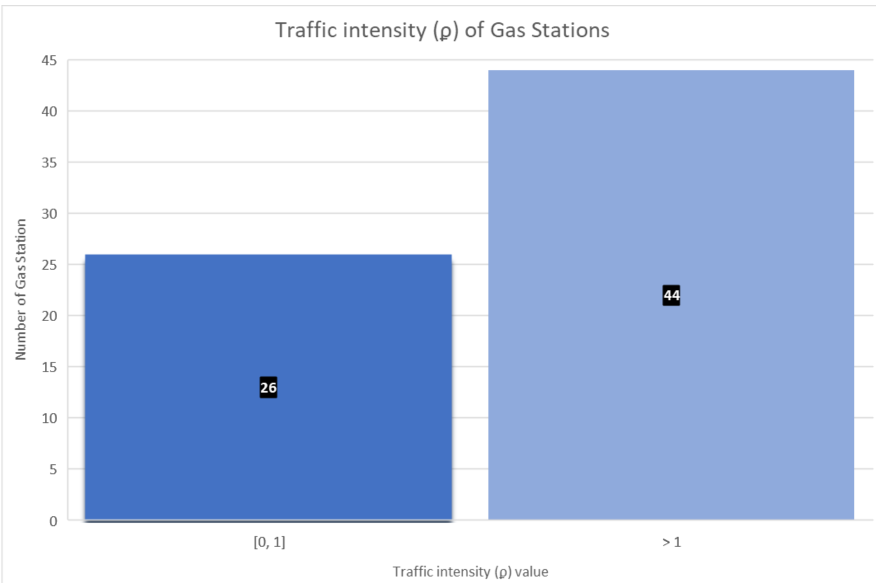

Figure 1-18 Traffic intensity of Fuel Station (Source: Organized by the author, (2023))

As seen in the figures below when queues of vehicles form, especially in the context of Fuel Stations or any other points of interest along a road, these queues typically occupy one lane of the road. This means that a portion of the road's width, typically equivalent to the width of one lane, becomes dedicated to the vehicles waiting in the queue.

Figure 1-19 image how queues are formed (Source: Google Earth (2023))

Figure 1-20 sampled Fuel Station (Source: Photo taken by author on site, (2023))

3.2.1 Traffic intensity on CS road type

It is clear from the sample of 8 Fuel Stations that are part of the CS road type that demand exceeds their operational capacity in all 8 of them. This traffic intensity or utilization factor is greater than 1, none of these stations have traffic intensity below 1, indicating that they are always operating in high demand.

Figure 1-21 sampled Fuel Station on CS road type (Source: Google Earth (2023))

Figure 1-22 photo showing queues formed (Source: Photo taken by author on site, (2023))

Table 1-3 Traffic data of Fuel Filling Station found on CS road type

No	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	ELIYAS ALI	Total	KIRKOS	/6/	AU/BULGARYA TOTAL	Above 150 meters	3	55	8	2.291
2	SADYA HUSSIEN	Kobil	ARADA	/2/	70 DEREJA	Above 150 meters	1	15	8	1.875
3	ZERTIHUN MARKOS	Oilibya	A/KETEMA	/4/	EHIL BERENDA	Above 150 meters	4	34	7	1.214
4	DAWIT MOKENEN	Oilibya	KIRKOS	/8/	KASANCHIS SUPER	Above 150 meters	4	36	7	1.285
5	HAYMANOT SHENKUTE	Oilibya	ARADA	/6/	RAS MEKONEN	Above 150 meters	6	90	7	2.142
6	ABATE BEKELE	Total	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	15	7	1.071
7	TEFERI MENGSTE	Oilibya	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	19	7	1.357
9	BIZUWORK DEBEBE	Total	ARADA	/9/	B/S MATEMIYA	Above 150 meters	3	45	8	2.812

(Source: Organized by the author, (2023))

3.2.2 Traffic intensity on SAS road type

Of the 22 Fuel Stations in the SAS road type sample, 19 have traffic intensity or utilization factor greater than one, indicating that demand exceeds capacity." In contrast, three of these stations have traffic intensities less than one, indicating that demand exceeds capacity.

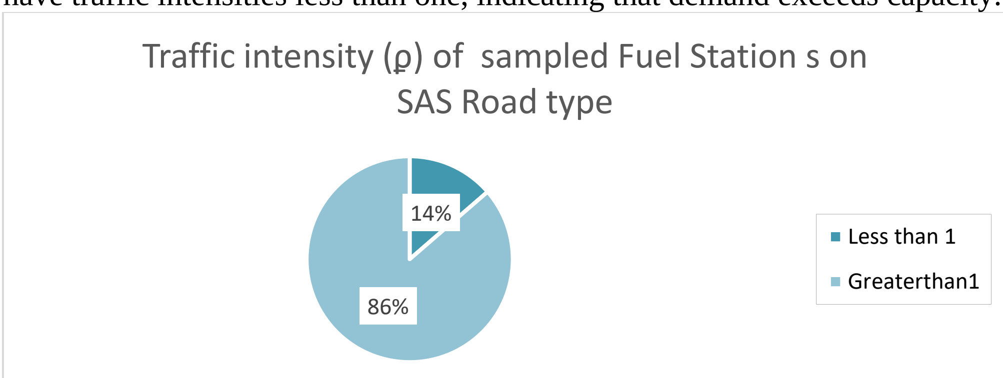

Figure 1-23 Traffic intensity (ρ) of sampled Fuel Stations on SAS Road type (Source: Organized by the author, (2023))

Table 1-4 Traffic data of Fuel Filling Station found on SAS road type

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	QUEENS SUPERMARKET PLC	NOC	GULELE	/9/	PASTOR	Above 150 meters	8	70	8	1.093

2	MR x	NOC	NIFAS SLK	/06/	Gofa NOC	Above meters	150	5	52	7	1.485
3	BAHIRU NEGASH	NIL E	NIFAS SLK	/1/	JEMO 1	Above meters	150	6	63	9	1.166
4	MEKBIB WERKU	Oilib ya	KIRKO S	/7/	RAS HOTEL	Above meters	150	1	25	8	3.125
5	TIGIST BIRUK	Total	A/KETE MA	/8/	MERKATO	Above meters	150	4	82	7	1.107
6	HAYAT BIRHANU	Total	YEKA	/9/	LAMBERET	Above meters	150	6	63	8	1.312
7	TAMIRAT BELAY	Oilib ya	A/KETE MA	/5/	PASTOR	Above meters	150	4	58	9	1.611
8	ZELALEM AYSHESHIM	Oilib ya	KIRKO S	/7/	Gihon hotel	Above meters	150	4	40	7	1.111
9	MELESE TADESSE	Oilib ya	YEKA	/9/	LAMBERET	Above meters	150	2	38	8	2.375
10	HIWOT BIRHANU	NOC	BOLE	/7/	GERJI ST. MARY	Above meters	150	3	34	9	1.259
11	FISEHA KEBEDE	Total	ARADA	/1/	KULSEN TOTAL	Above meters	150	2	30		2.142
12	KENEA DABA	Oilib ya	LIDETA	/10/	AFRICAN UNION	Above meters	150	8	60	7	1.071
13	FASIL BAYE YILMA	Total	BOLE	/4/	MEGENAGN A	Above meters	150	6	60	9	1.111
14	W/GIYORGIS ATRESO	Oilib ya	LIDETA	/7/	TIKUR ANBESA	Above meters	150	2	30	8	1.875
15	KASSAYE TEGEGN AND LIJOCHU	NOC	LEMI KURA	/13/	WESEN	Above meters	150	6	62	8	1.291
16	YIGEREM WOLDE	YBP	YEKA	/9/	ETHIO CHINA	Above meters	150	7	51	7	1.040
17	ABIY SHIFERAW EJIGU	Oilib ya	LIDETA	/3/	TEKLEHAY MANOT	Below meters	150	7	65	8	1.160
18	ALEM TADESSE	NOC	A/KALI TI	/13/	TULU DIMTU	Below meters	150	10	60	8	0.75
19	NESRO GIRAG OBSE	TOT AL	NIFAS SLK	/3/	GERMAN SQUARE	Below meters	150	15	52	7	0.495
20	AZENEW MUHAMMED	Kobi l	GULEL E	/7/	ADDISU GEBEYA	Below meters	150	5	39	8	0.975
21	WUDENESH BEFEKADU SEMU	Total	ARADA	/5/	PIYASA	Below meters	150	4	54	7	1.928
22	ALEMAYEHU TESFAYE	Oilib ya	ARADA	/7/	KEBENA	Above meters	150	3	62	8	2.583

(Source: Organized by the author, (2023))

Figure 1-24 sampled Fuel Station on PAS road type (Source: Google Earth (2023))

Figure 1-25 photo showing queues formed (Source: Photo taken by author on site, (2023))

3.2.3 Traffic intensity on PAS road type

Among the 40 Fuel Stations sampled from the PAS road type, 19 have traffic intensity or utilization factor more than one, indicating that demand exceeds capacity. In contrast, a large majority of 21 of these 40 stations have traffic intensity less than one, indicating that they are running at or below capacity.

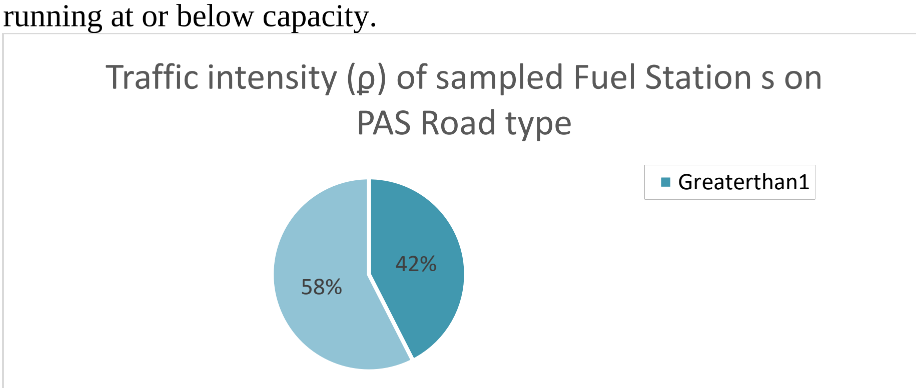

Figure 1-26 Traffic intensity (ρ) of sampled Fuel Stations on PAS Road type (Source: Organized by the author, (2023))

Table 1-5 Traffic data of Fuel Filling Station found on PAS road type

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	SAMSON BEDASA	Total	BOLE	/3/	BOLE BRASS	Below 150 meters	6	47	7	1.119
2	ELENI TAFESSE	Oilibya	KIRKOS	/9/	ESTIFANOS	Below 150 meters	6	108	8	2.25
3	EFREM GIZACHEW	NOC	BOLE	/3/	INFRONT OF SKY LIGHT	Below 150 meters	6	59	9	1.092

4	DILARGACHEW BELAY	Oilibya	LIDETA	/1/	LIDETA	Below meters	150	4	45	8	1.406
5	ADEM BEDRE	Total	A/KETEMA	/2/	SEBATEGHA TOTAL	Above meters	150	4	33	9	0.916
6	HABTAMU AKLILU	Total	LEMI KURA	/2/	AYAT	Above meters	150	2	36	9	2
7	MERIF PETROLEUM	DALOL	LEMI KURA	/10/	SUMIT 72	Above meters	150	4	45	8	1.406
8	DAGACHEW ABRAHA	Oilibya	NIFAS SLK	/7/	GOTERA	Above meters	150	4	37	9	1.027
9	TSEGA ASAMERE & FAMILY P.L.C	YBP	A/KALITI	/7/	KALITI MAREMIYA	Above meters	150	10	45	8	0.562
10	FIKREMARIYAM BELAY	NOC	LEMI KURA	/10/	SEMIT PEPSI	Above meters	150	7	65	9	1.031
11	ABAYNEHE DENQU	Total	A/KALITI	/6/	ADDEY ABEBA	Above meters	150	6	49	7	1.166
12	TILIKSEW GEDAMU	SKY Petroleum	LEMI KURA	/9/	SEMIT MEDHANIY ALEM	Above meters	150	2	17	9	0.944
13	MIKIYAS AKLILU	TAF	NIFAS SLK	/2/	JEMO	Above meters	150	8	62	8	0.968
14	TERECHE GETACHWE	TERA	A/KALITI	/1/	ALEM BANK	Above meters	150	8	52	8	0.812
15	MR c	TOTAL	A/KALITI	/08/	AKAKI STADIUM	Above meters	150	8	45	7	0.803
16	KAFDM TRADING P.L.C	Oilibya	A/KALITI	/12/	KALITI MENAHARIYA	Above meters	150	4	30	7	1.071
17	MELAKU W/MEDIHIN	TAF	A/KALITI	/4/	GELAN CONDOMINIUM	Above meters	150	8	29	6	0.604
18	FATUMA KELIFA	Oilibya	NIFAS SLK	/6/	GOTERA	Above meters	150	8	64	9	0.888
19	MULAW WERASH	Total	A/KALITI	/7/	KALITI CROWN	Above meters	150	4	35	8	1.093
20	BELETE G/SIELASSE WOLDEYOHANNES	Total	A/KALITI	/8/	kality total	Above meters	150	4	30	8	0.937
21	MARKOS LAKEW	PETROL	LEMI KURA	/3/	SUMIT 72	Above meters	150	6	46	8	0.958
22	ESAYAS BERHE	NOC	LEMI KURA	/13/	CIVIL SERVICE	Above meters	150	7	71	9	1.126
23	HABTAMU TAFERA BEYENE	PETROL	NIFAS SLK	/1/	JEMO/LEBU	Above meters	150	8	62	9	0.861
24	SADYA BESHIR	YBP	NIFAS SLK	/2/	JEMO	Above meters	150	6	53	9	0.981
25	NETSANET BIRHANU	NOC	KIRKOS	/7/	DEBREWORK TOWER	Above meters	150	3	25	8	1.562
26	JEMAL ALI	Total	A/KALITI	/9/	TULU DIMTU	Above meters	150	5	40	9	0.888
27	ESKEDAR ALEMAYEHU	NOC	LEMI KURA	/10/	SUMMIT NOC FIYEL BET	Above meters	150	7	57	9	0.904

28	MEKONEN MENGISTE	JR PETRO LEUM	A/KALI TI	/4/	GELAN CONDOMINI UM	Above meters	150	4	21	7	0.75
29	Goldmark P.L.C	NOC	LEMI KURA	/5/	SUMIT 72	Above meters	150	4	47	8	1.468
30	HAILE T/KIROS	Total	NIFAS SLK	/2/	HAILE GARMENT	Above meters	150	14	79	9	0.626
31	EMEBET ABEBE	Oilibya	LIDETA	/3/	3 KUTIR MAZORIYA	Above meters	150	6	42	8	0.875
32	MR z	TOTAL	KIRKOS	/02/	BEKELO BET TOTAL	Above 150 meters					
33	LICHEYA MEHARI	AFRIC A OIL	A/KALI TI	/10/	KOYE FECHE	Above meters	150	10	62	7	0.8857 14
34	TEFERA TESEMA	Oilibya	KIRKOS	/7/	LEGEHAR	Above meters	150	2	21	8	1.315
35	ABAC TRADING	ALPHA PETRO LEUM	A/KALI TI	/9/	TULU DIMTU SQUARE	Above meters	150	5	37	8	0.925
36	ABEBE ALEMU	DELTA	A/KALI TI	/5/	kality maseltgna	Above meters	150	5	43	8	1.075
37	DEGNEW NEGASH	YBP	A/KALI TI	/1/	AQAQI YETEBABRU T/ALEM BANK	Above meters	150	7	42	7	0.857
38	TEWEDROS ERIKE	HABES HA	LEMI KURA	/5/	SUMIT PEPSI	Above meters	150	3	36	8	1.5
39	MEKETAYE GIRMA	Total	KIRKOS	/1/	BOLE MENGED	Above meters	150	4	35	4	1.093
40	SELOME TADESSE	NOC	YEKA	/10/	LEM HOTEL	Below meters	150	5	52	7	1.485

(Source: Organized by the author, (2023))

Figure 1-27 sampled Fuel Station on PAS road type (Source: Google Earth (2023))

Figure 1-28 photo showing queues formed (Source: Photo taken by author on site, (2023))

3.2.4 Traffic intensity of Fuel Stations that are within 150 meters of traffic intersection

It is interesting that 9 of the sample's 12 Fuel Stations, which are all located within 150 meters of traffic junctions, show traffic intensity or utilization factors that are higher than 1. This implies that a sizeable fraction of these stations experiences high demand, which could cause congestion and service issues. The next three stations, in contrast, have traffic intensities below 1, even if they are still close to crossings, indicating a considerably lesser demand compared to their operational capacity. This difference in traffic volume highlights the wide range in service demand across Fuel Stations located close to traffic crossings, which is an important consideration when evaluating their influence on traffic flow.

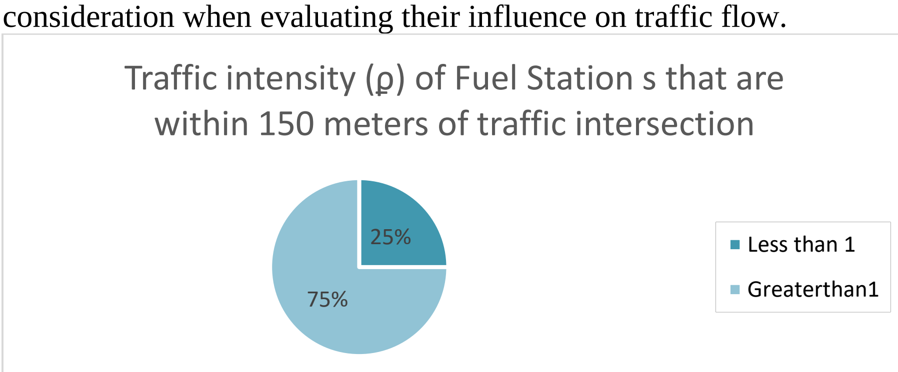

Figure 1-29 Traffic intensity (ρ) of Fuel Stations that are within 150 meters of traffic intersection, (Source: Organized by the author, (2023))

Table 1-6 Traffic intensity (ρ) of Fuel Stations that are within 150 meters of traffic intersection data

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)

1	SAMSON BEDASA	Total	BOLE	/3/	BOLE BRASS	Below 150 meters	6	47	7	1.119
2	ELENI TAFESSE	Oilibya	KIRKOS	/9/	ESTIFANOS	Below 150 meters	6	108	8	2.25
3	EFREM GIZACHEW	NOC	BOLE	/3/	INFRONT OF SKY LIGHT	Below 150 meters	6	59	9	1.092
4	DILARGACHEW BELAY	Oilibya	LIDETA	/1/	LIDETA	Below 150 meters	4	45	8	1.406
5	ABIY SHIFERAW EJIGU	Oilibya	LIDETA	/3/	TEKLEHAYMANOT	Below 150 meters	7	65	8	1.160
6	ALEM TADESSE	NOC	A/KALITI	/13/	TULU DIMTU	Below 150 meters	10	60	8	0.75
7	NESRO GIRAGOBSE	TOTAL	NIFASSLK	/3/	GERMAN SQUARE	Below 150 meters	15	52	7	0.495
8	AZENEW MUHAMMED	Kobil	GULELE	/7/	ADDISU GEBEYA	Below 150 meters	5	39	8	0.975
9	WUDENESH BEFEKADU SEMU	Total	ARADA	/5/	PIYASA	Below 150 meters	4	54	7	1.928
10	ABATE BEKELE	Total	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	15	7	1.071
11	TEFERI MENGSTE	Oilibya	KIRKOS	/8/	KASANCHIS	Below 150 meters	2	19	7	1.357
12	SELOME TADESSE	NOC	YEKA	/10/	LEM HOTEL	Below 150 meters	5	52	7	1.485

(Source: Organized by the author, (2023))

4 Chapter Five Conclusion and Recommendations

4.1 Conclusion

The spatial distribution analysis showed a varied landscape with 131 Fuel Stations placed throughout the different metropolis sub cities. Notably, it was discovered that a significant number of these stations were located in specific sub-cities, including Akaky Kaliti and Nifas Silk-Lafto, demonstrating the need to serve densely populated areas.

The Nearest Neighborhood Analysis for spatial distribution and the M/M/S Queuing System for traffic impact were both used in the analysis, which produced important results. A significant number of Fuel Stations, especially those found along SAS and CS road type, were found to have traffic volumes that were higher than their operational limits. This suggests that there are significant congestion problems during rush hour, which could have an effect on traffic flow, air quality, and road safety.

Beyond these numerical results, the study emphasizes the significance of thorough urban planning standards. There are currently no specific planning guidelines for where to locate Fuel Stations in Addis Ababa City. The results show that adhering to such standards can lessen traffic congestion, lessen pollution, improve road safety, and guarantee effective urban mobility.

A service station may increase traffic volume and the nature and intensity of the traffic created may distinguish this use from other types of drive-in businesses. The traffic generated by a service station can have several consequences. A station increases the number of roadway access points. This, in turn, impairs vehicle movements and can affect the capacity of the street to carry the volume of traffic for which it was designed. The concentration of service stations along a

traffic artery may compound the problem and multiply these effects.
A service station located at an intersection increases the number of points of conflict between vehicle and pedestrian. This effect is much more marked when there is a concentration of service stations, as they can significantly impact traffic flow. However, the utilization factors of these stations vary significantly, with most stations experiencing high traffic intensity, causing congestion and service issues, while some have lower traffic intensities.

4.2 Recommendations

Service stations located in the Central Business Core shall be considered integral with adjacent development if they are designed as part of a building complex with obvious pedestrian and vehicular circulation provided to surrounding activities..

- **Urban Planning Standards:** Develop and implement specific urban planning standards and regulations governing the location and distribution of fuel stations within Addis Ababa City.
- **Investment in Infrastructure:** Encourage Fuel Station operators to invest in infrastructure upgrades in collaboration with relevant authorities.
- **Operational Efficiency:** Increase operational efficiency by training Fuel Station employees to provide quick and efficient service.
- **Zoning and Land Use Policies**: Incorporate zoning and land use policies that consider the spatial distribution of fuel stations.
- **Traffic Impact Assessments:** Detailed traffic impact analyses should be required before approving any new fuel station construction permits.
- **Traffic Management Strategies**: Utilize traffic management techniques during peak times, particularly in areas with a lot of Fuel Stations.
- **Community Engagement:** Involve in decision-making processes relating to the construction of fuel stations with local stakeholders and communities.
- **Monitoring and Compliance:** Establish mechanisms for regular monitoring and compliance checks of existing fuel stations to ensure they adhere to planning standards.
- **Interagency Collaboration:** Encourage cooperation between important government organizations, such as those in charge of transportation, environmental protection, and city planning. Decision-making and policy implementation can be streamlined through interagency coordination.
- **Public Awareness Campaigns**: Launch public awareness campaigns to educate motorists about responsible fuel station usage during peak hours. Encourage off-peak refueling when traffic congestion is less likely.
- **Research and Innovation:** Encourage more investigation into novel approaches to urban planning, such as designing Fuel Station layouts for smooth traffic flow and investigating alternate forms of transportation.

By implementing these recommendations, Addis Ababa City can work toward a more balanced and sustainable distribution of fuel stations, mitigating the impact on traffic flow and enhancing overall urban livability. These measures will contribute to a more efficient transportation network and a healthier urban environment for its residents.

5 Reference

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Annex 2 Calculated traffic intensity of Fuel Stations.

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	ROAD_TYPE	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
1	SAMSON BEDASA	Total	BOLE	/3/	BOLE BRASS	PAS	Below 150 meters	6	47	7	1.119048
2	ELENI TAFESSE	Oilibya	KIRKOS	/9/	ESTIFANOS	PAS	Below 150 meters	6	108	8	2.25
3	EFREM GIZACHEW	NOC	BOLE	/3/	INFRONT OF SKY LIGHT	PAS	Below 150 meters	6	59	9	1.092593
4	DILARGACHEW BELAY	Oilibya	LIDETA	/1/	LIDETA	PAS	Below 150 meters	4	45	8	1.40625
5	ADEM BEDRE MOHAMED	Total	A/KETEMA	/2/	SEBATEGHA TOTAL	PAS	Above 150 meters	4	33	9	0.916667
6	HABTAMU AKLILU	Total	LEMI KURA	/2/	AYAT	PAS	Above 150 meters	2	36	9	2
7	MERIF PETROLEUM	DALOL	LEMI KURA	/10/	SUMIT 72	PAS	Above 150 meters	4	45	8	1.40625

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	ROAD_TYPE	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
8	DAGACHEW ABRAHA HAMZA	Oilibya	NIFAS SLK	/7/	GOTERA	PAS	Above 150 meters	4	37	9	1.027778
9	TSEGA ASAMERE & FAMILY P.L.C	YBP	A/KALITI	/7/	KALITI MAREMIYA	PAS	Above 150 meters	10	45	8	0.5625
10	FIKREMARIYAM BELAY	NOC	LEMI KURA	/10/	SEMIT PEPSI	PAS	Above 150 meters	7	65	9	1.031746
11	ABAYNEHE DENQU MEHERETE	Total	A/KALITI	/6/	ADDEY ABEBA	PAS	Above 150 meters	6	49	7	1.166667
12	TILIKSEW GEDAMU	SKY Petroleum	LEMI KURA	/9/	SEMIT MEDHANIY ALEM	PAS	Above 150 meters	2	17	9	0.944444
13	MIKIYAS AKLILU	TAF	NIFAS SLK	/2/	JEMO	PAS	Above 150 meters	8	62	8	0.96875
14	TERECHE GETACHWE MAMO	TERA	A/KALITI	/1/	ALEM BANK	PAS	Above 150 meters	8	52	8	0.8125
15	MR c	TOTAL	A/KALITI	/08/	AKAKI STADIUM	PAS	Above 150 meters	8	45	7	0.803571
16	KAFDM TRADING P.L.C	Oilibya	A/KALITI	/12/	KALITI MENAHARIYA	PAS	Above 150 meters	4	30	7	1.071429
17	MELAKU W/MEDIHIN	TAF	A/KALITI	/4/	GELAN CONDOMINIUM	PAS	Above 150 meters	8	29	6	0.604167
18	FATUMA KELIFA	Oilibya	NIFAS SLK	/6/	GOTERA	PAS	Above 150 meters	8	64	9	0.888889
19	MULAW WERASH	Total	A/KALITI	/7/	KALITI CROWN	PAS	Above 150 meters	4	35	8	1.09375
20	BELETE G/SIELASSE WOLDEYOHANNES	Total	A/KALITI	/8/	kality total	PAS	Above 150 meters	4	30	8	0.9375
21	MARKOS LAKEW	PETROL	LEMI KURA	/3/	SUMIT 72	PAS	Above 150 meters	6	46	8	0.958333
22	ESAYAS BERHE	NOC	LEMI KURA	/13/	CIVIL SERVICE	PAS	Above 150 meters	7	71	9	1.126984
23	HABTAMU TAFERA BEYENE	PETROL	NIFAS SLK	/1/	JEMO/LEBU	PAS	Above 150 meters	8	62	9	0.861111

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	ROAD_TYPE	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
24	SADYA BESHIR	YBP	NIFAS SLK	/2/	JEMO	PAS	Above 150 meters	6	53	9	0.981481
25	NETSANET BIRHANU	NOC	KIRKOS	/7/	DEBREWORK TOWER	PAS	Above 150 meters	3	25	8	1.5625
26	JEMAL ALI	Total	A/KALITI	/9/	TULU DIMTU	PAS	Above 150 meters	5	40	9	0.888889
27	ESKEDAR ALEMAYEHU MOLLA	NOC	LEMI KURA	/10/	SUMMIT NOC FIYEL BET	PAS	Above 150 meters	7	57	9	0.904762
28	MEKONEN MENGISTE	JR PETROLEUM	A/KALITI	/4/	GELAN CONDOMINIUM	PAS	Above 150 meters	4	21	7	0.75
29	Goldmark P.L.C	NOC	LEMI KURA	/5/	SUMIT 72	PAS	Above 150 meters	4	47	8	1.46875
30	HAILE T/KIROS	Total	NIFAS SLK	/2/	HAILE GARMENT	PAS	Above 150 meters	14	79	9	0.626984
31	EMEBET ABEBE MEKA	Oilibya	LIDETA	/3/	3 KUTIR MAZORIYA	PAS	Above 150 meters	6	42	8	0.875
32	MR z	TOTAL	KIRKOS	/02/	BEKELO BET TOTAL	PAS	Above 150 meters				
33	LICHEYA MEHARI G/TATIYOS	AFRICA OIL	A/KALITI	/10/	KOYE FECHE	PAS	Above 150 meters	10	62	7	0.885714
34	TEFERA TESEMA	Oilibya	KIRKOS	/7/	LEGEHAR	PAS	Above 150 meters	2	21	8	1.3125
35	ABAC TRADING	ALPHA PETROLEUM	A/KALITI	/9/	TULU DIMTU SQUARE	PAS	Above 150 meters	5	37	8	0.925
36	ABEBE ALEMU	DELTA	A/KALITI	/5/	kality maseltgna	PAS	Above 150 meters	5	43	8	1.075
37	DEGNEW NEGASH G/MDHEN	YBP	A/KALITI	/1/	AQAQI YETEBABRUT/ALEM BANK	PAS	Above 150 meters	7	42	7	0.857143
38	TEWEDROS ERIKE MINAYE	HABESHA	LEMI KURA	/5/	SUMIT PEPSI	PAS	Above 150 meters	3	36	8	1.5
39	MEKETAYE GIRMA	Total	KIRKOS	/1/	BOLE MENGED	PAS	Above 150 meters	4	35	4	1.09375
40	QUEENS SUPERMARKET PLC	NOC	GULELE	/9/	PASTOR	SAS	Above 150 meters	8	70	8	1.09375

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	ROAD_TYPE	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
41	MR x	NOC	NIFAS SLK	/06/	Gofa NOC	SAS	Above 150 meters	5	52	7	1.485714
42	BAHIRU NEGASH TEGEGNE	NILE	NIFAS SLK	/1/	JEMO 1	SAS	Above 150 meters	6	63	9	1.166667
43	MEKBIB WERKU	Oilibya	KIRKOS	/7/	RAS HOTEL	SAS	Above 150 meters	1	25	8	3.125
44	TIGIST BIRUK	Total	A/KETEMA	/8/	MERKATO	SAS	Above 150 meters	4	82	7	1.107143
45	HAYAT BIRHANU	Total	YEKA	/9/	LAMBERET	SAS	Above 150 meters	6	63	8	1.3125
46	TAMIRAT BELAY	Oilibya	A/KETEMA	/5/	PASTOR	SAS	Above 150 meters	4	58	9	1.611111
47	ZELALEM AYSHESHIM	Oilibya	KIRKOS	/7/	Gihon hotel	SAS	Above 150 meters	4	40	7	1.111111
48	MELESE TADESSE	Oilibya	YEKA	/9/	LAMBERET	SAS	Above 150 meters	2	38	8	2.375
49	HIWOT BIRHANU	NOC	BOLE	/7/	GERJI ST. MARY	SAS	Above 150 meters	3	34	9	1.259259
50	FISEHA KEBEDE	Total	ARADA	/1/	KULSEN TOTAL	SAS	Above 150 meters	2	30		2.142857
51	KENEA DABA	Oilibya	LIDETA	/10/	AFRICAN UNION	SAS	Above 150 meters	8	60	7	1.071429
52	FASIL BAYE YILMA	Total	BOLE	/4/	MEGENAGNA	SAS	Above 150 meters	6	60	9	1.111111
53	W/GIYORGIS ATRESO	Oilibya	LIDETA	/7/	TIKUR ANBESA	SAS	Above 150 meters	2	30	8	1.875
54	KASSAYE TEGEGN AND LIJOCHU	NOC	LEMI KURA	/13/	WESEN	SAS	Above 150 meters	6	62	8	1.291667
55	YIGEREM WOLDE	YBP	YEKA	/9/	ETHIO CHINA	SAS	Above 150 meters	7	51	7	1.040816
56	ABIY SHIFERAW EJIGU	Oilibya	LIDETA	/3/	TEKLEHAYMANOT	SAS	Below 150 meters	7	65	8	1.160714
57	ALEM TADESSE	NOC	A/KALITI	/13/	TULU DIMTU	SAS	Below 150 meters	10	60	8	0.75
58	NESRO GIRAG	TOTAL	NIFAS SLK	/3/	GERMAN SQUARE	SAS	Below 150	15	52	7	0.495238

No	OWNER_NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL NAME	ROAD_TYPE	distance from traffic intersection	number of servers	arrival rate	service rate	Average server utilization (r)
	OBSE						meters				
59	AZENEW MUHAMMED	Kobil	GULELE	/7/	ADDISU GEBEYA	SAS	Below 150 meters	5	39	8	0.975
60	WUDENESH BEFEKADU SEMU	Total	ARADA	/5/	PIYASA	SAS	Below 150 meters	4	54	7	1.928571
61	ELIYAS ALI AHMED	Total	KIRKOS	/6/	AU/BULGARYA TOTAL	CS	Above 150 meters	3	55	8	2.291667
62	SADYA HUSSIEN AHMED	Kobil	ARADA	/2/	70 DEREJA	CS	Above 150 meters	1	15	8	1.875
63	ZERTIHUN MARKOS ALI	Oilibya	A/KETEMA	/4/	EHIL BERENDA	CS	Above 150 meters	4	34	7	1.214286
64	DAWIT MOKENEN	Oilibya	KIRKOS	/8/	KASANCHIS SUPER	CS	Above 150 meters	4	36	7	1.285714
65	HAYMANOT SHENKUTE	Oilibya	ARADA	/6/	RAS MEKONEN	CS	Above 150 meters	6	90	7	2.142857
66	ABATE BEKELE	Total	KIRKOS	/8/	KASANCHIS	CS	Below 150 meters	2	15	7	1.071429
67	TEFERI MENGSTE	Oilibya	KIRKOS	/8/	KASANCHIS	CS	Below 150 meters	2	19	7	1.357143
68	SELOME TADESSE	NOC	YEKA	/10/	LEM HOTEL	PAS	Below 150 meters	5	52	7	1.485714
69	BIZUWORK DEBEBE	Total	ARADA	/9/	B/S MATEMIYA	CS	Above 150 meters	3	45	8	2.8125
70	ALEMAYEHU TESFAYE	Oilibya	ARADA	/7/	KEBENA	SAS	Above 150 meters	3	62	8	2.583333

Annex 3 List of Fuel Station in Addis Ababa

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
1	WORKU GETANEH	Total	KIRKOS	/9/	AMBASSADOR/HARAMBE	472930.9688	996605.474	SAS	Below 150 meters
2	TEDDY P.L.C	Kobil	LIDET	/7/	TEMAMA FOQ	4720	9973	SAS	Above 150

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
			A			24.2813	24.4137		meters
3	KENEA DABA	Oilibya	LIDETA	/10/	AFRICAN UNION	471683.875	995509.7633	SAS	Above 150 meters
4	W/GIYORGIS ATRESO	Oilibya	LIDETA	/7/	TIKUR ANBESA	472202.875	997059.2844	SAS	Above 150 meters
5	DILARGACHEW BELAY	Oilibya	LIDETA	/1/	LIDETA	470795.8438	995889.125	PAS	Below 150 meters
6	ABIY SHIFERAW EJIGU	Oilibya	LIDETA	/3/	TEKLEHAYMANOT	471512.0938	997638.5556	SAS	Below 150 meters
7	DEREJE ASFAW	YBP	LIDETA	/2/	OLD AIRPORT	469863.8125	995973	PAS	Above 150 meters
8	ALEMAYEHU TESFAYE	Oilibya	ARADA	/7/	KEBENA	475347.9688	998374.7938	SAS	Above 150 meters
9	AREGASH MESELE	Total	ARADA	/2/	SEBARA BABUR	472202.375	998888.7974	SAS	Above 150 meters
10	HAYMANOT SHENKUTE	Oilibya	ARADA	/6/	RAS MEKONEN	473196.5938	998849.5834	CS	Above 150 meters
11	FIKADU KEBEDE	Oilibya	ARADA	/10/	PIYASA	472829.9063	998413.0703	SAS	Above 150 meters
12	FISEHA KEBEDE	Total	ARADA	/1/	KULSEN TOTAL	473147.1875	997631.3308	SAS	Above 150 meters
13	WUDENESH BEFEKADU SEMU	Total	ARADA	/5/	PIYASA	472667.3438	998877.6031	SAS	Below 150 meters
14	ABDELA TKUY	Kobil	ARADA	/1/	CHERCHLE	472621.875	997312.624	PAS	Above 150 meters
15	BIZUWORK DEBEBE	Total	ARADA	/9/	B/S MATEMIYA	473675.875	998365.9334	CS	Above 150 meters
16	KHALID MUHAMMED	Oilibya	ARADA	/2/	ATKILT TERA	472082.8	998510.2	PAS	Above 150 meters

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
						125	875		
17	TESFALIDET HABTEAB	Total	A/KETEMA	/9/	MESALEMIYA	469483.5313	998637.825	CS	Above 150 meters
18	ERGOYE ABDULKADIR	Total	A/KETEMA	/3/	AMANUEL HOSPITAL	469253.9375	997458.3012	CS	Above 150 meters
19	ZERTIHUN MARKOS ALI	Oilibya	A/KETEMA	/4/	EHIL BERENDA	469458.5938	998050.9973	CS	Above 150 meters
20	ENGEDA YEMANE	Oilibya	A/KETEMA	/6/	GOJAM BERENDA	471292.125	998575.8079	CS	Above 150 meters
21	ENANA TAZEB	Total	A/KETEMA	/5/	MEDHANIALEM	469372.6563	1000313.125	SAS	Below 150 meters
22	TIGIST BIRUK	Total	A/KETEMA	/8/	MERKATO	470708.4688	997914.835	SAS	Above 150 meters
23	BEREKA DELIL	Total	A/KETEMA	/1/	CINEMA RAS	471459.5625	998103.6267	CS	Above 150 meters
24	ADEM BEDRE MOHAMED	Total	A/KETEMA	/2/	SEBATEGHA TOTAL	470551.4375	997624.7808	PAS	Above 150 meters
25	TAMIRAT BELAY	Oilibya	A/KETEMA	/5/	PASTOR	469760.5938	1000045.46	SAS	Above 150 meters
26	ALEM TADESSE	NOC	A/KALITI	/13/	TULU DIMTU	480000	980714	SAS	Below 150 meters
27	ABEL YESHIWAS ENGEDAWE	GOMEJU	A/KALITI	/13/	TULU DIMTU	480085.9375	980505.802	PAS	Above 150 meters
28	KAFDM TRADING P.L.C	Oilibya	A/KALITI	/12/	KALITI MENAHARIYA	474948.5	982954.7687	PAS	Above 150 meters
29	DAGNACHEW ABREHAM	Oilibya	A/KALITI	/13/	TULU DIMTU	480091	980407	PAS	Above 150 meters
30	TERECHE GETACHWE MAMO	TERA	A/KALITI	/1/	ALEM BANK	477709.4063	979966.4629	PAS	Above 150 meters
31	ROZA DIFAVRE	Total	A/KALITI	/1/	YESHI TOTAL	477940.4	979462.9	PAS	Above 150 meters

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
						063	624		
32	ASSEFA ARGAW	NOC	A/KALITI	/6/	SARIS ABO	474743.9375	988044.6615	PAS	Above 150 meters
33	DEGNEW NEGASH G/MDHEN	YBP	A/KALITI	/1/	AQAQI YETEBABRUT/ALEM BANK	478042.8125	979210.3376	PAS	Above 150 meters
34	TSEGA ASAMERE & FAMILY P.L.C	YBP	A/KALITI	/7/	KALITI MAREMIYA	473817.8438	985208.8589	PAS	Above 150 meters
35	MULAW WERASH	Total	A/KALITI	/7/	KALITI CROWN	473860.5938	984990.411	PAS	Above 150 meters
36	MELAKU W/MEDIHIN	TAF	A/KALITI	/4/	GELAN CONDOMINIUM	474353.375	980471.3856	PAS	Above 150 meters
37	MEKONEN MENGISTE	JR PETROLEUM	A/KALITI	/4/	GELAN CONDOMINIUM	474405.5313	980405.7739	PAS	Above 150 meters
38	BELETE G/SIELASSE WOLDEYOHANNES	Total	A/KALITI	/8/	kality total	474965.5	983052.6246	PAS	Above 150 meters
39	ABEBE ALEMU	DELTA	A/KALITI	/5/	kality maseltgna	474398.9688	987033.3271	PAS	Above 150 meters
40	YEGHA PETROLUM	DELTA	A/KALITI	/13/	ASTU JERBA	479440.4375	983336.6102	PAS	Above 150 meters
41	HIRUT KEDEME	Total	A/KALITI	/4/	GELAN CONDOMINIUM/INFRONT OF KIDANEMHERET CHURCH	475307.8438	981902.6829	PAS	Above 150 meters
42	MOHAMMED FENTAW	TAF	A/KALITI	/1/	TULU DIMTU	478526.5	980214.7339	PAS	Below 150 meters
43	LICHEYA MEHARI G/TATIYOS	AFRICA OIL	A/KALITI	/10/	KOYE FECHE	479984.8125	986539.7252	PAS	Above 150 meters
44	JEMAL ALI	Total	A/KALITI	/9/	TULU DIMTU	479359.125	980459.037	PAS	Above 150 meters

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
45	EYOB ALEMU	TAF	A/KALITI	/7/	KALITY GABRIEL	473941.1875	984718.297	PAS	Above 150 meters
46	ABAYNEHE DENQU MEHERETE	Total	A/KALITI	/6/	ADDEY ABEBA	473983.4063	990175.32	PAS	Above 150 meters
47	ALEMAYEHU AYALEW GEBRE	TAF	A/KALITI	/2/	university of south Africa/ gelan public	478014.0625	978744.6842	SAS	Above 150 meters
48	ABAC TRADING	ALPHA PETROLEUM	A/KALITI	/9/	TULU DIMTU SQUARE	479066.1563	980351.7314	PAS	Above 150 meters
49	BIRHANU TEKLE KEBEDE	Oilibya	A/KALITI	/6/	SARIS ABO	474025.3125	989039.4696	PAS	Above 150 meters
50	YIGEREM WOLDE	YBP	YEKA	/9/	ETHIO CHINA	480608.9063	997399.8062	SAS	Above 150 meters
51	SADYA HUSSIEN AHMED	Kobil	ARADA	/2/	70 DEREJA	473270.8125	998755.5338	CS	Above 150 meters
52	ESAYAS BERHE	NOC	LEMI KURA	/13/	CIVIL SERVICE	481872.3438	997087.2875	PAS	Above 150 meters
53	KASSAYE TEGEGN AND LIJOCHU	NOC	LEMI KURA	/13/	WESEN	481847.1875	997866.5126	SAS	Above 150 meters
54	TEMESGEN YEDEG GIDEY	BARO	LEMI KURA	/13/	TAFO (around gebriel)	486524.2813	997595.3329	PAS	Above 150 meters
55	HAYAT BIRHANU	Total	YEKA	/9/	LAMBERET	479244.125	996977.5133	SAS	Above 150 meters
56	EYOB ALEMU	TAF	LEMI KURA	/2/	TAFO	486474.4063	1000847.325	PAS	Below 150 meters
57	HABTAMU AKLILU	Total	LEMI KURA	/2/	AYAT	486407.0625	997372.8985	PAS	Above 150 meters
58	MELESE TADESSE	Oilibya	YEKA	/9/	LAMBERET	479203.0938	997030.2136	SAS	Above 150 meters
5	SELOME	NOC	YEKA	/10	LEM HOTEL	4772	9966	PAS	Below 150

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
9	TADESSE			/		81.9688	07.7239		meters
60	TAMRNEW GETACHEW	YBP	LEMI KURA	/10/	CMC	483786.4063	996895.5062	PAS	Below 150 meters
61	FIKREMARIYAM BELAY	NOC	LEMI KURA	/10/	SEMIT PEPSI	484120.5	994844.6512	PAS	Above 150 meters
62	RAHEL G/MESKEL	Oilibya	LEMI KURA	/9/	GORO (WOJI) /MEDHANIALEM CHURCH	482183.2813	994671.5999	PAS	Above 150 meters
63	FASIL BAYE YILMA	Total	BOLE	/4/	MEGENAGNA	477584.4688	996635.2761	SAS	Above 150 meters
64	LEMMA ABEBAW TESHOME	NILE	LEMI KURA	/8/	CMC MICHAEL	482604.7813	996970.1496	PAS	Above 150 meters
65	ESKEDAR ALEMAYEHU MOLLA	NOC	LEMI KURA	/10/	SUMMIT NOC FIYEL BET	483681.0625	995329.4408	PAS	Above 150 meters
66	TEWEDROS ERIKE MINAYE	HABESHA	LEMI KURA	/5/	SUMIT PEPSI	484444.5313	994889.3002	PAS	Above 150 meters
67	ABC P.L.C	NOC	BOLE	/5/	AMCHE	478362.25	995837.6312	PAS	Above 150 meters
68	GOLDMARK P.L.C	NOC	KIRKOS	/15/	BAMBIS	474317.25	995786.0779	PAS	Above 150 meters
69	SAMSON BEDASA	Total	BOLE	/3/	BOLE BRASS	477252.8125	993600.1718	PAS	Below 150 meters
70	EFREM GIZACHEW	NOC	BOLE	/3/	INFRONT OF SKY LIGHT	476900.75	993387.8983	PAS	Below 150 meters
71	HIWOT BIRHANU	NOC	BOLE	/7/	GERJI ST. MARY	478302	994729.7469	SAS	Above 150 meters
72	TILIKSEW GEDAMU	SKY Petroleum	LEMI KURA	/9/	SEMIT MEDHANIYALEM	482457.4688	994788.9746	PAS	Above 150 meters
73	ABERA BITEW	Total	GULELE	/8/	SULULTA ROAD	470539.3	1001923.	SAS	Above 150 meters

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
						125	084		
74	ENGDASHET MENGSTE	NOC	GULELE	/10/	ADDISU GEBEYA	470959.7188	1001269.206	SAS	Above 150 meters
75	HENOK MEKONNEN	Oilibya	GULELE	/7/	GOJAM ROAD	470807.5313	1002155.522	SAS	Above 150 meters
76	QUEENS SUPERMARKET PLC	NOC	GULELE	/9/	PASTOR	470798.2813	999889.6208	SAS	Above 150 meters
77	AZENEW MUHAMMED	Kobil	GULELE	/7/	ADDISU GEBEYA	470842.6875	1001503.368	SAS	Below 150 meters
78	BIRHANE SHEWANGZAW	NOC	GULELE	/8/	WINGET ADEBABAY	468511.9375	1001049.463	PAS	Below 150 meters
79	ABATE BEKELE	Total	KIRKOS	/8/	KASANCHIS	474839.625	996438.2875	CS	Below 150 meters
80	TEFERI MENGSTE	Oilibya	KIRKOS	/8/	KASANCHIS	474590.7188	996474.9608	CS	Below 150 meters
81	DAWIT MOKENEN	Oilibya	KIRKOS	/8/	KASANCHIS SUPER	474222.8125	996480.7474	CS	Above 150 meters
82	ELENI TAFESSE	Oilibya	KIRKOS	/9/	ESTIFANOS	473801.8125	995965.0117	PAS	Below 150 meters
83	YEMISRACH DAFO	NOC	KIRKOS	/4/	KERA	472186.1563	993846.1998	PAS	Above 150 meters
84	ETHIO.SERAT EGNOCH MAHIBER	Kobil	KIRKOS	/4/	GOTERA MASALECHA	473419.2188	992865.6375	PAS	Above 150 meters
85	ZELALEM AYSHESHIM	Oilibya	KIRKOS	/7/	Gihon hotel	473164.5	996250.3116	SAS	Above 150 meters
86	JENEDE JEMAL	Total	KIRKOS	/6/	AFRICA UNION	471998.4375	994916.3695	CS	Above 150 meters
87	ELIYAS ALI AHMED	Total	KIRKOS	/6/	AU/BULGARYA TOTAL	472115.5	994545.7229	CS	Above 150 meters

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
88	MEKETAYE GIRMA	Total	KIRKOS	/1/	BOLE MENGED	474723.8438	994497.7166	PAS	Above 150 meters
89	TEKALGN BEKELE	Oilibya	KIRKOS	/1/	DEMBEL	474346	995325.401	PAS	Above 150 meters
90	HIWOT YEHUALASHET	TOTAL	KIRKOS	/5/	KERA SELAM MOSQUE	472290.25	993331.219	SAS	Above 150 meters
91	YOHANNES MEKBIB	TOTAL	KIRKOS	/2/		474754.8438	994559.7124	PAS	Above 150 meters
92	GIRMA ASSEFA	Total	KIRKOS	/7/	MESKEL SQUARE	473421.125	995879.5062	PAS	Below 150 meters
93	NIGUSE WENDMNEH	Total	KIRKOS	/6/	WABI SHEBELE	471918.8125	995842.825	SAS	Below 150 meters
94	NETSANET BIRHANU	NOC	KIRKOS	/7/	DEBREWORK TOWER	472473.0625	995955.1594	PAS	Above 150 meters
95	MEKBIB WERKU	Oilibya	KIRKOS	/7/	RAS HOTEL	472716.1563	996218.2755	SAS	Above 150 meters
96	TEFERA TESEMA	Oilibya	KIRKOS	/7/	LEGEHAR	472558.7188	995916.4594	PAS	Above 150 meters
97	TEKESTE KEBEDE	Total	KIRKOS	/7/	STADIUM	473078	995946	PAS	Above 150 meters
98	EMEBET ABEBE MEKA	Oilibya	LIDETA	/3/	3 KUTIR MAZORIYA	468951.875	994091.1833	PAS	Above 150 meters
99	MULUGETA ALEM	Total	NIFASSLK	/2/	KOSHE	468659.5313	991528.4906	PAS	Above 150 meters
100	NESRO GIRAG OBSE	TOTAL	NIFASSLK	/3/	GERMAN SQUARE	470427.2188	990676.8072	SAS	Below 150 meters
101	BAHIRU NEGASH TEGEGNE	NILE	NIFASSLK	/1/	JEMO 1	468265.125	990192.9879	SAS	Above 150 meters
10 0	ZEMEN TILAYE	ZEMEN OIL	NIFASSLK	/1/	LEBU	470259.2	988990.0	SAS	Above 150 meters

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
2						188	912		
103	SADYA BESHIR	YBP	NIFAS SLK	/2/	JEMO	468799.0625	990513.7964	PAS	Above 150 meters
104	ARSEMA HAGOS ABERA	NOC	LIDETA	/6/	MECHARE MEDA	470596.6875	994230.3262	SAS	Above 150 meters
105	MAHIDER TSEGAYE	sky Petroleum	NIFAS SLK	/1/	JEMO 1	468026.9375	990246.4183	PAS	Above 150 meters
106	MIKIYAS AKLILU	TAF	NIFAS SLK	/2/	JEMO	467310.6563	990032.4573	PAS	Above 150 meters
107	HAILE T/KIROS	Total	NIFAS SLK	/2/	HAILE GARMENT	470619.0313	987115.4933	PAS	Above 150 meters
108	ADVANCED FUTURE TRADING PLC	YBP	NIFAS SLK	/6/	MEKANISA	470509.4375	990394.6271	PAS	Above 150 meters
109	FATUMA KELIFA	Oilibya	NIFAS SLK	/6/	GOTERA	473524.3125	992123.2292	PAS	Above 150 meters
110	DAGACHEW ABRAHA HAMZA	Oilibya	NIFAS SLK	/7/	GOTERA	473478.1563	992026.8257	PAS	Above 150 meters
111	NURHUSSEN ABEDELA WASE	ZOBLE	NIFAS SLK	/1/	LEBU HAILE GARMENT	470755.75	988184.3088	PAS	Above 150 meters
112	MEKDES ABERA DEGEBASA	Oilibya	NIFAS SLK	/7/	OILIBYA DEPO	473553.9688	991780.9114	SAS	Above 150 meters
113	YONAS MEKONEN	Oilibya	NIFAS SLK	/10/	ADEY ABEBA	473936.375	990081.8723	PAS	Above 150 meters
114	HABTAMU TAFERA BEYENE	PETROL	NIFAS SLK	/1/	JEMO/LEBU	470266.9688	987881.6508	PAS	Above 150 meters
115	YONAS BEKELE	NOC	KOLFE KERANIO	/18/	18 ADDEBABAY	468462.3438	998397.7	CS	Below 150 meters
11	SINAFKSH W/MARIYAM	Oilibya	KOLFE	/9/	MULU WENGEL	469115.6	995671.1	PAS	Above 150 meters

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
6			KERANIO			563	291		
117	GEZAHEGN G/KIDAN	Oilibya	A/KETEMA	/14/	SAMSON	466232.3438	1001917.883	SAS	Below 150 meters
118	QUEENS SUPERMARKET PLC	NOC	KOLFE KERANIO	/9/	TOR HAYLOCH	468764.4063	996149.525	SAS	Above 150 meters
119	EPHREM TESFAYE	NOC	GULELE	/14/	ASKO GEBRIEL	466033.5625	1001797.65	SAS	Above 150 meters
120	ALMAZ SEBSIBE	YBP	KOLFE KERANIO	/3/	WELETE	464323.125	991628.2358	SAS	Above 150 meters
121	ELSA BERIHUN W/YOHANNES	HABESHA	A/KETEMA	/4/	CHEMADE AREA	468964.2188	998726.0865	CS	Above 150 meters
122	FRAOL BERHANU WOLDEMICHALE	YBP	KOLFE KERANIO	/2/	AYER TENA	467450.1875	993033.8138	PAS	Above 150 meters
123	Goldmark P.L.C	NOC	LEMI KURA	/5/	SUMIT 72	485405.75	995452.2814	PAS	Above 150 meters
124	MARKOS LAKEW	PETROL	LEMI KURA	/3/	SUMIT 72	485271.2188	995367.0471	PAS	Above 150 meters
125	MERIF PETROLEUM	DALOL	LEMI KURA	/10/	SUMIT 72	485279.375	995465.878	PAS	Above 150 meters
126	MR x	NOC	NIFAS SLK	/06/	Gofa NOC	472304.1875	990999.1582	SAS	Above 150 meters
127	Mry	NOC	KIRKOS	/11/	BEKELO BET NOC	473455.4375	994209.7617	PAS	Above 150 meters
128	MR z	TOTAL	KIRKOS	/02/	BEKELO BET TOTAL	473425.4375	994471.3789	PAS	Above 150 meters
1	Mr. a	TOTAL	KOLF	/07	BETHEL FUEL STATION	4657	9951	CS	Above 150

No_	OWNER NAME	TRADE NAME	SUBCITY	WOREDA	LOCAL_NAME	X coordinates	Y coordinates	ROAD TYPE	distance from traffic intersection
29			E KERANIO	/		09.9063	24.78		meters
130	Mr. b	NILE	NIFAS SLK	/01/	LEBU ST ARSEMA CHURCH	470458.375	989437.9996	PAS	Above 150 meters
131	MR c	TOTAL	A/KALITI	/08/	AKAKI STADIUM	475238.9688	982584.206	PAS	Above 150 meters

Annex 4 Data collection Form

Data Collection Form for M/M/S Queuing System.		
Date of data collection ___________.		
Data collector name: ________________________________.		
Fuel Station location		
Name of Fuel Station Owner		
Address: longitude:		Latitude:
Sub city:	Woreda:	Local name:
Trade Mark:	Road type: ☐ PAS ☐SAS ☐CS	
Distance from traffic intersection		
☐Greater than 150 meters ☐ Less than 150 meters		
DATA COLLECTION		
Start Time:		End Time:
Number of servers:		
Arrival rate:		
Service rate:		
Additional Notes and Comments		