UNIVERSITY FOR DEVELOPMENT STUDIES

ASSESSMENT OF FIRE RISK VULNERABILITY OF THE TAMALE METROPOLITAN AREA OF GHANA

MAVIS ADAGYINNE AYAMGA

2023

UNIVERSITY FOR DEVELOPMENT STUDIES

ASSESSMENT OF FIRE RISK VULNERABILITY OF THE TAMALE METROPOLITAN AREA OF GHANA

BY

MAVIS ADAGYINNE AYAMGA

(B.Sc. Agricultural Technology)

(UDS/MES/002/19)

A THESIS SUBMITED TO THE DEPARTMENT OF ENVIRONMENT AND SUSTAINABILITY SCIENCES, FACULTY OF NATURAL RESOURCES AND ENVIRONMENT IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN

(ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY)

APRIL, 2023

DECLARATION

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere:

Candidate:

Signature:..... Date: 4TH JULY, 2022

MAVIS ADAGYINNE AYAMGA

Supervisors

I hereby declare that the preparation and presentation of the thesis was supervised following the guidelines on supervision of thesis laid down by the University for Development Studies.

Principal Supervisor

Signature:..... Date: 4th July, 2022

PROF. EBENEZER OWUSU - SEKYERE

Co-Supervisor

Signature:..... Date: 4th July, 2022

DR. ZIBLIM ABUKARI IMORO

ABSTRACT

In the last three decades, devastating fire disasters have challenged the ability of city authorities in Tamale to protect lives, property, and the city's fragile ecologies. Available studies on the phenomenon have often focused on effects and build-back processes after fire disasters have occurred. There have therefore been urgent calls on researchers to extend research on fire disasters to cover their complex nature and how they can be minimized. This research therefore maps fire risk zones and assesses fire risk vulnerability in the Tamale Metropolitan Area using the mixed method approach. The fire risk zones were mapped using Geospatial Techniques while multistage sampling techniques were used to select 196 households from five residential categories to participate in the survey. This was supplemented by in-depth interviews with heads of fire management institutions. The results show that the fire risk zones were found Aboabo, Sakasaka Lamashiegu, Sabonjida, Zogbeli, Tishigu, Shieshegu, Kalpohini, Koblimahagu, Kukuo, Fuo, Old Vittin Duhinnayili, Choggu, Gumani, Gumbihini, Nyohni, and Kanvili Among the factors that contributed to increased fire risk vulnerabilities were unauthorized electrical connections, congestion, lack of exits and access routes, inadequate fire hydrants among others. It also emerged that limited collaboration and coordination among state entities in charge of disaster management heightened fire risk vulnerability in the city. The research recommends that for Tamale to be counted among cities with limited vulnerability to fire disasters in Ghana, it will not only be vital to strengthen fire disaster risk reduction policies, but more importantly the policies should be matched with the appropriate institutional structures with the political will and capacity to provide risk reduction interventions.

ACKNOWLEDGEMENT

This thesis would not be possible without the assistance, encouragement, and inspiration of many people. First and foremost, I would like to extend my sincere gratitude to my supervisors, Professor Ebenezer Owusu-Sekyere and Dr. Ziblim Abukari Imoro, for their perseverance, inspiration, enthusiasm, vast knowledge, and, most importantly, for their inspiring suggestions and insightful comments, which were invaluable for the development of this thesis's content. I want to thank everyone at the Faculty of Natural Resources and Environment, especially the members of the Department of Environment and Sustainability Sciences, for their unwavering support while I was a student.

Thirdly, I owe a debt of gratitude to Professors Saa Dittoh, Gustav Mahunu, and Dr. Richard W. N. Yeboah, who have served as a continual source of inspiration and enthusiasm throughout the entire period of my MPhil program as well as during the production of this thesis. I would especially like to thank my program mates for the information and skill exchanges that contributed to enhance my experience.

A special gratitude to the Chief Fire Officer, Management and Staff of Ghana National Fire Service for granting me the Opportunity to pursue further Studies. I equally acknowledge the support of the Northern Regional and District Commanders of the four fire stations in Tamale Metropolitan Area, the staff of NADMO, VRA, GWCL. TAMA, Statistical Service Department for providing me with the information and data from their departments. The assembly members and elders of the study communities. In addition, I sincerely appreciate the love and support that my family has given me throughout my studies, especially my mother, Madam Vivian Atarebuuro Ayamga, my siblings, and my daughter.

DEDICATION

I dedicate this piece of work to my daughter, Audrey Ayuuranzanga Ayamga and family.

Contents

LIST OF TABLES, FIGURES AND PLATES

CHAPTER ONE

INTRODUCTION

1.0 Background of Study

The world is witnessing some significant changes in society and the economy. Rapid urbanization and the emergence of various types of buildings in cities and marketplaces are the result of these developments. With advancements in corporate scale, architectural designs, and business climate, marketplaces have experienced major changes. It's worth noting that these improvements come with certain unintended consequences, such as fire dangers and hazards (Yang and Chen, 2014).

Fire has had a significant role in human culture and history. People used fires as a source of light in the past, and others sat around them at night to develop friendships and family relationships, as well as to ward off predators, which accelerated the evolution of early humans. However, it also presented significant risks and obstacles to the early inhabitants, such as the difficulties in starting and managing fire, as well as the possibility of burns and wildfires (Barnett, 2008). People nowadays utilize flames to cook their meals and perform other necessary tasks. The ability of one's best friend to turn into one's worst enemy cannot be overstated, since poor fire handling and use has resulted in numerous accidents in homes, schools, and other public places, all of which have resulted in significant consequences (Ayarkwa et al., 2010).

Most English speakers are familiar with the adage that fire is a good servant but a poor master. This statement is brought to life by the World Health Organization (WHO), when it reported in the 2015 Global Health Estimates that; on a yearly basis, 265,000 people lose their lives to fire worldwide. Apart from the deaths, millions more are left

permanently disfigured yearly, due to burns from fires (WHO, 2015). The report further stated that 96% of deaths and injuries occur in low – and middle – income countries, of which Ghana is one. According to the Fire Service Bureau of Ministry of Public Security, in the year 2011 in China about 125,417 fires were reported with 1108 civilian deaths, 571 civilian injuries, and 2057 million Yuan (RMB) direct property loss (Xin and Huang, 2013). Building fires accounted for 52,661 of the fires mentioned resulting in 853 civilian deaths, 347 civilian injuries and property damages amounting to 309million Yuan (RMB) (Xin and Huang, 2013). In the United States, the National Fire Protection Association (NFPA) reported that, 481,500 structural fires were recorded in 2019 resulting in a total property loss of $14.8 billion. The NFPA reported that they responded to fire outbreaks every 24 seconds on the average (Insurance Information Institute, 2021).

Ghana has not been spared in recent years when it comes to these significant changes in society and the economy, and as a result has been confronted with disasters. Owusu-Sekyere et al., (2017) recount some of Ghana's most noteworthy tragedies with terrible results over the decades: the cholera outbreak in 2014 that directly impacted more than 22,000 people and killed more than 200 lives in 5 months (May-September 2014; Ghana Health Service [GHS], 2014); the fire at the Central Medical store in 2010; the earthquake in James Town and its surroundings in 1939 that recorded 17 fatalities (Amponsah, 2004); the 2010 floods in Accra and Swedru that claimed 42 lives; The whole warehouse was destroyed by the fire, which also destroyed apparatus and pharmaceuticals. And the June 3, 2015, twin disaster (flood and fire disaster) which occurred at the Kwame Nkrumah interchange in Accra of which more than 158 people

lost their lives (Owusu-Sekyere et al., 2017). Such events serve as sharp reminders that disasters can leave an indelible effect on human development (Songsore et al., 2009), and they highlight the importance of disaster risk mitigation and improving adopting ability to cope with fire disasters as important governance concerns (Popoola et al., 2016).

Fire outbreaks in Ghana are not a new thing. As far back as 1983 a fire outbreak in Ghana caused so much havoc which led to the popularly known '1983 famine' (Sam-Okyere, 2010). Today, fire breakouts are widespread, and scarcely a day goes by without news of fire outbreak in some region of Ghana, prompting a suspicion of sabotage, bad luck, and religious differences (Ayarkwa et al., 2010). The question that must be answered is, "What is the true cause of these recent fire breakouts throughout the country?" Many causes have led to the occurrence of this problem and the risk that it entails. Many reconstructed buildings have low fire-resistant materials, a large fire load and hazard, insufficient information on fire safety management and poor fire safety management practices and awareness, a significant electricity load and insufficient information on how to use electrical appliances, blocking of escape routes makes it difficult to put out fires, and narrow evacuation exits are just a few examples (Yang and Chen, 2014). According to Anaglatey (2013), electrical problems caused by defective wiring, improper usage of electrical gadgets, and other factors are the leading cause of fire breakouts in Ghana (Anaglatey, 2013). Most of these electrical works in people's houses are not done by competent electrical engineers, resulting in problems later (Simpson, 2010). These causes have been responsible for the frequent occurrence of serious fires in recent times. Several measures have been implemented in different places of the world to reduce the damage caused by fire. These include the development of fire departments,

insurance, fire safety education, building design to reduce the impact of fires, and controlling the usage of electrical equipment in buildings, among other things. The Ghana National Fire Service (GNFS) oversees preventing and managing undesired fires in Ghana while management of victims is the responsibility of the National Disaster Management Organisation (NADMO). Furthermore, because of the delegation of political, administrative, and legislative powers to the Metropolitan, Municipal, and District Assemblies (MMDAs), the MMDAs are in charge of developing regulations to prevent disasters and mobilizing financial and technical assistance to aid in the recovery of disaster victims. Section 15 of the NADMO Act, 1996 (Act 517) encourages the institutions to work together to improve coordination and effectiveness.

Even though these agencies were established by law with various tasks and responsibilities, it is the strong and effective joint efforts of these institutions that are required to handle disasters. The Ghana National Fire Service (GNFS) has often been chastised and attacked by the public for its slowness, failure to respond to emergencies quickly enough, or arriving at scenes without adequate water (Daily Graphic, 2014). The GNFS, on the other hand, blamed their inability to properly put out a recent fire outbreak at the Makola market in Accra on the non-functioning and lack of water in fire hydrants placed within the Central Business District (CBD)

(myjoyonline.com, 2021). As a result, the GNFS and the Ghana Water Company Limited (GWCL) is entangled in a blame game. All of these blame games undermine the intent and implementation of the Hyogo Framework for Action by treating disaster risk management, which should be considered as a communal obligation, as an individual affair by various state entities. (Owusu-Sekyere et al, 2017).

Managing fire risk in marketplaces, apartments, and other structures is difficult since it typically involves large buildings, a large population, a lack of fire safety management, flammables, complicated electricity (including illegal connections), and gas consumption. Thus, fire risk assessments must be implemented to reduce fire risk, suitable fire safety management information and guidance must be provided, and fire risk mitigation measures must be implemented. The fact that 10 of the 17 Sustainable Development Goals (SDGs) are linked to the need to reduce disasters is unsurprising. As Ghana strives to achieve a long-term, effective disaster risk preparedness as outlined in the Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goals, particularly Goal 11 (making cities and human settlements inclusive, safe, resilient, and sustainable), strenuous efforts are required.

1.2 Problem Statement

There is a need to recognize assets at risk and establish more efficient and productive risk reduction techniques is continually being brought to the attention of the scientific, technological, and political communities by terrible disaster events that occur across the world. This reality has grown even more apparent in urban areas where the effects of these disasters are more severe because of uncontrolled growth and inadequate government administration. The idea that municipal management typically reacts to crises and prevention is an underrated tactic is another factor that contributes to this reality. The majority of technical, institutional, and financial resources are really frequently concentrated on post-disaster operations, leading to a lack of information on pre-disaster preparations and precautions. In 2013, approximately 11000

Ghanaians were hit by fire outbreak which led to loss of property worth about $7 million

(Tulashie et al., 2016; Simpson, 2010). A report by the Ghana National Fire Service showed that 10 people died as a result of bush fires in the Northern Region of Ghana with 145 sustaining different degrees of injuries in 2016 (www.newsghana.com.gh). The causes of fire outbreaks have been linked to a variety of factors. According to Pantuliano et al. (2012), fast urbanization promotes humanitarian disasters such as fires in urban settings, population growth, and illegal and poor electrical connections, among other things. In Ghana, and by extension the Tamale Metropolitan Area, one of the country's five major cities and West Africa's fastest growing city, residents face these challenges, indicating that they are at risk of fire outbreaks. As a result, there is an urgent need to learn about residents' perceptions of the causes of fire outbreaks. For example, while the Northern region of Ghana had 277 fires in 2013, the Tamale Metropolitan Area alone was responsible for 212 of them.

Several studies have been undertaken into the causes and effects of fire outbreaks in Ghana but there is inadequate information on the vulnerability of fire risk in the cities and variables that increase the area's exposure to fire catastrophes. For example, Banyeh and Adda (2021) explored fire incidence in Tamale by focusing on spread and extent of damage. The vulnerability, historical trends, and challenges in fire disasters were not examined which this study seeks to examine. Sebbeh- Newton (2018) examined fire preparedness and emergency response in

Tarkwa, which is in a different setting compared to this research, with different objectives. Boakye (2017) studied emergency fire response in Ghana by using Kumasi as a case study which is also in a different setting as compared to this research. Sarpong (2013) sought to determine fire risk vulnerability in Ashaiman which is also in a different setting as compared to this research. Finally, Agyemang (2015) examined fires in the

dry forests of Ghana, frequency, management and effects. The study was done countrywide, whiles this research focuses on the Tamale Metropolis. The current study is motivated by the research gap to assess the vulnerability of fire risk of Tamale Metropolitan Area of Ghana by providing answers to the questions posed in the study.

1.3 Purpose of the Study

The purpose of the study is to assess fire risk vulnerability of the Tamale Metropolitan Area.

The specific objectives are to

1. Map out fire risk zones in the Metropolitan Area
2. Assess the historical trends and perceived causes, and factors influencing fire disasters in the study area
3. Examine fire disaster management strategies in the study area
4. Ascertain the challenges confronting fire disaster response in the Metropolitan Area

1.4 Research Questions

The study was guided by the following research questions:

1. Which parts of the city are at risk of fire, and what factors contribute to their vulnerability?
2. What have been the historical patterns and perceived causes of fire disasters in the Metropolitan

   Area?
3. What type of fire disaster management system has been put in place in the research area?
4. What are the challenges in the study area when it comes to fire disaster response?

1.5 Significance of the Study

The problem of people's and their property's vulnerability to fire disasters should be seen as a critical governance issue. As a result, it is a source of worry for responsive governance, which might be addressed by lowering susceptibility and implementing measures to improve the adaptive capacity to cope with fires. Building on the foundations of the Millennium Development Goals (MDGs), which highlighted the importance of disaster risk reduction (DRR) in the 15 years since their implementation, the Sustainable Development Goals, which are currently the new development agenda for the global community, emphasize the need for disaster risk reduction integration in order to achieve 10 out of the 17 goals. It is more important than ever for government mandated institutions, particularly at the local level, to take vital steps toward DRR in structures and programs to assure effective developments aimed at attaining inclusive, safe, resilient, and sustainable city development. An assessment of fire risk vulnerabilities provides a vital foundation for authorities, stakeholders, and the TaMA, allowing them to gain a better understanding of the Tamale Metropolitan Area's vulnerability to fire disasters. Authorities and stakeholders can use this information to identify places where fire protection systems might be improved to reduce vulnerability and increase adaptive capability. Finally, the study not only lays the groundwork for future research, but also adds to the literature and dialogue on the dangers of constant fires to national growth.

1.6 Limitations of the Study

Because of the differences in geographical location, literacy levels, financial situation, religious and cultural influences, a generalization of the findings for all Areas may not

be a possible or true portrayal. As a result, the conclusions of this study are limited to those based on prior literature and primary data acquired in the field. The researcher had difficulty finding crucial informant interviewees, which resulted in the length of time it took to collect data for the study to be extended. Since some of the fire victims were still recovering from their injuries, it was difficult to convince them to agree to an interview.

1.7 Organization of the Study

Five chapters make up the organization of the study. The study's overall orientation is provided during the first chapter. This includes an introduction, problem statement, list of objectives, description of research methodology, and justification for the entire exercise. A thorough review of the data as well as the theoretical underpinnings of fire risk vulnerability is presented in Chapter 2. It took into account and reviewed earlier research on the issue, identifying any gaps that needed to be filled. The study neighborhood's profile is discussed in chapter three, and the analysis, presentation, and interpretation of the field measurements are covered in chapter four. It entails gathering field data for analysis, employing particular methods for data analysis, and presenting a debate based on the organizational viewpoint on the issue. The original study summation is presented in chapter five, which is also the closing chapter. Then, conclusions are reached along with suggested fixes for the issue.

1.8 Operational Definitions

1.8.1 Vulnerability

An internal risk factor of the subject or a system that is exposed to a hazard is described as vulnerability and corresponds to its inherent propensity to be affected or vulnerable to damage. It depicts a community's ability to absorb and sustain effects as well as its

physical, economic, and social sensitivity to harm in the event of dangerous natural and man - made situations (Emrich and Cutter, 2011; Cardona, 2003).

1.8.2 Hazard

Hazards are described as "events or physical conditions that have the ability to cause deaths and injuries, injuries, property destruction, infrastructure investment malfunction, farmland loss, environmental harm, interference of business, or other different kinds of loss or injury" by the Federal Emergency Management Agency (FEMA) of the United States (Coppola, 2007: 24).

1.8.3 Risk

Risk is characterized as a circumstance when danger is present (McKean, 2005). It is defined as the potential for negative effects or anticipated losses stemming from interactions between hazards caused by the environment or by humans and vulnerable situations. However, risk is frequently stated as the sum of vulnerabilities and hazards in the domain of hazards and catastrophe study (Gencer, 2007).

1.8.4 Disasters

According to the International Federation of Red Cross (IFRC), a disaster is a sudden, catastrophic event that sincerely impairs a community's or society's capacity to perform and results in losses to people, property, and the surroundings that are greater than what the community or society could reasonably expect to be able to recover from using its own resources. Disasters can have anthropogenic causes even if they are frequently caused by nature.

1.8.5 Disaster Risk

The possible hazardous losses to a social system over a certain time period. As a result of lives lost, health status, occupations lost, assets lost, and services lost (UN/ISDR, 2009).

1.8.6 Disaster Risk Reduction

Subjected to a number to hazards, decreased vulnerability of people and property, sensible land and resource stewardship, and increased preparations for adverse reactions are only a few examples of the idea and implementation of disaster risk reduction (UN/ISDR, 2009).

1.8.7 Coping Strategies

Coping mechanisms, according to Catherine T. MacArthur (University of California, USA), are the particular behavioral and psychological actions people take to control, tolerate, lessen, or limit stressful situations. There are two main types of coping mechanisms: While emotion focused coping methods aim to control the emotional effects of stressful or possibly stressful events, dilemma strategies attempt to take some concrete action to lessen unpleasant situations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Introduction

The chapter review existing literature on fire risk vulnerability. The review is structured into three main sections. The first section reviews theoretical literature on the subject matter. The second section review empirical literature on the subject matter. The third section reviews general observation of fire in the world. The fourth section reviews general observations of fire in Ghana.

2.1 Review of Theoretical Literature

2.1.1 Fire risk analysis process of buildings

The product of the likelihood that a fire will occur and the severity or amount of the destruction that can be anticipated as a result of a fire is known as fire risk (Watts and Hall, 2002).

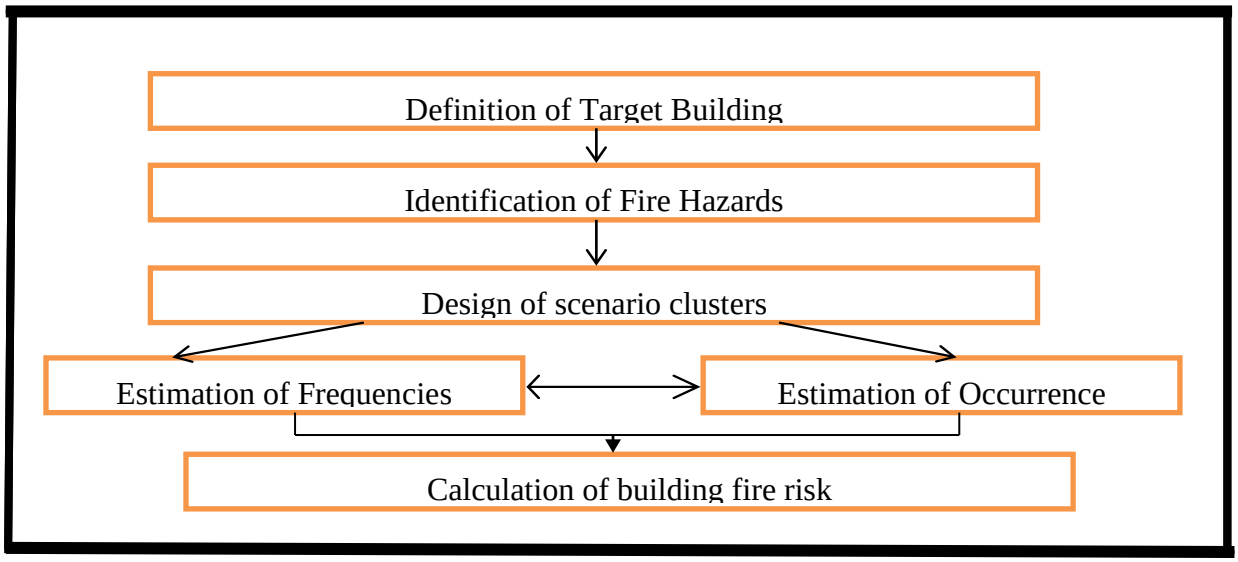


Fig. 2.1 Flow chart of fire risk analysis of buildings
Source: Xin and Huang (2013)

It depends on three things: the decline or damage of doing something valuable (for instance, life, real estate, contingency planning, heritage, the environment, or some combined effect of these), the scenario that could result in the loss or damage, and an assessment of the likelihood that the loss or injury will occur.

2.1.2 Definition of the target building

Getting pertinent data from the targeted building is the initial step. The size, location, architecture, procedures used inside the property, fire safety preventive systems, the type and likely condition of residents, and details on the fire department, such as the proximity to the innovation efforts, are all necessary pieces of information relating to the constructing.

2.1.2.1. Identification of fire hazards

The method involves selecting fire dangers involves acknowledging their existence and describing their features. The design fire's location, the building's occupancy at all times, the state of the system of the fire protection systems system, and the presence of fire sprinklers all need to be taken into consideration.

2.1.2.2. Design of fire scenario clusters

A group of related fire accidents is referred to as a "fire scenario cluster." To ensure that all the necessary compounds are present, it might divide the world of potential fires into a manageable number of scenario subsets (John, Hall, and Sekizawae, 2010). A fire scenario is a series of fire incidents connected by the success or failure of particular fire protection measures (Custer and Meacham, 1997). A fire event is an occurrence that is connected to the start of a fire, its spread, the dispersion of smoke, tenant behavior, or the response of the fire department (Yung & Benichou, 2003). Three fire scenario

clusters a fire scenario cluster, a fire automatic suppression scenario cluster, and a behavior patterns cluster can be regarded as crucial to the comprehension of fire risk assessment in order to support estimations of occurrence and consequences (Schröder, 2018). The entire fire scenario cluster, including the design fire curve and many other factors that affect the fire's environment, such as compartments geometry and characteristics, the size of the fire source chamber, and the thermal characteristics of the partition boundary, must be specified (Margrethe, Helsloot, Vries, & Pot, 2010). Design fire curve refers to the idea that additional information, such as the site of genesis of the fire and its growth rate, is necessary for a complete description (Society of Fire Protection Engineers, 2006). The fire automated suppression scenario cluster explains the process of suppressing a fire, either by putting it out or containing it from spreading by employing, for instance, construction engineering expertise. The starting condition of smoke control systems (Klote, 2002), fire sprinklers (Madrzykowski, Bryner, & Kerber, 2006), and fire detection and warning systems (Bukowski, Peacock, Averill, et al., 2007) would all be incorporated and might create several firefighting situations. In the instance of fire outbreaks, the behavioral scenario cluster depicts how inhabitants act in reaction to the start of the incident and the arrival of fire and rescue personnel. Location, personality, knowledge, experience, observational and decision-making skills, mobility, awareness, jobs or

responsibilities in buildings, and familiarity with the layout of buildings are all factors that affect how people behave (Babrauskas, Fleming, & Russell, 2010). Intervention time, crew number, and defensive water resources are important variables affecting fire brigade involvement (Australasian Fire Authorities Council, 1997; Merchant, Kurban, & Wise, 2001).

2.1.2.3 Estimation of frequencies

Based on three scenario clusters created it during fire evaluation process in building structures, the frequency of occurrence of an accidental fire that develops in a building's ground area A over the course of a year is determined by the ignition frequency (P1), the likelihood that an automatic extinction system will fail to put out the fire (P2), and the likelihood that users or even the fire department will fail to put out the fire (P3) (P3).

$P_f = \boldsymbol{P_1}\, \boldsymbol{P_2}\, \boldsymbol{P_3}$

2.1.2.4 Estimation of consequences and calculation of fire risk

Building fire repercussions include more than only occupant deaths; they also include lost property, lost revenue, and other things due to flames. The effects of building fires are limited in this essay to those brought on by resident fatalities and intentional property damage. Statistics on fires can be used to determine the number of passenger fatalities and the destruction of important property for various building types. The building's fire risk is then calculated using Equations (2) and (3), for example, the predicted risk to the lives of the residents and the anticipated loss of important property (3).

2.1.3 The impetus for understanding fire in the built environment

The prevention of urban firestorms and the concerns of the insurance market drove many of the foundational research in the field of fire in the building design. In the late nineteenth and early twentieth centuries, large urban fires partially devastated numerous American urban areas. The reaction to these incidents was primarily focused in the fields of engineering and public administration, which were engaged with, alternately, planning regulations and fire prevention services and fire safety measures in building design and practice (Jennings, 1999; Rosen, 1986). Despite this lengthy history,

disciplinary isolation and fragmentation of research on burning in the communal based guidance have persisted.

Fire is a social and physical phenomenon, in fact. Fire surpasses the ordinary person and instantaneously impacts the built environment, which has an impact on community economic well-being and also the capabilities of different buildings and the neighborhoods they are located in to serve as healthy and productive hubs for human activity, which would include societal procreation and economic sustainability and advancement. After the conflagration issue was under control, there was gradual improvement in the decrease of catastrophe losses, particularly in non-residential structures like manufacturing operations that were subject to additional regulations from the government, insurance, and industry authorities. Despite these developments, residential fires remained to cause serious harm to those who live in these buildings and attracted a lot of attention.

2.1.4 The history of residential fire research

A wide range of academic fields have historically paid little or no emphasis towards the knowledge of home fires. As a result, a lot of work was completed in isolation by discipline with little to no follow-up. The history of funding for social research into home fires will indeed be examined in this section of the essay along with the interdisciplinary and methodological focus of these early initiatives.

2.1.4.1 United States federal government role

The release of America Burning, the 1973 report of the National Commission on Fire Prevention and Control, may be considered the main impetus for research into home fires in the United States. The then-federal government's strategy towards the urban fire

dilemma was reorganized as a result of this report, which was written by a Congressionally appointed panel comprised of a range of stakeholders in the fire problem. It also made the public aware of the lack of understanding needed to develop therapies to even further start reducing the fire problem.

However, the Fire Research and Safety Act of 1968 (PL 90-259), which was the source of both this report and the Commission, was responsible. The increase in fires that took place in the late

1960s in connection with racial unrest, urban economic deterioration, and prominent high-profile fires undoubtedly had an impact on the enactment of this Act. President Lyndon Johnson emphasized the high fire loss numbers for the US, out-of-date firefighter methods, and the necessity to launch a coordinated fire research facility in his signing statement for the Act establishing the Commission (Johnson, 1968). According the Commission's preliminary assessment, fires cost as much as crimes do, hence they "need the major attention of the people and authorities at all stages" (National Commission on Fire Prevention and Control, 2013).

Institutionally, the Department of Commerce established the National Fire Prevention and Control Administration (NFPCA) in response to a 1974 federal law. The Department served as the National Bureau of Standards' (then) fire laboratory for the federal government. This bureau's won awards include the creation of a national network for gathering fire data from local fire departments and the launch of a well-funded multidisciplinary research initiative to better comprehend the scope of the fire problem. The NFPCA was transformed through into United States Fire Administration within several years, while at the same time, its financing was substantially reduced, which

significantly decreased sociological theories into the home fire issue. The funding of academic fire research in a similar fashion was never done again on the same scale.

2.1.4.2 Limitations of early research

Much of the early work in this field was performed during a short time period and was predictably explorative due to the government funding granted in the short time between the NFPCA's inception and its later reorganization and budget reductions (Jennings, 1999). Due to the parallel nature of much of this research, there was little chance to draw lessons from earlier work. Furthermore, with the introduction of the National Fire Information Reporting System, accurate national data were that only became accessible in the United States (NFIRS) (Ratushny, et al., 2019). Moreover, the development of personal computers and contemporary geographic information systems had not yet occurred, so the simplicity through which data sources could be combined was significantly constrained.

Studies on the relationship between social, economic, and building stock factors as well as the geographic elements of the fire problem were time-consuming, expensive, and frequently required manual mapping (Ratushny, et al., 2019). The majority of these early research had to be descriptive in character. Some research analyzed statistical relationships between different facets of the population and building stock and fires. Multiple regression was used in more comprehensive research to investigate the relationships between these traits and different conceptualizations of fire danger. Although some research was completely theoretical and explanatory, others drew their conclusions from current theories or beliefs (Pan & Zhang, 2020).

2.1.5 Historical Research on Fire Incidences

These pioneering studies made clear that flames were neither inevitable nor "acts of god," but instead could be avoided. There was systematic diversity in the type and intensity of the fire hazard throughout urban centers, which contributed to the fact that the incidence or burden of these fires was not spread consistently or randomly (Pan & Zhang, 2020). To create insightful hypotheses, ecological techniques to analyzing fire danger were utilized (Amos, 1986). Urban planning literature first discussed these early ecological approaches to fire risk, frequently in relation to housing characteristics and neighborhood population density. Gunther (1981), Karter & Donner (1977), and Munson & Oates are a few examples of such works (1983). The ecological method was successful because it acknowledged the intricate network of organizational, economic, technological, and human elements that interact with the constructed environment by creating fire losses (Pan & Zhang, 2020). Associations between unemployment and living conditions were often recognized as being connected with higher incidences of fires in apartment complexes, despite conflicting findings across research. Factors in the neighborhood, such as the functional or financial obsolescence of dwelling units, may increase the danger of fires, arson, and property abandonment. (1990; Cloninger; John & Balzer, 2013).

Wallace & Wallace (2011) independently created an amazing body of literature connecting fires to additional harmful effects, such as poor public health. They postulated that unregulated fires could cause social circumstances that would erode community trust, resulting in a downward spiral and increased fire danger (Liu, Chen & Chen, 2021). Particularly, overpopulation puts additional strain on the infrastructure of

buildings, increasing the frequency of fires brought on by mechanical flaws (Wallace, 1981; Wallace & Wallace, 2011). Sternleib discovered that these fire-damaged structures had a high desertion rate (Sternlieb & Burchell, 1973). The influences of social structure, household income, housing stock, and broader societal factors were captured by these studies utilizing a variety of metrics. Numerous studies also revealed a connection between the family type (single parent households with young children) and the frequency of residential fires. The hypothesized links between greater fire incidence, poor or congested housing, and poverty were generally demonstrated (Fahy & Miller, 1989; Schaenman et al., 2017; Southwick & Butler, 2015).

Munson and Oates found a connection among wealth and the capacity or willing to exert a safety gear investment. The idea of positive income elasticity of demand for expenditures like smoke detectors was recognized. That is, having a higher income increases the likelihood that you will maintain your safety equipment (Musson & Wallace, 2013). A small number of preliminary studies that show promise looked at the psychological mindsets of people neighborhoods with high with a high fire incidence (Liu, Chen & Chen, 2021). According to research done in New Orleans by Bertrand and McKenzie, locals experienced low communal harmony and have had low aspirations for the future of their communities. These results confirmed research conducted at about that time in the UK by Chandler et al (Chandler, Chapman, & Hallington, 2014).

Numerous studies have broken down fires by cause and discovered intriguing differences across precincts in high- and low-income communities (Ducic & Ghezzo, 2010; Gunther, 2011). These researches may help develop specific strategies to address particular fire scenarios and provide greater understanding of particular causes. These pioneering

researchers discovered that the mediation effect of their multivariate regression-based models was stronger at the census tract level, highlighting the significance of scale in identifying and understanding variation in fire rates (Karter & Donner, 2017). Early research efforts firmly established that fire incidence changes consistently in relation to inhabitants' social and economic attributes, and secondarily in relation to housing and community circumstances. Although there are many ways that implement these characteristics, the early studies provided a solid framework for thinking about moving beyond investigation to explanation (Liu, Chen & Chen, 2021).

2.1.6 Geographic Information Systems and Fire Incidence Research

In the past fifteen years, there has been a slight uptick in interest in residential fires and dangers related to socioeconomic and, to a smaller extent, building stock factors. The timing of this study corresponded with the development of geographic information systems (GIS) software, which enabled researchers to easily integrate various types of data. The introduction of GIS as an analytical tool by academics in this field has unquestionably resulted in the biggest advancement in research on home fires. Through improvements in processing power and statistical software, geographical statistics are being enhanced, which is a parallel and related development. These have made it possible to manage huge amounts of data, leading to the development of more complicated statistical methods and models. Spatial statistics and geographic information systems (GIS) have lately emerged as new tools for field study. As a result, academic interest in the concept of residential fire in the urbanized built environment and its connection to social and economic situations or resident characteristics has grown recently.

Research on social and economic factors and fire risk is ongoing. These studies set themselves apart from earlier ones by moving beyond exploratory studies to interpretation and placing more attention on developing correlations between fire incidence and other traits found in earlier studies. These investigations have taken place in various contexts and have come from various disciplinary viewpoints. Shai used multiple regression analysis to research fires in Philadelphia and forecast fire injuries at the census tract level. She discovered substantial findings for factors evaluating the age of housing, income, and non-English speaking community using the accident rate relative to population of each tract. A substantial connection existed between oldest continuous with low income. Additionally, a number of specific fire situations as well as community consequences of abandoned housing increasing the risk of injuries were noted (Shai, 2016).

In Toronto-Canada, Asgary et al. (2010) looked at the temporal and spatial aspects of structural fires. They gave an example of how GIS may help with data display and analysis. They manufactured maps of spatial concentration utilizing support vector machine algorithm, and they plotted tragedies by time of day and month of every year utilizing 6 categorizations of fires: misuse, electrical and mechanical failures, vandalism, deficiencies in design, fabrication, or maintenance; arson, and children playing (in decreasing frequency). They discovered that there were distinct patterns in both location and time that changed depending on the fire types under study. Furthermore, they created a number of presentation approaches that allowed for replication (Asgary et al., 2010). By utilizing the spatial characteristics of GIS, several other investigations created more sophisticated analytic approaches. These studies are more sophisticated than previous

ones and provide opportunities for deeper explanation that are not available in earlier research. The specific studies will be discussed here because they are so recent and because they improve upon the methodologies employed in the past. In Baltimore, Maryland, Schacterle et al. (2012) investigated how unoccupied buildings affected the frequency of fires. Buildings that are vacant increase the risk of fire spreading to other premises since these fires are more prone to do so. The distance between unoccupied properties and houses damaged by fire was evaluated by Schacterle et al. (2012) in order to separate between the simple existence of vacant homes in the population group. They discovered statistically extensive proof that vacant properties increased the fire hazard for properties within 100 m and that the danger increased the closer a building was to an empty property by geocoding both fires and vacant residences. Owner occupancy of homes was linked to risk unfavorably in their study (Schacterle et al., 2012). They were able to unequivocally prove the connection between abandoned housing and fire danger by utilizing GIS and a large data set. This connection was once only an association, frequently at the local level.

In recent years, various research using GIS and spatial statistics have been reported by Corcoran et al. (2017). They have made substantial progress and are creating their own body of work, which holds enormous promise for deepening knowledge and setting methodological standards for subsequent research. The use of GIS within the fire services was first investigated by Corcoran et al. (2017), who then used this technology to analyze fire issues. GIS techniques were utilized the depict the frequency of flames against geographic areas or other proxies of the population at risk using the spatial statistic of kernel density estimation. They were able to link socioeconomic traits to the

risk and spending enough time of particular types of occurrences by classifying serious accidents according to category (Corcoran et al, 2017).

In a different study, Corcoran et al. also employed co-plots and co-maps to present the data on fire incidents along their x and y coordinates and also including some dependent variables, in this case, the time of day. Additionally, they used kernel density estimation to get beyond the effects of imposing administrative boundaries on data visualizations, which could hide patterns in the data (Schröder, 2018). They were willing to show how the approaches can help in understanding and displaying trends in information through breaking down fires by category (location, cause, etc.) and studying their temporal and spatial patterns (Corcoran et al., 2017). Corcoran et al.

(2017) evaluated census socioeconomic data against fires by kind to examine the events of Brisbane (Australia) and Cardiff (UK) in comparative research. They created composite variables using the data both from cities and relied on already-developed social poverty indexes from the census. Among these composites were family structure, the availability of automobiles in the home, the length of the property lease, ethnicity, level of education, and the kind of dwelling.

Composite laminates measurements were meaningful for each of the fire types examined building fires, car fires, secondary (outside) fires, and malicious false alarms when data from both cities was analyzed using singular value decomposition. Corcoran et al. (2017) evaluated census socioeconomic data against fires by kind to analyze the events of Brisbane (Australia) and Cardiff (UK) in comparative research. They created composite variables using the data from both cities and relied on already-developed social deprivation indexes from the census. Among these composites were family

structure, the availability of automobiles in the home, the length of the property lease, ethnicity, level of education, and the kind of dwelling (Biabani, Fotouhi & Yazdani, 2020). Different composite measures were significant for each of the fire types examined building fires, car fires, secondary (outside) fires, and malicious false alarms when data from both cities was analyzed using principal component analysis (pca). Even though there were variations between the two locations, they observed links between social poverty and the majority of incident types (Jennings, 2011). Southeast Queensland, Australia, building fires were studied by Chhetri et al. in 2010. They connected socioeconomic disadvantaged to fire occurrence using both regression analysis and ANOVA using data on socioeconomic factors from the Australian Bureau of Statistics. In order to forecast fire rates, their regression model discovered five factors: unemployment, indigenous population, one-parent couples with kids, and a low percentage of households living in independent (detached) buildings. Every term was statistically significant, and the model's total R-squared was 0.45. Chhetri et al. (2010) constructed the index of social deprivation and compared it across census areas using about twenty-two socioeconomic factors. First, the socioeconomic traits of these locations were contrasted. Between the high-incidence and low-incidence groups, there were found to be statistically significant differences in socioeconomic traits. Fire incidence and socioeconomic status were found to be negatively correlated. There were more fires in areas with poor socioeconomic level (Biabani, Fotouhi & Yazdani, 2020). According to the frequency of fires, these locations were categorized, and the tendencies remained. They looked at the number of fires and the properties of the homes in these areas (Chettri et al., 2010). Recent studies are building on earlier ones and showing the value that spatial statistics and GIS can add to the study of data on house fires. These

investigations have made it easier to analyze data using techniques that have a finer resolution than multiple regression, which predominated earlier research. The usage of GIS is beneficial for displaying data that policymakers can quickly use. Additionally, GIS has the ability to act as a unifying platform for many disciplines to conduct analysis and maybe merge different lines of inquiry (Kamari, Kirkegaard & Schultz, 2021). A formal, experimentally supported theory of differential fire incidence can now be developed.

2.1.7 Conceptualizing Causes of Residential Fire Incidences

To learn something about rising fire rates in low-income communities of urban areas, Gunther (1981) examined fire-cause trends in Toledo, Ohio, neighborhoods. He divided the census data for Toledo into five groups, with its own set of racial and socioeconomic characteristics. Regression analysis was used by Gunther to demonstrate that there was a substantial inverse relationship between income and fire rates (Kamari, Kirkegaard & Schultz, 2021). However, it declined in the two census tracking regions with the highest median salaries, where fire incidences already were tending to have a lower, as income grew. Similar to this, he found that income was strongly correlated with four of the eight fire causes he examined: mysterious or incendiary fires, smoking, cooking, and children playing with fire. According to regression analysis, each of these characteristics markedly expanded the fire rate for census tract groups with lower average salaries. Significantly, each of these causes is frequently related to human behavior but instead of technical failure. This demonstrates that the most practical method for lowering the frequency of these kinds of fires is public education (Hosseinnia, Khakzad & Reniers, 2018).

The other three fire causes investigated by Gunther were fires caused by heating sources, electrical distribution within a housing unit, and gadgets. He found that there was no discernible income effect on fire rates within these categories of fire causation. The bottom two percentile income groups had lower fire rates than the next richest households for heating fires, but there was no discernible difference between the five income groups for equipment fires (Kamari, Kirkegaard & Schultz, 2021). Gunther attributed the latter result to a higher proportion of households in the two income brackets living in private or public homes that had central heating.

The statistics clearly showed the effects of wealth on fire rates, but it was more challenging to identify the effects of race. Gunther found that the overall incidence of fires from all causes did not seem to be correlated with race after taking into consideration the effects of affluence (Hosseinnia, Khakzad & Reniers, 2018). Gunther asserted that the data for specific fire causes were less clear, but he was unable to provide any proof that race had a substantial effect independent of income. The foundations of a conceptual perspective for domestic fire occurrence are the single biggest development over the previous ten years. The scope and accurate formulation of risk must be considered in order to comprehend the creation of a theory of fire risk. Risk, for instance, can be quantified at various levels, including those of the individual, the home, the structure, and the area. Similar to how risk to persons or property can be thought of, so can risk from fire (Zhang, eta al., 2019).

Additionally, it might be measured in terms of monetary loss, harm, fatalities, or other types of casualties (injuries plus deaths). Depending on the amount of study, the dynamics of the fire risk may change. When attempting to draw conclusions about

household or individual behavior or risk from higher-level statistical data, researchers would have to be try to prevent making the ecological fallacy or cross-level inference (Achen & Shiveley, 2010). It is simple to confuse race with wealth as a proxy. For instance, according to the US Centers for Disease Control and Prevention, cigarette use is more common among people with low incomes. Those families must have a higher risk of fires due to the likelihood of smoking. Given the high cigarette consumption and increased fire danger and fatalities in low-income families, smoking may be a contributing factor (Zhang, eta al., 2019). Therefore, efforts to reduce tobacco use will also reduce the intended population's risk of fire. Without taking into account these behavioral or contextual distinctions, race risks being used as a blanket term for various characteristics that are prone to change (Hosseinnia, Khakzad & Reniers, 2018).

Jennings (1996) distinguished between fire initiation and fire loss using an analytical distinction. Consolidating past exploratory research, defining fire risk, and identifying the distinctive characteristics of fire start and fire loss were all goals of this work. Specifically, fire incidence, which is when a fire occurs, and fire losses (the resulting damage or loss inclusive of damage to the property, and injury to occupants of the dwelling unit or exposed properties). This difference was made as part of an effort to generalize knowledge of home fires across many settings and to acknowledge the significance of something like the physical environment, protective gear, and behaviors, such as fire control services, in estimating the loss from fire (Zhang, eta al., 2019). For a cross-cultural investigation of either the residential fire hazard, this conceptual strategy gives some hope. The method also made a clear distinction between fires brought on by deliberate human action and those brought on by careless or negligent behavior and

distant human action, such as electrical failures (Jennings, 1996). Four years of residential structure fire data from Memphis, Tennessee (USA), a city with a high rate of fire incidence and fire loss in comparison to national figures, were used to test Jennings' model. In order to understand the variation in fire incidence (expressed as fires/capita) across Memphis census tracts, Jennings created a four-variable model. Based on a survey of the literature and in accordance with the conceptual model, these four variables were chosen. (1) The percentage of unoccupied housing units; (2) The percentage of persons under the age of 16 or over 65; (3) The percentage of households with children managed by a single parent; and (4) The percentage of the population

(Herzberg, et al., 2019). These factors were picked because they were in line with the conceptual model and had a direct impact on the frequency of house fires. Due to their strong association with the other variables in the model, additional factors were dropped from the final analysis. For instance, Jennings found that income and schooling had a strong positive correlation, meaning that as education standards rose, so did income, making it necessary to exclude education from the regression analysis. A stacked least squares regression was used in the model, which explained 83% of the difference in fire rates across tracts (Jennings, 1996).

Concept	**Variable**
Building stock	Percent of vacant dwelling units
Social/household system	Percent of households headed by female single parents
Demographics	Percentage of population less than 17 or older than 65
Economics	Medium household income

Comparing this to earlier multiple regression models showed that it had more explanatory power and theoretical consistency. The notional fire start and fire loss model developed by Jennings in 1996 is shown in the figure below. For fires that originate

indoors (Class 1 and Class 2), the model shows interactions between four socioeconomic elements: structure stock features, social or home incorporating innovative, household demographics, or household economic considerations (Herzberg, et al., 2019). A fire may start as a result among these interactions either actively or passively, depending on whether it requires urgent human intervention, gadget misuse, or malevolent intent (arson).

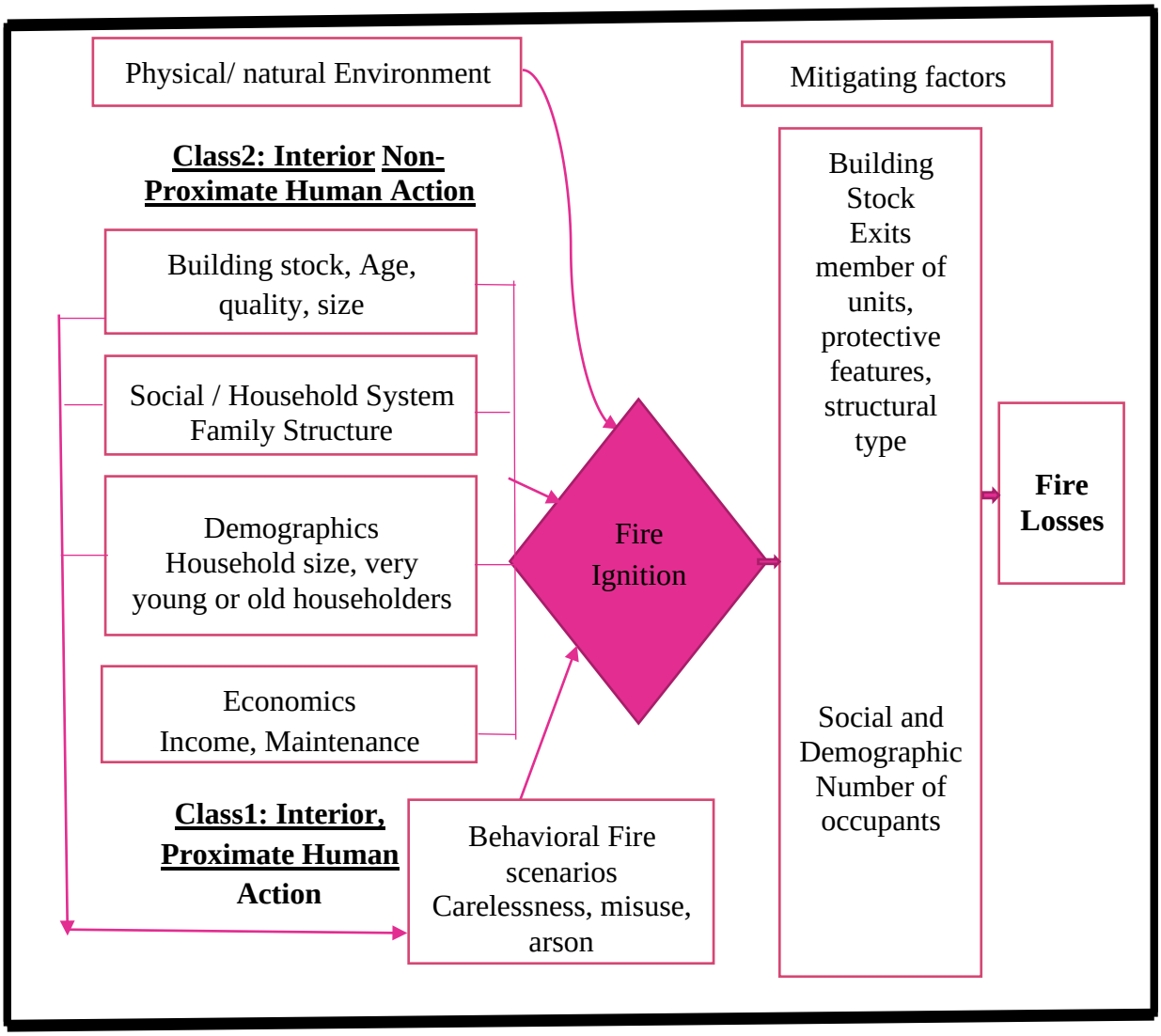


Figure 2.2: Fire risk causing factors
Source: Jennings (1996)

A fire ignition and loss hypothesis must be developed and tested using Jennings' model. In terms of finding traits that could be used to predict fire rates in various areas or dwellings, his work goes beyond the current studies. Finding predictor variables is not the same as finding reasons for higher fire rates, as Schaenman et al. (1987) note. Although poverty has been associated with a higher risk of fire, deprivation does not in and of itself start fires. The Jennings model is used to create theories about how different socioeconomic traits and ignition conditions are related to residential fire rates. The socioeconomic factors connected to fire incidents can be investigated at three different levels, according to Jennings (1996): community, household, and individual. He stated that differences on wildfire incidences are related with community quality or that a residential community's wellbeing is related to the caliber of its housing stock. However, the interplay between processes of fire and household density could lower the resource's quality (Chen, et al., 2022). According to Jennings, poor neighborhoods are more exposed to a risk of fire than other neighborhoods. First, the high household density and low-income levels in disadvantaged neighborhoods deter building owners and tenants, who are frequently living on the edge, from making investments in their properties, particularly in terms of care.

The condition of the living units in those buildings is significantly impacted by the loss of routine maintenance services, increasing the risk of fire owing to inadequately managed construction stock and electrical systems (Chen, et al., 2022). According to Jennings, arson is a significant contributor to fires and fire fatalities in many low-income neighborhoods. According to Jennings, there are many critical variables that affect the fire frequency at the rural households, including the quality of individual housing units, their affordability to residents, and the social structure of the families that reside in them.

In most cases, accessibility and living conditions are closely intertwined. A housing unit's quality, which is influenced by its location, facilities, and services, amongst many other things, determines its price, whether it is for rental purposes. As a result, higher-income households can typically afford to live in higher-quality units than lower-income households. In studies exploring the close association between some of these parameters, money is seen as the most important predictor of fire.

According to Jennings, residing in an old, poorly maintained housing unit enhances a household's risk of fire for a multitude of reasons. According to Jennings, older plumbing, electrical, and appliance systems need to be properly maintained for the duration of their useful lives to ensure continuing safe functioning. If this is not done, there is a greater chance that something will break mechanically and a fire will start in the neighborhood. Second, defective electrical wiring is a common problem in older homes and can result in fires. According to Jennings, this is mostly due to the fact that earlier wire was not designed to support the electrical loads put on it by contemporary devices like microwave ovens, televisions, and audio equipment, and that too many loads might result in electrical fires. Similar to something like this, numerous homeowners attempt to compensate for inadequate electrical systems in newly built homes by breaking the law and using excessive amounts of the available electrical outlets, tactics that, according to Jennings, may overload a socket or circuit and result in an electrical fire.

The pricing of a home also has an impact on its fire danger. If a household is unable to pay their rent and does not have enough money to cover other essential expenses like food, clothes, and other household supplies, they are deemed to be "shelter poor." The

impact of housing deprivation on a family's fire risk can be complex. Due to a lack of truly "disposable" funds, households are unlikely to purchase fire alarm system like a fire extinguisher or other firefighting tools. This is known as the "positive income elasticity of fire safety demand" by Munson and Oates (1983), whereby a household would spend so much money on fire prevention the more money it makes. Along with physical and monetary concerns like the caliber and cost of a dwelling unit that can catch fire, Jennings also noted different social aspects of household structures. A prevalent household characteristic is the presence of youngsters, elderly persons, single parent families (usually headed by women), and crowded housing. For instance, the relevance of single parent homes for increased fire risk is correlated with the presence of children in the home (Moussa, et al., 2020). In general, there are two ways that single parent households are associated with a higher risk of fire. To begin with, two-parent families are more financially successful than single-parent households. Due to all of the issues that are frequently connected to low-income families, such households are more likely to suffer from.

Second, a single-parent family has less leeway in handling unexpected situations in the home or with the kids. It was found that children in urban areas were left alone more often than those in rural or suburban areas (1990). Some parents prepare their kids to ask friends or family for assistance if anything bad happens. Jennings offers a further argument regarding the risks of leaving kids unattended at home, which also holds true when an adult is present but no one is watching the kids. The risk of fire is increased in each of these circumstances by children's fascination with fire and their propensity to play with matches, lighters, and other items associated to fire. Children lack the personal

experiences necessary to fully appreciate the seriousness of reckless fire conduct. Gunther's research supports this claim by demonstrating that children playing with flames is a greater issue in low-income neighborhoods than in some other places (Gunther, 1981). On the other side, low-income families have a harder time affording or accessing a high-quality, reputable childcare center, and their kids spend more time at home alone, which raises the danger of a fire. The fact that there is only one adult accessible to respond to a daycare emergency puts single parent families at an extra disadvantage.

Jennings also talks on the fact that the risk they face is double-edged. First, they might be more vulnerable than the general public, and second, people with physical or mental impairments might find it harder to escape a fire. Because routine actions, especially cooking, can become more dangerous when a person's physical or mental capabilities decline, fires are now more probable to appear among the elderly. Those who smoke and drink alcohol on their own, or who are taking drowsy-inducing drugs, are more at danger of a fire. However, it is important to understand if elderly people with low incomes are more likely than other seniors to experience or be impacted by dementia. It is necessary to note that while the effect of overpopulation on fire incidence is unknown, its documented how it affects fire injury and fatality (Jennings, 1996; Oteng-Ababio and Osman 2012; Oteng-Ababio and Sarpong, 2015). Due to a scarcity of accessible housing, low-income families frequently share residences with their extended families or acquaintances in order to make ends meet. Of course, as the population of a home increases, so do the number of possible victims of a fire. In other words, the bigger the family, the harder it is to evacuate everyone out of a burning building. This is crucial in

houses with kids or senior citizens who might not be able to flee fire or Jennings cited a number of personal risk factors, such as negligence, smoking, intoxication, substance abuse, and illiteracy. Due to some kind of scarcity available accessible housing, low-income families usually share residences with their extended families or acquaintances in order to make ends meet. Of course, as the population of a home increases, so do the number of possible victims of a fire. In other words, the bigger the family, the harder it is to evacuate everyone out of a burning building. This is crucial in households with young children or senior citizens who might not be able to flee fire or smoke on their own. Jennings cited a number of personal risk factors, such as negligence, smoking (Moussa, et al., 2020).

Housing tenure is another factor which has been interconnected to fire rates. To add to the discussion, Fahy and Norton (1989) point to a lack of understanding as a factor in fire danger, asserting that those with limited education are less likely to "understand the full import of community fire education messages." According to Munson and Oates (1983), owner-occupiers have a tendency to better maintain their homes because they own them, reducing the chance of fires started by mechanical means. Additionally, they exercise greater caution in their everyday routines, reducing the possibility of fires started by carelessness in the course of cooking, smoking, or other activities. Corcoran et al. (2017) later expanded on traditional conceptions of fire risk modeling to consider Along with socioeconomic trends, calendar occurrences like the weather also play a role. Domestic fires were one of five main fire types that Corcoran, Higgs, Rohde, and Chhetri (2017) investigated in Australia. They compared each incidence to the socioeconomic index for areas (SEIFA), a measure of numerous family, household, and income factors,

for that particular region. Public holidays, school holidays, and significant sporting events were all featured in the calendar. Finally, the weather's components of temperature, precipitation, and humidity were measured (Corcoran et al., 2011). The researchers created a "surface" (continuous data of points on a plane) across any one of the attributes researchers utilized in their model using spatial statistics. The information was divided into two groups: one for buildings that had fires, and the other for a haphazardly chosen group of buildings that had no fires during the same time periods (Huang, Chen & Khan, 2022). Traditional 2-sample parametric null-hypothesis methods of analysis are reviewed for their methodological shortcomings, and alternative ways utilizing cutting-edge statistical techniques and charting for data visualization are provided. According to the survey, winter months were the most likely time for residential structure fires. Smaller rises were seen throughout long weekends and school breaks, but public holidays saw a tiny decline. Residential fire risk was also linked to SEIFA scores below average. Residential fires were not positively correlated with precipitation, but they were adversely correlated with excessive atmospheric humidity (Corcoran et al., 2013).

According to the findings of Corcoran et al. (2013), "conceptualization of fire incidence necessitates the development of an includes conditions that is able to deal with events within a multi-scaled context." They then put forth a more complex conceptual framework for understanding residential fires, one that took into account the physical environment, neighborhood traits, dwelling traits, weather, calendar events, and behavior.

Finally, even if Jennings recognize the distinction a variety of fire origins, it can be difficult to pinpoint which of those is to blame for a given fire incidence. It is typical for a fire to be started by the combination of several different factors. This is more likely to be the case in informal settlements, where the position of inhabitants is first driven by poverty, which can be brought on by a number of circumstances, including social, economic, political, and physical issues. This study examines fires in Tamale Metropolis using Jennings' model in an attempt to identify the key causes that have contributed to the buildup of risk factors and, consequently, the metropolis' level of vulnerability (Huang, Chen & Khan, 2022). This model was selected because it will help with the examination of the key socioeconomic factors that increase a city's comprehension of its fire danger.

2.2 Review of Empirical Literature

2.2.1 Fire Risk Analysis of Residential Buildings and Its Application in Fire Risk Management

Xin and Huang (2013) looked at the use of simulation clusters with fire risk administration and indeed the assessment of fire risk in residential buildings. The study proposes an approach for the study of architectural fire risks based on scenario clusters and details how it may be used to manage fire risks in buildings. Understanding and describing the risks of a fire, the undesirable outcomes that could emerge from it, and the likelihood that a fire and undesirable outcomes would occur are all steps in the building fire risk analysis process (Kean, et al., 2019). The goal is to assess the level of fire risk and make a decision regarding whether or not to implement suitable risk management measures. As a result, the foundation for fire risk administration is

constructing fire risk analysis. The number of fatalities and direct property loss are chosen as the construction fire risk indexes in the article, and scenario clusters are built during the building fire risk analysis method. Finally, a detailed quantification of the typical fire risk in housing developments is provided (Sanni-Anibire, et al., 2020). With the kinds of thorough fire risk models created here, fire risk management steps could be taken to raise the building fire safety rating and lower fire risk levels, as well as the damage they could cause.

Granda and Ferreira (2019) looked at the fire danger of Quito's Old Town. Risk reduction is now considered to be a high topic on the global agenda. Previous natural calamities having increased public awareness and prompted scientists and organizations to look for more effective ways to reduce risk. These initiatives are crucial for large historic centers because they frequently combine a high heritage value with a high degree of physical fragility, making them particularly sensitive and pertinent (Kean, et al., 2019). The current effort intends to illustrate and discuss the fire danger in Quito's Historic Centre, one of the oldest and most significant Spanish colonial towns in South America, in light of the aforementioned. Given the challenges presented by the size of the case study, the evaluation is conducted on a neighborhood level using a streamlined method for evaluating fire sensitivity and risk (Sanni-Anibire, et al., 2020).

Vulnerability and risk indicators are incorporated into a Geographical Information System tool to do the spatial analysis of the outputs, and the findings are displayed as vulnerability maps. These maps are then integrated with pre-existing vulnerability data in a second-order analysis to identify targets and priorities for risk mitigation methods. In order to focus fire protection efforts,

Higgins, Taylor, Jones, and Lisboa (2013) studied the community fire risk using a geographical model. The paper summarized current studies conducted in collaboration with Liverpool John Moores University and Merseyside Fire and Rescue Service. The research's goal was to look at how to create and apply a customized spatial model that could be used to target services according to risks and needs. The study specifically looks into two consumer insight strands created for Merseyside Fire and Rescue Service (Sanni-Anibire, et al., 2020). These community profiles use a cluster analysis approach to analyze the dangers that exist within communities and the vulnerability index, which uses information supplied under information sharing agreements to identify those people most at risk from fire. Nationally recognized risk modeling toolkits, such the Fire Service Emergency Cover toolkit, are able to detect risk at the individual level but do not use local information. This intelligence is required to enable proactive targeting of services like the Home Fire Safety Check. The study looked into some of the obstacles and problems as well as some of the important operational and strategic areas that profit from this information (SanniAnibire, et al., 2020).

2.3 General Overview of Fires in Ghana

2.3.1 Institutional Compliance in Disaster Prevention in Ghana

Over the previous two decades, Ghana's urbanized environment has experienced a number of catastrophes, including floods, earthquakes, and fires, all of which have had devastating effects.

One of the most well-known was the fire that occurred at the Central Medical store on January 13, 2015. The fire completely destroyed the warehouse and all of the supplies, including medicines. What might have started the fire that destroyed one of West Africa's

major medical storage facilities was examined in research by Owusu-Sekyere et al., (2017) that used the CMS catastrophe as a gauge of institutional compliance in disaster prevention in Ghana. They claim that the crisis not only resulted in property loss but also badly disrupted vital medical supplies to neighboring nations. Following an in-depth discussion with the key parties, the scientists know that the tragedy destroyed health services, equipment, and medications valued at hundreds of thousands of dollars that belonged to Ghana and the World Health Organization (Yan & Xu, 2018). They also disclosed that the nation squandered three months' worth of medicine reserves and that medical supplies worth GHS 237 million (US$68 million) were destroyed. Their research demonstrated significant institutional arrangements for disaster preventive actions, preparation, and mitigation appear to really be lacking. It also showed that, had to have some preventive measures been in place, the tragedy may have been avoided or its effects lessened.

2.3.2 Geographic Information System Based Fire Emergency Response System

Forkuo and Jonathan (2013) conducted research to develop a Geographic Information System (GIS)-based fire emergency response solution for the Ghana National Fire Service to determine the most advantageous path from its position to any fire occurrence inside the Kumasi Metropolis. Forkuo and Jonathan (2013) took into account the journey distance, the slope of the roadways, and the delays in travel times when performing geospatial analysis on the position of fire hydrants for the Ghana National Fire Service. The researcher did a Global Positioning Systems (GPS) survey to coordinate the Fire Stations, fire hydrant's locations, and institutions such as residential, official facilities, factories, and warehouses in the study region. They also corrected road names and home

addresses (Wang, 2019). The results of the study showed that the Ghana National Fire Service's ability to quickly respond to fire emergency services or to lower firefighting costs would be enhanced by the combination of several impendence criteria in modeling the most advantageous path. The GNFS was able to easily ascertain the locations of the fire hydrants and their conditions, including whether they are operational, experiencing high or low pressure, or disconnected from a water source, thanks to the digital environment (Wang, 2019). The findings of their investigation show that there haven't been enough fire hydrants in the locations where fires are always prevalent, and their distribution did not follow regulations.

2.3.3 Causes of Fire Outbreak in Ghana

Ayarkwa et al. (2010) conducted a study to ascertain the real causes of current fire outbreaks in Ghana, as well as the broad sense public's level of understanding, and to provide suggestions for appropriate fire prevention and safety indicators. The study served as a foundation for the discussion surrounding the country's debate following the recent fire outbreaks, which has been centered on rumors about politics, sabotage, and religious divides (Adams & Antwi, 2021). A multi-method approach, including standardized questionnaires and interviews, was used to conduct a survey of the citizens of the Accra, Kumasi, and Tema Metropolitan Areas as well as GNFS officials, industry experts in building, and the general public. The study also examined ten-year fire statistics from the three metropolises (2000-2009). The study's findings indicated that electricity was the primary cause of home fires, which were also brought on by objects like outdated wiring, improper wiring, and overloading of electrical circuits. In the study areas, candles, cooking, and smoking were also acknowledged as significant causes of

residential fires (Ilori, Sawa & Gobir, 2019). The public feels that not enough is being done to prevent house fire outbreaks, despite the fact that they appear to be aware of the risks involved. They thus promoted, among other things, the replacement of outdated cables, the employment of qualified electricians, routine inspections of electrical systems, and the use of high-quality electrical components (Adams & Antwi, 2021). To help lower the high number of domestic fires in the nation, they also promoted extreme fire safety education, the affordability of escape routes, the use of fire extinguishers, and the funding, retooling, and training of GNFS employees (Ilori, Sawa & Gobir, 2019).

2.3.4 Trends of Fire Outbreaks in Ghana

In research released, Addai et al. (2016) demonstrate the trend in fire accidents in Ghana from 2000 to 2013 and discuss several fire prevention methods. The study examined the pattern of fire incidence in Ghana as well as in each location, as well as the causes, mechanisms, and preventive measures against the hazard employing data from the GNFS. The study found that among 2000 and 2010, there were fewer than 3000 fire events, but from 2011 to 2013, there was a sharp rise in the number of fire accidents. A little over 3000 cases were reported in 2011, but by 2013, that number had sharply increased to well over 5000. There were little over 600 firerelated injuries and fewer than 200 fatalities in 2007, but by 2013, there were 1800 injuries and 400 fatalities (Yiran, Ablo & Asem, 2020). In their study, Addai et al. (2016) also noticed a rise in fire cases in Ghana's Northern Region. A little over 100 cases were reported in 2011, but by 2013, there were about 300. It was found that the frequency of fires rose year over year. This increase was attributed to a number of factors, including urbanization, carelessness, population expansion, industrialization, and the country's energy crisis at the time, which

led to an inconsistent electrical supply and some people to resort to violence. The researchers recommended strengthening neighborhood fire volunteers, implementing fire safety laws, creating and regularizing informal settlements, and raising public fire safety awareness. the adoption of stricter building regulations and the placement of fire hydrants in key sites across the nation. Additionally, they argued for technical aid in capacity building as well as foreign support to help Ghana improve fire safety in areas including policy planning, formulation, and execution.

2.3.5 Socioeconomic Consequence of Fire Outbreaks in Ghana

Gyasi (2016) looked into how industrial fires affect the economy. Finding strategies to stop fires from starting in manufacturing units was the goal of this research. He chose seventeen respondents using both quantitative and qualitative methods, including open-ended and closedended questionnaires and a straightforward random sampling technique. All of the participants were senior officers, in particular safety officers in the manufacturing sectors of the Tema metropolis (Ntim, 2018). The research lists the following as the financial effects of industrial fires: a rise in insurance rates for manufacturing businesses; the acquisition of new equipment as a result of industrial fires; compensation for fire victims; and, in some cases, the temporary closure of businesses. As important contributors to fires in manufacturing companies, defective equipment, overheating equipment, poor wiring, power fluctuations, and overloading of sockets have all been noted (Owusu & Nursey-Bray, 2019). According to Gyasi (2016), the best ways to prevent industrial fires in Ghana include adhering to fire safety standards during the design and construction stages of residential and commercial buildings, properly storing hazardous materials, regularly maintaining equipment, and promoting

fire safety awareness. The researcher encouraged the Ghana National Fire Service to conduct regular fire safety audits to assess the state of fire safety and to confirm the compliance of fire safety measures prior to the construction of any industrial facilities (Owusu & Nursey-Bray, 2019).

2.2.6 Fire Risk Vulnerability and Accumulation in Ghana

Sarpong (2013) carried out research on the informal settlements' vulnerability to fire as well as some of the people' coping mechanisms. In Ghana's largest informal settlement, Ashaiman, two slum sections served as the site of the research. Among other qualitative and quantitative approaches, he used a well-structured questionnaire, key informant interviews, focused group discussions, and direct GPS observations. Results of the field survey. The data was analyzed using the Pearson Chi-Square test. Unauthorized power connections for residential and commercial purposes were found to be the main cause of fire outbreaks in the area. Many of the respondents had unlicensed and untrained electricians connect their energy sources (Soliku, et al., 2021). The results show that just 36% of respondents obtain their power legally, such as through ECG, while 52.9% do so illegally, such as through private contractors. State law forbade the connection of the national grid to unapproved structures, the bulk of which were found to be composed of wooden planks, which was the reason for this. Additionally, it was found that the majority of the wiring's materials were of poor quality, raising concerns about the contractors' competence and making the area very susceptible to fire outbreaks (Soliku, et al., 2021). The study also found that such locations under examination lacked fire hydrants, which made their situation worse. According to the research, residents turned to the colleagues, family, local community, religious organizations, NGOs, and other

associations to aid in their recuperation. He concluded by saying that residents are exposed to fire on all scales, including the community, the household, and the individual. Residents' vulnerability has been increased by their lack of risk ownership as well as their failure to understand some of the factors that make them vulnerable to fire. He continued by saying that many of the coping strategies put forth by individuals in the event of a fire outbreak and in the aftermath were unsustainable (Stacey, Grant and Oteng-Ababio, 2021). In order to address the existing building fire situation, the researcher went on to claim that the settlements be regularized and redeveloped on the side, that public fire safety education be increased, that community fire volunteers be formed, that a communitybased approach to disaster mitigation be implemented, and that fire safety protocols be enforced. Additionally, he recommended that similar studies be conducted to ascertain the degree of fire susceptibility in both planned and unplanned areas. In a similar research, Oteng-Ababio and Sarpong (2015) examined the risk of fire at the Makola market's various levels of vulnerability as well as the ways in which a community-based risk assessment could lessen this danger. The study also examined the market stall occupants' and key stakeholders' perceptions of the fire risk as well as the traders' access to local resources (coping mechanisms) for handling issues. The community-based risk assessment (CBRA) instrument was utilized in the study's communitybased disaster management plan. The CBRA is a technique that enables all interested parties in a region to work together to identify risks and develop mitigation plans for them. For the study, about 15 market participants were selected from the different market segments. A fire risk map was produced in collaboration with the participants and researchers (Stacey, Grant & OtengAbabio, 2021). According to the researchers' recommendations, policymakers should think about short- to long-term

efforts to reduce the level of risk by including disaster mitigation measures into the urban design process and enforcing appropriate construction and fire safety regulations.

Owusu-Sekyere and Attakorah-Amaniampong conducted a study in 2017 at the Kumasi central market to evaluate the risk accumulation processes in Ghana's largest open-air market that led to recurrent fire tragedies. They aimed to examine traders' awareness of risk accumulation brought on by their choices or lack of choices. The researchers chose 500 traders from the market's zones, including fire and non-fire victims, using a multi-directional methodological strategy (Kaku,
2018). About 50 people from each zone responded to a questionnaire to participate in the study. In-depth interviews with 10 zone members, five city authorities, and market administrators were undertaken in addition to the survey. According the study, difficult socioeconomic conditions, untenable planning & design practices, and a subpar management framework all influence traders' decisions to engage or not act, which has increased market risk (Kaku, 2018). The study also revealed that the mechanisms that lead to danger accumulation are not well understood or recorded, which discourages traders from taking the essential precautions to prevent fire disasters. The researchers advocate a discussion about creating a vibrant economy which it involves many crucial participants rather than government investment and development enrichment of this important public meeting venue.

2.4 Fire Safety Management and Policies in Ghana

For many years, Ghana has developed and deployed a number of fire safety laws and regulations to lessen the effects of fire disasters on both wildlife and populated regions. The past's policies and practices in the field of managing wildfires (Sewu, et al., 2019).

When fighting flames, management wasn't first prioritized. The first attempt to manage flames was made formally in 1934 with the Savanna Woodland Policy. The aim of this initiative was to persuade local groups to accept fire control as a tool for managing savannah woodlands rather than imposing it on them (Asigri, Afram & Ameyaw, 2021). The policy supported campaigns to raise public awareness about wildfires and to stop agriculture and grassland burning.

2.4.1 The Ghana National Fire Service Act, 1997 (Act 537)

The National Fire Service was reinstated by this Act, which also included measures for related matters to help handle uninvited fires.

- The following roles were formed by the service to handle fires and indeed the associated losses when the GNFS Act of 1997 was passed. The Ghana National Fire Service is in charge of the following duties: Planning public education campaigns on fire safety to increase public awareness of the risks associated with fire and highlight the role that each individual plays in fire prevention Giving technical guidance on building plans' machinery and institutional layouts to aid in fire escape, rescue efforts, and fire;
- Provide technical guidance and a fire extinguisher inspection; Coordinate and offer guidance on staff training at other institutions' firefighting departments; Provide rescue and evacuation assistance to people trapped by fire or in other situations; train and organize Fire Volunteer Squads at the local level; and perform any other task incidental to the goals of the Service (Asigri, Afram & Ameyaw, 2021).

2.4.2 Local Government Act, 1993 (Act 462)

The decentralized governance entities in the nation are supported by the Local Government Act of 1993 (Act 462). According to the Act, the principal organizations

responsible for organizing and carrying out development programs are Metropolitan, Municipal, and District Assemblies (MMDAs). The District Assembly (DA), in accordance with Section 10 of the Act, is in charge of exercising political and administrative authority in the district as well as directing, advising, and supervising all other administrative authorities (Boamah, 2018). The district's DA will also have executive, legislative, and deliberative authority. Due to the aforementioned duties and powers, the DA is responsible for formula oversight (Poku-Boansi & Cobbinah, 2018).

According to the Act's stipulations, the MMDAs have regulatory authority over the regions' physical development. They should therefore enact building codes and development restrictions to curb physical growth within their own domains. Effective regulatory measures like monitoring and fines may be able to reduce the frequency of disasters (Poku-Boansi & Cobbinah, 2018). In other words, the regulatory responsibilities of something like the MMDAs specify their roles in emergency planning, so even though their development-oriented stance combined with administrative action makes them the primary government agents in charge of ensuring the longterm rehabilitation of catastrophe victims and impact areas. In order to ensure disaster mitigation and a quick and effective recovery, MMDAs' role in disaster management is essential (Boamah, 2018). According to Section 11 of the Act, a District Assembly is in charge of creating and approving its annual budget. Similarly, section 34 gives the District Assembly the authority to charge fees for any resources and facilities provided by the Assembly and also for whatever licenses or permits granted on its behalf. These provisions grant the Assembly the ability to raise money for district development

initiatives. The District Assembly might be able to gather funds to aid disaster victims in their recovery with such power (Poku-Boansi & Cobbinah, 2018).

Each District Assembly must establish a Disaster Prevention Department in order to exercise its authority under Section 38 (1) of the First Schedule to the Act. This department would be in charge of putting plans in place to avoid disasters from occurring in the districts. Part of the disaster prevention obligations are delegated to the MMDAs under this section of the Act. However, if the Disaster Prevention Department is given appropriate resources and legal support, it will be able to properly carry out its responsibilities (Sulemana, Musah & Simon, 2018). "A District Planning Authority may, for the purpose of enforcing an approved development plan" says Section 53 (1).

- Remove, tear down, or alter any physical development that does not comply to the terms of the approved plan, or the abatement, removal, demolition, or alteration of which is essential for the execution of an approved plan; and
- prohibits the use of any land or building for a purpose or in a manner that is inconsistent with the provisions of an approved plan.

The following rules allow the MMDA to ensure that physical development in a given geographical unit follows a set of guidelines in order to promote land use patterns' compatibility with human activities and avert disasters. As a result, the MMDA has the authority to ban any physical activity that violates the land use plan. This necessitates the MMDA's involvement in the monitoring of physical development activities within its authority. Maintaining order in spatial growth will also necessitate the strong support of law enforcement forces. The effective implementation of this clause may aid in the reduction of disasters (Siiba, Adams & Cobbinah, 2018).

The District Assemblies Common Fund Administrator is also required by Section 86 (2) of the Act to distribute funds from the District Assemblies Common Fund to District Assemblies in accordance with the provisions of the District Assemblies Common Fund (DACF) Act, 1993. (Act 455). This provision enables MMDAs to achieve certain financial capacities to carry out their development initiatives and implement pre- and post-disaster recovery programs. However, the quantity of resources allocated to disaster-related operations by an MMDA may be determined by the DACF Administrator's financial allocation to the district, as well as the district's ability to generate revenue (Siiba, Adams & Cobbinah, 2018).

2.4.3 National Disaster Management Organisation Act, 1996 (Act 517)

The management of areas impacted by catastrophes and other emergencies, and even the restoration of disaster victims and other related issues, are all under the control of the National

Disaster Management Organization (NADMO). According to Section 2 of the Act, "the Organization's objective is to manage disasters and comparable events in the country." The

Organization must comply with the following requirements under Section 2 Paragraph 2 of the Act in order to manage disasters and emergencies in the nation: prepare major disaster arrangements for attempting to prevent and minimizing the effects of disasters; monitor, evaluate, and update major emergency plans; ensure the formation of satisfactory facilities professional training and the institution of educational programs to provide community understanding, warning systems, and broad sense contingency planning for its staff and the broader population; ensure that there are accurate and effective facilities for the requirement of relief, regeneration, and other assistance;

The clauses prove that NADMO is in charge of both pre- and post-disaster situations. By preventing and minimizing their effects, national disaster plans seek to lessen the toll that disasters take on society. On the other hand, minimizing the frequency of disasters and their effects on society may depend on how committed all stakeholders are to putting the disaster plans' principles into practice. At various levels of government, separating disaster planning from growth goals may also make disaster plans challenging to finance. Governments and donor organizations for development may therefore be more dedicated to implementing development plans than disaster plans. The separation of the two plans could also lead to incompatibility in the application of particular legislation, which would impede the attainment of the goals (Arkorful, et al. 2021). According to Section 12 of the Act, the Organization shall have Regional and District Coordinators, who shall be chosen by the President in accordance with the recommendation of the Council made in collaboration with both the Public Services Commission. The National Committee or the Council designates the duties that the Regional and

District Coordinators carry out as they supervise the Organization's regional and district offices. The Section 12 phrase exemplifies the Organization's decentralized management style. The objective is to increase the adaptability of catastrophe plans to the requirements and actions of citizens within a certain geographic area.

However, the President's selection of District and Regional Coordinators might not promote the steady advancement of disaster management professionals who have the technical proficiency and experience to take on major administrative and political responsibilities in the Organization's management. The workforce of the Organization can become less dedicated to disaster management as a result. In a similar vein, highly trained disaster management experts may be discouraged from entering given the lack

of career progression it through ranks of the organization for becoming District and Regional Coordinators (Arkorful, et al. 2021). Each district must establish a District Disaster Management Committee, chaired by the District Chief

Executive, with representation from the Armed Forces Garrison Commander, a member of

The District Information Officer's participation in the District Disaster Committee is meant to facilitate the dissemination of disaster knowledge and information and to notify them of the

Committee's approved hazard mitigation strategies. It is anticipated that the District Planning Coordinating Unit's (DPCU) removal from the District Disaster Committee will affect how district development plans are integrated with disaster plans. The National Development Planning Commission (NDPC) and NADMO currently share responsibilities that go all the way down to the district level. Because of this, it would also be challenging to implement disaster preparations with adequate funding (Twumasi-Ampofo, Oppong & Quagraine, 2021). The cause of this is that catastrophe management isn't seen as a development issue as much as it is as an emergency. However, in order for disaster management at all levels to obtain the essential financial and political priority, there must be significant coordination between the NADMO and the NDPC in the creation of catastrophe plans. This would enable the NDPC to include disaster management considerations into national and district development plans. This would change the way catastrophe management is perceived from an emergency to a developmental concern. As a result, in order to secure the necessary financial and

political backing for catastrophe plans to be efficiently implemented, disaster management's role in national development issues is crucial.

The sources of finance for the Organization are listed in Section 22 of the Act. It states that the Institution's funds consist of both payments made to the Organization in the form of grants, donations, and gifts, as well as money granted by Parliament for the Organization's functions (Twumasi-Ampofo, Oppong & Quagraine, 2021). The consequence is that the Organization should be able to support both its pre- and post-disaster initiatives if Parliament is to act as a reliable source of funding. However, the nation's approach to major accident management is probably going to make it difficult for the Organization to get funding for its pre-disaster

activities.

2.4.4 Fire Protection to Buildings'

The National Building Code of Canada defines fire safety as,

a goal to lessen the likelihood that someone in or near a structure may be subjected to an intolerable fire risk as a result of the facility's design and building (Canadian Wood Council, 2002).

So, using tried-and-true building design elements intended to reduce the danger of harm to people from fire to the greatest extent possible, fire safety in a building can be achieved.

Life safety and property protection were highlighted by Fredericks and Ricket (200l) as two separate components of fire protection. Despite the fact that the two objectives are incompatible, addressing one usually has a protective effect on the other. However,

Fredericks and Ricket (2001) acknowledged that complete fire safety is unachievable (Twumasi-Ampofo, Oppong & Quagraine, 2021). The British Standard Institution in 1997, outlines a few essential rules for guaranteeing fire safety. These are achieved by promoting safe design, fabrication, and management techniques in the following categories: Planning and protecting escape routes from any area that may be under fire threat; Using appropriate fire-resistant building and completing materials; Segregating high fire risk areas; Fire warning systems, and also where acceptable, mechanisms for the automatic detection of fire; Smoke control measures to maintain the effectiveness of fire suppression systems and the supply of firefighting tools (Osei-Asibey, te al., 2021).

Everyone participating in the building design process needs to be aware of the fire protection engineering challenges that need to be taken into account at each stage of the process, according to Lataille (2003). In Ghana, reinforced concrete makes up the majority of structures, and beams and columns work together to support the structure. If the tensile strength of the beams and columns is reduced considerably by the attack of the fire on the reinforcement bars, the entire structure would collapse. To avoid this issue, the Ghana Building Code advises giving the reinforcement appropriate cover. (National Committee on Building Regulations, 1989). According to the regulation, a building's structural components must be made fire resistant for a length of time that will delay the spread of the fire and the eventual collapse of the building. Additionally, it needs to be fire resistant long enough for anyone in danger to flee and for fire crews to work efficiently. Unhindered escape paths from inside the building to streets or safe areas are provided as options of escape (OseiAsibey, te al., 2021).

2.4.5 Fire Precaution (Premises) Regulations, 2003

Following the passage of the Ghana National Fire Service Act 1997 (Act 537), which saw the GNFS established, little attention was devoted to fire management involving owners or occupiers of various types of sites and also provide technical advice for building plans in respect of machinery and structural layout to facilitate escape from fire, rescue operations and fire management (Government of Ghana, 2004). The Fire Precautions (Premises) Regulation (2003), L1 l724, was passed to enable the GNFS to carry out inspection of proposed and existing premises, review building plans regarding fire safety and issuance of Fire

Certificate (The Government of Ghana, 2003). The regulation provides that a Fire Certificate be obtained for public residential and other accommodation. Consideration should be given to the type and quantity of flammable and smoke-producing elements that might be involved in a fire when designing any structure so that it has the tools necessary to put out a fire quickly. Examples of this kind of equipment include tiny, transportable extinguishers for small fires, hoses attached to large, pressured water supplies, and automatic fire sprinklers. Fire and smoke detectors, as well as fire alarm systems that warn building occupants, are crucial for ensuring everyone's safety. (Barnett, 2008; UK Fire Statistics, 2008; Frederick and Ricket, 2001). The GNFS required a fire certificate for any buildings used as public residential accommodation, for the purpose of amusement, recreation, or as a club, as a place of work, as a health-care institution, or for the care of newborns, disabled, or elderly people. To training, teaching, or research, and for a purpose that requires public access to the premises, whether for a fee or not. The GNFS has a task team that is going from place to place,

informing owners and occupiers of impacted properties on the importance of obtaining a fire certificate to assist mitigate fire damage.

2.4.6 Fire Precaution (Premises) (Amendment) Regulation, 2016

Domestic fires were left out of legal instrument (LI) 1724, which forced its amendment to include domestic fires and the precautions that should be taken to prevent domestic fire outbreaks. Some of the objections made against LI 1724 were addressed in the legal instrument (LI) 2249, 2016, which included home fire as part of the premises that required a fire certificate.

To achieve these adjustments, provisions of the rules in (LI) 1724 were changed. Regulations 1, 2, 4, 5, 8, 9, 11, 12, 12A, 20, 21 and 22 of (LI) 1724 were altered, and schedule 4 of (LI) 1724 was annulled (Osei-Asibey, te al., 2021).

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter focuses on the methods utilized in this study to accomplish its research aim and objectives. It provides a description of the research design for something like the study and details the demographic, sample, sampling procedures, and data collection equipment. It also discusses an appropriate statistical plan and sampling techniques.

3.1. Study Area

Tamale is one of the 14 MMDAs in the Northern Region and one of Ghana's 260 Metropolitan,

Municipal, and District Assemblies (MMDAs). Tamale also acts as the capital of the Northern

Region and the location of the Tamale Metropolitan Assembly. The Tamale Metropolitan

Assembly (TAMA) was granted metropolitan status in 2004 by legislative instrument (LI 2068). The Sagnarigu District Assembly (SDA) was established in 2012 by Legislative Instrument (LI) 2066 in response to the metropolitan area's growing populations and the necessity to reroute development projects to the north - northwest of the Metropolis. (GSS, 2013a; Fuseini et al. 2017,

3.1.1 Location

It is located in the heart of the region, bordered to the west by the Tolon and Kumbungu Districts and to the north by the Savelugu Municipality. Mion District is located in the east, East Gonja is in the south, and Central Gonja is in the west (GSS, 2012). It has an elevation of 180 meters above sea level and is located between latitudes 9o16 and 9o34 North and longitudes 0o36 and

0o57 West. According to the Tamale Metropolitan Assembly (2010), the Metropolis has a total estimated land area of 922 km2, 17 peri-urban towns, and 115 villages (Fuseini, 2014). The majority of rural communities contain sizable tracts of land suited for farming, which operate as the Metropolis' food supply. However, these towns continue to lack basic social and economic infrastructure, such as safe roads, schools, clinics, markets, and recreation centers, which hinders socioeconomic growth, the fight against poverty, and the phenomenon of rural-urban migration as a whole.

3.1.2. Demographic Characteristics

The population is 379,543, or 15.4% of the total population of the region, according to the 2010 census. In comparison to women, who make up 50.3% of the population, men make up 49.7%. 16.1 percent of the 219,971 households in the city have a head of household, with 24.2 percent of male heads and 8.1 percent of female heads. The preponderance of something like the average household members 66 are children (40.4 percent). Male-headed households outnumber femaleheaded families, according to the data. Again, approximately 48.6% of the population aged 12 and over is married, while 44.2% has never married. Widowed people make up 4.0% of the population, while divorced people make up 1.6%. The number of people who have been divorced is 1.0% Ghanaians by birth account for 94.6% of the metropolis' overall population, with 2.1% having dual nationality and 0.8% being naturalized. ECOWAS citizens make up 1.5% of the population, whereas Africans born outside of ECOWAS make up 0.6%. This means that Ghanaians account for more than two-thirds of the population in the metropolis. Dagombas are the main ethnic group in the Metropolis, which is a cosmopolitan area. Gonjas, Mampurusis, Akan, Dagarbas, and tribes from the Upper

East region such as Grune, Kasena, and Kusasi are among the minority ethnic groups. Festivals, naming ceremonies, and marriage ceremonies are all part of the local culture. The Dagomba Kingdom can be traced back to Tohazie (the Red Hunter) through Naa Gbewaa to the current traditional administrative system.

Islam is the largest religious group in the metropolis. Muslims account for around 90.5 percent of the population of the metropolis, followed by Christians. African traditional religious people account for 0.2% of the population. The proportion of the people living in urban areas (80.8%) is higher than the proportion living in rural areas (19.1%) in the Metropolis. It has one rainy season followed by a long dry season marked by dry Harmattan winds and bright sunshine. The temperature swings from a low of 25°C to a high of 39°C. Sadly, the metropolis has few water bodies, with only a few streams that dry up when the rains stop (GSS, 2012).

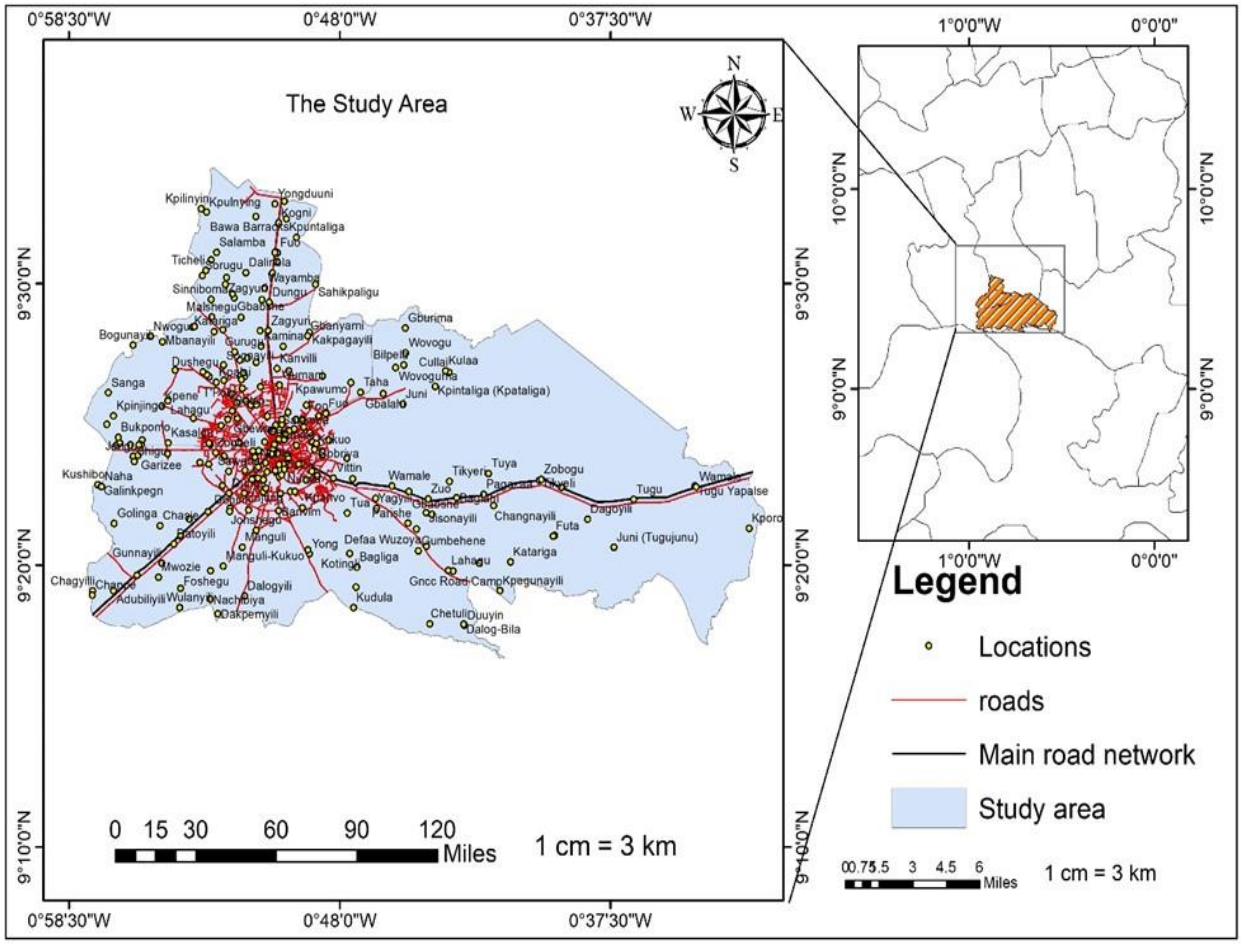


Figure 3.1: Map of TAMA
Source: Field Survey, (2021)

3.1.3 Socio-Economic Characteristics

The population of the study area economically active is 63.3%, with 92.6% employed and 7.4 % jobless. Economically active males account for 65.5% of the population, with 92.8% employed and 7.2% jobless, while economically active females account for 61.1% of the population, with

92.3% employed and 7.7% unemployed. 67 Service and sales activities employ a large percentage of the working population (33.0%). This is it. Craft and allied trades employees make up 2.15% of the workforce, while skilled agriculture, forestry, and fisheries workers make up 17.6 percent. Almost all vocations have more males than

females, except for service and sales, which have 16.5% and 50.3% males and females, respectively. In addition, in the category of elementary jobs, there are more females (11.3%) than males (6.1%). Most of the population in the Tamale Metropolitan Area work in agriculture and trade. The majority of farmers practice subsistence farming, with only a minority practicing commercial farming (GSS, 2014). The city is still a center for agricultural produce and inputs, and it hosts various wholesale, retail, and informal economic activity (Yakubu et al. 2016). The Tamale Central Market, Aboabo Market, Kukuo Market, and the Tamale Central Market are the five markets in the metropolis.

3.1.4 Housing and Structural Characteristics

The total number of housing units in the area under consideration is referred to as the housing stock (GSS, 2010). Tamale Metropolis has a population of 43,834 people who live in 3366.262 households. The urban population accounts for 70.6% of total housing stock, while the rural population accounts for 29.4%. The average household size in the Metropolis is 6.2 people in urban areas and 7 people in rural areas (GSS, 2012a). According to the Ghana Statistical Service (2010) population and housing census, compound houses are the most common type of dwelling in the metropolis, accounting for 80.6% of all dwellings. The second most prevalent type of residence is a separate house, which is solely made up of one room. The principal types of houses in the Metropolis have not altered since the 2010 population and housing census period.

In Tamale, there is also a significant discrepancy between housing demand and availability (Yakubu, Akaateba, and Akanbang, 2014). After the SAPs, the economy was deregulated, which altered Ghana's dynamics for housing supply and placed more of a focus on private sector involvement (Owusu, 2011). Private individuals are becoming

the primary housing providers as a result. Cement blocks and marble, that were used to build 55.9% of all dwelling units in the city, are the most widely utilized material for exterior wall construction. The percentage is larger in urban areas (60.3%) compared to rural areas, where only 36.8% of residential units have cement block or concrete outer walls. Mud/brick/earth, which make up 35.2% of the city, is also widely used. They are the major material used to construct the outside walls of 30.0% of urban dwelling units and 57.5% of rural dwelling units.

3.2 Research Design

A research design is "a plan for carrying out a study with maximum control over elements that may impact the accuracy of the findings," according to Brink (2002). It is the foundational framework that outlines the connections between the several research activities necessary to adequately answer the primary research question (Burns and Grove, 2001). According to Pasick et al. (2009), qualitative research is the overall approach for tying conceptual study problems to applicable and practicable empirical studies. As a result, while diagnosing a study problem and effectively treating it, the style of structuring data and methodologies in research is critical. Over the years, two fundamental approaches, namely quantitative and qualitative viewpoints, have influenced the design of research endeavors (Babbie, 2005). In quantitative research, data is numerically represented and altered in order to define and clarify the phenomenon it depicts. As opposed to quantitative research, qualitative research entails the non-numerical analysis and interpretation of observations with the aim of identifying underlying themes and patterns of interactions (Babbie, 2007). The interpretivism research paradigm is used to explain qualitative research design, whereas the positivist

viewpoint is used to explain quantitative research design. The study employed a mixed-methods approach. A mixed method study is "an approach to inquiry that integrates or associates both qualitative and quantitative forms" in parallel, creating a study that is "bigger overall than either qualitative or quantitative research," according to Creswell (2009). (Creswell and Plano Clark, 2007). To fully understand the scientific studies, it enables the researcher to blend qualitative and quantitative data. According to Pasick et al. (2009), mixed methods research begins with the notion that researchers gather data dependent on the type of the investigation and theoretical orientation to understand a social phenomenon. The aim of social inquiry is to examine the various dimensions and resources that have an impact on a particular topic (e.g., policies, organizations, households, individuals). Both data are gathered simultaneously, and the information is used to understand the overall result. Combining quantitative and qualitative data, according to Pasick et al. (2009), maximizes the benefits and reduces the drawbacks of each type of data.

3.3 Mapping Approach

3.3.1 Choosing the fire risk influencing factors

Fire risk is associated with wide range of factors which include slope, topography, nearness to sources of water, location of hydrants, rainfall, wind, humidity Fire Service areas (distance to the fire stations Normalize vegetation index (NDVI), and land use land cover (urban density).

3.3.1 Data Collection and Processing

Review of literature has showed that researchers across the globe has adopted the use of different models in assessing fire risk areas and they include frequency ratio (source),

weights of evidence (source), artificial intelligence (source), machine learning (source), and logistic regression (source). However, the use of AHP in this study is because of its resilience in handling complex decision in fire risk assessment. The land use land cover in this study is considered a very important factor because studies have reported the impacts of land use change on fire risk distribution. Greater vulnerability to many disasters, including fire hazards, is found in denser and more crowded places. In this present study, the data using for the LULC map was Sentinel2A (table 1) acquired from the www.usgsearthexplorer.gov database. The use of this data type is because of its resolution of 10 m compared to Landsat and LiDAR. The major LULC classes found include vegetation, agricultural lands, settlements, and bare land as seen in table 3.1. Rainfall, humidity, and wind data was acquired from the www.esa.usgs.gov database. Distance to water, road, and hydrants were generated by developing a geodatabase and computing it in ArcGIS.

Table 3.1: Description of satellite imageries used in LULC change detection

Year	Date	Cloud cover	Satellite Imagery	Number of bands	Spectral Resolution
2021	26-12-2021	None	Sentinel-2	13	10 m, 30 m, 60 m

Table 3.2: Land use /Land use Description of the area (Bright, 2019)

Category	Description
Urban 1	Mixed urban areas (Regular settlements within some residential areas)
Urban 2	Residential areas (Organized settlements within well-furnished buildings)
Urban 3	Transportation facilities, Industrial, and Commercial units
Forest	Deciduous forestland, Mixed Forestland, Forest areas, and /or Evergreen forestland
Agricultural areas	Farmlands, Irrigated farmlands, and Gardens
Shrubland	Shrub and bush areas, Herbaceous vegetation, and/or few scattered trees

3.3.2 Analytic Hierarchical Process (AHP)

In the areas of agricultural, environmental, hydrological, and subsurface investigations, AHP is one of the frequently utilized multi-criteria decision-analysis tools. This study used the Saaty (1987)-originally conceived analytical hierarchical process (AHP) to give each determinant a weight (spatial layers). This method compares the assigned scores for each layer to create a pairwise comparison matrix. According to table 3.3, the scores

are often given between 1 (equal importance) and 9 (high importance). A pairwise comparison matrix for the 8 layers was constructed in the AHP model. The eigenvector approach was used to produce the normalized weights for each layer. This is possible to access AHP as an extension in both software, but this study uses the AHP calculator 2019 to ascertain the weights to be used in developing the fire risk maps.

Table 3.3 scale of assignment of weights and the pairwise comparison process

Intensity	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and adjustment slightly favor one element over the other
5	Strong importance	Experience and adjustment strongly favor one element over the other
7	Very strong importance	One element is favor very strongly over another, it dominance is demonstrated in practice.
another is of 9 affirmation	Extreme importance	The evidence favoring one element over the highest possible order of
2,4,6, and 8 can be used to expressed intermediate values		

The weight of each determining factor is derived from the maximum eigenvalue in the normalized eigenvalue in the pairwise comparison matrix as seen in figure 3,2. The

reliability of the judgment is dependent on the consistency ratio (CR) and its value must be less than or equal to 0.1. In case it exceeds this limit, it is suggested to revise the process again until a consistency of 0.1 is achieved. The CR is computed using equation 1. CR = CI/RI Here RI is the Random Consistency Index

$$CR = \frac{CI}{RI} \ldots\ldots\ldots\ldots (eqn\ 1)$$

Where, RI is the Random Consistency index and CI is computed using equation 2

$$CI = \frac{\lambda_{max} - n}{n - 1} \ldots\ldots\ldots\ldots (eqn\ 2)$$

In this equation, λ is the principal eigenvalue of the matrix and n is the number factors used in the estimation (Saaty 1987). Fire risk zones were derived from 8 spatial layers integrated into the ArcGIS environment to compute the fire risk index (GWPI). This is done by weighted linear combination (WLC), as suggested by Malczewski (1999) seen in equation 3.

Figure 3.2 Pair wise matrix used in assigning weight to the different layers

Matrix		Distance to water	Slope	distance to fire station	building materials	rainfall	NDVI	distance to road	LULC	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
Distance to water	1	1	1	1	5	3	1	1	1	-	-	18.04%
Slope	2	1	1	1	3	3	1	1/3	3	-	-	15.55%
distance to fire station	3	1	1	1	1	1	2	1	3	-	-	12.44%
building materials	4	1/5	1/3	1	1	1	3	3	3	-	-	13.61%
rainfall	5	1/3	1/3	1	1	1	3	1	3	-	-	11.22%
NDVI	6	1	1	1/2	1/3	1/3	1	3	1	-	-	10.51%
distance to road	7	1	3	1	1/3	1	1/3	1	3	-	-	12.90%
LULC	8	1	1/3	1/3	1/3	1/3	1	1/3	1	-	-	5.73%

$$FRI = m \sum w = 1 \sum 1(W_j \times X_i) \ldots \ldots \ldots . (eqn\ 3)$$

Here FRI is the fire risk index, Xi is the normalized weight of the ith feature of the thematic layer, wj is the normalized weight of the jth thematic layer, m represents total number of themes, and n is the total number of classes in a theme. However, this phenomenon in ArcGIS uses the overlay tool.

3.4 Determination of Sample Size and Characteristics

The study used a total sample size of 196 respondents. Two representatives from the Planning

Departments (Tamale and Sagnarigu), two representatives from the Metropolitan (Tamale and Sagnarigu), VRA, GWCL, two representatives from NADMO (Tamale and Sagnarigu), and four representatives from the Metropolitan GNFS were among the 12 institutional representatives interviewed. Due to operating schemes of the GNFS,

GWCL, and VRA, the Tamale and Sagnarigu were integrated in the study. According to the information provided by these institutions, the study area is categorized into four zones, making it difficult to compile information for Tamale alone. Because the study involved a large population and five study communities, the sample size was calculated using Snedecor and Cochran's (1989) formula, which claims that the formula below is appropriate in determining a representative sample for proportion in surveys with a large population.

$$N = z^2pq/d^2 \quad [1]$$

where N is the sample size desired, z^2 is the desired confidence level of 95% (1.96), p is the Standard Deviation at 0.5, q is a constant (1-p) = 0.5 and d is margin of error (confidence interval) of +/- 7

$$N = \frac{(1.96)^2 \times (0.5)(0.5)}{(0.07)^2} \quad [2]$$

$$N = \frac{3.8416 \times 0.25}{0.0049}$$

Therefore, N (sample size) = 196

3.4.1 Sampling Technique

The methods used involved a multi-stage sampling process. First, the study classified the city's civilian neighborhoods into Indigenous Residential Areas (IRAs), Medium Class Residential

Areas (MCRAs), High-Class Residential Areas (HCRAs), and New Development Residential Areas in accordance with the Tamale Metropolitan Assembly's Medium-

Term Development Plan (Kanton, 2007: TAMA, 2003). (NDRAs). Every stratum had a randomly selected village. The number of respondents to be recruited from each household category was determined using proportionate sampling. The goal was to guarantee that the sample sizes for the five communities were representative.

To calculate the sample size for each residential class, the number of households in each residential category was divided by the sum of the five residential categories and multiplied by the sample size. The distribution of sample size in the residential categories is shown in the table 3.4. Because most houses were compound in character and multi-habited, the systematic sampling technique was employed to pick houses for the 196-household interview schedule survey, which was then further classified into blocks. In each block, the fifth house was chosen. In a multi-home compound, the most willing household was chosen. The poll targeted household heads: however, if the household head was unavailable, a spouse was interviewed. However, to get data that accurately reflect the situation in the area, 20 fire victims were purposefully chosen, five from each of the Fire Department's four operational zones.

Representatives from disaster management-related institutions were sampled using purposive sampling. Because the representatives of such institutions were thought to have in-depth knowledge and expertise in the management of fire disasters and other emergencies in the Metropolitan Area, this sample strategy was used. The institutional respondents were represented by ‘representatives' to ensure their anonymity, as required by study guidelines.

Table 3.4: Distribution of sample size for study communities

Residential class	Localities	Population	Households	Sample size	Percentage (%)
IRAs	Aboabo	10,485	1,951	62	32
MCRAs	Gumbihini	11,423	1,746	55	28
HCRAs	Russia Bungalow	2,114	476	16	8
LCRFs	Dungu	2,623	496	16	8
NDRAs	New Jisonayili	9,359	1,472	47	24
	Fire Victims	-	-	20	-
TOTALS		33,890	6141	196	100

Source: Author's construct based on GSS, 2010

3.5 Data Collection and Study Instrument

There are two categories of data: primary data and secondary data. Primary data is obtained from field surveys and observations, while secondary data is data that has already been gathered (Yeboah, 2005).

3.5.1 Primary Data Source

Data was gathered from both primary and secondary sources for the study. Using administration of research equipment, a field survey was utilized to collect primary data. The interview guide was the primary data gathering instruments. Opinion leaders from the sampled communities and some fire victims participated in Focused Group Discussions to assess the levels of fire risk, issues they face at the community level

during fire outbreaks, and some of the coping techniques they apply. Expect interviews with the Ghana National Fire Service Regional and Metropolitan

Commanders and Directors, the National Disaster Management Organization (NADMO), Ghana Water Company Limited (GWCL), and the Volta River Authority. Their perspectives on the risk accumulation process inside the Metropolis were sought in order to determine the fire management techniques implemented and the obstacles faced while responding to fire disasters. Field observations were also used to gather more information on the fire risk hazard, elements that contribute to risk accumulation, and some of the coping techniques people use in their homes and communities.

3.5.2 Secondary Data Source

The Ghana National Fire Service provided secondary data, such as monthly and yearly reports of fire occurrences, which were analyzed and compiled. Trends during the last 17 years, from 2004 to 2020, were investigated. Data on number of hydrants and their locations were also gotten from the Fire Service. Data on population and housing conditions were also obtained from the TAMA and the Ghana Statistical Service. Journals, newspapers, articles, books, and online blogs were also used to conduct the literature study.

3.6 Data Collection

The approach for gathering data was through interviews. The study relied on the survey data collection approach. Because some of the respondents were thought to be illiterate and unable to read, comprehend, and administer the study instruments without the assistance of the researcher, this data collection approach was used. Furthermore, the respondents' busy work schedules made it impossible to ensure the administration of surveys, as it was assumed that many of them would misplace and never return them.

The use of interview guides as instrument for data collection was needed by the reasons stated above. To assist with the data collection process, the researcher hired two research assistants. The fieldwork took place between June 1st and September 2nd, 2021. With introductory letters, the study team reported to the Administrative Heads of the selected institutions. briefed them about the study and made request to interview representatives of the institutions. The institutions were given copies of the interview guides for their files, and the representatives were scheduled for interviews. The goal was for the representatives to be able to obtain all the essential documents and data to aid in the interviewing process and increase the quality of the data that would be created. It was also to uphold the ethical issue of ensuring that the timing was suitable. The interviews dates and hours were adhered to by the study team. To administer the interview schedule, the research team went to the study communities' assembly members and opinion leaders as part of the community admittance process and identified themselves and the study's aim. Before the data gathering process began, the respondents' permission was asked. The respondents were asked questions based on the study items, and the answers were recorded on their individual research instruments. Households who refused to participate in the study were not included. The household heads were the objective of the interview guide, but if the household head was not present, the spouse or the next senior person of 18 years or older was interviewed.

3.6.1 Data Collection Instruments

For data collection, the study used an interview guide and interview instructions. Data was collected from households and fire victims using an interview guide, while officials from disaster management-related agencies were interviewed using interview schedules.

Because some were viewed as illiterate, an interview schedule was employed as an instrument to collect data from households and fire victims because they could read, comprehend, and self-administer the research instrument without the assistance of the researcher. In addition, due to the busy working schedules of households, the study used an interview schedule. When the characteristics of the study population or sample frame prevent questionnaire administration, according to Sarantakos (2005), an interview guide is utilized for quantitative research.

The interview guide included both closed-ended and open-ended research items. The respondents were guided in answering the questions by the closed-ended research items. The goal was to see how much the responses agreed with or disagreed with problems raised in the literature. The open-ended research items, on the other hand, were utilized to find answers to open-ended questions as well as gather in-depth information from locals on their knowledge and perceptions about fire outbreak causes., the precautions they have taken in their houses to prevent and manage fire-related disasters, the problems they face when a fire breaks out in the region, and how quickly they receive assistance

There were five components to the interview guide. The respondents' background information was covered in the first part. Gender, level of education, age, occupation, and income levels were some of the concerns addressed in this section. Housing characteristics were covered in Section B. The type of material utilized in the construction of the house, the sorts of fuel used for lighting and cooking, and the accessibility of fire and other emergency engines were all covered in this part. The respondents' perspectives about the causes of fire outbreaks were discussed in Section C of the interview schedule. Section D focused on home and community-level fire

prevention and management measures. The fifth portion focused on the obstacles individuals face at home and in the community during emergency response, as well as some of the coping techniques they employ to recover.

3.7 Data Analysis

With the help of descriptive statistics in Microsoft Excel and Stata 15, the data acquired from the households' survey was computed, evaluated, debated, and presented. The demographics and information received were represented using graphs, charts, and tables. Factors influencing fire outbreak among the household within Tamale Metropolis was measured using Logit regression analysis. This is because of the dichotomous nature of the dependent variable i.e. experience of fire outbreak or not. The experience of fire outbreak was categorized into 1 if the household experience fire outbreak and 0 otherwise. For ease of interpretation, the odds ratio was used. Empirically, the model is expressed as;

$$P_i F(Z_i) = 1 + \frac{1}{1+e^{-(\alpha+\sum \beta_i X_i)}} = \ln(\frac{P_i}{1-P}) = \beta_0 + \sum \beta_0 X$$

The model is implicitly stated as

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k \beta_k + e$$

And explicitly as;

$$Fire\_outbrea = \beta_0 + \beta_1 Age + \beta_2 Sex + \beta_3 Marital\_Stat + \beta_4 Edu\_Level + \beta_5 Avr\_mntly\_ic + \beta_6 Lightnin\_Soure_i + \beta_7 Sour\_Cooking\_fuel + \beta_8 Ownership\_Hous + e$$

The marginal effect is given as;

$$\frac{\partial E(Y_i|x_i)}{\partial x_i} = \emptyset(X`\beta)\beta$$

The qualitative data from the focus groups and expert interviews was transcribed, processed, and used to supplement the survey study. GIS pictures were delineated using Digital Elevation Models.

3.8 Research Ethics

The interaction between researchers and the target population is the focus of research ethics. The primary goal of research ethics is to safeguard the participants' well-being. As a result, ethical considerations are critical and important to social science research, and proper protocols must be followed to ensure the research's trustworthiness. The following ethical criteria informed this research:

Before beginning the data collection, the researcher first commits and submits to the University for Development Studies Ethical Review Process, as well as following all institutional protocol. This was accomplished by an opening letter that stated the researchers identify, the study topic, and the study's objective. (For more information, check the appendix.)

- Before any information was shared or disseminated, the researcher was mindful of anonymity and obtained informed consent from the research participants.
- Respect for the rights of the participants was observed. The right to privacy was not violated in any way.
- Participants were informed of their right to participate in the study as well as their right to withdraw at any time.
- Participants were also informed that the study is solely for academic purposes, and that the results will be disclosed in conformity with that objective. Participants will not be

harmed in any way. The study's relevance, benefits, and consequences will be communicated to respondents, and the study's relevance, benefits, and consequences will not be exploited in any way.

- To avoid plagiarism, the researcher was meticulous about documentation, identifying the many sources and study methodology employed.

The researcher took EMS 503 Ethical concerns in environment and resource management as part of a taught course, and as a result, is aware of ethical difficulties. Where there were shortfalls, the researcher sought advice from the designated supervisors. Before administering the questionnaires, the family heads were also asked for their permission. Respondents were advised that participation was entirely voluntary and that they might withdraw at any time if they felt uncomfortable. The study's identity and confidentiality were likewise guaranteed to the participants. The information is only used for scholarly purposes.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

The study's analysis is presented in this part. This chapter specifically presents the findings and discussions of the study in five sub sections: Demographic and Socio-economic Attributes of the

Respondents, Housing Characteristics, Map of Fire Prone Zones, Historical Trends and Perceived Causes of Fire Disasters, Fire Disaster Management Strategies, and Challenges Facing Fire Disaster Response. The previous chapter describes the evidence-based strategies utilized in relation to the research objectives.

4.1 Demographic and Socioeconomic Characteristics of Respondents

The social status or class of an individual or group is viewed as the socioeconomic qualities of research participants, and is frequently assessed as a mix of educational achievement, income, and occupation (American Psychological Association, 2016). This includes research demographics including location, role in the family, size of the home, and age and sex differences among respondents in the city. It was crucial to ascertain the respondents' demographics in order to put their worries into proper context and to comprehend the challenges resulting from the problem and the relevant main data. Given the severity of the situation under consideration, it was crucial to find study participants who were old enough to comprehend the problems and provide insightful comments that would aid in determining the best course of action for resolving the issue.

4.1.1 Sex, Age, Marital Status and Ethnicity of Respondents

As regards the respondents' gender, 61% were males and 39% were females. For the age distribution of the sample population, a good percentage of persons sampled were in the economically active age as only 11% were above 60years. Marital status indicated that, 64% were married and living with their spouses while the remaing were without their any spouse because they were either single, widowed or divorced.

Ethnicity was considered in this research. As various tribes or ethnic grouping have them believe and this may have an influence on the usage and handling of fire. For instance, the Dagomba celebrate the 'Bugum' Fire festival during which gymnastics of naked fire or flames is displayed.

The population and ethnicity forming the study area varies from one ethnic group to another with the predominant ethnic group made up of Dagombas and other groups from other parts of Ghana.

However, 35% of the respondents interviewed were Dagombas, 18% Gonjas, 8% and 5% being

Frafaras and Dagabas respectively. Akan and other tribes from the rest of the country were 35%. There is a clear sign that the communities under the study area are made up of different ethnic groups co-existing peacefully.

Table 4.1: Demographic and Socioeconomic Characteristics of Respondents

Characteristics	Categories	Frequencies	Percentage
Sex	Male	119	61
	Female	76	39
Total		**196**	**100**
Age (Years)	18-30	29	15
	31-40	56	28
	41-50	64	33
	51-60	36	18
	Above 60	11	6
Total		**196**	**100**
Marital status	Single	48	24
	Married	125	64
	Divorced	11	6
	Widowed	12	6
Total		**196**	**100**
Ethnicity	Dagomba	69	35
	Gonja	35	18
	Dagare	9	5
	Frafara	15	8
	Others	68	35
Total		**196**	**100**
Level of Education	No Formal	40	20
	Primary	15	8
	SHS/Voc/Tech	77	39
	Tertiary	64	33
Total		**196**	**100**
Occupation	Informal	139	71
	Formal	47	24
	Unemployed	9	5
Total		**196**	**100**
Income capacity	GHC 0-300	32	16
	GHC 301-500	15	8
	GHC 501-700	9	5
	GHC 701-1000	52	26
	Above GHC 1000	88	45
Total		**196**	**100**
Household size	1-5	52	27
	6-10	78	40
	11-15	43	22
	16 and above	23	11
Total		**196**	**100**

Source: Field Survey (2021)

4.1.2 Levels of Education of Respondents

Under the level of education, the literacy level can also have said to be high as only 20% had no formal education, while 80% hand different levels of education ranging from primary up to

tertiary levels.

4.1.3 Occupation of the Respondents

For the occupation of the respondents, 71% were engaged in the informal sector namely, artisans, traders and other business, 24% respondents were engaged in the formal sector, while 5% were unemployed. It was observed that, while most of the respondents engaged in the informal sector, resided in Aboabo and Gumbihini, majority of respondents of Russian

Bungalows were engaged in the formal sector. This finding is in concordance with the Ghana Living Standard Survey (GLSS) which suggests that majority of residents of Tamale who are employed are in the informal sector.

4.1.4 Income Capacity of the Respondents

The income capacity of the households was sought and was observed that, 16% of respondents, earned GHC 300 and below, 8% earned between GHC 301-500. Another 5% also earned between GHC 501-700, those who earned between GHC 701-1000 were 26% and 45% earned GhC1000 and above. Details on the income of respondents showed a larger population represented by 55 % who earned a thousand Ghana Cedis (GHC1000) and below. A dollar equivalent of 128.2 monthly. Respondents are mostly of the middle- and lower-class income levels. The findings are in line with the Ghana Living Standards

Survey (2012) which suggests that residents of the region are mostly meddle-and-low-income earners.

4.1.5 Household size and composition

The household size reveals that, 73% of households have 6 persons and above. The household size analysis revealed the average household size is 8 persons and the average room occupancy is

3.8 people to a room.

4.1.6 Material composition of housing units

The research also delved into the material composition of housing units which gravely influence the levels of vulnerability to fire. The use of low heat or fire resistant and combustible materials for housing units increases the vulnerability of the household to fire outbreak. Majority of respondents 62% had their wall constructed with cement blocks, 22% had their wall constructed with mud, while 1.5% had their walls built with burnt bricks, another 1.5% had their walls constructed with wooden shacks and 13% also had their walls built with sandrete/Landcrete. Roofing materials used by the surveyed households include aluminum sheets, asbestos roofing sheets and thatch/grass/raffia. About 88% of the houses were roofed with aluminum/iron sheets. Nine percent were roofed with grass/raffia and only 3% of the houses had asbestos roofing sheets. It was observed during the survey, that most of the houses that had galvanized aluminum roofing sheets, were old and won out. These were obvious in the IRAs, MCRAs and LCRF. Thatch/grass/raffia roofs were considered as susceptible to fire outbreaks and damp conditions and out of tune with modernity according to Yakubu et al., (2014), often require frequent replacement and maintenance to make them suitable for continuous

habitation. Asbestos roofing materials have been banned in the West for its negative health consequences on residents

(Karley, 2008; KonaduAgyeman, 2001a; Tipple, Korboe, Willis, & Garrod, 1998).

With regards to ceiling material used was generally encouraging with as much as 61% of households using plywood while 16% had no ceiling at all. Another 37% ceiled their houses with plastic materials only 3% had PoP for their ceiling. The most common flooring material was found to be cemented floor, 68% followed by ceramic tiles/Terrazzo, 11%, 4.5% used plastic tiles, mud mixed with cow dung for their flooring recorded 10%, and 6.5% had concrete floors.

Table 4.2: Material composition of housing units

Material	Frequency	Percentage
Building		
Cement blocks	121	62
Mud	43	22
Burnt bricks	3	1.5
Wooden shacks	3	1.5
Sandcrete	26	13
Total	**196**	**100**
Roofing		
Aluminum	174	88
Thatch	13	7
Shingle	4	2
Others	5	3

Total	196	100
Ceiling		
No ceiling	31	16
Plywood	119	61
Pop	9	3
T&G	37	18
Total	**196**	**100**
Floor		
Cemented floor	133	68
Ceramic tiles/Terrazzo	22	11
Plastic tiles	9	4.5
Mud/cow dung	19	10
Concrete	13	6.5
Total	**196**	**100**

Source: Field Survey (2021)

4.1.7 Forms of energy use in households

The forms of energy used was considered in this research as the type of energy, when not properly connected, used or handled inappropriately, results in fire outbreaks. The common source of energy used for lightening is electricity from the national grid as shown on Table 4.3 The data indicates that, 98.6% of respondents were connected to the national grid, the rest of the respondents' used candles, and Solar PV as sources of lightening. During power outages, all forms of energy sources ire used to either provide lightening or for cooking. Naked fires such as firewood, thatch brooms and candles are

sometimes used which not handled appropriately can result into undesired fire. For alternate source of energy for lightening on the event of power cut from the national grid, 58.00% indicated they use torchlight, 24% use candles, 11% use Kerosene lamps, 4% use Solar PV, 1.00% use Fuel powered generator set, 2% indicated they do not use any form of energy when whenever there is a power cut.

Table 4.6 also shows the type of fuel used for cooking in the households of the surveyed communities. In all a total, three major fuel sources have been discovered (the use of gas, firewood, and charcoal). According to the survey, 65.7% of respondents' cook using charcoal, while 26.9% use firewood. Only 7.4% of those polled said they cook with liquefied petroleum gas. The Ghana Water Company Limited (GWCL) is responsible for urban water supply for domestic, commercial, and other purposes such as firefighting within the Tamale Metropolis Most households rely on portable water supply from the Ghana Water Company as indicated by 69.4% of respondents, those who relied on Vendors for water were 19.4%, 11% use water from borehole/well/dugout. The first water delivery for the Tamale metropolitan assembly and its environs, which began in 1972 with the building of an intake at Nawuni on the White Volta River, 37 kilometers north of Tamale, and a Water Treatment Plant at Dalun. Three (3) water treatment plants are operated by the region. In Nawuni, on the White Volta, Dalun is a source of raw water. The Dalun Treatment Plant's Total Installed Production Plant Capacity has steadily increased throughout the years, as indicated below. Results fom the field indicates that

1972 – 2.8MGD (approx. 13,000.00m^3/day)

1999 – 4.3MGD (approx. 19,545.00m^3/day)

2008 – 10 MGD (approx. 45,000.00m^3/day)

When the expansion and rehabilitation work, which were awarded to Messrs-Bi-water Construction and completed in August 2008, the water production capacity increased from 19,545.00 m/d to 45,000 m/d, as well as distribution network extensions and a program to reduce water losses (NRW) through leak detection and pressure management, the water production capacity increased from 19,545.00 m/d to 45,000 m/d. Replacement of pumps in the existing water intake structure, 7 km of 600 mm raw water pipeline, a new treatment plant, replacement treated water pumps, 22 km of 700/800 mm transmission pipeline, a 20,000 m3 reservoir at

Kukuo-Yapalsi, and 96 km of new distribution mains were among the modifications. The GWCL, however, is unable to supply current demand for portable water for domestic and commercial purposes due to fast urbanization and increased population growth, as well as other technical and operational factors.

The extension project was completed in 2008 and the water supply was 45000 cubic meters per day, which was sufficient for the metro and surrounding districts. However, rapid population development and urbanization have resulted in a surge in demand for portable water. Currently, the company supplies 28,000 cubic meters, but Tamale Metro alone requires 78,000 cubic meters each day" The GWCL has resorted to a daily and weekly rationing scheme in order to equitably distribute water to fulfill the city's demand. This means that water is delivered to residences and hydrants on a weekly basis rather than daily. According to a GWCL spokesperson, one of the most significant issues in providing water to inhabitants in the city and its environs has been the substantial increase in demand for water, which has resulted in water rationing in the metropolis.

Water theft (illegal connection), escalating water treatment costs, unpredictable power supplies, and insufficient funds. Fire hydrant, is a very crucial installation where firefighters can connect to a water supply. Hydrants are water extraction devices that are used in pipelines and water distribution systems. A hydrant can ensure rapid water flow in the event of a fire. The hydrant wrenches and hydrant standpipes are used to tap into the pipes, which are then linked to the fire trucks.

Currently, the Tamale Metropolitan Area has 46 fire hydrants strategically placed across the city at vantage places where the Ghana National Fire Service can easily access them (GNFS).

However, for a city the size of TAMA, 46 hydrants are far insufficient to deal with fire emergencies. It isn't enough to simply have fire hydrants. Their physical placements and constant flow of water are also crucial. Different persons and groups have proposed a distance of 150 meters as the minimum distance between two fire hydrants (State of Oregon fire code, 2007;

Aydinoglu, Demir and Yomralioglu, 2011). Whereas Portland, Oregon, with a population of

632,309 people in 2015 and a land area of 376 km2, has a total of 16000 fire hydrant installations (The City of Portland, Oregon, 2016), Tamale, with a projected population of over 400,000 people and a land area of 922 km2, has only 46 fire hydrant installations, of which only 18 are serviceable, due to low pressure, water supply and distribution challenges, coupled with other challenges, only one hydrant works as at the time of Data collection. The alarming lack of fire hydrants in Tamale contributes the fire risk vulnerability levels.

One query looked at the causes for the city's low number of fire hydrants, factors considered when placing fire hydrants, and the company's intentions for adding more hydrants. The distribution lines for fire are separate from those for residential and other purposes, according to the spokesman, the expensive expense of laying hydrant distribution lines and installing them is limiting the company's capacity to install additional hydrants. He did, however, imply that the company had inked a $272 million deal with Bi water to build and expand the water supply infrastructure in Tamale and other parts of the region (which will include the installation of new fire hydrants). When completed, the project will provide 135,000 cubic meters of water per day.

The Volta River Authority's Northern Electricity Distribution Company (VRA/NEDCO) is the TAMA's primary electricity distributor. An applicant must submit a site plan, a building permit, and a quotation from a certified electrician to be connected to the National grid for electrical supply. According to a VRA/NEDCO official, most inhabitants do not hire certified electricians to wire their houses and businesses, resulting in haphazard wiring and illegal connections. He further stated that, 45% of power is lost to illegal connection, leading to the loss of GHC8.5 million every month. Aside the power losses, it increases the vulnerability and risk levels of the metropolis to fire outbreaks. Table (4.3) also captures the sources of services respondents contracted for electrical wiring and repair works in their homes, 63% of respondents indicated that, they relied on the services of way-side electricians for wiring and electrical repair works. According to them, they could not afford the charges of certified electricians, and the procedures of hiring their services were too cumbersome. Majority of respondent who patronized the services of uncertified electricians were from Aboabo and Gumbihini.

Plate 4.1a and 4.1b Electrical connection in Aboabo and New Jisonayili

Source: Field Survey (2021)

Respondents who claimed to employ the services of certified electricians were 37%. All respondents from Russian Bungalows stated they employed the services of certified electricians. They indicated that, they were not allowed to employ the services of any electricians except electricians certified by VRA or the Estate and works department of the regional coordinating council. However, 4% indicated that, they wired and do repair works by themselves.

Table 4.4: Details of household energy source and Connectivity

Energy	Frequency	Percentage (%)
Energy for Lighting:		
National Grid	**193**	98.5
Candles	**3**	1.5
Total	**196**	**100**
Alternative Energy:		
Torchlight	111	57
Candles	54	28
Solar P V	7	4
Kerosene lamp	21	11
Total	**193**	**100**
Energy for Cooking:		
Charcoal	120	61
Fire/Fuelwood	51	26
LPG	25	13
Total	**196**	**100**

Water for domestic use		
Borehole/Well/Dugout	21	11
Standpipe	134	68
Vendors	41	**21**
Total	**196**	**100**
Electricity Connectivity		
Certified Electrician	83	43
Uncertified Electrician	111	57
Total	**193**	**100**
Cooking facility		
Kitchen	60	31
Courtyard	90	46
Verander	36	18
Sleeping room	10	5
Total	**196**	**100**

Source: Field Survey (2021)

4.1.8 Distribution of household's cooking facilities/options in TAMA

For places designated in the households for cooking, 38% of respondents had kitchens, 40% cook in the court yard, 18% do their cooking in the verandeh and 4% cook in their sleeping rooms**.** Coocking in the court yard and sleeping rooms exposes the residents to the risk of fire. A fire in the open according to Sarpong (2013) can easily get out of control. Embers can be blown around the home by the wind and ignite a fire as most of the houses had some form of thatch roof in parts of the homes. A premesis with insufficient fire seperation in the rooms can lead to uncontrolled fire, the result is that part of the room is used as a cooking space which help build enough heat in the room thereby igniting flamble materials when it attains its combustible temperature range.

4.2 Research Objective One: Map Out Fire Risk Zones in the Metropolitan Area

4.2.1 Fire Risk Maps

The Tamale Metropolitan Area's fire risk was rated using GIS Grid displays. These were divided into four categories: (1) Very high risk, covering an area of 73.1 km2; (2) High risk, covering an area of 236.4 km2; (3) Low risk, covering an area of 552.02 km2; and (4) Very low risk, covering an area of 447.01 km2. (1) Area infrastructure, high urban density (high population density), and high building density (high housing density make people more exposed to a wide range of calamities, including fire) are the elements that influence the fire risk rate. Due to the enormous number of individuals who will need to share a small area for evacuation, such as a tiny bedroom or a narrow roadway, there is a high risk of fire. Crowded conditions give enormous contribution to mortality (Challenger and Clegg, 2011). It also makes fire spreading more rapid, more casualties and affects the neighborhood. The study also considered road dimension and fire engine

accessibility, and water source for firefighting, included hydrant, (2) building material type, included combustible and non-combustible building, (3) response time service of firefighting

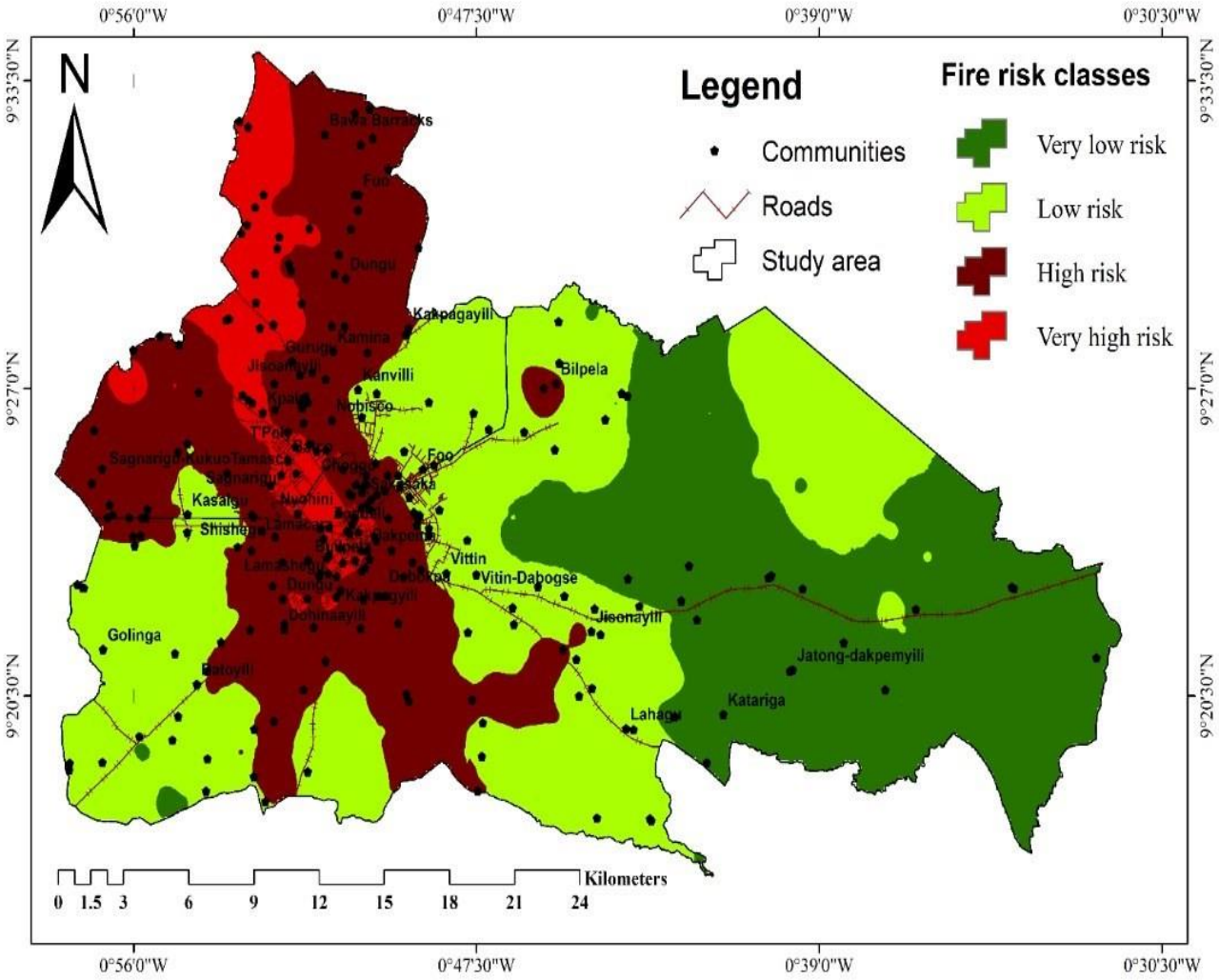


Figure 4.1: Map of fire Risk zones in the TAMA

Source: Field survey (2021)

Only four (4) firefighter stations in Tamale Metropolis are able to respond to all emergencies, which greatly lowers the risk level there. The response time of the firefighters is slowed considerably as a result. According to NFPA 1710 (2001), the

minimum fire response time for an occurrence involving fire suppression is four (4) minutes (240 seconds) for the arrival of the first arriving engine company and/or eight (8) minutes (480 seconds) for the deployment of a complete first alarm assignment. In Tamale, the average response time was fifteen (15) minutes, above both the global average of four (4) minutes and the national average of eight (8) minutes. According to Murray's (2013) study comparing the number of firefighter stations in Dubai and the fire service response times, twenty-five (25) fire stations are needed for a three-minute response, twenty (20) for a four-minute response, and thirteen (13) for a five-minute response.

This suggests that in order to maintain the required four (4) minutes response time, the Tamale Metropolitan Area will need sixteen (16) extra firefighter stations. The GPS coordinates of the fire stations and the fire hydrants installed in the Study area were used

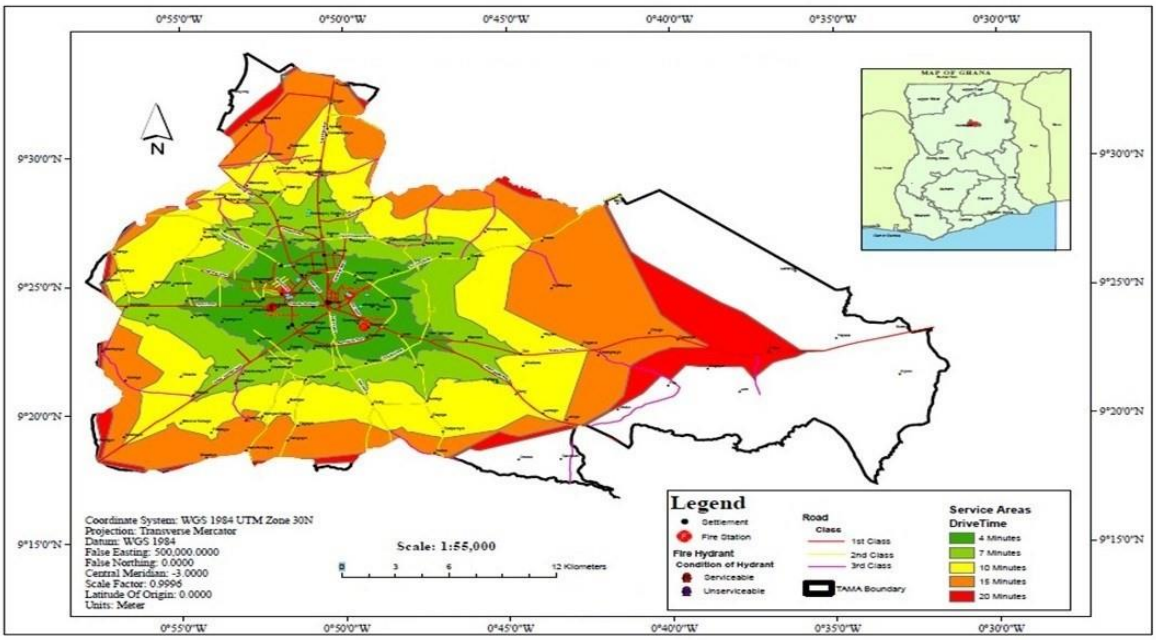


Figure 4.2: Map showing service areas under different drive time and hydrant locations.
Source: GNFS Data Base (2021)

Findings showed that, the fire risk zones of the study area are areas with high housing density and communities with high denes the population. Owing to the high population, there is usually disregard to fire precautions making such areas prone to fire outbreaks. The findings further indicated that the high congested areas have little accessibility to fire engines and also lack hydrants for firefighting. Agyemang et al. (2015) discovered all fires in Ghana occurred in the dry season (November-April), with the most flames and the most burned area happening in

January and February and occurring in the dry parts of the country. While pre-suppression and suppression activities were made, the primary focus was on preventing future fires. The findings of Storr (2008) are in tandem with the findings of this research when it was found that fire disasters occur usually in dense areas with wooden structures, shoddy electrical wiring, and obsolete electrical appliances. However, Storr (2008) made a further interesting observation that markets have seen the most fire outbreaks in recent years, prompting fear and panic among the populace. Many fires have erupted in Kumasi's central market, which is regarded as West Africa's largest open-air market. Recent findings of Banyeh and Adda (2021) are congruent with the findings of research that, electrical fires accounted for 53.9% of all fires, with residential buildings accounting for 55.4% of all fires, and fires occurring in the dry season accounting for 577.6% of all fires. Wet season fire spread was less likely than dry season fire spread.

4.3 Perceived Causes of Fire Disasters in the Study Area

Residents' opinions were solicited on what they believe are the key causes of fire disasters, as well as the variables that account for fire disasters in their community based on their acts or inactions. Figure 4.4 depicts residents' responses to what factors

contribute to fire disaster risk were revealed in the field survey. Majority of the respondents, 58%, believe that, electrical equipment and wiring are the major causes of fires. The second major causes of fires according the findings, smoking representing, 14%, while 13% agreed that, accident while cooking is a leading cause where as 7% and 5% were of the view that candles and children playing with fire source were the main causes of Residents' reactions regarding what elements contribute to the risk of a fire disaster were revealed in the field survey as shown in figure 4.4, only 2% believed that Arson (intentional fires) was a major cause of fire disasters.

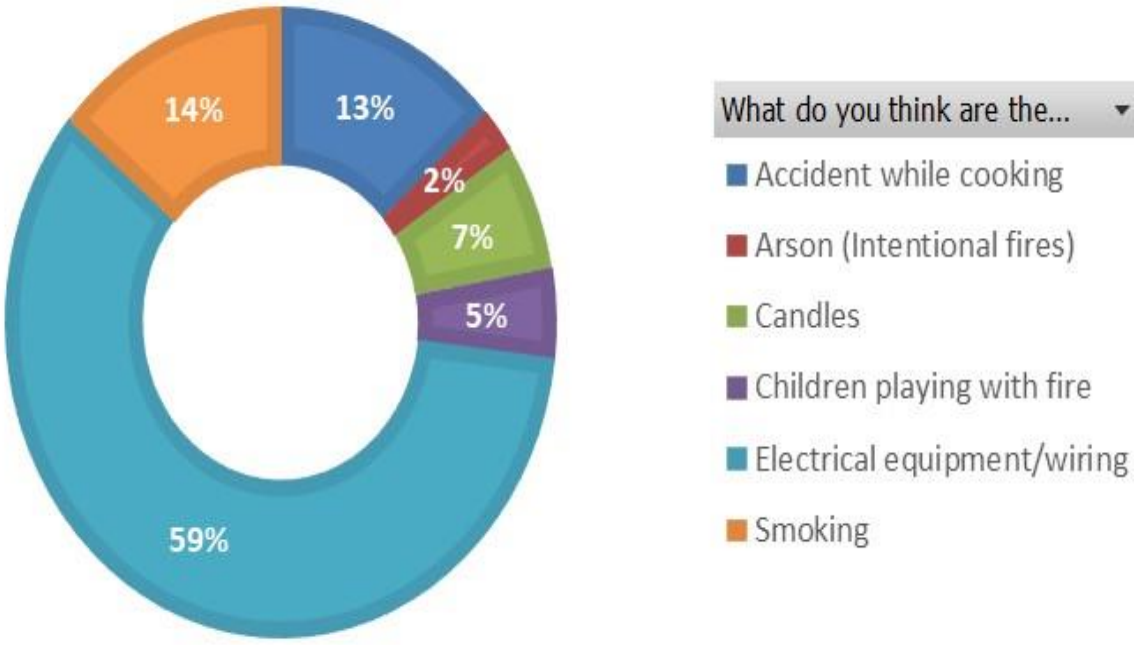


Figure 4.3.1 Respondent's perception of causes of fire outbreak

Source: Field Survey (2021)

Respondents mentioned illegal connections, overaged wiring, engaging the services of unqualified electricians, the use of substandard electrical wires and gadgets, overloaded sockets as being the main factors that lead to electrical fire incidence. Understanding the

causes of fire and the factors that contribute to risk buildup aids in determining the appropriate prevention strategies This is because, as Pyles (2007) points out, understanding the origin of a disaster occurrence aids in the development of short, medium, and long-term prevention efforts.

4.3.1 Actual cause of fire outbreaks among fire victims

In all 43 respondents indicated that they have ever experienced fire outbreak in their homes. While 58% stated that, the cause of the fire they experienced were electrical related, 13% stated their fire outbreak was as a result of children playing with ignition source, another 16% mentioned accident while cooking as the cause of they experienced, 9% said the fire experienced was as result of unattended garbage and bush burning, 2% mentioned smoking and improper use of candles and mosquito coil.

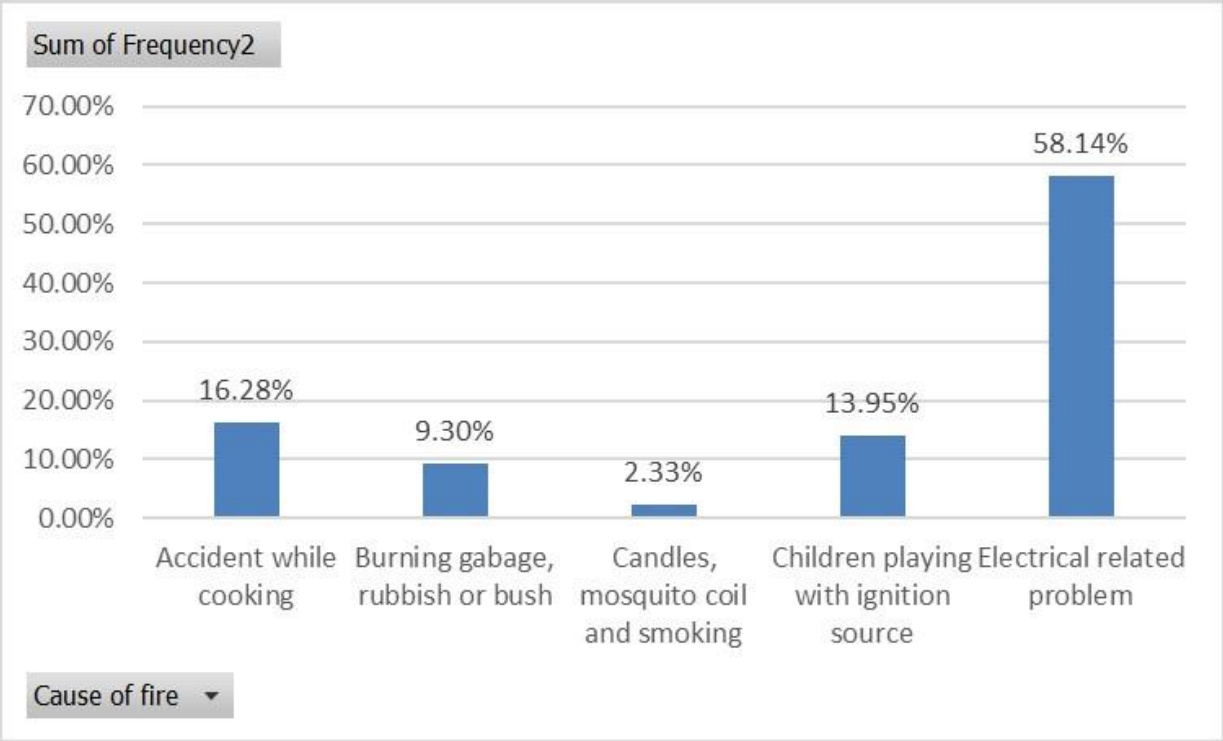


Figure 4.3.2 Causes of fire outbreak among fire victims

Source: Field Survey (2021)

4.3.2 Historical Trends of Fire Out Breaks in Tamale

A review of the trend of fire outbreaks was done using data obtained from the GNFS annual fire incidence report. It should be noted that, these figures were incidents that were reported to the

GNFS. Figure 4.5 below illustrates fire incidents recorded in the Northern region and Tamale Metropolitan Area from 2004 to 2020. It can be seen that, the number of fire incidents generally increased in each year. Fire incidents in the Northern region ranged between 65 and 146 from

2004 to 2012 but however saw a sharp increase to 277 in 2013 and has since been ranging between 261 and 370. Fire outbreaks in 2004 were 94, and begun recording fir outbreaks in the

100s in 2005 and 2006, reduced to 65 outbreaks in 2007. It experienced an increase again to 98incidents in 2008, it further went up to 119 in 2009 and declined by 5 in 2010. It again increased to 149 outbreaks in 2011 and witnessed a very sharp to 277 outbreaks in 2013. It however decreased marginally to 261 in 2014 but gained astronomical increase to 310 in 2015 and continued to record figures above 300 for 3 years, witnessing another decrease to 261 in

2019, but went up again to 314 in 2020. Tamale on the other hand, has seen annual increase from

2004-2006 and witnessed a slight decline 2007and 2008. The figures started rising again from 2009 to 2013 where it witnessed a sharp increase of less 100 outbreaks to 212 in 2013. It again experienced a decrease to 148 in 2014. The number of incidents went up again in 2015 and has since seen an annual increase. These findings are in line with Addai et al., (2016) The details of the causes of fire from the GNFS investigations reports placed electrical related problems as the cause of 60% of the reported fire incidents,

accident while cooking 14%, children playing with ignition source 13%. It further noted that, unattended garbage or bush burning, caused about 10% of the fires, whereas improper use of candles, mosquito coils and smoking were responsible for3% of the fires, LPG also caused 3%.

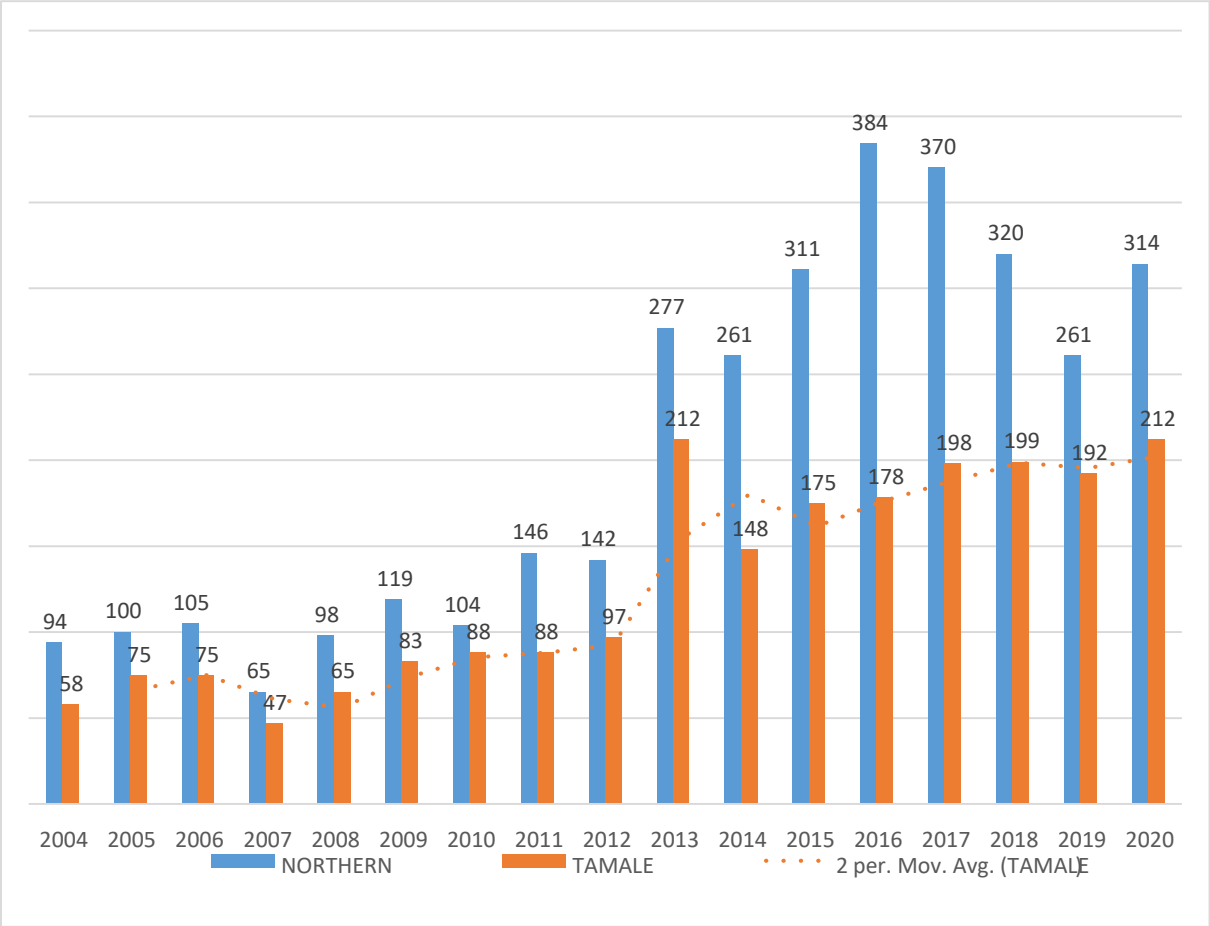


Figure 4.4.1 Trends of fire outbreak in the TAMA from 2004 to 2020

Source: GNFS data base 2021

This sharp rise in 2013 was attributed to power fluctuations and increased population, urbanization, industrialization and other activities. The results are in line with the findings of Addai et al. (2016) attributing it to the energy crises the country was facing then and the tremendous, rapid and unprecedented urbanization of the city as observed

by (Owusu-Sekyere & Amamiampong, 2017). It was revealed that, the total number of fire incidents in the Northern for the period under review, was 3,571 and out of this, Tamale metropolitan area alone recorded 2,226 representing 62.34% of the regional occurrences. There was a total of 38 people who sustained various degrees of injury and 17 other persons lost their lives to fire incidents in the region. Tamale metropolis recorded 23 of those who sustained injuries and 11 of those who lost their lives were recorded in the Tamale metropolitan area alone.

4.3.3 Cost of Damage

The total estimated cost of damage caused by fire from 2004-2020 in the Northern region was

GHC 7,916,973.00. the total estimated cost of damage for Tamale Metropolitan Area, was GHC 4,359906.00 representing 55.1% of the region's total figures. From figure (4.6), 2019 recorded the highest cost of damage and this could be attributed to the fire that gutted Mafara Hotel belonging to the late former vice president, Alhaji Aliu Mahama and a number of commercial fires as they usually come with losses.

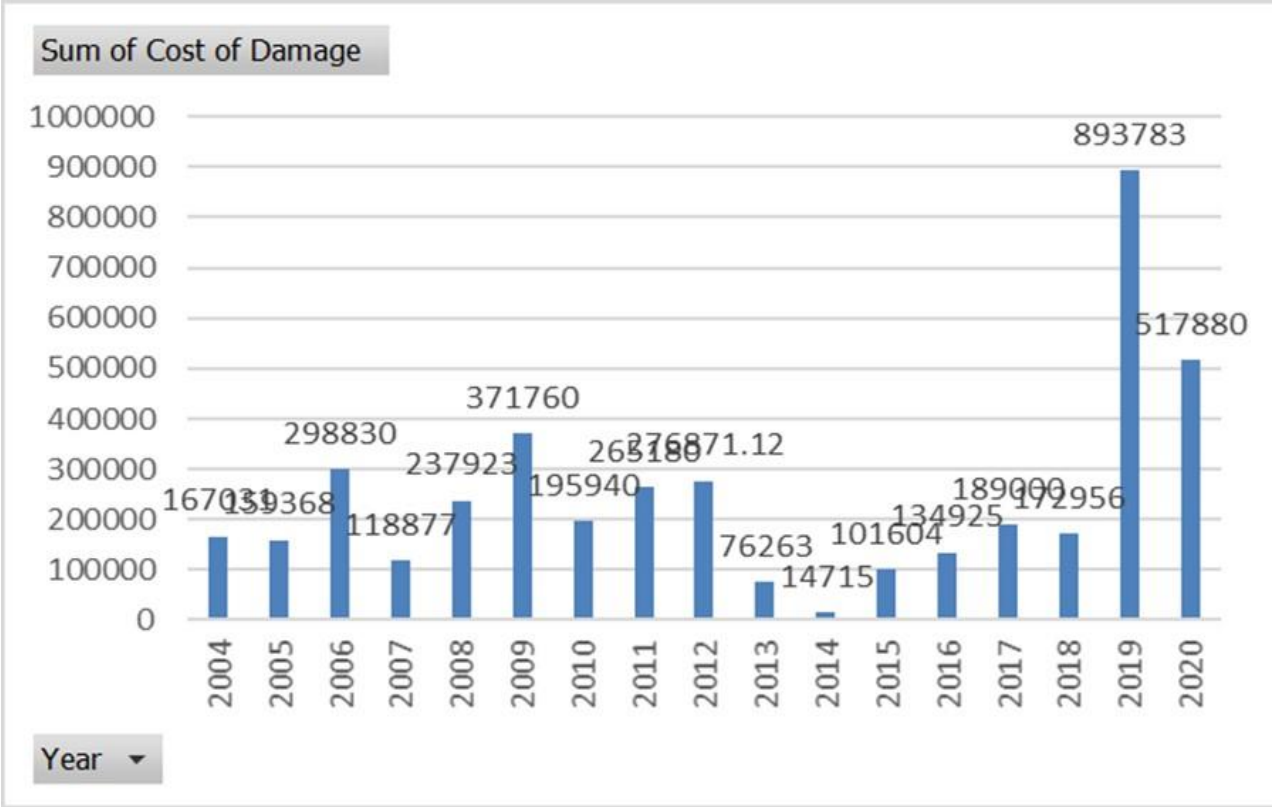


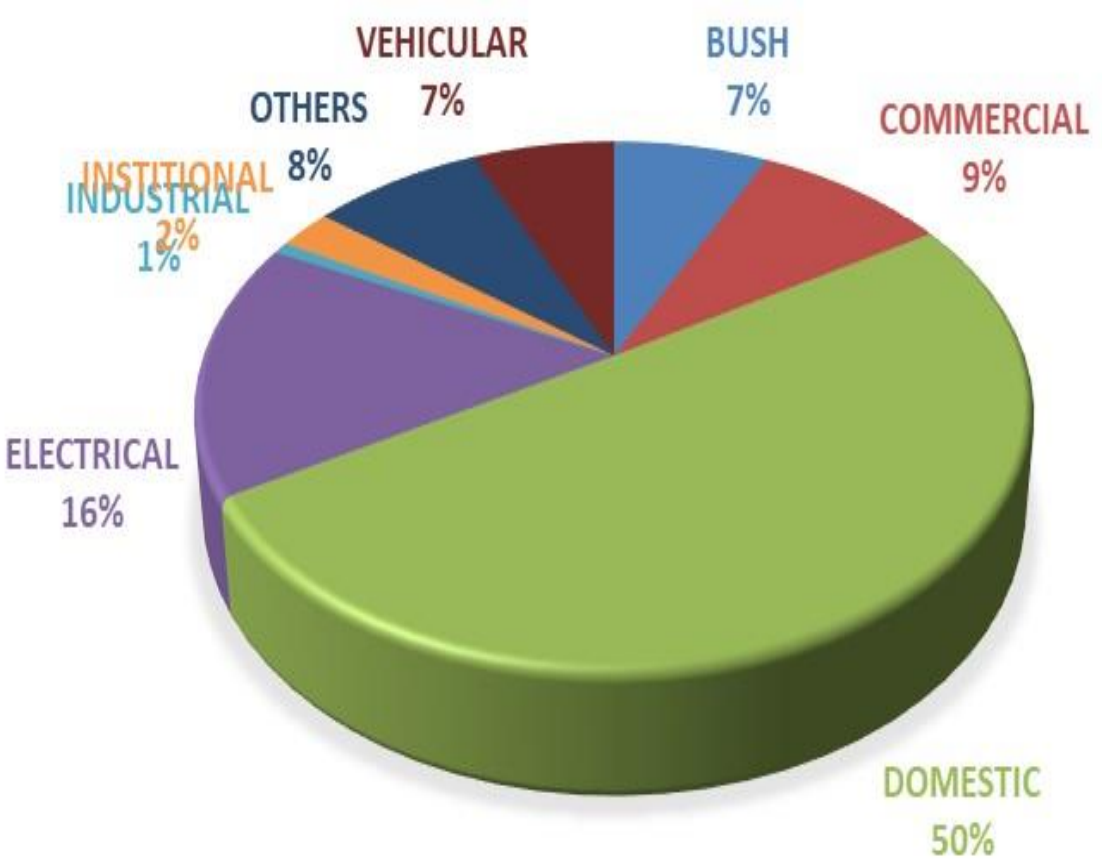
Figure 4.4.2 Cost of Damage by fire outbreaks from 2004 to 2020

Source: GNFS Data Base (2021)

4.3.4 Details of fire outbreaks

With regards to the origin of various fire incidents, the GNFS classified them as follows: domestic, industrial, vehicular, intuitional, electrical, commercial (market) fires, bush fires and others, Ad.ai et al., (2016) made a similar observation. From the total number of fire incidents for the period, domestic fires topped with 50% followed by electrical fires which accounted for 16%, others accounted for 8%, Commercial (market) fires accounted for 9%, Vehicular and Bush fires accounted for 7% each institutional and industrial fires accounted for 2% and 1% respectively.

Figure 4.4.3 Details of fire outbreaks



Source: GNFS Data Base (2021)

4.3.5 Mode of reporting fire incidents

The finding of the study further reveals that, he mode of call or reporting of these fire incidents were done by running call. Meaning, the reporters of the incidents went to the fire station personally to report. About 20% were reported through the personal lines of fire officers on the remaining 20% called through the stations' telephone or emergency lines to report the incidents. Findings from the study showed a consistent increase in fire outbreaks in the study area. The Fire incidents in the Northern region increased from 65 in 2004 to 277 in 2013. This represents an over 500% increase in fire outbreaks in the study area. It can be inferred from the findings that; fire outbreaks are at an alarming rate

and historical trend proves this. Addai et al. (2016) made a similar observation about a yearly increase in fire incidence in Ghana as a whole. Findings from this research related to the perceived causes of fire disasters in the study area indicated frequent power fluctuations and increased population. There have been frequent power outages which sometimes cause electrical faults leading to fire outbreaks. The study area has also experienced a massive population rise over the years causing disregard for fire precautions and increased activities leading to frequent fires. Respondents indicated that perceived causes of fire outbreaks are illegal connections, overaged wiring, engaging the services of unqualified electricians, the use of substandard electrical wires and gadgets, and overloaded sockets as being the main factors that lead to electrical fire incidence. According to Addai et al. (2016) many factors, including population development and industrialization as well as unstable electricity, urbanization, negligence, and illicit electrical connections, contributed to the rise in the number of fire incidents. A third of all fire events in Ghana were caused by a home fire, the researchers assert. Sarpong (2013) also made an advanced observation that in Ashaiman the usage of wooden planks and lack of fire hydrants in buildings aggravate the problem of fire outbreaks. Agyemang et al. (2015) found that the most common cause of fires was farming, hunting, or charcoal manufacture in the forest, which accounted for 19 percent of all fires. Miller (2005) indicated that fires in their study neighborhood are often started as a result of social problems which include individuals' recklessness, intoxication, illiteracy, and drug addiction. Source of energy, building design, and climatic circumstances are all linked to fire events in the Tamale

Metropolis, as found by Banyeh and Adda (2021). The findings of Banyeh and Adda (2021), Addai et al. (2016), Agyemang et al. (2015), Sarpong (2013), and Miller (2005)

concerning trends and causes of fire disasters are consistent with the findings of this study as discussed.

4.3.6 Factors Influencing Fire our Break in Tamale Metropolitan Assembly

Table 4.5 presents the output of the logit regression model on the determinants of fire out breaks in the Tamale metropolis. The diagnosis from the table shows that, the Likelihood ratio is 173.11 and is significant at 1% implies that the model fit the data. Also, the pseudo R^2 is 0.8518 means that the 85.18% of the changes in household experience of the fire outbreak is being explained by the explanatory variables. Age of the household head, educational level, and average monthly income all have a negative influence on the probability of experiencing fire outbreak. Also, sex and marital status had a positive influence on the chances of the household experiencing a fire outbreak while the source of lightning, the ownership of a house and the source of fuel for cooking all has no significant influence on the likelihood of experiencing fire outbreak.

Table 4.5 Determinants of fire Outbreak in Tamale Metropolis

Variable	Coefficient	Odd Ratio	Standard Error	P-Value
Age	-2.3983**	0.0908	0.999	0.016
Sex	2.4991**	12.1713	1.196	0.037
Marital Status	3.9955**	54.3508	1.819	0.028
Education Level	-1.1093*	0.3298	1.819	0.054
Average Monthly Income	-1.1640*	0.3123	0.597	0.051
Source of Lightning (Kerosene Lamp)	0.6132	1.8462	3.109	0.844
Solar Panels	-0.7833	0.4569	6.558	0.905
Torchlight	0.1831	1.2009	1.199	0.879
Cooking Fuel	-0.3452	0.7081	1.895	0.855
Household Ownership	1.1227	3.0732	1.564	0.473
Constant	4.5761**	97.13	2.373	0.054
Likelihood Ratio (10)	173.11			
Pseudo R2	0.8518***			
Number of	190			

Observation

Note: *, **, *** represent the level of significance at 10%, 5% and 1% respectively

Age from table 4.5, which is continuous is negative and statistically significant at 5%. This implies that, as the age of the household heads increases, the probability of the household experiencing fire outbreak decreases by 0.09 times given that all other things are constant. This is plausible because, as the age of the household heads increases, the likelihood that they might have had experience and be cautious of fire outbreak or even do away with the materials that could spark fire within the premises.

Also, sex that is being a male is statistically significant at a 5% and a positive regression. This means that, when the head of the household is a male, the probability of experiencing fire outbreak as compared to their female counterparts increases by 12.17 times. The reason for this could be that when the household is a male, there could be tendency for him to be careless at handling some materials which could generate fire in the house. Especially in our settings when it is believed that it is the women that usually handle fire related objects. Marital status is positive regression and statistically significant at 0.5% indicates that, when the head of the household is married, the likelihood of experiencing fire outbreak increases by 54.35 times. This is credible in that, when a household is married, there is every tendency that they will be children and other younger persons around who would not know how to handle things that can spark light or even play with the light equipment that can easily got the house engulfed with fire as stated by

Munson and Oates (1983) and again the tendency for married couples to think that the other will do the needful could be the reason for the findings. Singles do not have anyone to depend on and would always carry out their activities without expecting someone to do it. Educational level is negative regression and statistically significant at 10% with odds ratio of 0.3298. This means that when the level of education of the household head increases, the likelihood of the household experiencing fire outbreak decreases by 0.33 times. This is plausible because, the more the level of education, the higher the likelihood that the person is exposed and experience on the use of handling appliances and even give orientation on the precaution measure in the family as indicated by Gunther (2011), Jennings (1999) and Munson and Oates (1983)

Average monthly income is also significant at 10% and negative regression with the odd ratio of 0.3123. This means that, as the income of the household head increases, the likelihood of the household experiencing fire outbreak decreases by 0.3123 times. This is conceivable in that, when the average monthly income of the household increases, there is likelihood that he might have money to engage the services qualified or certified professional and quality appliances which could prevent the household from possible fire outbreak. These findings corroborate the findings of Munson and Oates (1983) that low incomes means that households are unlikely to invest in fire prevention and protection devices and the higher the income of household, the more it is willing to spend money on fire safety.

4.4 Research Objective Three: Fire Disaster Management Strategies in the Study Area

Knowing the fire departments and other emergency service providers' phone numbers is critical in an emergency. Early communication with service providers will result in a timely reaction, decreasing the level of harm caused by the incident. From table 4.6, It can be noted that the majority of respondents (87.03%) do not know how to contact emergency service providers, while just 13.4% claim to have the number. This means that calling the fire service for assistance in an emergency will be difficult, putting them at greater risk. This is in line with InahE's findings (2018). Because of the nature of fire hazards, it was believed that people would have emergency phone numbers on hand, which they could call for help if needed.

Table 4.6 Number of households with contacts of emergency service providers

Community	No		Yes		Total	
	No.	(%)	No.	(%)	No.	(%)
Aboabo	49	79.03	13	20.97	62	100
Gumbihini	49	89.1	6	10.9	55	100
Russian bungalows	13	81.25	3	18.75	16	100
Dungu	15	93.75	1	6.25	16	100
New Jisonayili	45	95.74	2	4.26	47	100
Total	171	87.2	25	12.8	196	100

Source: Field Survey (2021)

4.4.1 Fire engine accessibility to houses

The research sought to determine the accessibility to homes by fire engines and others emergency vehicle in the event of a disaster. 51% of respondents agreed their homes was not accessible, 49% of respondents agreed their houses were accessible. This finding is in line with Sarpong (2013) who found out that over 50% of houses in communities with low-income status are not accessible by fire and emergency vehicles.

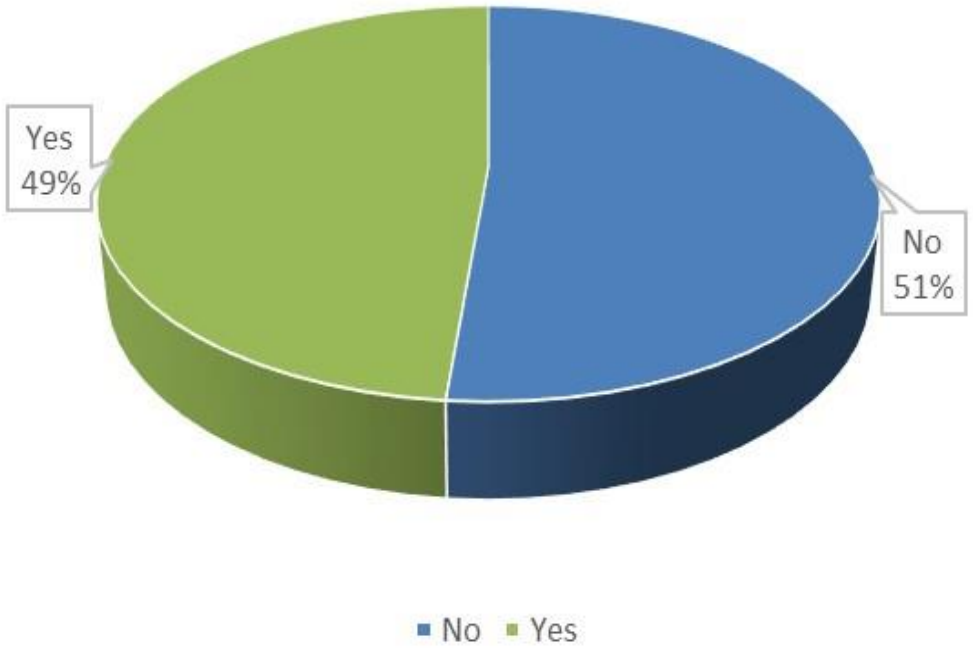


Figure 4.5 Fire Engine Accessibility to houses

Source: Field Survey (2021)

4.4.2 Fire prevention measures implemented at home

The following responses were given as to what they have put in place to avoid fire outbreaks, a little over 38% of respondents indicated that, they carry out regular checks of electrical installations, 28% of respondents performed housekeeping practices, 9%

respondents said they do regular check on their kitchen installations. 1 respondent ensured proper building lay out and

23% of respondents indicated they did nothing at all to avoid fire out breaks.

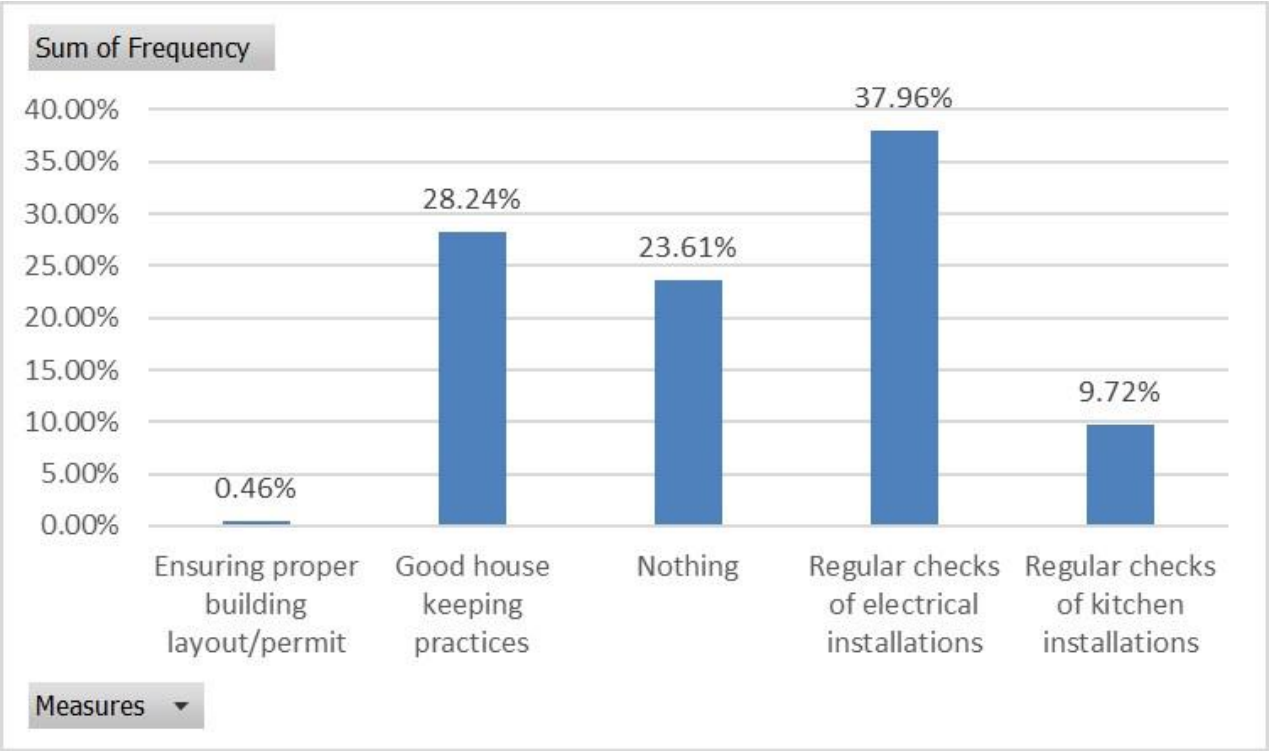


Figure 4.6 Fire prevention measures adopted by respondents

Source: Field Survey (2021)

4.4.3 Fire detection equipment and suppression equipment

Fire detectors aid in the early discovery of fires, when there is still enough time for inhabitants to be safely evacuated. Early detection is also important for ensuring the safety of emergency response personnel. Early detection can limit property loss and reduce downtime for the operation since control operations can begin while the fire is still small. They also provide firefighters with information about the location of the fires, which reduces fire response time. Respondents were asked to know if they have installed any form of fire detection or suppression equipment in their homes. The results of the

survey reveal that, none of the 196 respondents had installed any form of fire detection equipment in their homes, however, only 2 respondents had installed a fire extinguisher in their homes but unfortunately, indicated that, they did not know how to operate it.

4.4.4 Measures adopted to manage fire out breaks

Respondents were asked to know the measures they have adopted to manage fire out breaks. it was discovered that, 192 respondents representing 88.69% had no measures put in place to douse out any potential fire. 15 respondents however, indicated they always stored enough water to be used in the event of a fire outbreak, 4 respondents had buckets filled with sand, 3 respondents said they always ensure that escape routes are cleared, 2 respondents had fire extinguishers.

Table 4.7: measures adopted by respondents to manage fire outbreaks at home

Measures	Frequency	Percentage
Buckets filled with sand	4	1.85
Creating access to home	3	1.39
Installation of fire extinguishers	2	0.93
Nothing	192	88.89
Storage of enough water	15	6.94
Totals	216	100

Source: Field Survey (2021)

Most respondents did not see the reason to put in place fire preventive and firefighting measures due to the perception that, it will not happen to them. Some residents even assigned spirituality to fire outbreaks. A similar gap was observed by Maddux and

Rogers (1983) who concluded that the sense of a frightening event's seriousness, sympathy for its occurrence, self-efficacy (belief in one's capacity to deal with threats and take action to lessen them), and reaction efficacy all contribute to people's willingness to take precautions against disaster. The findings also support the core tenets of structural and system functionalism theories, which contend that disaster prevention requires cooperation from all stakeholders with clearly defined roles and responsibilities (Aning-Agyei 2018). This suggests that when group efforts to avert disasters fail, individuals use unauthorized tactics, increasing the dangers in a location. Findings indicate that most of the respondents do not have any strategy in place to manage fire disasters. There is no fire detection equipment in their homes. The respondents rely solely on the Fire Service to manage any occurrences of fire disasters. Findings further showed that few respondents use fire extinguishers as a strategy to manage fire disasters in their homes. However, the respondents lacked knowledge of the operation of the fire extinguishers. Storage of water and sand were the least utilized strategies for managing fire disasters in the study area. The findings of Sarpong (2013) are consistent with the observation of this research when the author found that, respondents used sand to put out fires in creative ways. On the large scale, non-governmental and community-based/faith-based organizations, such as ethnic associations, ethnic groups, and other non-governmental and community-based/faith-based groups, are frequently called upon by locals in the midst of their current fire challenges. Agyemang et al. (2015) advocate for ongoing education and capacity building, alternative farming methods, stricter enforcement of wildfire laws, increased patrols and inspections, the maintenance of fire breaks, the installation of lookout towers and other detection systems, the provision of suppression equipment, and collaboration amongst stakeholders. Addai et al. (2016)

recommended that based on current fire conditions in Ghana, efforts to improve public education be stepped up. In view of the fact that most fires are caused by people's lack of knowledge and carelessness, both the Fire Service and the National

Disaster Management Organization should launch a comprehensive educational campaign to educate the public on fire safety and prevention. Community fire volunteers, regularization and reconstruction of informal settlements, better building codes, and fire hydrants in strategic areas are other suggested strategies by Addai et al. (2016) to mitigate fire outbreaks in Ghana. Based on the findings of Mubita et al. (2020) the proposed strategy for fire disaster prevention management in Zambian markets was maintaining market fire facilities, monitoring the market environment, educating and training marketers and consumers, and ensuring the quality of market structures.

4.5 Research Objective Four: Challenges Confronting Fire Disaster Response in the Metropolitan Area

4.5.1 Disregard for Building Codes and Regulations

With regard to challenges confronting fire emergency response in their community, 86 respondents were of the view that, poor accessibility by way of haphazard buildings blocking access routes, bad road network poses as challenges to fire incidents in their communities. This was confirmed by institutional heads as a great challenge to fire disaster response in the Metropolis. '*You will find people disregards building codes and put-up structures blocking access routes, some even build their structures without exit routes for emergency purpose*' an official from the Fire Service laments

A staff of the TaMA indicated that, *whenever there is a plan on decongestion or demolition of unapproved structures to make way for emergencies, then you have interferences by higher authorities and traditional leaders compelling us to stop.*

4.5.2 Challenge Contacting Emergency Service Providers (Information and Communication Challenge)

Some respondents on the other hand, mentioned difficulty in contacting the Fire Service during emergencies, as resident rely on the emergency call numbers which are sometimes not reachable. The findings from the expect interview indicates that, the emergency short code are not decentralized and therefore all calls go through to the National control centres before being redirected to the local call center.

4.5.3 Inadequate Resources for Fire Disaster Response

34 respondents claimed, lack of resources for firefighting that is, inadequate number of fire stations, hydrants and fueling of the fire engines as challenges they encounter during fire emergencies, 10 respondents were also of the view that, lack of communal spirit posed a challenge, only 2 respondents mentioned improper addressing system as a challenge facing their communities.

Table 4.8: Challenges confronting firefighting according to respondents

Challenge	Frequency	Percentage
Challenges contacting the Fire Service	84	38.89%
Challenges with resources for firefighting	34	15.74%
Improper addressing system of communities	2	0.93%
Lack of communal spirit	10	4.63%
Poor accessibility by fire engines	86	39.81%
Grand Total	216	100.00%

Source: Field Survey (2021)

Findings showed that poor accessibility by way of haphazard buildings blocking access routes posed the greatest challenge in the Tamale Metropolis. According to the Fire Service Officials, they find it difficult to access areas on fire because of haphazard buildings and extensions, illegal siting of metal container shops blocking alleys and access routes and bad road network. Difficulty in contacting the Fire Service during emergencies was the second-highest ranked challenge in fire response. Other important challenges identified by the research were the lack of resources for firefighting. These included an inadequate number of fire stations, utility vehicles to carry out regular education, training and inspection. hydrants, and fueling of the fire engines Personal Protection Equipment (PPEs). The lack of these resources impedes the effectiveness of the work of the Ghana National Fire Service. The least challenges encountered in responding to fires in the study area are lack of communal spirit and improper addressing system in the communities. Agyemang et al. (2015) found that a lack of incentives for

people to help put out flames and a lack of protection and suppression equipment hampered the efficiency of fire management. Laws exist to enable good disaster management but the execution is a major difficulty, according to Sowah (2019). Disaster management efforts in Ghana continue to be hampered by political, social, and resource constraints, as well as the difficulty of coordinating the actions of disaster management agencies per the findings of Sowah (2019) which

corroborates the findings of this research.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATION

5.0 Introduction

This chapter presents a summary of findings, conclusions, and recommendations. Section one presents the summary of the findings. Section two presents the conclusion of the study. Section three presents the recommendations of the study.

5.1 Summary of Findings

5.1.1 Fire risk zones in the Tamale Metropolitan Area

The fire risk zones were found to be Aboabo, Sakasaka Lamashiegu, Sabonjida, Zogbeli, Tishigu, Shieshegu, Kalpohini, Koblimahagu, Kukuo, Fuo, Old Vittin, Duhinnayili, Choggu, Gumani, Gumbihini, Nyohni, and Kanvili. The findings showed that the fire risk zones of the study area are areas with high housing density and communities with dense population. Owing to the high population, there is usually disregard for fire safety precautions making such areas prone to fire outbreaks. The findings further indicated that the high congested areas have little access routes for fire engines and also lack hydrants for firefighting.

5.1.2 Historical trends and perceived causes of fire disasters in the study area

Findings from the study showed a consistent increase in fire outbreaks in the study area. The Fire incidents in the Tamale Metropolitan Area increased from 65 in 2004 to 277 in 2013. Findings from this research related to the perceived causes of fire disasters in the study area indicated frequent power fluctuations, unprofessional wiring and increased

population. There have been frequent power outages which sometimes cause electrical faults leading to fire outbreaks. The study area has also experienced a massive population rise over the years causing disregard for fire precautions and increased activities leading to frequent fires. Illegal connections, overaged wiring, engaging the services of unqualified electricians, use of substandard electrical wires and gadgets, and overloaded sockets were the perceived causes of the frequent fire outbreaks in the study area. The different sources of energy, building design, and climatic circumstances were all linked to fire events in the Tamale Metropolis.

5.1.3 Fire disaster management strategies in the study area

The study indicated that although disaster management institutions carry out their various mandate in the Metropolis, most of the residents do not have any strategy in place at home to manage fire disasters. There is no fire detection equipment in their homes. The respondents rely solely on the Fire Service to manage any occurrences of fire disasters. The findings further showed that few respondents use fire extinguishers as a strategy to manage fire disasters in their homes. However, the respondents lacked knowledge of the operation of the fire extinguishers. Storage of water and sand were strategies utilized by a few for managing fire disasters in the study area.

5.1.4 Challenges Confronting Fire Disaster Response in the Tamale Metropolitan Area

The findings of the study showed that poor accessibility by way of haphazard buildings blocking access routes posed the greatest challenge in the Tamale Metropolis. Firefighting officers find it difficult to access areas on fire because of bad road network. Difficulty in contacting the Fire Service during emergencies was the second-highest ranked challenge in fire response. Other important challenges identified by the research

were inadequate resources and logistics, which include inadequate number of fire stations, hydrants, and fueling of the fire engines for firefighting. The least challenges encountered in responding to fires in the study area were lack of communal spirit and improper addressing system in the communities. These challenges impede the effectiveness of the work of the National Fire Service.

5.2 CONCLUSIONS

The following conclusions are drawn from the findings and discussions of the research.

The Tamale Metropolitan Area has fire risk vulnerability in different areas. The fire risk zones of the Metropolis are areas with high housing density and communities with dense population.

There has been a consistent increase in fire outbreaks in the Metropolis since 2004 especially in the densely populated areas. Besides high population and improperly laid structures, frequent power outages and illegal electricity connections are the major causes of fires in the Tamale Metropolitan Area.

Despite the risks of fires in the Metropolis citizens do not have adequate strategies in place to manage fire disasters as they employ rudimentary methods such as buckets of sand and water, which pose a serious threat to lives and properties in the area.

Fire disaster responses in the Tamale Metropolitan Area are challenged by the poor road accessibility, inadequate resourcing and funding, poor house addressing systems poor institutional collaboration.

5.4 RECOMMENDATIONS

The following recommendations are made based on the conclusions of the study.

- Populated areas should be restructured and the areas properly demarcated and the structures that do not conform to the required standards should be demolished and appropriate places identified for resettlement.

- The Northern Electricity Distribution Company (NEDCo) should reassess all connections in the Tamale Metropolis and illegal connections disconnected and Citizens who are found to be perpetrators should be made to face the laws of Ghana.
- Frequent public education through the media, churches, community durbar, and door to door to create fire safety awareness should be intensified by the fire management institutions.
- Ghana Water Company should as a matter of urgency, service faulty and sealed hydrants and construct more hydrants to serve the Metropolis
- Ghana National Fire Service should be empowered to enforce fire safety protocols and regulations as stipulated in LI 1724 (2003) and LI 2249 (2016). The Government of Ghana should provide additional fire tenders for the fire stations as well as other equipment necessary for effective firefighting.
- The Tamale Metropolitan Assembly should put up more fire stations within the Metropolis to cater for the growing population.
- For Tamale Metropolitan to be counted among cities with limited vulnerability to fire disasters in Ghana, it will not only be vital to strengthen fire disaster risk reduction policies, but more importantly the policies should be matched with the appropriate institutional structures with the political will and capacity to provide risk reduction interventions.

- Future studies should assess the fire emergency preparedness of the Fire management institutions in the Tamale Metropolis.

REFERENCES

Adams, E. D., & Antwi, M. (2021). Modelling the risk of forest to fire for the Bosomkese Forest Reserve, Ahafo Region, Ghana. *South African Journal of Geomatics*, *10*(1).

Adarkwa, K. K. (2012). The changing face of Ghanaian towns. African Review of Economics and Finance, 4(1), 1–29.

Addai, E. K., Tulashie, S. K., Annan, J-S. and Yeboah, I. (2016). Trend of Fire Outbreaks in Ghana and Ways to Prevent These Incidents. *Safety and Health at Work* **7**(4), 284-292.

ADPC, (2004). Reducing Fire Threat to Homes: Piloting Community-Based Fire Risk Assessment in Ban Hatsady Village.

Agyekum, Kofi & B. Boateng, Emmanuel & Opoku, De-Graft. (2016). Fire Safety Preparedness in the Central Business District of Kumasi, Ghana.

Agyemang, S. O., Muller, M., and Barnes, V. R. (2015). Fire in Ghana's dry forest: Causes, frequency, effects and management interventions. In: Keane, Robert E.; Jolly, Matt; Parsons, Russell; Riley, Karin. *Proceedings of the large wildland fires conference;* May 19-23, 2014; Missoula, MT. Proc. RMRS-P-73. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 15-21.

Amponsah, P. E. (2004). Seismic activity in Ghana: The past, present and future. Annals of Geophysics, 46, 539-543.

Anaglatey P. B. (2013). Accra continues to record fire outbreaks. The Chronicle. 2013 Jul 30.

Aning-Agyei, P. G. (2018). Managing post disaster recovery of market fire victims in Ghana: PhD thesis. Cape Coast (Ghana). University of Cape Coast: 2018

Arkorful, V. E., Lugu, B. K., Hammond, A., & Basiru, I. (2021, May). Decentralization and citizens' participation in local governance: Does trust and transparency matter? –an empirical study. In *Forum for development studies* (Vol. 48, No. 2, pp. 199-223). Routledge.

Asgary, A., Ghaffari, A., Levy, J. (2010). *Spatial and Temporal analyses of structural fire incidents and their causes: a case of Toronto, Canada*., Fire Safety Journal 45 (2010) 44–57

Asigri, E. O., Afram, S. O., & Ameyaw, C. (2021). Fire Safety Design Attributes of Students'housing Facilities in KNUST Ghana. *African Journal of Built Environment Research*, 41.

Ayarkwa, J., Danso, A. K. and Adinyira, E. (2010). Incidence of domestic fire outbreaks in Ghana: causes and prevention. Ghana Surveyor 2Wadsworth.

Babbie, E. R. (2007). *The practice of social research* (11th ed.). Belmont, CA.: Wadsworth.

Babrauskas, V., Fleming, J.M. & Don Russell, B. (2010). RSET/ASET, a flawed concept for fire safety assessment, Fire and Materials 34. 341–355.

Banyeh, M., and Balinia, G. (2021). Fire Incident Statistics in the Tamale Metropolitan Area in the Northern Region of Ghana: A Retrospective Study.15(9), 37–47. https://doi.org/10.9734/AJARR/2021/v15i930425

Barnett J. R. Fire. Microsoft Student 2009 (DVD). Redmond (WA): Microsoft Corporation;

2008.

Betrand, A. L. and McKenzie L. S. (2016). *The Human Factor in High Fire Risk Urban Residential Areas: A Pilot Study in New Orleans*, Loisiana. Washington D.C. Department of Commernce, National Fire Prevention and Control Administration.

Biabani, M., Fotouhi, H., & Yazdani, N. (2020). An energy-efficient evolutionary clustering technique for disaster management in IoT networks. *Sensors*, *20*(9), 2647.

Boakyi K. A. (2017). Emergency fire response in Ghana; The case of Fire Stations in Kumasi. MSc Thesis.Texas (USA). University of North Texas: 2017

Boamah, E. F. (2018). Constitutional economics of Ghana's decentralization. *World Development*, *110*, 256-267.

Brink, H. (2002): Fundamentals of research methodology for health care Professionals, Vol 6, 116-143, Cape Town, Juta.

Buchanan, A. H. (2001). *Structural Design Fire Safety*. John Wiley and Sons: West Sussex, UK.

Bukowski, R.W., Peacock, R.W. and Averill, J. D. (2007). Performance of home smoke alarms analysis of the response of several available technologies in residential fire settings, NIST Technical Note 1455. 23–24.

Burns, N., and Grove, S. K. (2001). *The practice of nursing research: Conduct, critique and utilization* (4th ed.). Philadelphia: WB Saunders.

Cardona, O. D. 2003. The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management. Mapping vulnerability: Disasters, development and people, pp.17.

Challenger, R. and Clegg, C. W. (2011) 'Crowd disasters: a socio-technical systems perspective', Contemporary Social Science, 6(3), pp. 343–360.

Chandler, S. E., Chapman, A., and Hallington, S. J. (2014) *Fire incidence, housing, and social conditions—the Urban Situation in Britain.*, Fire Prevention 19 (no. 172).

Chen, Z., Goldwasser, J., Tuckman, P., Liu, J., Zhang, J., & Gerstein, M. (2022). Forest Fire Clustering for single-cell sequencing combines iterative label propagation with parallelized Monte Carlo simulations. *Nature communications*, *13*(1), 1-13.

Chhetri, P., Corcoran, J., Stimson, J. R. and Inbakaran R. (2010). Modelling potential socioeconomic determinants of building fires in South East Queensland. Geographical research, Vol. 48 issue 1 Pp 75-85. https://doi.org/10.1111/j.1745-5871.2009.00587.x.

Coppola, D. (2007). Introduction to international Disaster Management 3rd Edition pp 24.

Corcoran, J. Higgs, G., and Higginson A. (2013). Fire incidence in metropolitan areas: A comparative study of Brisbane (Australia) and Cardiff (United Kingdom), Applied

Geography 31 (1) (2011) 65–75.

Corcoran, J., Higgs, G., Brunsdon, C. and Ware, A. (2017). The use of comaps to explore the spatial and temporal dynamics of fire incidents: a case study in South Wales, United Kingdom, Prof. Geographer 59 (4) 521–536.

Creswell, J. W. (2009). Research design: Qualitative, quantitative and mixed methods approach. 3rd ed. SAGE publications Inc.

Creswell, J. W. and Plano Clark, V. L. (2007). Designing and conducting mixed methods research. Thousand Oaks, CA: Sage

Custer, R. L. P. and Meacham, B. J. (1997) Introduction to Performance-Based Fire Safety,

Society of Fire Protection Engineers and National Fire Protection Association, Quincy, MA, 1997.

Ducic, S. & Ghezzo, H. (2010) Epidemiology of accidental home fires in Montreal, Accident Analysis and Prevention 12. 68–69.

Emrich, C. T. and Cutter, S. L. (2011). Social vulnerability to climate sensitive hazards in the southern United States. Weather, Climate, and Society, 3(3): 193-208.

Fahy, R., and Norton, A. (1989). "How Being Poor Affects Fire Risk." Fire Journal. Vol. 83, no.1(January/February), pp. 29-36.

Forkuo, E. K., and Jonathan A. Quaye-Ballard, (2013). GIS-based fire emergency response system. International Journal of Remote Sensing and GIS 2 (1), 32-40

Fuseini, I. (2014). Land use competition: its implication for food security in the peri-urban Tamale, Ghana. Saarbuucken: Lambert Academy Publishing.

Fuseini, I., Yaro, J. A. and Yiran, Gerald A. B. (2017), 'City Profile: Tamale, Ghana', Cities,60: 64–74. https://doi.org/10.1016/j.cities.2016.07.010

Gencer, E. A. (2007). Vulnerability in Hazard-Prone Megacities: An Overview of Global Trends and the Case of the Istanbul Metropolitan Area. Summer Academy for Social Vulnerability (Draft 01)

Ghana Health Service. (2014). Special Ghana Health Service Report on the 2014 Cholera Outbreak. Accra, Ghana: Assembly Press

Ghana National Fire Service Ghana National Fire Service Act, 1997 [Internet].2014 [cited

2021 June]. Available from: http://www.epa.gov.gh/ghanalex/acts/

Acts/GHANA%20NATIONAL%20FIRE%20SERVICE%20ACT, 1997.pdf.

Ghana Statistical Service (2013a). 2010 population and housing census: regional analytical report: Northern Region. (Accra)

Ghana Statistical Service (2013b). 2010 population and housing census: regional analytical report: Ashanti Region. (Accra)

Ghana Statistical Service (2013c). 2010 population and housing census: regional analytical report: Greater Accra Region. (Accra)

Granda, S. and Ferreira, T. M. (2019). Large-scale Vulnerability and Fire Risk Assessment of the Historic Centre of Quito, Ecuador, International Journal of Architectural Heritage, DOI: 10.1080/15583058.2019.1665142

GSS (2012) '2010 Population and Housing Census: Final Report', Ghana Statistical

Service, Accra.

GSS. (2014). 2010 Population and Housing Census: District Analytical Report: East Gonja Municipal Ghana statistical service.

Gunter, P. (1981). "Fire-Cause Patterns for Different Socioeconomic Neighborhoods in Toledo, Ohio." Fire Journal. Vol. 75 (May), pp. 52-58.

Gunther, P. (2011) Fire-cause patterns for different socioeconomic neighborhoods in Toledo, Ohio, Fire Journal 75. 52–58. (May).

Herzberg, S., Hansen, M., Schoonover, A., Skarica, B., McNulty, J., Harrod, T., & Guise, J. M. 2019). Association between measured teamwork and medical errors: an observational study of prehospital care in the USA. *BMJ open*, *9*(10), e025314.

Higgins, E., Taylor, M., Jones, M. and Lisboa, P. (2013). Understanding community fire risk: A spatial model for targeting fire prevention activities, Fire Safety Journal, 62, pp20-29.

Hosseinnia, B., Khakzad, N., & Reniers, G. (2018). Multi-plant emergency response for tackling major accidents in chemical industrial areas. *Safety science*, *102*, 275-289.

Huang, K., Chen, G., & Khan, F. (2022). Vulnerability assessment method for domino effects analysis in chemical clusters. *Process Safety and Environmental Protection*, *164*, 539554.

Hyogo Framework for Action, 2005–2015, 'Building the resilience of nations and communities to disasters', An extract from the final report of the World Conference on Disaster Reduction (A/CONF.206/6), ISDR, Kobe, Japan, January 18–22, 2005. [Google Scholar]

Ilori, A. E., Sawa, B. A., & Gobir, A. A. (2019). Application of cause-and-effect-analysis for evaluating causes of fire disasters in public and private secondary schools in Ilorin Metropolis, Nigeria. *Archives of Current Research International*, *19*(2), 1-11.

InahE. O. (2018). "The Location of Fire Hydrants and Implications to Fire Disaster Management in Calabar, Cross River State, Nigeria" IOSR Journal of Humanities and Social Science

(IOSR-JHSS). vol. 23 no. 07, 2018, pp. 42-55 Information Insurance Institute. 2021. Facts statistics: Fire. https://www.iii.org/fact-statistic/facts-statistics-fire.

Institute of Statistical, Social and Economic Research. (2010). The state of the Ghanaian economy. Legon: Institute of Statistical, Social and Economic Research Institute, University of Ghana.

Jennings CR (1999) Socioeconomic characteristics and their relationship to fire incidence: a review of the literature. Fire Technol 35(1):7–34 Google Scholar

Jennings, C. R. (1996). Urban Residential Fires: An Empirical Analysis of Building Stock and

Socio-Economic Characteristics for Memphis, Tennessee. Unpublished Doctoral Dissertation, pp 105-107.

John, R. and Hall, Ai Sekizawae (2010). Revisiting our 1991 paper on fire risk assessment, Fire Technology 46. 789–801.

Kaku, Augustine (2018). *The socio-economic impact of oil and gas discovery in the Eellembelle district of Ghana* (Doctoral dissertation, University of Ghana).

Kamari, A., Kirkegaard, P. H., & Schultz, C. P. L. (2021). PARADIS-A process integrating tool for rapid generation and evaluation of holistic renovation scenarios. *Journal of building engineering*, *34*, 101944.

Kanton, O. (2007). Household environment and health in the Tamale Metropolitan Area. Unpublished PhD thesis. Legon: Department of Geography and Resource Studies, University of Ghana.

Karley, N. K. (2008). Ghana residential property delivery constraints and affordability analysis. Housing Finance International, 22e29. ABI/INFORM Global.

Karter, M. and Dooner, A. (1977). Fire Rates and Census Characteristics – A Descriptive Approach. Boston: National Fire Association, June 1977.

Kean, J. W., Staley, D. M., Lancaster, J. T., Rengers, F. K., Swanson, B. J., Coe, J. A., & Lindsay, D. N. (2019). Inundation, flow dynamics, and damage in the 9 January 2018 Montecito debris-flow event, California, USA: Opportunities and challenges for postwildfire risk assessment. *Geosphere*, *15*(4), 1140-1163.

Klote, J. H. (2002). Smoke Control, in SFPE Handbook of Fire Protection Engineering, National Fire Protection Association, Quincy, MA.

Konadu-Agyeman, K. (2001a). The political economy of housing and urban development in

Africa: Ghana's experience from the colonial times to 1998. Westport: Praeger Publishers.

Krazier et al, (1990). “Children in Self-Care: A New Perspective.” *Child Welfare* (November/December), pp.571-581.

Lentz, C. (2006). In J. D., C., & S. (Eds.), Ethnicity and the making of history in northern Ghana. Edinburgh: Edinburgh University Press.

Maddux, J. E., and Rogers, R. W. (1983). Protection motivation and self-efficacy: A revised theory of fear appeals and attitude change. *Journal of Experimental Social Psychology*, *19*(5), 469-479.

Madrzykowski, D., Bryner, N., & Kerber, S.I. (2006) The NIST station night club fire investigation: physical simulation of the fire, Fire Protection Engineering Magazine 31.

35–46.

Malczewski, J. (1999). GIS and multicriteria decision analysis. John Wiley & Sons.

Margrethe, K., Helsloot, I., Vries, B. & Post, J.G. (2010). Building safety and human behavior in fire: a literature review, Fire Safety Journal 45. 1–11.

McKean, E. (2005). The New Oxford American Dictionary. 2nd Ed New York: Oxford University Press.

Moussa, N., Hamidi-Alaoui, Z., & El Belrhiti El Alaoui, A. (2020). ECRP: an energy-aware cluster-based routing protocol for wireless sensor networks. *Wireless Networks*, *26*(4), 2915-2928.

Mubita, K., Milupi, I., Monde, P. N., and Simooya, M. (2020). A Proposed Holistic Approach to Fire Safety Management in Zambian Markets. 7(11), 93–101.

Munson, M. J., and Oates, W. E. (1983). "Community Characteristics and the Incidence of Fire:

An Empirical Analysis." *In the Social and Economic Consequences of Residential Fires.*Chester Rapkin, Ed. Lexington, MA: D. C Health and Co., 1983, p.62 and p.73.

National Committee on Building Regulations and Codes (1989), *Ghana Building Code,* Ministry of Works and Housing, Kumasi, Ghana.

National Fire Protection Association (2008), "Residential Structure Fires", availableat http://www.usfa.dhs.gov/statistics/national/residential.shtm. (Accessed on April, 2021,)

Ntim, D. O. (2018). Mitigating the effects of fire outbreaks on the socio-economic lives of women in the Kumasi Metropolis of Ghana: the role of microinsurance institutions. *IOSR Journal of Humanities and Social Science (IOSR-JHSS)*, *23*(2), 48-52.

Oregon Fire Code (2007). Fire Hydrants Locations and Distribution (Appendix C)

Punch (2016). Explosion Rocks CBN office in Calabar. Retrieved September, 2021 from www.punchng.com/explosion-rocks-cbn-office-calabar/

Osei-Asibey, D., Ayarkwa, J., Acheampong, A., Adinyira, E., and Amoah, P. (2021). Stakeholders' Compliance with Existing Construction Health and Safety Related Laws and Regulations in Ghana. *Journal of Building Construction and Planning Research, 9*
(2), 138-159.

Oteng-Ababio M., and Sarpong, O. A. (2015). Fire risk reduction through a community-based risk assessment: reflections from makola market, Accra, *Ghana.Disasters,*2015,39(3):

570−591. c 2015 The Author(s). *Disasters* Overseas Development Institute, 2015 Published by John Wiley & Sons Ltd, 9600 Garsington Road, Oxford, OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA

Oteng-Ababio, M., & Osman, A. (2012). Hulking Hazards: Exploring Fire Risk Vulnerabilities in Ghanaian Markets. For African Urban Risk Analysis Network (AURAN). (Forthcoming).

Oteng-Ababio, M., Ohene Sarfo, K., and Owusu-Sekyere, E. (2015). Exploring the realities of resilience: Case study of Kantamanto Market fire in Accra, Ghana. International Journal of Disaster Risk Reduction, 12, 311-318.

Owusu, G. (2011). Urban Growth, Globalization and Access to Housing in Ghana's Largest Metropolitan Area, Accra. A Paper Presented at the *4th European Conference on African Studies* (ECAS4), Uppsala, Sweden, June 15 – 18, 2011

Owusu, M., & Nursey-Bray, M. (2019). Socio-economic and institutional drivers of vulnerability to climate change in urban slums: the case of Accra, Ghana. *Climate and Development*, *11*(8), 687-698.

Owusu-Ansah D. (1994). Population distribution. In: La Verle B, editor. A country study: Ghana. Library of Congress Federal Research Division; November 1994 [This article incorporates text from this source, which is in the public domain.].

Owusu-Sekyere, E. and Attakora-Amaniampong, E. (2017). Market fires and risk accumulation in Ghana's built environment. Conference Paper. (Available at https://www.researchgate.net/publication/326674993).

Owusu-Sekyere, E., Adjuik, R. and Wedam, E. (2017). The Central Medical Store Fire Disaster: A Test for Institutional Compliance in Disaster Prevention in Ghana. SAGE Open. 7. 215824401769952. 10.1177/2158244017699528.

Pantuliano, S., Metcalfe, V., Haysom, S. and Davey, E. (2012). Urban vulnerability and displacement: A review of current issues. Disasters, 36, 1-22

Pasick, R. J., Burke, N. J., Barker, J. C., Galen, J., Bird, J. A. and Otero-Sabogal, R. (2009). Behavioural theory in a diverse society: Like a compass on Mars. *Health Education Behaviour, 36*(5), 11S-35S.

Poku-Boansi, M., & Cobbinah, P. B. (2018). Are we planning for resilient cities in Ghana? An analysis of policy and planners' perspectives. *Cities*, *72*, 252-260.

Popoola, Ayobami & Adekalu, Oluwafemi & Audu, A. (2016). Analysis of Causes and Characteristics of Market Fires in Lagos State Nigeria.

Pyles, L. (2007). Community organizing for post-disaster social development International Social Work 50(3): 321–333 Sage Publications: Los Angeles, London, New Delhi and Singapore DOI: 10.1177/0020872807076044

Rahikainen, J. & Keski-Rahkonen, O. (1998). *Determination of ignition frequency of fire in different premises in Finland,* Fire Engineers Journal 58 (197) (1998) 33–37. Retrieved September, 2021. www.newsghana.com.gh

Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. Mathematical modelling, 9(3-5), 161-176.

Sam-Okyere, E. (2010). Infernos in our offices; demystifying the facts. The Chronicle. 2010

Feb 25; p. 3. Retrieved August 2021

Sanni-Anibire, M. O., Mahmoud, A. S., Hassanain, M. A., & Salami, B. A. (2020). A risk assessment approach for enhancing construction safety performance. *Safety science*, *121*, 15-29.

Sarantakos, S. (2005). *Social research* (3rd ed.). New York, NY: Palgrave Macmillan.

Sarfo, A. K. (2020). Spatial planning legislation in Ghana: exploring the evolution, contributions, and the way forward. *UDS international journal of development*, *7*(2), 398-413.

Sarpong, A. O. (2013). Fire risk vulnerability in informal settlements the case of Ashaiman. MPhil thesis. Accra (Ghana): University of Ghana; 2013.

Satterthwaite, D. (2011). What role for low-income communities in urban areas in disaster risk reduction? (Global Assessment Report). Geneva, Switzerland: International Strategy for Disaster Reduction.

Schachterle, E. S., Bishai, D., Shields, W., Steptniz, R. and Gielen C. A. (2012). Proximity to vacant buildings is associated with increased fire risk in Baltimore, Maryland, homes. Injury Prevention 2012; 18:98e102. doi:10.1136/injuryprev-2011-040022

Schaenman, P. (2007). *Global Concepts in Residential Fire Safety: Part 1- Best Practices from England, Scotland, Sweden and Norway.* Arlington, VA: TriData.

Schaenman, P. G. Landquist, B., Stambaugh, H. (1987). *Overcoming Barriers to Public Education in the United States.* Arlingon. VA. TriData Corporation, 1987.

Schröder, B. (2018). *Multivariate methods for life safety analysis in case of fire* (Doctoral dissertation, Universität Wuppertal, Fakultät für Architektur und Bauingenieurwesen» Architektur» Dissertationen).

Sebbeh- Newton, S. (2018). Fire Emergency Preparedness among Staff of Tarkwa Municipal Hospital URI: http://ugspace.ug.edu.gh/handle/123456789/32778 Date: 2018-12

Sewu, G. J. A., Gyabeng, E., Dadzie, A. A., & Nkrumah, N. K. (2019). The effect of occupational health and safety management on performance in the banking sector, Ghana. *International Journal of Business and Management*, *14*(10).

Shai, D. (2016), Income, housing and fire injuries: a census tract analysis, Public Health Reports 121. 149–154.

Siiba, A., Adams, E. A., & Cobbinah, P. B. (2018). Chieftaincy and sustainable urban land use planning in Yendi, Ghana: Towards congruence. *Cities*, *73*, 96-105.

Simpson DE. Fire protection and safety. A presentation of Ghana National Fire Service (GNFS). Ashanti Regional office at a Symposium of Building Technology Students Society (BTSS) Week celebration, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, 24–27 March 2010.

Snedecor, G. W. and Cochran, W. G. (1989). *Statistical Methods* (8th ed.). Ames: Iowa State University Press. Society of Fire Protection Engineers (2006). Engineering guide: fire risk assessment, SFPE, 2006.

Soliku, O., Kyiire, B., Mahama, A., & Kubio, C. (2021). Tourism amid COVID-19 pandemic:

impacts and implications for building resilience in the eco-tourism sector in Ghana's Savannah region. *Heliyon*, *7*(9), e07892.

Songsore, J., Nabila, J. S., Yangyuoru, Y., Avle, S., BosqueHamilton, E. K., and Amponsah, P.

E. (2009). Environmental health watch and disaster monitoring in the Greater Accra Metropolitan Area (GAMA). Accra: Ghana Universities Press.

Stacey, P., Grant, R., & Oteng-Ababio, M. (2021). Food for thought: Urban market planning and entangled governance in Accra, Ghana. *Habitat International*, *115*, 102400.

Sternlieb G, and Burchell R. (1983)" Fires *in abandoned buildings*". In: Rapkin C, ed. The social and economic consequences of residential fires. Lexington, MA: LexingtonBooks, 1983

Storr, V. H. (2008). The market as a social space: On the meaningful extra economic conversations that can occur in markets. The Review of Austrian Economics, 21, 135–150.

Sulemana, M., Musah, A. B., & Simon, K. K. (2018). An assessment of stakeholder participation in monitoring and evaluation of district assembly projects and

programmes in the Savelugu-Nanton Municipality Assembly,Ghana. *Ghana Journal of Development Studies*, *15*(1), 173-195.

Swetnam, T.W. (1993). Fire history and climate change in giant sequoia groves. *Science*, **262**

(1993), pp. 885-889.

TAMA. (2003). Medium term development plan 2003e2006, prepared under the medium-term development policy framework. Accra: Ministry of Local Government and Rural Development.

Tamale Metropolitan Assembly (2010). Medium term development plan (draft), 2010-2013. (Tamale).

The City of Portland, Oregon (2016). All About Portland's Fire Hydrants. Retrieved September, 2021 from http://www.portlandoregon.gov/fire/article/321828

The Government of Ghana (1996), *National Building Regulations; L.J. 1630, Part JV, Structural Fire Precautions*, The Ghana Government Printer, As- sembly Press, Accra, Accra, pp. 42-53.

The Government of Ghana (2004), Ghana National Fire Service Act 537 (1997), in: *Laws of Ghana*, Vol. 4, 2004. pp. IV-290 I.

The Government of Ghana. (2003), *Fire Precaution (Premises) Regulation, L. I 1724, Ghana.*

Tulashie, S. K., Addai, E. K. and Annan, J. S. 2016. Exposure assessment, a preventive process in managing workplace safety and health, challenges in Ghana. *Saf Sci*, **84** (2016), pp. 210-215

Twumasi-Ampofo, K., Oppong, R. A., & Quagraine, V. K. (2021, August). Heritage Impact

Assessment: A Sustainable Tool for Historic Buildings and Sites Preservation in Ghana. In *Applied Research Conference in Africa* (pp. 38-48). Springer, Cham.

Twum-Barima, L. M. (2014). An assessment of the awareness of fire insurance in the informal sector: a case study of Kumasi central market in Ghana. *Int J Hum Soc Sci Educ* (IJHSSE), 1 (2014), pp. 41-47

UN/ISDR, (2004). Living with Risk: A Global Review of Disaster Reduction Initiatives. 2 vols. Geneva: United Nations.

UN/ISDR, (2009). Global Assessment Report on Disaster Risk Reduction.

UNISDR (United Nations International Strategy for Disaster Reduction) (2011).'Statement of commitment by the private sector for disaster prevention, resilience and riskreduction'.http://www.unisdr.org/files/19873_statementofcommitmentbyt heprivatese.df (last accessed July, 2021)

United Nations Human Settlements Programme (UN-HABITAT) (2012) State of the World's Cities Report. Nairobi, Kenya: United Nations Environmental Programme.

Waheed, M. A. A. (2014) 'Approach to fire -related disaster management in high density urban- area', Procedia Engineering. Elsevier B.V., 77, pp. 61 –69. doi10.1016/j.proeng.2014.07.007.

Wang, W. (2019). Site Selection of Fire Stations in Cities Based on Geographic Information System and Fuzzy Analytic Hierarchy Process. *Ingénierie des Systèmes d'Information*, *24*(6).

Watts, J. M. & Hall, J. R. (2022). Introduction to Fire Risk Analysis, SFPE Handbook for Fire Protection Engineering, third ed., NFPA, Quincy, MA.

WHO (World Health Organization) (2002). Environmental health in emergencies and disasters: A practical guide. https://www.gdrc.org/uem/disasters/1-dm_cycle.htm

Xin, J, and Huang, C. (2013). Fire risk assessment of residential buildings based on fire statistics from China, Fire Technology. http://dx.doi.org/10.1007/ s10694-013-0327-8.

Xin, J. and Huang, C. (2013). Fire Risk Analysis of Residential Buildings Based on Scenario Clusters and Its Application in Fire Risk Management. *Fire Safety Journal* **62**, Pages 72-78.

Yakubu, I., Akaateba, M. A., & Akanbang, B. A. A. (2016). A study of housing conditions and characteristics in the Tamale Metropolitan Area, Ghana. Habitat International, 44,394–402

Yakubu, L., Akaateba, M. and Akanbang, B. (2014). "Drivers of Housing Development in Tamale Metropolitan District, Ghana" Norsk Geografisk Tidsskrift Norwegain Journal of Geography, 70(4): 247-58. https://doi.org/10.1080/00291951.2016.1192679.

Yan, F., & Xu, K. (2018). A set pair analysis-based layer of protection analysis and its application in quantitative risk assessment. *Journal of Loss Prevention in the Process Industries*, *55*, 313-319.

Yang, J-T. and Chen, Y. (2014). Research and Application of Fire Risk Assessment System for Marketplace Buildings. *Procedia Engineering* **71**, Pages 476-480

Yeboah, I. E. A., Codjoe, S. N. A., and Maingi, J. K. (2013). Producing an urban system for the spatial development of Ghana: lessons for sub-Saharan Africa. African Geographical Review, 32(2), 140–156.

Yeboah, R.W.N (2005). Climate variability and small farmer's economic decision-making process: the case of Bongo District, Upper East Region, Ghana. PhD thesis, Legon.

Yin, R. K. (2009): Case Study Research Design and Method. 4th Edition. London: Sage Publications Ltd.; 2009.

Yiran, G. A. B., Ablo, A. D., & Asem, F. E. (2020). Urbanisation and domestic energy trends: Analysis of household energy consumption patterns in relation to land-use change in periurban Accra, Ghana. *Land Use Policy*, *99*, 105047.

Yung, D. & Benichou, N. (2003). Concepts of fire risk assessment, Report No. NRCC46393, National Research Council Canada, Ottawa, ON.

Zhang, L., Wu, X., Liu, M., Liu, W., & Ashuri, B. (2019). Discovering worst fire scenarios in subway stations: A simulation approach. *Automation in Construction*, *99*, 183-196.

APPENDICES

Appendix A: Interview Schedule for household

QUESTIONNAIRE FOR A STUDY ON ASSESSMENT OF FIRE RISK VULNERABILITY OF THE TAMALE METROPOLITAN AREA OF GHAHA

This research is being carried out as part of Master of Philosophy Degree from the Department of

Environment and Sustainability Sciences, Faculty of Natural Resources and Environment, University for Development Studies.

This questionnaire is designed to elicit Information solely for academic purpose. I assure you that your identity and the information you provide will be treated with the utmost confidentiality.

Kindly fill in the spaces provided and tick in the boxes with the most appropriate response(s).

Thank you for your anticipated participation.

NAME OF COMMUNITY……. Date……...

House No.……

SECTION A: BACKROUND INFORMATION OF RESPONDENT

1) The respondent for this survey is:

a) Head of household ☐ b) Spouse ☐ c) relative ☐ d) Tenant ☐

2) Gender: a) Male b) Female ☐

3) What is your age? A) 18-30 b) 31- 40 c) 41- 50 d) 51- 60 e) 61 and above

4) Marital status: a) Single ☐ b) Married c) Divorced d) Separated e) Widowed ☐

5) Religious Affiliation: a) Christian ☐ b) Islam ☐ c) Traditionalist d) No religion e) Other,

please specify…….

6) Ethnicity:

7) Educational Level: a) No Formal Education b) Primary/Junior High c) Senior

High/Vocational/Tech d) Tertiary

8) Main occupation of respondent?

……

9) What is the average monthly income (Ghana cedis) of your household?

10) How many people live in this house?

SECTION B: HOUSING CHARACTERISTICS

11) Do you own the house?

a) Yes b) No

12) Do you have a building permit? a) Yes b) No

13) What material was used in building your house? Please observe the type of dwelling and tick as appropriate.

a) Wooden shacks b) Cement blocks c) Burnt bricks

d) Mud e) Sandcrete

14) What material was used in roofing your house?

a) Thatch b) Aluminum Sheets c) Asbestos d) Roofing Tiles

e) Other, please specify…….

15) What is the main energy source of lighting for your dwelling?

a) Candle b) Kerosene Lamp c) Solar d) Generator

e) Electricity

16) If electricity, who connected it to your home?

a) Certified electrical contractor b) way-side electrician

17) How old is your wiring?

18) What is the main source of fuel for your house for cooking?

a) Firewood b) LPG (Gas) c) Charcoal d) Kerosene/Paraffin stoves e) Electric stove

19) What are the major sources of water for domestic use?

a) Standing pipe b) Borehole c) Water from vendors' d) stream 20) where do you do your cocking?

a) Kitchen b) Sleeping room c) Hall d) Veranda e) courtyard

SECTION C: FIRE RISK PERCEPTIONS

21) What are the major causes of fire outbreaks?

a) Electrical equipment/wiring b) Burning of Rubbish c) Candles d) Smoking e) Arson (Intentional fires) f) Accident while cooking g) Children playing with fire

22) What are the factors that account for the causes?

……
……

23) Have you ever experienced a fire outbreak in your home? If no, skip to question 27

a) Yes b) No

24) If yes, what was the main cause of the fire?

25) What did you do during the fire outbreak? Multiple responses are allowed

a) Called the Fire Service Department on a phone □ b) Started packing my property □

c) Shouted for help □ d) Started quenching the fire □ e) Was motionless □ 26) How long did it take the Fire Service to arrive at the fire scene?

a) 5- 30 minutes □ b) 30-60minutes □ c) 60 minutes and above □

27) How far is the nearest Fire Service Department from your home?

a) 0-1km □ b) 2km □ c) 3km □ d) 4km and more

28) Can a fire fighting vehicle access your house?

a) Yes □ b) No □

SECTION D: MANAGEMENT COPING STRATEGIES OF FIRE RISK VULNERABILITY

29) Who came to your aid in your recovery process?

a) NADMO b) Relatives c) Religious Groups d) NGOs e) No one

30) Do you know the emergency numbers of the Ghana Fire Service Department? a) Yes

b) No

31) If no, how do you contact the emergency Service providers for help?

a) Call a radio/TV station b) Go to the nearest fire station personally to report c) Call friends d) shout for help from Neighbors

32) How often does the Fire Services Personnel visit to educate you on fire safety?

(a) Every Quarter (b) Every Six Month (c) Once a Year (d) Not all

33) Do you have fire certificate? Yes, No

34) If Yes, how often do you renew it? …….

35) If No, have you made the necessary effort to certify your house?

---

36) What fire detection /firefighting equipment do you have? If none, skip to question 39

……

37) Do you know how to operate it?

a) Yes b) No

38) When was the last servicing date? .....

39) Do you have an insurance cover for your house?

a) Yes b) No

40) Are you aware of any program/projects aimed at reducing the incidence of fire in the

Metropolis? Yes [ ] No [ ]

41) If yes, mention them.

(i)……..……
……...

(ii)……

(iii)……

42) What measures have you put in place to avoid fire outbreaks?

a) ……

b) ……

c)……

43) What measures have you put in place to manage fire outbreaks when they occur?

a) ……..

b) ……

c)……

SECTION E: ASCERTAIN THE CHALLENGES CONFRONTING FIRE DISASTER RESPONSE

44) What are the challenges your community encounter when there is a fire outbreak?

a) ……

b) …….

c)……

THANK YOU.

Appendix B: Interview Guide for GNFS

QUESTIONNAIRE FOR A STUDY ON ASSESSMENT OF FIRE RISK VULNERABILITY

OF THE TAMALE METROPOLITAN AREA OF GHANA

This research is being carried out as part of Master of Philosophy Degree from the Department of

Environment and Sustainability Sciences, Faculty of Natural Resources and Environment, University for Development Studies.

This questionnaire is designed to elicit Information solely for academic purpose. I assure you that your identity and the information you provide will be treated with utmost confidentiality.

Kindly fill in the spaces provided and tick in the boxes with the most appropriate response(s).

Thank you for your anticipated participation.

INSTITUTIONAL QUESTIONNAIRE

GHANA NATIONAL FIRE SERVICE DATE:

(a) Name of Respondent…… (b) Designation…… …….

How long have you been working in your current job?

1. Core functions of institution

(i)…… …..

(ii)…… ……

(iii)…… ……..

(iv)…… …….

2. Do you have any special regulations to control fire activities in the Metropolis? Yes [ ] No [ ]
3. If yes, are they being enforced? Yes [ ] No [ ]
4. How many fire stations do you have in the Metropolis?
5. Are they enough for the Metropolis as per international Standards?
6. How many fire hydrants are available in the Metropolis?

i) Serviceable……. ii) Non-serviceable…….

7. Aside hydrants, what are the sources of water you rely on for firefighting in the Metropolis?

8. Are you aware of any program/projects aimed at reducing the incidence of fire in the

Metropolis? Yes [ ] No [ ]

9. If yes, mention them.

(i)……..……
……...

(ii)……
……...

(iii)……
……..

10. What specific actions do you take in fire prevention in the Metropolis?

(i)……
……..

(ii)
……
…..

11 What specific actions do you take in fire disaster management in the Metropolis?

(i)……
……..

(ii).....
.....

(iii)…….....
.....

12. Is the institution adequately resourced to carry out its responsibilities?

Yes [ ] No [ ]

13. If No, in what areas are you challenged?

Human

……
……

Financial

……
……

Logistics & Equipment

……
……

Legal

……
……

Others (specify)

.....……
……

14. What steps are being taken to address them?

(i)……
.....

(ii)……
……

(iii)……
……

15.Do you collaborate with any agencies in fire disaster management and prevention with specific reference to the TaMA?

Yes [ ] No [ ]

16.If Yes, which are these agencies?

(i)……
……...

(ii)…….....

(iii)…….....

..... 17. Are you satisfied with the level of collaboration? Yes [ ] No [ ]

18 If no, why?

……
……
……
.....

19 What do you think are the causes of fire incidence in the Metropolis?

(i)…….....
.....

(ii)…….
…….

(iii)…….
…….

(iv)…….
……

20. What are the key areas of fire risk vulnerabilities in the Metropolis?

……
……

21. What level of urgency does your organization attach to solving these vulnerability/ risk problems?

……
……

22. Is there any specific strategy your organization has developed and want to implement to reduce the present fire risk.

……
……

23. How often are there fires in these Areas?

……
……

24. How severe are fires in these Areas?

……
……

25. (a) Do you involve the citizenry in the Metropolis in the activities of the institution?

Yes [ ] No [ ]

26. If yes, at what level?

……
……

27. How do you rate their level of participation?

High [ ] Average [ ] Low [ ] Nil [ ]

28. What do you think accounts for this level?

……
……

29. If No, why?

……
……

30.What do you think the following should do to solve the problem of fire incidence in the

Metropolis?

Household

……....
.....

Communities

.....

Works, Town and County Planning Department of TaMA

.....
.....

Central Government

.....
.....

Additional Observation/Comments (if any):

.....

.....

THANK YOU

Appendix C: Interview Guide for NADMO

QUESTIONNAIRE FOR A STUDY ON ASSESSMENT OF FIRE RISK AND VULNERABILITY OF THE TAMALE METROPOLITAN AREA OF GHANA

This research is being carried out as part of Master of Philosophy Degree from the Department of Environment and Sustainability Sciences, Faculty of Natural Resources and Environment, University for Development Studies.

This questionnaire is designed to elicit Information solely for academic purpose. I assure you that your identity and the information you provide will be treated with utmost confidentiality. Kindly fill in the gaps and tick in the boxes with the most appropriate response(s). Thank you for your anticipated participation

INSTITUTIONAL INTERVIEW
DATE……....

NATIONAL DISASTER MANAGEMENT ORGANIZATION (NADMO)

BASIC INFORMATION:

1. Name of Respondent…….

2. Designation …….

How long have you been working in your current job?

1. What the core functions as an organization?

……..……
……

2. How would you assess the discharge of your responsibility? 1. Very good [ ] 2. Good [ ] 3. Weak [ ] 4. Very weak [ ]

Explain……
….

4. What is NADMO‟s role in the management of fires within the TaMA?
……

. What are the main challenges faced with reference to fire management in the metropolis?

……
…

6. What measures are put in place to help in the recovery of fire victims in the metropolis?

……
….

7. How often do NADMO collaborate with other Service providers to mitigate fire risk vulnerability in the Metropolis?

……
…

8. Do you collaborate with any agencies in fire disaster management and prevention with specific reference to the TaMA?

Yes [ ] No [ ]

9.If Yes, which are these agencies?

(i)……
…….

(ii)……
…….....

(iii)…….....

..... 10. Are you satisfied with the level of collaboration? Yes [ ] No [ ]

11. If no, why?

……
……

12. Is the institution adequately resourced to carry out its responsibilities?

Yes [ ] No [ ]

13. If No, in what areas are you challenged?

Human

……
……

Financial

……
……

Logistics & Equipment

……
……

Legal

……
……

Others (specify)

.....……
……

14. What steps are being taken to address them?

(i)……
.....

(ii)……
……

(iii)……
……

THANK YOU

Appendix D: Interview Guide for GWCL

QUESTIONNAIRE FOR A STUDY ON ASSESSMENT OF FIRE RISK AND VULNERABILITY OF THE TAMALE METROPOLITAN AREA OF GHANA

This research is being carried out as part of Master of Philosophy Degree from the Department of Environment and Sustainability Sciences, Faculty of Natural Resources and Environment, University for Development Studies.

This questionnaire is designed to elicit Information solely for academic purpose. I assure you that your identity and the information you provide will be treated with utmost confidentiality. Kindly fill in the gaps and tick in the boxes with the most appropriate response(s). Thank you for your anticipated participation.

INSTITUTIONAL INTERVIEW	**DATE**…….....
Ghana Water Company Limited (GWCL)	

BASIC INFORMATION:

1. Name of Respondent……

2. Designation ……

How long have you been working in your current job?

1. What are your core functions as an organization?

……
……

2. How would you assess the discharge of your responsibility? 1. Very good [ ] 2. Good [ ] 3.

Weak [ ] 4. Very weak [ ]

Explain……
...…

3. What is the type of water service provided in TaMA?

……
……

4. What are the key challenges encountered in the provision of water to Metropolis?

……
……

5. How many fire hydrants are mounted within TaMA?

6. How many are not working and why?

……..……
……...

7. What are your plans for the provision of more hydrants in the Metropolis?

……

8. What are some of the challenges faced in the provision of water for firefighting?

……
……

THANK YOU

Appendix E: Interview Guide for VRA

QUESTIONNAIRE FOR A STUDY ON ASSESSMENT OF FIRE RISK VULNERABILITY

OF THE TAMALE METROPOLITAN AREA OF GHANA

This research is being carried out as part of Master of Philosophy Degree from the Department of

Environment and Sustainability Sciences, Faculty of Natural Resources and Environment, University for Development Studies.

This questionnaire is designed to elicit Information solely for academic purpose. I assure you that your identity and the information you provide will be treated with utmost confidentiality. Kindly fill in the gaps and tick in the boxes with the most appropriate response(s). Thank you for your anticipated participation

INSTITUTIONAL INTERVIEW	**DATE**……....
VRA/NEDCO	

BASIC INFORMATION:

1. Name of Respondent…….

2. Designation ……

How long have you been working in your current job?

1. What are your core functions as an organization?

……
……

2. How would you assess the discharge of your responsibility? 1. Very good [ ] 2. Good [ ] 3.

Weak [ ] 4. Very weak [ ]

Explain……
...……

3. What is the type of electricity service provided in TaMA?
   ……
   ……

4. What are the key challenges encountered in the provision of electricity to Metropolis?

……
……

5. Is there any mechanism in place to check the haphazard (illegal) electricity connections in

Metropolis?

a) Yes ❑b) No❑

6. If yes, what are the mechanisms to check the haphazard electricity connections?

……..……
…….

THANK YOU

Appendix F: Interview Guide for TAMA

QUESTIONNAIRE FOR A STUDY ON ASSESSMENT OF FIRE RISK AND VULNERABILITY OF THE TAMALE METROPOLITAN AREA OF GHANA

This research is being carried out as part of Master of Philosophy Degree from the Department of Environment and Sustainability Sciences, Faculty of Natural Resources and Environment, University for Development Studies.

This questionnaire is designed to elicit Information solely for academic purpose. I assure you that your identity and the information you provide will be treated with utmost confidentiality. Kindly fill in the gaps and tick in the boxes with the most appropriate response(s). Thank you for your anticipated participation.

INTERVIEWS

INSTITUTIONAL INTERVIEW **Tamale Metropolitan Assembly (TaMA)**	**DATE**……....

BASIC INFORMATION:

1. Name of Respondent…….

2. Designation ……

How long have you been working in your current job?

1. What are your core functions as an organization?

……

2. How would you assess the discharge of your responsibility? 1. Very good [ ] 2. Good [ ]

3. Weak [ ] 4. Very weak [ ]

Explain……

4. What is TaMA's role in the management of fires within the metropolis?

……
…

5. What are the main challenges faced with reference to fire management in the metropolis?

……
…

6.What measures are put in place to help in the recovery of fire victims in the metropolis?

……

7. How often does Assembly collaborate with other Service providers to mitigate fire risk vulnerability in the Metropolis?

……
…

8. Is the institution adequately resourced to carry out its responsibilities?

Yes [ ] No [ ]

9. If No, in what areas are you challenged?

Human

……
……

Financial

……
……

Logistics & Equipment

……
……..

Legal

……
……

Others (specify)

.....……
……

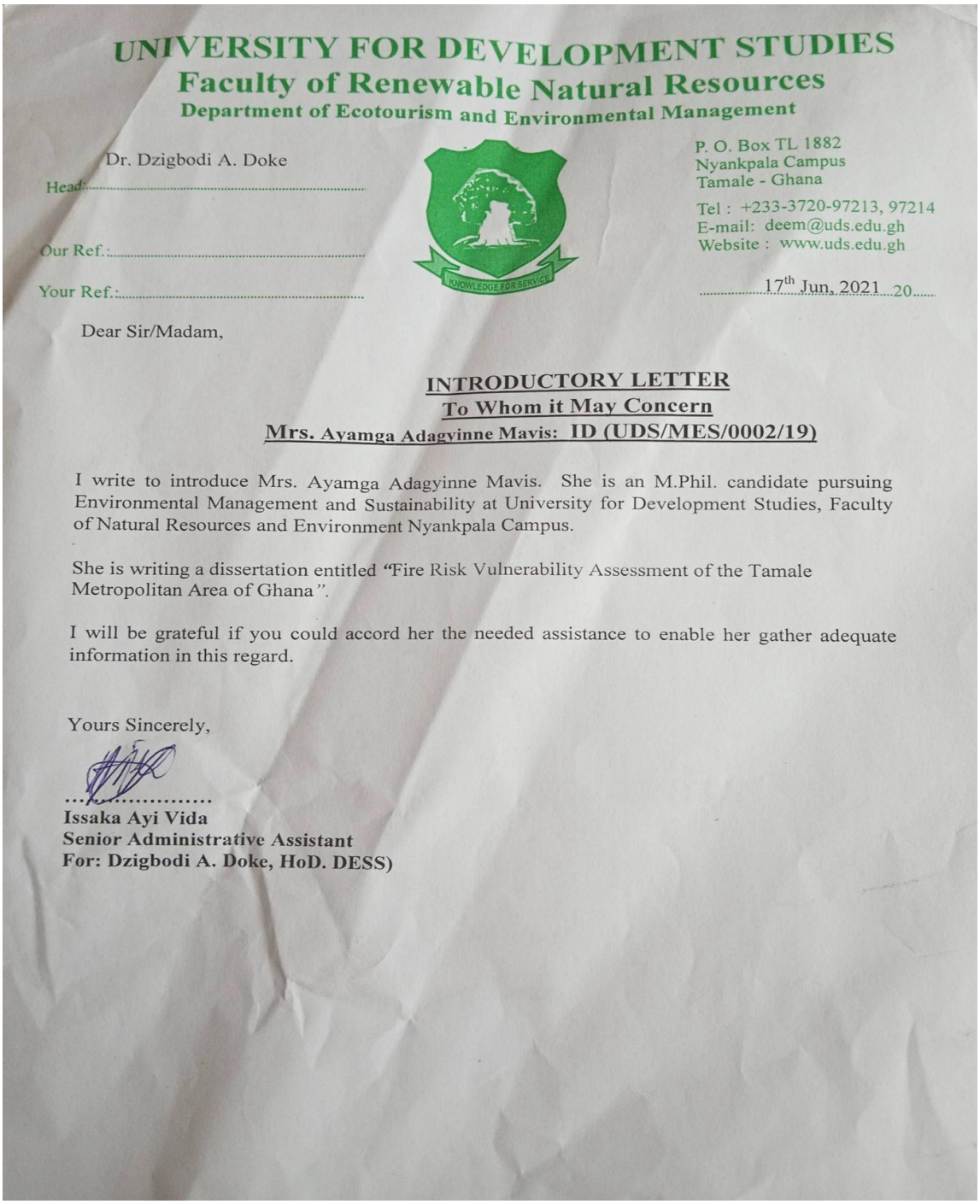
10. What steps are being taken to address them?
(i)……
…….....

(ii)……
……..

(iii)……
……..

THANK YOU

Appendix G: Introductory Letter from University for Development Studies



UNIVERSITY FOR DEVELOPMENT STUDIES
Faculty of Renewable Natural Resources
Department of Ecotourism and Environmental Management

Dr. Dzigbodi A. Doke
Head:.....

Our Ref.:.....

Your Ref.:.....

P. O. Box TL 1882
Nyankpala Campus
Tamale - Ghana

Tel : +233-3720-97213, 97214
E-mail: deem@uds.edu.gh
Website : www.uds.edu.gh

17th Jun, 2021 20.....

Dear Sir/Madam,

INTRODUCTORY LETTER
To Whom it May Concern
Mrs. Ayamga Adagyinne Mavis: ID (UDS/MES/0002/19)

I write to introduce Mrs. Ayamga Adagyinne Mavis. She is an M.Phil. candidate pursuing Environmental Management and Sustainability at University for Development Studies, Faculty of Natural Resources and Environment Nyankpala Campus.

She is writing a dissertation entitled "Fire Risk Vulnerability Assessment of the Tamale Metropolitan Area of Ghana".

I will be grateful if you could accord her the needed assistance to enable her gather adequate information in this regard.

Yours Sincerely,

.....
Issaka Ayi Vida
Senior Administrative Assistant
For: Dzigbodi A. Doke, HoD. DESS)