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Modification and Installation of Water Hydrant System in Ogbete Main Market for Effective Fire Combating Operation

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Abstract

The modification of water hydrant system in Ogbete main market for effective fire combating operation was achieved by incorporating the overhead tank to the serve as an alternate water source and the distance between two water hydrants was reduced to 70m so as to make the hydrants more accessible to users. Also, Google earth, EPANET and SolidWORKS software were used to determine the pipe connection, sizes, numbers, and locations of pumps, valves. Hydrants distribution based on goods sold and services rendered at various locations of the market. The mapping, design and elevation studies of the Ogbete market were done using Google earth. The siting of components was done using EPANET software and then exported to AutoCAD. The cost analysis of the fire hydrant installation modification was carried out according to the design requirements. The design methodology prevented wastage in material and increased efficiency of 59.05%, since the shortest pipe network was applied for the design. The installation of the water Hydrant network for effective combating of fire outbreak cost 165,395,000NGN which is cost effective and relatively cheaper than maintaining the existing water hydrant at Ogbete Main Market; would aid in quickly arresting possible fire outbreak in Ogbete main market and other similar market space as well as helping the government in determining the cost implication for the installation of fire combating system in any densely populated market in Nigeria.

Keywords: Modification, installation, water hydrant system, ogbete main market, fire combating operation.

1. Introduction

In the heart of Ogbete, a bustling hub of commerce and activity, stands the Ogbete Main Market—a place where dreams are forged and livelihoods thrive. However, amidst its vibrant tapestry of trade and enterprise, lies an imperative concern that cannot be ignored: the need for a robust and effective fire combating operation. This is because Ogbete Main Market is more than just a place of commerce; it's a testament to the resilience and entrepreneurship of the people it serves (Ezeonwuka & Ezeofor, 2020). Ogbete Main Market is the beating heart of Ogbete, a sprawling city with a rich history. This market isn't merely a collection of stalls and shops; it's a vibrant microcosm of life itself, a place where dreams are nurtured and

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aspirations take root (Amadi, Nwangwu & Yusuf, 2021). From the early morning hours until the bustling evening rush, this market is a constant hive of activity. Sellers and buyers converge from all walks of life, representing the diverse tapestry of Ogbete's population. The market is a labyrinth of narrow alleys and bustling squares, each corner housing a different trade. From vibrant textiles to fresh produce, electronics, and handmade crafts, Ogbete Main Market offers an astounding variety of goods and services (Ape, Nwogu, Uwakwe & Ikedinobi, 2016). For many residents, it's not just a place to shop; it's a place to connect, celebrate culture, and create a livelihood.

Yet, as vibrant and essential as Ogbete Main Market is, it faces an ever-present threat: the risk of fire. With its densely packed stalls, flammable materials, and the constant presence of open flames from cooking stalls, the potential for a devastating fire outbreak is a grim reality that hangs over the market like a dark cloud. Fire, when unchecked, can be a merciless and indiscriminate destroyer (Yunus, 2021). It shows no favoritism, consuming everything in its path—livelihoods, dreams, and even lives. Ogbete Main Market has witnessed its share of fire incidents over the years, each one leaving behind a trail of devastation and despair. The consequences of a fire outbreak in a bustling market like Ogbete Main Market are manifold. First and foremost is the loss of life (Sunday, 2017). Shoppers, vendors, and market workers can find themselves trapped amidst the chaos, with escape routes often obstructed or inadequate. Lives are at risk, and every second counts when a fire breaks out.

The economic toll is equally significant. Small businesses form the backbone of Ogbete Main Market, and for many, their shops represent their entire livelihood. A fire can wipe out these businesses in a matter of hours, leaving families in financial ruin. The ripple effects extend beyond the market itself, affecting the entire community as income sources disappear, and economic stability crumbles. Moreover, the loss of cultural and historical artifacts cannot be ignored. Ogbete Main Market is not just a place of commerce but also a repository of culture and tradition. Handmade crafts, traditional clothing, and unique local products are part of the city's heritage. In the event of a fire, these invaluable treasures are at risk of being lost forever (Mwidege & Rogath, 2014). The urgent need for a comprehensive fire combating system in Ogbete Main Market is evident. Preventing fire outbreaks and effectively responding to them is not just a matter of necessity but a moral and communal duty.

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Markets are prone to fire outbreak due to its diversity in activities, the types of goods and services being sold in the markets. Little or no market has a muster point and the gang ways are hugely obstructed by illegally sited shops (Akinwumi, Oke & Ogunbode, 2022). The Ogbete main market is the choice market for wholesale buyers and sellers. Just like other major markets in the country, Ogbete is segmented into lines and lock-up shops. Each line is made up of various lock-up shops occupied by traders dealing on similar or related goods. In Ogbete, some of the lines are numbered alphabetically such as K-line, M-line D-line etc. However, some other major lines are not numbered alphabetically; they are railway line or electronics line, provision line, plastic line, cosmetic line, books line etc. These major lines should have fire hydrants installed in them to enable the fighting of fire in the minor lines.

Recognizing the gravity of the situation, the leaders and stakeholders of Ogbete Main Market have taken a bold step towards fortifying the market against the specter of fire. The visionary project of modifying and installing a Water Hydrant System represents a watershed moment in the history of this bustling marketplace (Wang & Shih, 2018). The Water Hydrant System is a sophisticated and multifaceted fire prevention and control system designed to provide a reliable and immediate water source in case of a fire outbreak. This system comprises a network of strategically placed hydrants connected to a centralized water supply, complemented by state-of-the-art firefighting equipment (Aram, Zhang, Qi & Ko, 2021). The goal is clear: to significantly reduce response times, contain fires swiftly, and minimize damage to life and property. This project's significance goes beyond its technical aspects; it embodies a spirit of proactive community engagement and collective responsibility to safety.

This Ogbete Main Market's commitment to the safety and well-being of its residents, patrons, and businesses is achievable through Environmental Protection Agency Network Evaluation Tool (EPANET). EPANET is a software application used throughout the world to model water distribution systems (Sayyed, Gupta & Tanyimboh, 2014). It was developed as a tool for understanding the movement and fate of drinking water constituents within distribution systems, and can be used for many different types of applications in distribution systems analysis. engineers and consultants use EPANET to design and size new water infrastructure, retrofit existing aging infrastructure, optimize operations of tanks and pumps, reduce energy usage, investigate water quality problems, and prepare for emergencies (Monteiro, Figueiredo, Dias, Freitas, Covas, Menaia & Coelho, 2014). It can also be used to model contamination threats and evaluate resilience to security threats or natural disasters. In

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order to portray the Earth as a three-dimensional globe, Google Earth is a geobrowser that connects to satellite and aerial photography, topography, ocean bathymetry, and other geographic data through the internet. Alternative names for geobrowsers include "virtual globes" or "Earth browsers."

Google Earth is a computer program that renders a 3D representation of Earth based primarily on satellite imagery. The program maps the Earth by superimposing satellite images, aerial photography, and GIS data onto a 3D globe, allowing users to see cities and landscapes from various angles (Mutanga & Kumar, 2019). Google Earth provides search capabilities and the ability to pan, zoom, rotate, and tilt the view of the Earth. It also offers tools for creating new data and a growing set of layers of data, such as volcanoes and terrain that reside on Google's servers, and can be displayed in the view. Users can explore the globe by entering addresses and coordinates, or by using a keyboard or mouse. The program can also be downloaded on a smart phone or tablet, using a touch screen or stylus to navigate. Users may use the program to add their own data using Keyhole Markup Language and upload them through various sources, such as forums or blogs. Google Earth is able to show various kinds of images overlaid on the surface of the earth and is also a Web Map Service client (Feizizadeh, Omarzadeh, Kazemi-Garajeh, Lakes & Blaschke, 2023). In 2019, Google has revealed that Google Earth now covers more than 97 percent of the world, and has captured 10 million miles of Street View imagery. In addition to Earth navigation, Google Earth provides a series of other tools through the desktop application, including a measure distance tool.

The aim of this research is to modify fire hydrant system in Ogbete Main Market for effective fire combating operation. The aim of the research would be achieved through the design of the fire hydrant network, incorporation of overhead tank, design analysis of fire hydrant flow network, Google earth extraction. The modification and design analysis of fire hydrant siting and operations in modern markets; Case Study: Ogbete Main Market would help in the effective combating of fire outbreaks in every nook and cranny of the market. A sustainable water supply system connected to fire hydrants would tackle insufficient water supply during fire fighting in Ogbete Main Market and such technology can be transferred to other modern markets. The cost analysis would aid the government or the private sector in estimating the product cost requirement for the design and installation of the plants. This research involves the modification, design and siting of fire hydrants in Ogbete Main Market Enugu using the

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google earth and EPANET. The research is basically centered on the mapping of the market in various sections as well as virtually representing the location of hydrants, the piping systems, the reservoir, pumps, junctions and valves.

2. Design analysis and specifications

2.1 Design Analysis and Calculations

The following design considerations were put in place;

2.2. Selection of water tank capacity

Considering the total square meter of the area under surveillance, 8-tank stand of 2000 litres each is selected.

Hence, volume of water is 16,000 litres.

2.3 Determination of volumetric flow rate

The volumetric flow rate Q, which is defined as the product of velocity of flow and cross-sectional area is given by

$$Q = v \times A \quad (1)$$

$$\text{but } A = L \times W \quad (2)$$

where Q is volumetric flow rate

v is velocity of flow

A is cross-sectional area

L is length

W is width

2.4 Determination of pressure head

In fluid mechanics, pressure head is the height is a liquid column that corresponds to a particular pressure exerted by the liquid column on the base of its container. It may also be called static pressure head or simple static head (but not static head pressure). Mathematically this is expressed as:

$$\varphi = \frac{p}{\gamma} = \frac{p}{\rho g} \quad (3)$$

φ = pressure head (which is actually a length, typical in units of meters or centimetres of water)

p is fluid pressure weight (i.e. force per unit volume, typically expressed in pascals)

γ is specific weight (i.e. force per unit volume, typically expressed in N/m^3)

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p is the density of fluid (i.e. mass per unit volume, typically expressed in kg/m^3)

g is acceleration due to gravity (i.e. rate of change of velocity, expressed in m/s^2)

2.5 Determination of hydraulic head

Hydraulic head or piezometric head is a specific measurement of liquid pressure above a vertical datum. It is usually measured as a liquid surface at the entrance (or bottom) of a piezometer. In an acquifier, it can be calculated from the depth to water in a piezometric well (a specialized water well), and information of the piezometric's elevation and screen depth.

Hydraulic head, $h = h_p + h_z$ (4)

h_p = pressure head

h_z = elevation head

2.6 Determination of distance between overhead and hydrant system

The distance between the overhead stand is designed to be around 120m with respect to the number of hydrant system installed and the total square meters of the area under survellaince.

2.7 Determination of pump flow rate

Design of the pump flow rate is based on the estimated daily water needs for hydrant system consumption divided by the quantity of diesel consumed per unit time as shown below:

$$\text{Flow rate (Q)} = \frac{Total\ operational\ Water\ requirement}{\text{Total diesel consumption} \times 120\text{min}} \quad (5)$$

To calculate the pump flow rate the following two important points are required:

1. Operational water needed is 16000 L
2. Quantity of fuel consumed

Change operational water requirements to unit time water requirements.

$$\text{Operational water requirement} = \frac{\text{Unit time water requirements)}}{\text{Number of mins}} \quad (6)$$

2.8 Determination of Total dynamic head (TDH) for the pump

The total dynamic head TDH for the pump was determined using the following equation:

Total dynamic head (m) = Total vertical lift (static head) + friction loss (7)

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TDH (m) = Total vertical lift (static head) + friction loss (8)

Where,

Vertical lift is the difference between the water surface at the intake or suction point and water surface at the delivery point.

Friction loss (HL) is the loss of the pressure due to the friction of the water as it flows through a pipe. It is determined by four factors:

1. Pipe size (inside diameter)
2. Flow rate
3. Length of a pipe
4. Pipe roughness

By using the Hazen-Williams empirical formula, the head loss that caused by a friction within a pipe is calculated.

2.9 Determination of pipe diameter

Velocity of fluid in a pipe is not uniform across section area. Therefore, a mean velocity is used and it is calculated by the continuity equation foe the steady flow as:

$$v = \frac{Q}{A} = \frac{4Q}{D2\pi} \quad (9)$$

Pipe can be calculated when volumetric flow rate and velocity is known as

$$D = \sqrt{\frac{4Q}{\pi v}} \quad (10)$$

where; D is internal pipe diameter

Q is volumetric flow rate

v is velocity

A is pipe cross sectional area

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2.10 Determination of Power consumption by the pump

The pump can be selected by comparing the flow rate and the TDH. The pump selected is a surface (centrifugal) pump, as this pump is suitable for areas for which the water level is within 7m below ground level. Surface pump is suitable for pumping from lakes and canals. This selected pump is diesel powered because of low combustion to minimize cost and enhance efficiency. The diesel water pump selected for the study was a typical medium head, direct current operated pump.

$$P = \frac{(Q \times H \times \gamma)}{n} \quad (11)$$

Where γ specific weight of water = pg

Q = volume flow rate = πDb (12)

H = head of the water at designed speed = $\eta \left(\frac{UV}{g}\right)$ (13)

3.0 Developmental procedure/description of the modified water hydrant system

The major components of the water hydrant system (Fig. 1) are, Water Supply & Storage Facility, Pipe work & Valves, Fire Brigade Booster Inlets, Fire Pump-sets, Hydrant or Landing Valve & Coupling, First Aid Hose Reels and Lay-flat Fire Hose. Fire hydrant installation consists of a system of pipe works connected directly to the water supply mainly to provide water to each and every hydrant outlet and it is intended to provide water for the firemen to fight a fire. The water is discharged into the fire engine form which it is then pumped and sprayed over fire. Overhead tank was provided as a storage facility to serve as alternative water supply to the water hydrant system. The distance between each hydrant outlet was reduced from 100m to 70m in order to make the water hydrant outlets accessible to fire fighters and other users and equally to avoid demolition of shops constructed on top of existing water hydrants.

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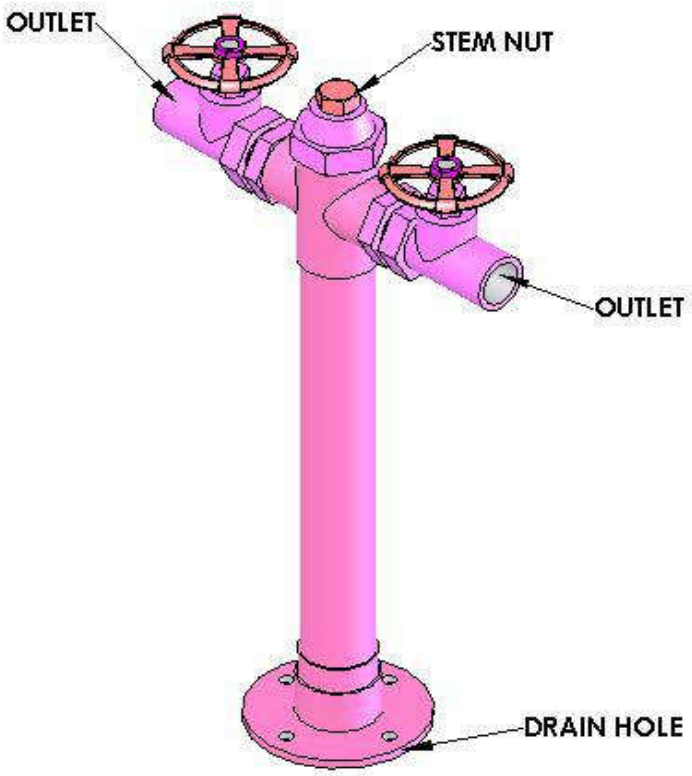

Fig. 1: The Isometric view of the modified water hydrant in Ogbete Main Market

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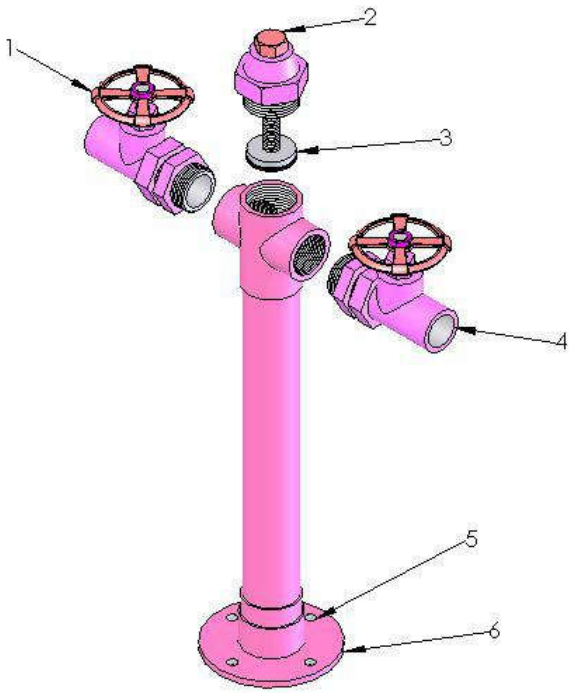

Fig. 2: The Exploded view of the modified water hydrant in Ogbete Main Market

The raised plunger allows water to flow through the valve body and up the stand pipe. In addition, raising the plunger closes off the drain port. The raised plunger closes off the drain port and allows water to flow through the valve port, past the plunger. A fire hydrant is a visible connection point placed in defined locations for firefighters to tap into a water supply. All buildings, parking areas.

4.0 Results and discussion

4.1 Installation and Performance Evaluation of the modified water hydrant in Ogbete Main Market

Google Earth Satellite Imaging: A satellite image of Ogbete Main Market would be acquired from google earth this is to aid the viewing of structures, lanes, the path for pipe laying and the distance along the path and facilitiesin Ogbete Main Market. Surveying has been an element in the development of the human environment since the beginning of recorded history. The planning and execution of most forms of construction require it. A land survey is taken to determine the placement of an overhead tank for water distribution and an

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underground reservoir for water storage. The overhead tank will be situated at the highest point in the school to enable proper flow. The google earth image will also guide in picking up strategic points for the placement of overhead tanks. The distance between each block and distance from each block or structure from the overhead tank would be measured using a measuring tape. This measurement is been carried out to determine the length of pipes required to aid distribution from the overhead tank to the structures. The height of the overhead tank above the datum level would be measured. The measurement of height of water point and the blocks would be measured. Water distribution network design would be made with the aid of google earth software design exported to EPANET. The software will be used to design the network using measurements taken and with the aid of the acquired satellite image.

The procedure for the google earth application entails searching for google earth on google. I searched for Ogbete Main Market Enugu on the search bar, from the search result the plan view and isometric view of the market can be seen from an elevation. Using the sketch and dimension tool, the market is being sectioned, the pipe and facility were sketch and measured.

Site examination and value verification: The site which is Ogbete Main Market was visited and measurements were taken to validate the values given by the satellite. The examination enables the visualization of close-range obstacle, installed utilities such as electric cables, drainage systems etc., the site was done to also determine the product sold in different locations in the market. Locations where flammable materials are being sold such as explosive chemicals and areas where fire prone services are being rendered were mapped out for more hydrant's installation. Locations with good access roads for fire trucks were mapped out for less hydrant installations. Locations with low dense population and scanty commercial activities were selected for a moderate number of hydrants according to the market plan and the prospect of expansion.

EPANET Design: The facility design which was done with google earth was further exported to EPANET software to modify and analyze the design. EPANET would help in determining the number and specification of the facilities required for the project. The software acknowledges the elevations, reservoir capacity, joint, pumps, flow velocity and pressure. This information would help in the cost analysis, hence, aid the purchase of premium materials for the design. The central reservoir is drawn according to the location

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and capacity of the exiting reservoir in the market. All section of the fire hydrant was drawn and the elevations were acknowledged the distribution pipes are being connected to a pump which is connected to a reservoir. this due to the amount of pressure needed for the design of fire hydrants.

Evaluation of the Efficiency of Developed Machine

To determine the efficiency of the developed machine, we have to use equation (14).

Therefore,

$$\text{Efficiency, \%} = \frac{\text{Flow, gpm x Total Dynamic Head, ft x 0.746 kw/hp}}{396 \text{ x Electrical demand KN}} \times \frac{100}{1} \qquad (14)$$

Given pumping flow rate = $0.8m^3/hr = 3.523gpm$

Total Dynamic Head = 13.56 = 44.49ft

Electrical demand = 0.5KW

$$\text{Efficiency, \%} = \frac{3.523 \times 44.49 \times 0.746}{396 \times 0.5} \times \frac{100}{1}$$

$$= 59.05\%$$

4.2 Google earth extraction

The image on Fig. 3 was captured at height of 300m in a bearing 6''26''05^{o}N 7"29'012^{o}E. The image shows that the market has the Holy Ghost Cathedral by the lower right-hand side, the Enugu state prison quarters at the upper left side and the back side facing Mgbemene.

Fig. 5 is a sectioned representation of the Ogbete main market. The section mapped with a yellow color is the major entrance and car park area of the market. The red mapped section is the major entrance from the Holyghost axis. The characteristics of Fig. 6, the green sectioned area: it has no access road that can contain fire trucks. The main lanes are between 1 to 1.2m wide which basically accommodate truck pushers and a few pedestrians at once.

Fig. 6 is the Orange colored section of Ogbete main Market. This section is the largest. It houses predominantly cloth and footwear vendors at the front and upper right. Chemical and Pharmaceutical products in the middle and food items at the lower region.

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Fig. 7 dark blue colored section of Ogbete main Market is the major entrance from the back of the market. This area consists of warehouses in which food stuffs are being stored, trucks and haulage vehicles.

Fig. 8 is the entrance section of Ogbete main Market from the Holy Ghost section. The entrance road separates the section into regions, the left region predominantly electronics dealers and at the right clothing, footwear and electronics It has a 4m wide entrance lane and the fire office is situated at the end of the section.

Fig. 3: Google earth image of Ogbete main market province

Fig. 3 is a google earth image of Ogbete main market province. The image was captured at height of 300m in a bearing 6''26''05^{o}N 7"29'012^{o}E. The image shows that the market has

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the Holy Ghost Cathedral by the lower right-hand side, the Enugu state prison quarters at the upper left side and the back side facing Mgbemene, Coal Camp. This location is lowly dense in residential buildings, the surrounding buildings are basically motor packs, banks and offshoot of smaller commercial activities. This location has a muddy seasonal lake at the Mgbemene axis of the market. Since the water is seasonal and requires purification, these might increase the cost of the project. From site assessment pipes were designed to supply water from the water corporation. These pipes have corroded due to lack of maintenance. The scope of this research centers on the fire hydrant installations and pipe design assuming water was supplied to the reservoir either through the purchasing of water with water trucks, rain water collected from water channels, etc.

Fig. 4 Color sectioning of Ogbete main Market

Fig. 4 is a sectioned representation of the Ogbete main market. The section mapped with a yellow color is the major entrance and car park area of the market. The red mapped section is the major entrance from the Holyghost axis. The lite blue area is the major market space. The green mapped space is the section where ethanol and wooden mortar and pestle are being sold. The dark blue section is the area where foods and other perishable goods are being sold. The black section represents the current location of the tank and reservoir. The buildings in this market are predominantly block buildings with wooden reinforced roofs.

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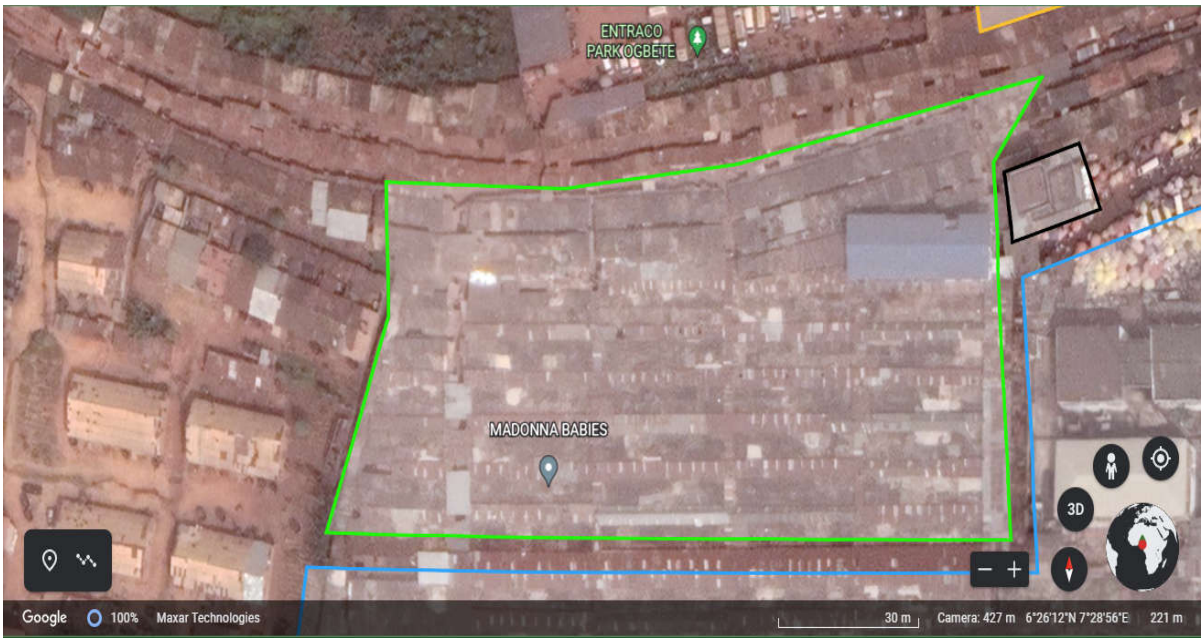

Fig. 5 Green colored section of Ogbete main Market

The characteristics of Fig. 5, the green sectioned area: it has no access road that can contain fire trucks. The main lanes are between 1 to 1.2m wide which basically accommodate truck pushers and a few pedestrians at once. The upper area of the section comprises traditional goods vendors. The section requires a 5 steps staircase. The lower region is hugely dominated by Ethanol and woodware dealers.

Fig. 6 Orange colored section of Ogbete main Market

Fig. 6 is the Orange colored section of Ogbete main Market. This section is the largest, it houses predominantly cloth and footwear vendors at the front and upper right. Chemical and

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pharmaceutical products in the middle and food items at the lower region. This section comprises large lanes which can accommodate fire trucks, although the top of the lanes is covered with plastic roofing sheets to enable illumination but such materials can increase combustion. More fire hydrants would be sited in the less motorable areas and explosive chemical product sales main and sub-lanes should be more ventilated and more hydrants.

Fig. 7 dark blue colored section of Ogbete main Market

Fig. 7 dark blue colored section of Ogbete main Market is the major entrance from the back of the market. This area consists of warehouses in which food stuffs are being stored, trucks and haulage vehicles. The section is an untarred open market space with less tendencies of fire outbreak. Fig. 7 is the section of Ogbete main Market where the reservoir and the overhead tank is located. A 120,000 liters underground reservoir and 80000 liters overhead tank. This location houses a 7.5KW water pumping machine.

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Fig. 8 red colored section of Ogbete main Market

Fig. 8 shows the entrance section of Ogbete main Market from the holy ghost section. The entrance road separates the section into regions, the left region predominantly electronics dealers and at the right clothing, footwear and electronics It has a 4m wide entrance lane and the fire office is situated at the end of the section. Due to accessibility, the availability of two standby fire trucks and the type goods and services rendered in the section, a smaller number of hydrants would be installed in this section. Fig. 8 is the entrance, mini stores and car park section of Ogbete main Market. This area has access road network and covering a space 471m perimeter. Considering the conditions of the location two hydrant would be ideal.

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5.0 Conclusion

In conclusion, the research conducted on the Modification and Installation of the Water Hydrant System in Ogbete Main Market has demonstrated the practicality and achievability of refining the system's design. The strategic placement of fire hydrants in high-priority areas has been successfully achieved. This placement has been guided by factors such as the nature of goods and services, the market's population density, and existing infrastructure. Furthermore, this research has contributed to a clearer understanding of the associated costs involved in materials and system design. This knowledge is instrumental for both government authorities and private sector stakeholders, enabling them to make well-informed decisions regarding the implementation of an effective fire combating operation in Ogbete Main Market. Notably, the design's emphasis on utilizing the shortest routes to prevent interruptions to existing buildings and minimize potential losses resulting from bends in the system highlights a commitment to both efficiency and safety. Overall, this research underscores the importance of a thoughtfully designed and strategically located water hydrant system in safeguarding Ogbete Main Market against the devastating impact of fire incidents.

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