# DESIGN FEATURES AND CHOICE OF CONSTRUCTION MATERIALS AS THE DETERMINANTS OF IDEAL FIRE HAZARDS -FREE FACTORY ARCHITECTURE IN AKWA IBOM STATE

By

Ogundele Joseph OLUROTIMI
Department of Architectural Technology
Federal Polytechnic
Bida, Niger State

&

Ifiok E. Mfon
Department of Architecture
University of Uyo, Akwa Ibom State

## ABSTRACT

*The main aim of the study was to assess* design features and choice of construction materials as the determinants of ideal fire hazards –free factory architecture in *Akwa Ibom State. The study was Akwa Ibom State. The study adopted both descriptive and case study survey research design. The population of the study consisted of all experts in architecture, civil engineering, structural engineering, electrical engineering, mechanical engineering and other sections of environmental science. Also included are workers of paint manufacturing industries in Akwa Ibom State. The sample size consisted of 150 respondents obtained from 30 architects, 30 civil engineers, 15 structural engineers, 30 electrical engineers, 15 mechanical engineers and 30 workers in locally paint manufacturing companies. They were selected using stratified random sampling technique. The data collected was analysed using statistical technique such as regression analysis. The statistical techniques helped in testing the hypothesis at 0.05 alpha level and at 148 degree of freedom. The study revealed that there is significant extent of design features, construction material choices on the extent of fire hazards in factory in the study area and that effective planning and design for prevention and control of fire significantly promotes the ideal factory architecture with a well-defined layout for paint production and packaging. The study concluded that fire incidents in a paint factory is a critical undertaking to identify their causes and implement effective prevention strategies. Paint factories pose unique fire risks due to the presence of flammable substances, volatile solvents, and ignition sources within their operations. Understanding the root causes of fire incidents is essential to mitigate potential hazards and safeguard the safety of employees, the environment, and valuable assets. Prevention strategies focuses on enhancing fire safety practices within the paint factory. One of the recommendations made was that the installation and maintenance of special installations and sensors to ensure their functionality in the industrial buildings is necessary in order hinder the occurrence of fire or possibly reduce its effect where its control becomes inevitable.*

KEYWORDS: Design Features, Construction Materials, Fire Hazards, Effective Planning, Prevention, Control, Architecture, Paint Production and Packaging.

## Introduction

Building design process is an uninterrupted series of actions by design team members such as architects, structural, mechanical, electrical and fire safety engineers, to achieve a comprehensive building design (Park, 2014). The design process according to Balcomb and Curtner (2000) involves four stages which include: pre-design (PD), schematic design (SD), design development (DD) and construction documents (CD). Design stages are realised using two patterns which can be either: conventional linear design or integrated design. In the linear design approach, architects primarily manage the design progress and request engineers and other consultants to take part when the design has advanced (Park, 2014). This method is effective for a small and uncomplicated building project, which is carried out by few stakeholders (Park, 2014). Integrated design on the other hand is used for large size building project where, parties in the projects such as the client, the project manager, architects and other consultants come together early in the design process to share project information. This process allows for identification of required building performance and reduces any possible risk of project failure.

According to (Park, 2014). is a serious threat to people, and the principal cause of death in building, beside falls, which is also responsible for a large number of deaths in building related incidents. Fire accounts for almost half of the insurance policies claims against fire and multiple perils (Park, 2014; Association of British Insurers (ABI), 2015 and a leading source of property loss and its contents (ABI, 2015). The ability of a building to either confine or fast-track the growth of fire depends on how it was designed. For instance, interior finishes might facilitate or restrict the spread of fire. Likewise walls, duct systems, barriers and routes can either allow or compartmentalize fire. Occupants' routes might or might not be protected, lighted, signage, of sufficient size, as well as the provisions of fire detection and suppression facilities or otherwise (Park, 2014). Fire prevention, control and safety is one among several other considerations such as functionality, aesthetics, human comfort, structural stability, cost-effectiveness, constructability, maintainability, and sustainability, etc (Kodur, 2012; Park, 2014), that building designers must fulfill at the early stages of building design process. This is to ensure safety of the building users in the event of a fire incident, as well as the protection of the built property using active and passive measures. For a building design to be effective in terms of satisfying both architectural and technical objectives, fire safety must be integrated early on in the building design process (Rasbash, 2004). Arguably, the duty of guaranteeing the fulfillment of fire safety objectives rests with the architect. (Rasbash, 2004) highlighted that, most of the passive fire protection design for structural framing remains within the project architect's responsibility, with little if any input from a fire protection or structural engineer. Although architects are not trained to be fire scientists, it is important for them to be aware of the fundamental principles of fire safety and prevention (Rasbash, 2004) because of their roles as principal designers. Architects should also ensure they are acquainted with specific safety issues of a structure being planned, as well as obtaining necessary advice and information from fire specialist early in the design stage (Megri, 2009).

## Statement of Problem

One of the problems facing the industrial buildings in Nigeria is the occurrence of fire, this was attributed to lack of knowledge about prevention, control and effective management plan and safety practices among stakeholders. Many major industrial and commercial buildings have been gutted by fire destroying lives and properties worth several billions of Naira (Oladokun, 2010). Protecting industries from disasters has been critical and important because disasters possess risk in terms of safety to occupants, building integrity, business interruption and the health of the community (Oladokun, 2010). Studies have shown that building designs contribute greatly to the magnitude of fire in building with severe consequences on safety of life and property. Hence, fire safety is an important consideration in building design which architects seek to fulfil at the early stage of design. Knowledge of fire safety amongst architects can aid the design of safer buildings interms of fire protection.

## Objective of the Study

1. To find out the impact of design features, construction material choices on the extent of fire hazards in factory in the study area.
2. To find out the impact of effective planning and design for prevention and control of fire significantly promotes the ideal factory architecture with a well-defined layout for paint production and packaging.

## Research Questions

1. What is the impact of design features, construction material choices on the extent of fire hazards in factory in the study area?
2. What is the impact of effective planning and design for prevention and control of fire significantly promotes the ideal factory architecture with a well-defined layout for paint production and packaging?

## Research Hypotheses

1. There is no significant impact of design features, construction material choices on the extent of fire hazards in factory in the study area.
2. There is no significant impact of effective planning and design for prevention and control of fire significantly promotes the ideal factory architecture with a well-defined layout for paint production and packaging.

## Conceptual Review

### Concept of Fire

Fire is the process of combustion, ignited through the chemical reaction of heat, oxygen, and fuel. The fuel is heated to its ignition point until gas is released from its surface called oxidation (Fessler, 2006). As heat is released, it feeds back into the combustion process, creating a continuous chemical reaction. The result of this process emits energy, light, exhaust, and heat. In ancient times, fire was seen as the primeval element, one of the many myths competing for the origin of how Architecture was formed. Fire is associated with energy, with the thermal adaptation needed for human life, and for handling and producing the materials, such as metal, glass, food, that are fundamental in survival (Meo, 2010). Generally, fire is connected to energy, light, purification, illumination, creation, destruction and metamorphosis. It has the properties of hot and dry, and once people ignited the first fire and gathered around it, it meant overcoming the hostility of the environment and adhering to the natural human needs. This has defined the first form of civilization and community. Langenbach, (2013) observe that all buildings are designed around fire, the idea of fire infiltrates every aspect of contemporary architectural construction guided by building codes and fire regulations. The relation of this element in Architecture remains a passive one as buildings are constructed to resist and decelerate the effects of combustion. Fire is ultimately one of the largest influences of the built environment, whether it is present or not.

### Concept and History of Paint Manufacture

Paint factory is a place of paint production characterized by the use of machinery, the large-scale of machinery differentiates factory production from simple manufacture. In factory, standardized goods are produced and sometimes sold more cheaply by the factory system, and occasionally the goods are better than those made by Artisans. The factory will change the face of nations, giving rise to urban centers requiring vast municipal services. It will create a specialized and interdependent economic life and make the urban worker more completely dependent on the will of the employer. The need for industrial architecture has been a matter for major concern to professionals and it has evolved through the periods, moving in phase with the march of civilization, occupation and the advancement in technology. Paint is a thin protective or decorative coat or a subdivision of surface coating. Painting, the art of laying color on a surface, therefore necessitated the development of paint. Paint was first developed in the prehistoric times when the early men recorded most of their activities in colors on the walls of their caves (Darton, 2001). These crude paints consisted of colored earth or clays suspended in water. However, the use of paint dated as far back as 1500 B.C. when the earliest paint works discovered in caves of Lascaux, France, Attemira and Spain were believed to have been done (Darton, 2001).

## Principal Types of Paints

Paints are classified into two principal types such as Resin based paints (Gloss finishes) and Latex based paints (Emulsion paints). The major difference between the two is only in the types of vehicle used and cost.

- Manufacturing Process of Paints

The sequences of operation which may be employed in the manufacture of paints are in four principal stages which are as follows:

- Dispersion stage
- Quality Control stage
- Scaling up stage/sieving
- Packaging and Shipping.

However, before discussing the four stages of paint manufacture, it is necessary to discuss general principal of paint manufacture.

- Dispersion Stage

This stage is the most essential and in fact determines the paint quality. It should also be pointed out that pigment is the most expensive paint component and is usually introduced into a finished product system in the physical state of dispersion. It followed quite naturally that a great deal of attention should be accorded the processing of dispersions in order to achieve maximum pigment utilization, that is optimum hiding power and colour. Dispersion is compared primarily of a combination of pigment, binder and solvent. In addition to these three main components, dispersion contains a fourth ingredient called additives. This dispersion process can be separated with three distinct phases. In practice, these stages overlap and occur simultaneously rather than strictly consecutively during the dispersion process. These three phases are:

- Wetting
- Particle separation and
- Stabilization.

- Quality Control Stage

This stage permits us to know when we have reached the desired end point. But before this, the paint content from the dispersion section will be transferred to the mixing machine through a rubber tube. The mixing machine or low-speed mill is fed by means of a rubber pipe from the dispersion container. Equipment’s used are: grind gauge, grind blade and spatula knife.

- Sieving and Scaling up Stage

Sieving involves the filtration of unused agglomerates thereby allowing only the passage of pure paint. The purpose of scaling up is to bring the paint to the required standard, quality and workable viscosity (Anthony, 2007). This is achieved by adding the remaining 58% by wt of the vehicle, 65% by (WT) of the solvent and then the paint additives and driers respectively into the paint slurry system. The paint is then transferred to a reservoir inside the production hall.

- Packaging and Shipping

From the reservoir the paint is then packed and subsequently shipped. All paint products are packed in cans made of tins or they may be packed in plastics made of P.V.C or polyethylene.

## Major Causes of Industrial Fire and Explosion

Industrial fires and explosions cost companies and governments billions of naira every year, not to mention the loss of life, which cannot be described in monetary terms (Buchanan, 2003). According to the most recent fire statistics from the National Fire Protection Association (NFPA), an average of 37,000 fires occurs at industrial and manufacturing properties every year. There are five most common causes of industrial fires and explosions.

- Flammable Liquid and Gases

These fires, which often occur at chemical plants, can be disastrous.

### *How to prevent flammable liquid and gas incidents*

There is danger inherent in any work involving flammable liquids and gasses, but all available safety precautions should be taken to mitigate these risks.

- Know the hazards: One major component of prevention is simply knowing the safety information for every liquid on your premises. This information is available on the material safety data sheet (MSDS) that comes with such products.
- Store flammable liquids properly: Make sure all hazardous materials are stored according to OSHA compliant procedures.
- Control all ignition sources: Except for when you're intentionally heating the flammable materials, keep ignition sources as far away from them as possible.
- Provide personal protective equipment: This is a must across all categories of fire hazards but especially when liquids and gasses are involved.

Figure 1: Flammable Liquid. Source: Hassan, 1999

- Equipment and Machinery

Faulty equipment and machinery are also major causes of industrial fires (Hassan, 1999). Heating and hot work equipment are typically the biggest problems here in particular, furnaces that are not properly installed, operated, and maintained. In addition, any mechanical equipment can become a fire hazard because of friction between the moving parts. This risk can be brought down to practically zero simply by following recommended cleaning and maintenance procedures, including lubrication.

*How to prevent equipment and machinery incidents?*

Strategies for preventing fires due to equipment and machinery issues fall into three main categories:

- *Awareness:* You can't prevent risks you don't know exist. Neither can your employees. Provide safety awareness training so everyone in your facility knows what risks to watch out for and what to do if they find one.
- *Cleaning and housekeeping:* Keep your equipment and machinery and the area surrounding it clean. Equipment, especially electrical equipment that is covered with dirt or grease constitutes a huge risk.
- *Maintenance:* Follow the manufacturer's recommended maintenance procedures for all of the equipment and machinery. In addition to reducing fire risk by preventing overheating, regular maintenance will also keep equipment working in tip-top shape.

**Figure 2:** Equipment and Machinery Source: Hassan, 1999

- Electrical Fire Hazards

Electrical fires are one of the top five causes of fires in manufacturing plants. A non-exhaustive list of specific electrical hazards includes, wiring that is exposed or not up to code, overloaded outlets, extension cords, overloaded circuits and static discharge. The damage caused by these fires can quickly compound thanks to several of the other items on this list. Any of the above hazards can cause a spark, which can serve as an ignition source for combustible dust, as well as flammable liquids and gasses.

*How to prevent electrical fire incidents*

As with the previous risks, the key to preventing electrical fires is awareness and prevention. This involves training, maintenance, and following best practices. Here are a few to put into practice right now:

- Do not overload electrical equipment or circuits.
- Do not leave temporary equipment plugged in when it is not in use.

- Avoid using extension cords, and never consider them permanent solutions.
- Use antistatic equipment where required by NFPA or OSHA.
- Follow a regular housekeeping plan to remove combustible dust and other hazardous materials from areas that contain equipment and machinery.
- Implement a reporting system so that anyone who observes an electrical fire risk can report it without consequences.

**Figure 3:** Electrical fire hazard. **Source:** Hassan, (1999)

Power machines, instruments and heating devices operated by electric energy, as well as the equipment for power transformation and lighting, typically do not present any fire disaster to their surroundings, provided that they have been installed in compliance with the relevant regulations of safety and requirements of standards and that the associated technological instructions have been observed during their operation. Regular maintenance and periodic supervision considerably diminish the probability of fires and explosions (Mathew, 2005).

- Fire Outbreak

Fire threat tends to be accidental or seasonal. The frequent occurrence of major fire accidents in industrial buildings, commercial buildings, shopping malls, and markets in Nigeria has become a serious threat to the nation's fragile economy. Many major industrial and commercial buildings have been gutted by fire destroying lives and properties worth several billions of naira (NEMA, 2006). The socio-economic impacts of these accidents are aggravated by the fact that victims of such fire disasters, mostly large scale industry, traders and without adequate insurance cover. Fire has continued to force many companies to close down, render many jobless, damage the environment and disrupt economic activities. Fire could originate from either external or internal sources. External sources include the risk of bush fire and lightning strikes. Internal risks of fire are ever present with our widespread reliance on the use of electrical appliances, such as desk lamps, heaters, computers, power boards and other equipment within the collection buildings. Other possible sources of fire could include chemical spills and other inflammable materials Oladokun et al., (2010) and Mathew (2005).

## Means of Escape

When fire occurs in building, large quantities of smoke and gases are produced. Smoke and hot gases may travel considerable distances within a building and will present a direct threat to life. Visibility also is considerably reduced, thereby affecting the viability of escape routes within and from the building. It is essential that escape routes are available to enable the staff to reach a place of safety and that they are adequate and capable of being safely and effectively used at all times (Herbert, 1998).

- *Escape Route Design*

Components of Escape Routes

The means of escape consist of the following components:

- Horizontal escape route and
- Vertical escape route (Herbert, 1998).

In bungalows, the means of escape will consist of horizontal escape routes only, while multi-storey buildings will require a combination of these two components

*Number of Escape Routes:* Basically, alternative escape routes should be available so that a person confronted by fire can escape in a direction which is away from the fire. Each storey of the building should be provided with at least two escape routes, except in the case of small premises which under certain conditions may be served by a single escape stairway. This provision is based on the possibility that, in the event of an outbreak of fire, one of the escape routes may become unavailable for use. Alternative escape routes from a storey should be remote from, and independent of each other (Herbert, 1998). In addition to a minimum of two escape routes from every storey, the floor layout and staff capacity will also influence the number of escape routes required for any situation. It is necessary to restrict the distance to be travelled along an escape route. The limitations on travel distance will depend on whether escape is possible in one direction or in more than one direction. The number of escape routes will also be influenced by the capacity of those routes to evacuate each area, taking into account the possibility of an escape route being unavailable for use as a result of the fire. A single escape route from a storey is only acceptable where there is little likelihood of this route being unavailable for use and where an alternative escape route cannot practicably be provided.

*Width of Escape Routes:* Escape routes should be sufficiently wide to enable evacuation of the occupant capacity of the rooms or areas they serve. The width of escape corridors should generally be not less than 900 mm (Herbert, 1998).

- Horizontal Escape Routes

Components of Horizontal Escape

According to Herbert (1998), the horizontal escape routes may be sub-divided into the following components:

- Travel within offices.
- Horizontal travel from offices to a protected stairway or to a final exit.

*Travel Distance*

For the purposes of escape, the travel distances along an escape route from any point in a building should be restricted to an extent which is dependent on the availability of alternative escape routes. For this purpose, a distinction is made between:

- Travel from any point from which escape can be made in one direction only (sometimes referred to as dead-end travel).
- Travel from any point from which escape can be made in more than one direction, by way of alternative escape routes. (Herbert, 1998). The limitations on travel distance depend on whether travel is available in one direction only or in more than one direction. The former is more restrictive due to the increased risk of a single escape route becoming unusable in a fire.

- Vertical Escape Routes

Vertical escape routes are those parts of the escape routes which lead from the upper storeys of the building to a place of safety in the open air at ground floor. Vertical escape routes are stairways which are protected from fire by means of fire resisting construction. The protection is provided to the enclosure to the stairway at all storeys and additionally by the provision of protected lobbies, where required, between the stairs enclosure and the accommodation. In some limited situations an external escape stairway may be the only practicable way of providing an alternative means of escape from a building (Herbert, 1998).

- *Protection of Vertical Escape Routes*

The protection of vertical escape routes, by enclosing the stairways in fire resisting construction, is essential to protect the escape routes from smoke and fire. The protection of stairways also restricts the spread of fire between storeys. To restrict smoke entering a protected stairway, doors opening into it must be self-closing fire doors.

- *Number and Location of Escape Stairways*

The number of escape stairways should be adequate to safely evacuate the building. Escape stairways should be located so as to provide alternative escape routes and to reduce, to a minimum, the dead-end travel.

### Doors on Escape Routes

All doors on escape routes should generally open in the direction of escape. Doors should not open across stairways, or obstruct the width required for escape of corridors, landings, or lobbies when open. A fire resisting vision panel should be provided in fire doors which are located on corridors for the purpose of sub-division.

- *Door Fastenings*

Exit doors should be readily and immediately openable at all times from the inside. They should not be dead-locked or fitted with barrel-bolts. The use of break-glass boxes containing keys for exit doors is not suitable. Fastenings should be of a type such as lever-handled latches or night latches that can be opened without use of a key. Panic-bolt type locking mechanisms should be used on doors on escape routes which may be used by 50 or more persons (Herbert, 1998). Doors which are opened by means of panic bolts should have a sign "PUSH BAR TO OPEN" displayed on them.

### Protection of Appliances and Installations

Fire protection appliances and installations are increasingly forming a part of an overall fire protection system. Active extinguishing systems are often installed to compensate for inadequate structural protection, or to facilitate an innovative concept or design which would be hampered by protective construction or division by fire walls (Menzies, 1999).

- *Hand Fire Appliances*

Extinguishers, fire buckets, fire blankets. First aid appliance for use by general public. The extinguishing medium of hand-held extinguishers varies to suit the risk; they are colour coded for quick reference.

- *Hose Reels*

First aid appliance for use by firefighters; connected to a pressurized water supply. Davies, (2008) described hose reel as hose coiled and placed in a designated cabinet at a fire point with a connection to a main, used by staff and firefighters in the event of a fire.

- *Automatic Sprinkler*

They provide an automatically released water spray above a fire to contain its growth and inhibit its spread. There are various types and systems for specific areas, applications and risk categories. It should be noted that some systems are meant for property protection only, and that special provisions relate to life safety (Menzies, 1999). Certain situations are not considered suitable for protection by sprinklers because of the potential water damage (art galleries, museums, and historical libraries), the risk of accidental discharge or the unsuitability of water as the extinguishing medium for certain processes and materials (Menzies, 1999). There may also be a need to provide large volumes for on-site water storage.

Water Spray Projector Systems

They are used for fires involving oils or similar flammable liquids.

- *Foam Installations*

This is of limited application; generally, for the extinction of flammable liquid fires. It may require space for on-site foam-making equipment. There are various forms; specialist advice will be needed (Menzies, 1999). A foam inlet is a fixed pipe through which foam can be pumped to protect places containing oil fuel, oil fired boilers etc.

- *Automatic Detectors*

Smoke detectors: detect the presence of smoke by optical (obscuration) or ionization methods and raise an alarm.

- Ionization detectors: are sensitive in the early stages of a fire when smoke particles are small; most suitable in a controlled environment such as a computer suite. Optical detectors: react to the visible products of combustion and are the most effective. Heat detectors: detect heat at a pre-selected temperature or on a rapid rise in temperature. It is used where smoke may be present as part of process or function but regard should be had to normal temperature of area where sited. Radiation and ultraviolet detectors: respond to distinctive flame flicker. It is suitable for large open areas and can detect certain chemical fires. Laser beam detectors: rising hot air affects laser beam being projected onto receiver by obscuration or movement. It is suitable for covering large open areas but note that the receiver may be subject to building movement; beware of false alarms from falling objects or birds (Menzies, 1999).
- Fire Alarms: A fire safety system which will sound an alarm or alarms in the presence of a building fire, triggered by a fire-detection system; as stated by Davies, (2008). The fire alarm system (manual or automatic) must be carefully chosen to meet specific needs – property or life safety; special needs of those with impaired hearing or sight; public entertainment application (possibly muted alarms) or a specific evacuation procedure (two stage/phase evacuation) (Menzies, 1999).

Design of Process Layout

Normally, a production system must be flexible enough to permit future changes brought about by production technology or changes in product design. In today's volatile and competitive environment, manufacturing facilities must be designed with enough flexibility to withstand significant changes in their operating requirements. The shortening of product life cycles and increased variety in product offerings require that facilities remain useful over many product generations and support the manufacturing of a large number of products. In the design of the process layout of a palm oil production plant, the process layout applies the principle of work place design and work space design to optimally arrange production facilities in a manner that fits the job to man so as to create conditions in work environment that furnishes operator's comfort and stress reduction. Process layout design is a process that deals with the arrangement of machine or production facilities in their correct relative position in the available workspace to create conditions in work environment that furnishes operator's comfort and stress reduction. Process layouts are found primarily in job shops or firms that produce customized, small quantity products that may

require different processing requirements and sequences of operations; process layouts are facility configurations in which operations of similar nature or function are grouped together.
Different literature on the design of a process layout has been on articles on various approaches for large and small scale industries. Riis (1992) as well as Gouzhn and Riis (2001) proposed methods for modern plant layout that can furnish optimum production. He emphasized that plant layout design should be viewed in the context of the whole production system. Moore (1978) proposed computer aided plant layout design and pointed out several limitations associated with computer aided layout design and made suggestions on how to improve its use. Ostresh (1975), Love and Moris (1975), Love and Juel (1982), Christofides and Viola (1971) all discussed the application algorithms to the optimization of the process layout design. Francis and White (1974) advocated an integrated approach to multi-criteria facility layout problem. It is worthy to note that, most of the works cited above have only theoretical value and perhaps their practicality has not been demonstrated.

## Methodology

The study was Akwa Ibom State. Both descriptive and case study survey research design was adopted for the study. The adoption of the design is due to the nature of the research. The population of the study consisted of all experts in architecture, civil engineering, structural engineering, electrical engineering, mechanical engineering and other sections of environmental science. Also included are workers of paint manufacturing industries in Akwa Ibom State. The sample size consisted of 150 respondents obtained from 30 architects, 30 civil engineers, 15 structural engineers, 30 electrical engineers, 15 mechanical engineers and 30 workers in locally paint manufacturing companies. They were selected using stratified random sampling technique. This study adopted both primary and secondary data collection tools. The primary data was obtainedfrom the field survey using case studies, taking of photographs and in-depth interview with professionals. The secondary data was obtained from comprehensive literature review from various sources including books, referred print and electronic journals. The data collected was analyzed using statistical technique such as regression analysis. The statistical techniques helped in testing the hypothesis at 0.05 alpha level and at 148 degree of freedom.

## Results/Discussions
### Hypotheses Testing

**Hypothesis One:** There is no significant extent of design features, construction material choices on the extent of fire hazards in factory in the study area. In order to answer the hypothesis, simple regression analysis was performed on the data (see table 1).

Table 1: Model summary of the impact of design features, construction material choices on the extent of fire hazards in factory in the study area

| Model | R | R-square | Adjusted R-Square | Std Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.87a | 0.75 | 0.75 | 0.90 |

*Significant at 0.05 level; df= 148; N= 150; critical R-value = 0.197

The above table 1 shows that the calculated R-value 0.87 was greater than the critical R-value of 0.197 at 0.5 alpha levels with 148 degree of freedom. The R-Square value of 0.75 predicts 75% of the extent of design features, construction material choices on the extent of fire hazards in factory in the study area. The rate of percentage is highly positive and therefore implies that there is significant extent of design features, construction material choices on the extent of fire hazards in factory in the study area. It was pertinent to find out if there is significant difference in the influence exerted by each independent variable (see Table 2).

Table 2: Analysis of variance of the difference in the influence exerted by each independent variable.

| Model | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 363.20 .000b | 1 | 363.20 | | 452.46 |
| Residual | 118.80 | 148 | 0.80 | | |
| Total | 482.00 | 149 | | | |

- Predictors: (constant), design features, construction material choices.
- Dependent variable: extent of fire hazards in factory.

Table 2 shows the calculated F-values as significant (425.46). As the computed critical value R-value (0.000a) is below probability level of 0.05. The result therefore means that there is significant difference in the influence exerted by the independent variable (design features, construction material choices) on the dependent variable which is extent of fire hazards in factory. The result is in agreement with the research findings of Fisher (2007), who stated that design concept could simply be defined as ideas that integrate various elements into a whole. In this context, it would suggest a specific way that programmatic requirements, content and beliefs can be brought together. The proposed paint factory is aimed at being a building complex that is designed to function as a single unit, housing all the functional units in order to create an industrial architecture and address spatial and functional planning problems. The result of the analysis caused the null hypotheses to be rejected while the alternative one was retained.

Hypotheses Two: The impact of effective planning and design for prevention and control of fire does not significantly promotes the ideal factory architecture with a well-defined layout for paint production and packaging. In order to answer the hypothesis, simple regression analysis was performed on the data (see table 3).

Table 3: Model summary of the impact of effective planning and design for prevention and control of fire significantly promotes the ideal factory architecture with a well-definedlayout for paint production and packaging.

| Model | R | R-square | Adjusted R-Square | Std Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.87a | 0.75 | 0.75 | 0.86 |

*Significant at 0.05 level; df= 148; N= 150; critical R-value = 0.197

The above table 3 shows that the calculated R-value 0.87 was greater than the critical R-value of 0.197 at 0.5 alpha levels with 148 degree of freedom. The R-Square value of 0.75 predicts 75% of the influence of fire safety measures on the level of prevention and control fire in a paint factory. The rate of percentage is highly positive and therefore implies that there is significant influence of fire safety measures on the level of prevention and control fire in a paint factory. It was pertinent to find out if there is significant difference in the influence exerted by the independent variable (see Table 4).

Table 4: Analysis of variance of the difference in the influence exerted by the independent variable.

| Model | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 335.67 | 1 | 335.67 | 452.03 | 0.000b |
| Residual | 109.90 | | 148 0.74 | | |
| Total | 445.57 | | 149 | | |

(a) Predictors: (constant), fire safety measures.

(b) Dependent variable: level of prevention and control fire in a paint factory.

Table 4 shows the calculated F-values as significant (452.03). As the computed critical value R-value (0.000a) is below probability level of 0.05. The result therefore means that there is significant difference in the influence exerted by the independent variable (fire safety measures) on the dependent variable which is level of prevention and control fire in a paint factory. The result is in agreement with the research findings of experts and other researchers in the field. The result of the analysis caused the null hypotheses to be rejected while the alternative one was retained.

## Conclusion

Fire incidents in a paint factory is a critical undertaking to identify their causes and implement effective prevention strategies. Paint factories pose unique fire risks due to the presence of flammable substances, volatile solvents, and ignition sources within their operations. Understanding the root causes of fire incidents is essential to mitigate potential hazards and safeguard the safety of employees, the environment, and valuable assets. Prevention strategies should focus on enhancing fire safety practices within the paint factory. This includes implementing robust fire prevention training for employees, establishing and practicing emergency responseplans, and enforcing strict adherence to fire codes and regulations. Regular inspections and maintenance of electrical systems and machinery can help identify potential hazards and mitigate risks. The assessment of fire incidents in a paint factory is a continuous process that requires collaboration between management, employees, and fire safety experts. By thoroughly examining the causes of previous incidents and implementing preventative measures, paint factories can significantly reduce the risk of fires, creating a safer working environment for all and protecting their assets and reputation.

## Recommendations

Based on the analysis of results and findings, the following recommendations are hereby made:

1. The installation and maintenance of special installations and sensors to ensure their functionality in the industrial buildings can help to hinder the occurrence of fire or possibly reduce its effect where its control becomes inevitable.
2. Compliance with the fire code and issuance of fire certificate should be approached right from the inception of the construction and appropriate follow up ensured after completion and throughout the buildings life span.

## REFERENCES

Anthony, S. (2007) “PAINT” Encyclopedia of Chemical Technology: 2nd Edition Vol. 14. New York, U.S.A.

Balcomb, J. D., and Curtner, A. (2000), ‘Multi-criteria decision-making process for buildings’. In Energy Conversion Engineering Conference and Exhibit, 2000 (IECEC) 35th Intersociety (Vol. 1, pp. 528-535). IEEE

Christofides, N. and Viola, P. (1971). The Optimum Location of Multi Centres on a Graph. *Operation Research Quarterly*, 22(2):48-67.

Darton, M. (2001), Illustrated Books of Architects and Architecture, Tiger Books International, London

Davies, N. (2008). Dictionary of Architecture and Building Construction, First Edition. Oxford: Architectural Press. pp. 872.

Fessler, Daniel M. T. A (2006). Burning Desire: Steps toward an Evolutionary Psychol- ogy of Fire Learning. Emmitsburg, MD: [National Emergency Training Center].

Fisher, T. (2007). Designing for Designers: Lessons Learned from Schools of Architecture. United States of America: Fairchild Pubilcation, Inc.

Francis, R. L. and White, J. A. (1974). Facilities Layout and Location; An Analytical Approach. Eaglewood Cliffs: Prentice Hall, pp. 678.

Gouzhu, J. and Riss, O. (2001). Development of the Integrated Design Process to Plant Layout and Its Application in a Medium Enterprises. New York: Addison, pp 269.

Hassan, H. (1999). Fire and Safety Management in Building. New York: John Wiley and Sons Inc. pp 674.

Herbert, G. (1999), Fire safety in hostels. London: McGraw-Hill, Inc. pp 771

Kodur, V., Garlock, M. And Iwankiw, N. (2012), ‘Structures in fire: State-of-the-art, research and training needs’, Fire technology, 48(4), pp. 825-839

Langenbach, R. “Better than Steel? (Part 2).” Structures and Architecture New Concepts, Applications and Challenges, 2013, 122-39.

Love, R. F. and Juel, H. (1982). Properties and Solution Methods for Large Location Allocation Problem. Journal of the Operational Research Society, 33(5):443-452.

Love, R. F. and Morris, J. G. (1975). A Computational Procedure for the Exact Solution of Location-Allocation Problems with Rectangular Distances. National Research Logistics Quarterly, 22(3):441-453.

Megri, A. (2009), ‘Teaching the integration of safety and fire protection elements into the building design process’, American Society for Engineering Education 2009, American Society for Engineering Education.

Menzies, B. (1999). Metric Handbook Planning and Design Data. Second Edition. Oxford: Architectural Press, pp. 118

Moe, Kiel. (2010). Thermally Active Surfaces in Architecture. New York: Princeton Ar- chitectural Press.

Moore, J. M. (1978). Computer Aided Facilities Design an International Survey. International Journal of Production Research, 12 (1):21-44.

Oladokun, V.O. And F.A. Ishola, M.Sc., (2010). A Risk Analysis Model for Fire Disasters in Commercial Complexes in Nigeria, Department of Industrial and Production Engineering, University of Ibadan, Ibadan, Nigeria

Ostresh, L. M. (1975). An Efficient Algorithm for Solving the Two Centre Location. *Journal of Regional Science*, 15(2):209- 276.

Park, H. (2014), 'Development of a holistic approach to integrate fire safety performance with building design', PhD Dissertation, Worcester Polytechnic Institute.

Rasbash, D., Ramachandran, G., Kandola, B., Watts, J., and Law, M. (2004), Evaluation of Fire Safety. John Wiley and Sons