# Factors Mitigating Against The Efficient Performance And Maintenance Of Elevators In High-Rise Buildings In Kwara State, Nigeria, Case-Study Federal Secretariat Complex, Ilorin, Kwara State

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## ABSTRACT

A current trend in modern cities all over the world is the development of high-rise buildings mainly to overcome the challenges of urban over population, for optimal use of scarce land resources, as status symbol, as tourist attractions and for beautiful skylines. However the development of high-rise buildings in Nigeria has been experiencing drawbacks. The retarding growth translates to the very fewness of high-rise buildings in existence in Nigerian cities just as even most of the few in existence are poorly equipped with elevators due to some persistent factors. The data used in this research was obtained through physical inspection and careful observations of the elevators (lifts) in the Federal Secretariat Complex, Ilorin, Kwara State. The building is an 8-storey government building within the area of study which contains about 16 Government ministries and agencies and numerous civil servants. Questionnaires was administered to samples of 250 respondents, These respondents included the property managers, visitors and civil servants working within the building. The sampling procedure used includes; purposive sampling method to ensure that all ministries and agencies are covered, and random sampling technique in selecting the civil servants and visitors alike. Result shows that all of the elevators studied have one problem or the other which rendered it not convenient for the passenger's use. It was recommended that all elevators' problems should be properly and effectively attended to as soon as the sign of failure is notice before it causes further damages that will increase costs. There is need for the property managers to consider periodic inspection and system diagnosis of the elevators by professionals to verify it conditions and advice on the way forward. It was concluded that, with adequate maintenance policy, adhering to the manufacturer's instructions, use of skilled and highly trained manpower in the maintenance of elevators and by ensuring only standard and approved spare parts are used majority of the problems hindering effective use of elevators in high-rise commercial buildings in Nigeria will be overcomed.

**Keywords:** Property manager**,** Elevator, High-rise Buildings, Civil servants, Government Ministry and Agency

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## 1. INTRODUCTION

A high-rise building is a building where the floor of an occupiable storey is greater than 75 feet (23m) above the lowest level of the fire department vehicle access (National Fire Protection Association, 2011). Smith (2002), a retired Deputy Fire Chief of the Philadelphia Fire Department, defines a high-rise building as the following:

a) Building more than seventy-five (75') feet tall and constructed for human habitation.
b) A building that is beyond the reach of the fire department's longest ladder.
c) A storey building with unreasonable evacuation time in the event of fire outbreak.

Imagine the skyline of a modern city if the elevator did not exist. Buildings would be limited to five or six stories. Most of the architecture of the 20th and 21st century would be impossible. Office towers, hotels and high-rise apartments would hardly stand in their present form. But in 1852, one man helped change the face of the world's cities. That was the year Elisha Graves Otis invented the safety elevator, giving rise to the modern skyline. To gain some idea of the effect of this one advancement, consider that today, elevators move the equivalent of the world's population every 72 hours. Most high-rises are built using a standard p to 15 feet (or more) per floor measurement. Therefore, it is safe to assume that a five to eight-storey building could be regarded as a high-rise (McGrail, 2007). The rapid increases of commercial activities have shown a characteristic growth in towns and cities. The high cost of land acquisition caused by scarcity has given rise to a vertical development of multi-storey buildings, (Streen, 2002).

A current trend in modern cities all over the world is the development of high-rise buildings mainly to overcome the challenges of urban over population, ensure optimal use of scarce land resources, to serve as status symbol, to serve as tourist attractions and for beautiful skylines. Regardless of these advantages, the development of high-rise buildings in Nigeria has been experiencing drawbacks. The retarding growth translates to the very fewness of high-rise buildings in existence in Nigerian cities just as even most of the few in existence are poorly utilized due to some persistent factors as a matter of fact (Ede, 2014). Elevators are the most commonly used mode of vertical movement in modern buildings having more than three stories. Imagine the skyline of a modern city if the elevator did not exist. Most of the architecture of the 20th and 21st century would be impossible. Office towers, hotels and high-rise apartments would hardly stand in their present form.

The need for vertical transport is as old as civilization. Over the centuries, mankind has employed ingenious forms of lifting. The earliest lifts used man, animal and water power to raise the load. Lifting devices relied on these basic forms of power from the early agricultural societies until the dawn of the Industrial revolution (Otis, 2015). The design of high-rise commercial buildings both for single or multiple occupations requires the incorporation of services necessary to support the buildings, business activities and its inhabitants, (Pearson and Wittels, 2008). Elevator is one of such services that serve as a means of vertical movement in a building. A multi-storey structure in which most occupants depend on elevators (lifts) to reach their destinations is referred to as 'high-rise buildings' (Challinger, 2008). In terms of height, a high-rise building can be defined as buildings reaching 75 feet (23meters) to 100 feet (30meters) tall or seven to ten stories. It is important to note that, the height and number of floors of a building to be called high-rise vary from one country to another or between continents. As in the case of the Nigerian context and for the purpose of this paper high-rise buildings are considered to be buildings with minimum of four floors as a matter of fact (three storey).

High-rise commercial buildings are more expensive to construct per square meter, they produce less usable space and their operation costs are more expensive than conventional office buildings. Most of these buildings suffered void for a long period at the initial stage of occupation that is after all aspects of construction has been completed especially the upper floors resulted to huge losses on the part of the overall investments (Pearson and Wittels, 2008). It was also established that tenants of high-rise buildings are more interested in occupying the lower floors than upper floors at a long run, that is, after some years of putting the building in to use (Alhassan, 2014). The reasons for such void period vary from one building to another, however, investigations have shown that problems that are connected to the elevators (lifts) system play a vital role and cannot be underestimated.

## 2. THEORETICAL BACKGROUND

This section of the paper highlights existing literature on escalators, hoist, lifts and elevators. It reviews related studies on the evolution of lifts, hoists and elevators.

### 2.1 Related Studies on High-rise Buildings and Elevators

Al-Kodmany (2015) stated that efficient vertical mobility is a critical component of tall building development and construction. When people think about the development of cities, rarely do they contemplate the critical role of vertical transportation. Consider, however, that each day, more than7 billion elevator journeys are taken in tall buildings all over the world (Wood, 2014 and Neyfakh, 2015). Efficient vertical transportation has the ability to limit or expand our ability to build taller and taller skyscrapers, and recent innovations in elevator design promise to significantly reduce energy consumption. Indeed, the race to build ever taller skyscrapers has sparked fierce competition among lift manufacturers to build faster,more efficient, safer, more comfortable and more economical elevators. For example, elevators in the Kingdom Tower in Jeddah, Saudi Arabia, under construction, will reach a height record of 660 m (2165 feet);and elevators in CTF Finance Center in Guangzhou, China, under construction, will travel with a speed record of 20 m/s (66 feet per second).

Daniel Levinson Wilk, a Professor of History at the Fashion Institute of Technology in New York and a board member of the Elevator Museum in Queens, explains in an article, 2014, titled "How the Elevator Transformed America" that the elevator is responsible for shaping modern life in ways that most people simply don't appreciate and that he would like people to be more conscious of the elevators in their lives (Wilk, 2006). Professor Wilk is particularly "disappointed with his fellow academics—people who are supposed to be studying how the world works- for failing to consider just how much elevators matter" (Wilk, 2006).Similarly, Andreas Bernard's (2014) research shows how elevators have been responsible for reshaping modern cities by concentrating large masses of people and activities in smaller areas, creating vibrant communities.

Spatially speaking, the elevator's role has been no less profound than that of the automobile in transforming modern cities. While cars have facilitated horizontal spread of cities and regions, encouraging sprawl and suburbia, elevators have enabled concentrating a large number of people and human activities in a smaller footprint. New advances in elevator technologies are likely to reshape cities further by enabling even taller buildings as a matter of fact (Wood, 2014 and Neyfakh, 2015).

Noordermeer (2010) asserted that vertical transportation of people and goods is one of the main focal emergency stairwells, regardless of building height. Everywhere in the world, buildings are growing in height. Arguably the greatest challenge while designing ever-taller buildings, is the aspect of vertical transportation. Travelling times for building occupants need to be acceptable while maintaining the economic feasibility of the building by preserving as much valuable floor space as possible. These interests clash with one other, essential requirement: the safety of the building, and in particular the ability to evacuate the building occupants safely and within an acceptable time frame. The precarious balance between economic feasibility and fire safety has been a topic of discussion for a long time (Noordermeer (2010).

### 2.2 Evolution of Lifts, Hoists and Early Elevators

The history of elevators began with the ancient Egyptians, who are generally credited with the first lifts for elevating, while building the pyramids. The Great Pyramid Cheops, built in the year 2569 BC, stands at 481 feet; it is taller than most 40-storey high-rise buildings and was the tallest structure on earth for 43 centuries (McGrail, 2007). The first written report of an elevator came in 1st century BC when Roman architect Vitruvius mentioned that Greek mathematician and inventor Archimedes has built his first elevator around 235 BC.

According to otis (2015) the first elevator was made in ancient Greece; Archimedes developed an improved lifting device operated by ropes and pulleys, in which the hoisting ropes were coiled around a winding drum by a capstan and levers. By A.D. 80, gladiators and wild animals rode crude elevators up to the arena level of the Roman Coliseum.At an abbey on the French seacoast, a hoist was installed in 1203 that used a large tread wheel. A donkey supplied the lifting power. The load was raised by a rope wound on a large drum. By the 18th century, machine power was being applied to the development of the lift.

In 1743, a counterweighted personal lift was commissioned by Louis XV in France for his personal chambers in Versailles. By 1833, a system using reciprocating rods raised and lowered miners in Germany's Harz Mountains. A belt-driven elevator called the "teagle" was installed in an English factory in 1835. The first hydraulic industrial lift powered by water pressure appeared in 1846. As machinery and engineering improve, other powered lifting devices quickly followed eventually. It was realized that some sort of safety brake was required. The brake had to function automatically, the instant the cable broke, if it were to save lives and property. Otis (2015) carried out an experiment by placing a wagon spring above the hoist platform. He then attached a ratchet bar to the guide rails on each side of the hoist way. The lifting rope was fastened to the wagon spring in such a way that the weight of the hoist platform exerted just enough tension on the spring to keep it from touching the ratchet bars. If the cable snapped, however, the tension would be released from the spring and it would immediately engage the ratchets, preventing the platform from falling.

In 1852, Elisha Graves Otis invented the safety elevator, giving rise to the modern skyline. On March 23, 1857, the world's first passenger safety elevator went into service in a store at Broadway and Broome Street in New York City. The elevator was powered by steam through a series of shafts and belts. As the safety and efficiency of the early elevators continued to improve, space in buildings' upper floors soon became more desirable, reversing a long-standing trend in commercial and residential leasing. In 1878, Otis Company introduced a hydraulic elevator that increased speeds to 244 meters (800 ft) per minute. That same year Otis installed its first hydraulic passenger elevator at 155 Broadway in New York City. In 1889, Otis innovation produced another first with the direct-connected electric elevator machine. This worm-gear electric unit was primarily used for carrying freight. As better gearing arrangements were developed, the speed of the geared electric elevator increased from 30 to 120 meters (100 to 400 ft) per minute. This brought the electric elevator into passenger service in medium height buildings. Although it offered the advantage of a more compact installation, it was not yet fast enough to compete with the steam-powered hydraulic systems in the taller buildings.

According to Siikonen, (1997), elevators have been built throughout history but the first modern passenger elevators were developed no more than about 150 years ago. Steam and hydraulic elevators had already been introduced by 1852, when Elisha Otis made one of the most important elevator inventions, the clutch, which prevented the elevator from falling. Following this, in 1857, the first passenger elevator was installed in the store of Haughwout and Company, New York. The development of elevator technology was fast. With the advent of modern high-rise buildings, more elevator history than in any other single location was made in 1889, when the 321-meter-high Eiffel Tower was built for the Universal Exposition in Paris (Siikonen, 1997). In the Eiffel Tower, hydraulic double-deck elevators operated between ground level and the second platform. Between the second and third platforms two cars counterbalancing each other handled the traffic. The early hydraulic and steam-driven elevators functioned with pressurized water, which was either taken from the city water pipes or provided by steam engines. The elevator car was connected to a long piston that moved up when water was pumped into a cylinder, and came down when water was released by a hydraulic valve. In 1880, Werner von Siemens introduced the utilization of electric power. Soon after, the geared or gearless traction electric elevators started to replace the hydraulic elevators.

The development of electric elevators added impetus to high points in high-rise buildings: as the average pedestrian doesn't traverse more than six floors, a building's lift system is the backbone of a high-rise building. During an emergency however, the traditional method of egress is via rise construction. The fastest elevators today move at about 10 meters per second (Siikonen, 1997).

### 2.3 Elevator Surfing

In the words of Pigg (2013), during the 1970s and 1980s, there were several accidents involving elevator passengers who manually pried open the car doors and attempted to exit an elevator stopped between floors. Youngsters living in public housing projects and students in college dormitories have been known to pry open the car doors of a moving elevator, which immediately stops the hoisting machine and sets the brake. This can stall the elevator between floors, enabling the passengers to climb on top of the car. Elevator surfing, as it is called, is undoubtedly a thrilling experience, riding the top of an elevator traveling at high speeds. Unfortunately, some of these "surfers" were killed when they were crushed between the elevator car hoist ways (shaft way), counterweights. As a result of reported injuries and the need to make these elevators a safe environment for people, the American Society of Mechanical Engineers, has incorporated required door restrictors since 1980. Additionally,the fear of liability for elevator accidents has resulted in the retrofitting of door restrictors on many older elevators.

### 2.4 Elevator Safety Mechanisms

In the words of Pigg (2013), **t**here are two basic types of mechanisms in these door opening devices, commonly called door restrictors. The clutch-type restrictor consists of a latch located at the top of the car doors. On some assemblies, the latch is released, permitting the car doors to fully open when the clutch or driving vane on the car doors lines up with the release rollers of the shaftway door. When the elevator is within its landing zone, the hoist way door release rollers depress a release mechanism located next to the driving vane or clutch of the car door. The release mechanism is connected to the latch at the top of the car doors by a reach rod, similar to the linkage between the door release rollers and the interlock at the top of the hoist way doors. The key to releasing this type of restrictor is to duplicate the pressure of the hoistway door release rollers on the restrictor release located on the
car door.

When the release mechanism is within reach, simply depress it and push open the car doors. When an elevator is too far above or below a floor landing to reach the release by hand, use a pike pole to depress the release or access the top of the car from a landing above the elevator and directly release the latch at the top of the car doors. The second basic type of door restrictor, the angle iron restrictor (commonly found on Otis elevators), consists of projections fastened to the car door and hoistway similar to an angle iron (Pigg, 2013). When an elevator equipped with this restrictor is outside its landing zone, the car door restricting angle will strike the angle iron on the shaftway doors and the shaft, preventing the car door from opening more than four inches. The car door can only open completely when the elevator car is within its landing zone, where the car door angle and shaftway angles do not line up to strike each other. On older installations, the angle-type door restrictor could not be manually released. Some Otis elevators, however, have restrictors that are hinged and spring-loaded. Depressing the angle on the car door will allow it to clear the angle iron fastened to the hoistway and hoistway doors (Pigg, 2013).

## 3. RESEARCH METHODOLOGY

### 3.1 Instruments of Data Collection

The data used in this research was obtained through physical inspection and careful observations of the elevators (lifts) in some selected high-rise buildings within the area of study Kwara state. The property managers (staff of Federal Ministry of Works) and visitors/civil servants patronizing the buildings were also interviewed, in addition to the structured questionnaire that was administered simultaneously.

### 3.2 Sampling Technique

Samples of 250 respondents were randomly selected. The sampling procedure used includes; purposive sampling method to ensure that all ministries and agencies are covered, and random sampling technique in selecting the civil servants and visitors alike. Special consideration has been given to the civil servants, especially those that spend five and above years in the buildings which experienced a lot on the functionality or otherwise of the elevators and visitors or other users of the buildings.

### 3.3 Interview, Questionnaire Designed and Techniques of Data Analysis

The interview conducted and the questionnaires designed give more consideration to the physical aspects which includes; the dwell time, capacity of the elevators, maximum available elevators, maintenance condition, usage especially at up peak times of demand, energy sources and the occupancy rate of the buildings particularly at the upper floors were studied. No mechanical (engineering) and/or scientific test of any kind was conducted. The data collected were analyzed in percentile form, chart and narrative description.

## 4. RESULTS AND DISCUSSION

The pie chart below shows the percentage of elevators in each of the towns visited within the case study area. This is imperative in order to have an insight into the spreads and availability of the elevators in the study area.

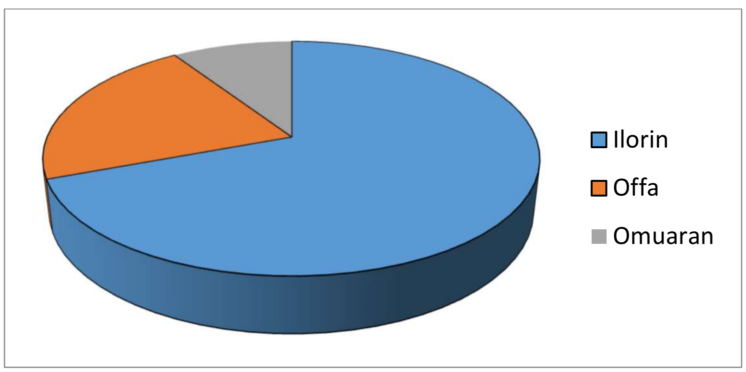


**Figure 1: Spread of Elevators in Kwara State**
Source: Field Survey (2018)

From the pie chart above, it be seen that 74% of the total lift systems are located in the state capital, Ilorin, 20% within the Offa, and 6% in Omuaran town. However, unfortunately, many of them are either not functioning efficiently or not functioning at all, as at the time of the inspection. Furthermore, it was also established that only 65% of the elevators in Ilorin are fully functioning in Ilorin while 35% are faulty, most of Offa are not functioning while most of Omuaran are in good shape as shown in the graph below.

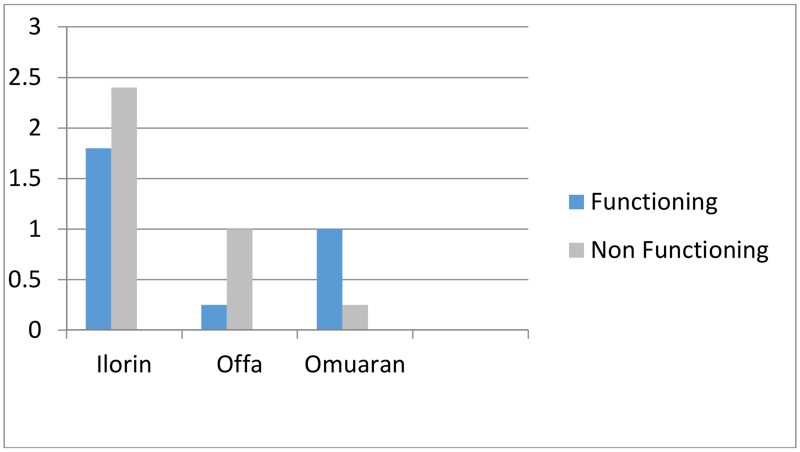


**Figure 2: Function status of Elevators in Kwara State**
Source: Field Survey (2018)

The investigations have shown that about 83% of the elevators studied have one problem or another which rendered it not convenient for the passenger's use. Some of these problems includes:

#### 4.1 Maintenance

Investigations have revealed that about 40% of the elevators currently serving the multi-tenanted high-rise buildings were installed more than 30 years ago. Most of these lifts are presently very weak due to poor maintenance, shortage of skilled manpower, and/or lack of qualitative spear parts. These variables are further examined in details.

#### 4.1.1 Poor Maintenance

Inspections reveal that, more than 24% of the buildings studied are lacking proper maintenance planning. The tenants also confirmed that in many cases property managers allow the system (lifts) to breakdown before fixing it. In other words small signs of elevator's failure are not attended to until it further deteriorate and affect its normal functions; as a result of lack of available skilled professionals to attend to it within the vicinity or the period of time it takes for the property manager to put request for the repairs.

#### 4.1.2 Shortage of Skilled Manpower

It was observed that, the property managers who are in charge of the maintenance of the high-rise buildings studied complained on the shortage of skilled labourers within the study area for the maintenance or replacement of parts. In many instances the professionals have to be outsource from far distance (Abuja, Lagos or abroad), which increase the cost of maintenance and sometimes worsen the condition of the elevators before it is being rectified.

#### 4.1.3 Lack of Spare Parts

Elevator comprises different parts which have separate life cycle, some part need to be replaced before the others in order to maintain shape, function and aesthetic. It is the experience in some of our high-rise commercial buildings that elevators used to be kept out of use for months due to the failure of its parts that needs to be transported from far distance or imported from abroad. At this period, tenants and other users of the buildings are left with no option than to use the stairs as a matter of fact. This discourage visitors or clients to patronise the offices at upper floors which if persisted will eventually force them to move to lower floors or relocate to other buildings. About 5% of the tenants are on the opinion that, property managers do purchase substandard spare parts or used parts from other elevators to serve as replacement for the faulty parts in the building they are managing which do not last after replacement.

### 4.2 Source of Power

Elevators required sufficient and reliable electrical energy to function. It was established that all the elevators studied have two sources of power supply; from the national grid and through the standby generators as a result of the unstable electric power supply from the national grid in Nigeria. However, over 20% of the high-rise buildings studied have faulty generators; they therefore, depend fully on the supply from the national grid to operate the elevators. This increases the fear of the tenants, as well as the visitors of the possible entrapment due to power failure. This is the reason why more than 30% of the users decided to be using the stairs instead of the elevators.

### 4.3 Usage

The study has established the following problems in the usage of the elevators during up peak and down peak periods:

#### 4.3.1 Queuing Problem

The flow of people through a high-rise building takes on different characteristics depending on the building use, time of the day, and other factors (Arthur et al, 2003). The efficient dispatching of people requesting service from an elevator in a high-rise building will also depend on many factors such as number of servers, queuing capacity, number of elevators, dispatch time or speed and so on. Majority of the high-rise commercial buildings studied have "twin elevators" however, only 65% operate them simultaneously as about 35% of the buildings used a single elevator at a time due to mechanical or other problems.These eventually cause queuing problem at lobbies especially at up peak period. As a result, passengers wait for long time before getting the service of the elevator.

#### 4.3.2 Passengers with Special Needs

More than 15% of the elevator users interviewed are either physically challenge people or illiterates; these kinds of people found the elevators to be difficult to operate due to disability or illiteracy. They depend on other users to reach their desired destinations. They are also exposed to greater risks and danger in an event of emergencies and waste a lot of time before reaching their destinations especially at down peak period when very few people are there to operate the elevators for them.

#### 4.3.3 Noise and Vibration

As a result of age and inadequacies in design and maintenance of some elevators, more than 20% of the lifts studied were found to be vibrating too much with rising interior noise making about 25% of the passengers uncomfortable especially the age class that could not use the stairs in getting to the upper floors easily.

## 5. CONCLUSION

High-rise commercial buildings development is known to be problematic and difficult to handle right from conception to the completion and occupation stage. Each stage has its own challenges which requires an independent solutions as it occur or anticipated. However, most of these problems will have been overcome or reduced from the early stage of design when certain facts are considered and implemented at the construction stage. An elevator system both for single or multiple occupations is one of such services which can be adequately attended to at this level (design), for all vertical developments above three floors. This is because it requires the incorporation of services necessary to support the building and its inhabitants. The current trend for constructing office buildings is to build higher and higher, and developers tend to compete with one another on heights. Vertical construction now in our modern cities and its transportation was achieved through the invention and development of elevators as one of the most important service in high-rise buildings for convenience, safety and comfort. With adequate maintenance policy, adhering to the manufacturers instructions, use of skilled and highly trained manpower in the maintenance of elevators and by ensuring only standard and approved spare parts are used, majority of the problems hindering effective use of elevators in high-rise commercial buildings in Nigeria will be exterminated, and tenants of these buildings will appreciate the landmark address due to symbolic role of high-rise buildings.

## 6. RECOMMENDATIONS

(i). **Maintenance Issue:** Elevators like any other machine have its maintenance requirements and standard. The life span of one part may be longer or shorter than another. Property managers should therefore consider the guidelines provided by the manufacturers in the design of their maintenance schedule. This will help a lot in reducing the failure of the lift and many problems will be taking care of before it occur. The shorter life span parts of the elevator should be replace before it breakdown, while longer life ones need to be adequately maintained. All elevators' problems should be properly and effectively attended to, as soon as the sign of failure is notice before it causes further damages that will increase costs. There is need for the property managers to consider periodic inspection and system diagnosis of the elevators by professionals to verify it conditions and advise them on the way forward.

(ii). **Shortage of Skilled Manpower:** There is need for the property managers where possible to employ the services of in-house professionals that can attend to repairs and maintenance of the elevators as at when due or needed. More professionals should be trained on elevators construction, repairs and maintenance in the country and abroad in order to meet the present demand and encourage specialisation in the building industry as a matter of fact.

(iii). **Issue of Spare Parts:** Elevators are manufactured overseas and imported to the country; same as its parts. There should be a government policy that ensures that spare parts imported are up standard requirements and clearance are obtain on time to avoid unnecessary delay of goods in seaports and airports of the country. Some elevator systems may need more than just a dispatch or spare parts change for safety, reliability or aesthetic reasons, but required full modernization in form of replacement.

(iv). **Sources of Power:** Property managers of multi-tenanted high-rise commercial buildings should ensure stable and reliable power supply in their buildings by providing other alternative sources such as standby generator and solar system that can be used when the supply from national grid went off. These other sources of power should always be in good condition and ready for use without any delay whenever the need arises. Government on the other hand and the electricity distribution companies should guarantee the supply of uninterrupted electricity by improving the present sources and developing new ones.

(v). **Queuing Problem:** The estimated number of passengers which an elevator will serve as well as the type of lift system that can withstand the service should be carefully considered since from the initial stage of the design. Property manager are required to conduct assessment periodically to ascertain whether adequate traffic flow exists in the building by measuring the elevator satisfactoriness in dealing with passengers at high demand period. Passengers waiting times are acceptable at all times and throughout the building and the speed of the elevators should be quick enough for the passengers to reach their destination on time especially when on direct journeys.

(vi). **Exceptional Passengers:** The services of an elevator operator should be employed by the facilities managers in each high-rise building to assist passengers who cannot operate the elevator due to system unfamiliarity, illiteracy or disability. The elevator operating system can also be upgraded through the use of the modern technology which can be understood and operate easily by the passengers such as "Schindler's Destination Interface" which allows passengers to select their desired floor number before entering the elevator.

(vii). **Noise and Vibration:** Elevator comfort is usually achieved from the early stage of design where the nature of the building to be served is determined (low-rise or high-rise, residential or commercial, high or low traffic building etc).

Each of the above factors identifies the level of elevator noise and vibration that could be acceptable or not. According to the Elevator Planning for High-rise Building (2015), elevator comfort is principally determined by interior noise levels and transverse car vibration. Cars should be designed to suppress interior noise levels to less than 48–52 dB (A) for superior ride comfort, as for low-speed elevators. Noise levels above 60 dB (A) are generally acknowledged being inadequate. In contrast to low-rise buildings, high-rise buildings require additional measures to reduce noise levels. Transverse car vibration also needs to be minimized to ensure acceptable comfort levels. This imposes high demands on suspension, track and roller guidance systems. At high speeds greater than 3.0 m/s (10 ft/sec), additional technological and alignment measures are vital to ensuring acceptable comfort levels.

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