ADVANCING INDUSTRIAL ENGINEERING IN NIGERIA THROUGH TEACHING, RESEARCH AND INNOVATION

A BOOK OF READING

Edited By
Ayodeji E. Oluleye
Victor O. Oladokun
Olusegun G. Akanbi

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(A Festchrift in honour of Professor O. E Charles-Owaba)

Professor O. E. Charles-Owaba

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FOREWORD

It gives me great pleasure writing the foreword to this book. The book was written in recognition of the immense contributions of one of Nigeria's foremost industrial engineers, respected teacher, mentor, and lover of youth – Professor Oliver Charles-Owaba.

His commitment to the teaching and learning process, passionate pursuit of research and demonstration of excellence has prompted his colleagues and mentees to write this book titled – Advancing Industrial Engineering in Nigeria through Teaching, Research and Innovation (A Festschrift in honour of Professor O. E Charles-Owaba) as a mark of honour, respect and recognition for his personality and achievements.

Professor Charles-Owaba has written scores of articles and books while also consulting for a medley of organisations. He has served as external examiner to various programmes in the tertiary educational system. The topics presented in the book cover the areas of Production/Manufacturing Engineering, Ergonomics/Human Factors Engineering, Systems Engineering, Engineering Management, Operations Research and Policy. They present the review of the literature, extension of theories and real-life applications. These should find good use in the drive for national development.

Based on the above, and the collection of expertise in the various fields, the book is a fitting contribution to the corpus of knowledge in industrial engineering. It is indeed a befitting gift in honour of erudite Professor Charles-Owaba.

I strongly recommend this book to everyone who is interested in how work systems can be made more productive and profitable. It represents a resourceful compilation to honour a man who has spent the last forty years building up several generations of industrial engineers who are part of the process to put Nigeria in the rightful seat in the comity of nations. Congratulations to Professor Charles-Owaba, his colleagues and mentees for this festschrift.

Professor Godwin Ovuworie
Department of Production Engineering
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CHAPTER 21

Computer Aided Design (CAD) of a Vertical Transportation System in High-rise Building: Case of Ivory Tower, University of Ibadan Ibadan

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Abstract

In compliance with the global building regulations, building with at least three floors and above must have lift. The Ivory Tower building in the University of Ibadan, Ibadan, Nigeria, for decades has been underutilized due to lack of convenient and less stressful vertical movement of the people within the building. The need therefore arise for the lift design system for the building. Analytical work involves in the design of lift system in building is often time consuming, laborious, rigorous and tedious. This work therefore aims at design and specifies lift system for the Ivory tower building using Computer Aided Design (CAD) approach. Standard Equation based on the lift system design was adopted in the study. Data were collected from the building site which includes the floor to floor distances and floor dimensions. The population in the 10-Storey Ivory tower building coupled with the 4 Storey Administrative building attached to it was determined using the Chartered Institute of Building Services Engineers (CIBSE) design guide (Peters R D Green 1995 and CIBSE 1991). Lift performance analysis for the building was then carried out using FORTRAN IV programming language. Appropriate and suitable lift and its specifications was then selected for the building. The maximum capacity, number of passengers, velocity, Round Trip Time, Handling Capacity, Interval, and number of lift cars of the selected lift system based on the quality of service are 450kg, 6 passengers, 2.0 m/s, 80.3seconds, 86 passengers, 17.54 seconds and 4 cars, respectively. The lift system therefore selected based on the required quality of services is four numbers 450kg-6passengers machine room less geared traction type. The lift shaft was successfully designed and the number of lift specified using the developed source code; hence the code can be used to design lift system for any building.

Keywords: Handling Capacity, Round trip time, Interval.

Word count: 295 words

Nomenclature

C_d	Car Interval Depth (mm)
C_w	Car Interval Width (mm)
E_h	Car Opening Height (mm)
L	Lift Travel (m)
N	Number of People or Car Capacity
P_h	Pit Depth (mm)
R_a	Machine Room Access (mm)
R_d	Machine Room Depth (mm)
R_w	Machine Room Width (mm)
S	Maximum Number of Stops
S_1	Probable Number of Stops
S_h	Headroom (mm)
T_d	Downward Journey Time(s)
T_o	Door Opening Time (s)
T_p	Passenger Transfer Time (s)
T_u	Upward Journey Time (s)
V	Car Speed (m/s)
V_d	Door Speed (m/s)
W	Door Width (mm)
W_d	Well Depth (mm)
W_w	Well Width (mm)

1. Introduction

Vertical Transport systems in buildings are the systems that are used to move people and goods from one level of a building to another. (Ramesh Nayaka. 2014). These majorly include lifts and escalators. A lift is a type of vertical transport equipment that efficiently moves people or goods between floors (levels, decks) of a building, vessel, or other structure. An elevator (lift) is a permanent lifting installation serving two or more defined landing levels, comprising an enclosed space, or car, whose dimensions and means of construction clearly permit the access of people, and which runs between rigid vertical guides. Elevators are driven directly by an electric motor (electric lifts) or indirectly through the movement of a liquid under pressure generated by a pump driven by an electric motor (hydraulic lifts). Electric lifts are almost exclusively driven by traction machines, geared or gearless, depending on car speed. Hydraulic lifts have become widely used since 1970s for the transportation of goods and passengers, usually for a height not exceeding six floors. Because of wheelchair access laws, elevators are often a legal requirement in new multistory buildings, especially where wheelchair ramps would be impractical. Type of elevators include Direct plunger Hydraulic elevators, Holeless Hydraulic elevators, Roped Hydraulic elevators, Geared Electric Traction elevators, gearless Electric Traction elevators.

Vertical transportation of goods and people has its origin in the depths of history, where simple rope and pulley block systems were used. In 1991, Elisha Graves Otis successfully pioneer vertical transportation systems that still bear his name till today. (Otis elevator PLC 1991). By 1850, steam and hydraulic elevators has been introduced, but it was in 1852 that Elisha Graves Otis successfully put a safety device into a lifting mechanism making possible the first passenger elevator.. Some of the very early passenger lifts installed before 1900 were operated from hydraulic water power and in recent years, the use of hydraulic power has been reintroduced but using oil as the pumping medium with pressure supplied by a motor driven pump. Apart from hydraulic lifts/elevators all earlier types of elevator machines were of driving drum type. In 1903, Otis introduced the design that becomes the backbone of the elevator industry and this is the gearless traction electric elevator. Electric lifts are now more commonly used compared to the hydraulic types. They have a greater performance efficiency, provide speeds up to 7m/s and can travel over fifteen floors unlike hydraulic lifts that cannot travel more than 5 floors and provide speeds up to 0.75m/s. In order to prevent accidents, elevator doors were being equipped with electrical inter locks in the late 1920s, hoist ways and elevator cars were being solidly enclosed and solid car doors were becoming standard. The concept of fireman's lift developed during the 1920's and 1930's, as the need for rapid emergency access responded to the growth in number of tall buildings. By the late 1940s, freight elevator hoist way, gates and gate locking and contact devices were being required, and the days of the worker opening a gate and falling into a hoist way were on the way out. Prior to 1950, there were few or no locks and people fell in regularly.

The elevator industry started to apply microprocessors in 1980 and since then a new generation of the most sophisticated controls has become available representing new and highly advanced technology. The inverter (VVVF – Variable Voltage, Variable Frequency) control is replacing the traditional ward – Lionard or thyristor – leonard for high speed elevator and primary voltage control of induction motors for medium or low speed elevators. Another important change is the use of the helical reduction gear for high speed AC elevators which is competing with the highly satisfactory 100 years application of the d.c. gearless machine. The first variable voltage and frequency elevator drive system was developed in the United States and put into service at the beginning of 1983. Since then, more than a thousand have been built and put into service in the United States. Other countries, in particular Japan, have active variable voltage and frequency elevator development programmes and several elevators of these types have been installed. (KONE 2020). In 2000, the first vacuum elevator was offered commercially in Argentina (KONE Lift. 2000). Otis Elevator Company is working on a new double-deck elevator design that will travel the world's tallest buildings. The company used a similar double-deck elevator car design for the Burj Khalifa, which was finished in 2010, OTIS Lift. (2018).

2. Fundamental bases of lift traffic analysis and performance evaluation

The sizing of the lift systems to serve the demands of a building's population has interested the lift community since the 1920s. The methods being used were somewhat rough. However, by the 1970s a recognized method of calculation had evolved for up-peak traffic sizing based on the mathematical determination of the N, S and P (average highest reversal floor, average number of stops and average number of passengers), Barney et al. (1985). In the 1970s digital computer simulation techniques evolved which allowed specific traffic and lift installations to be examined. The traffic sizing of lift system is conventionally carried out by determining the Round Trip Time (RTT), Graver et al. (1971) of a single lift car serving an up-peak traffic condition.

Methods for Traffic Analysis and Performance Evaluation (Jones, Basset (1923)

UPPINT = RTT/N

$$UPPHC = \frac{300}{UPPINT} \times 0.8 \times c.c$$

$$\% POP = \frac{UPPHC}{POPULATION} \times 100\%$$

Where N = No of lift cars

UPPINT = Up Peak interval

CC = Contract Capacity

RTT = Round Trip Time

UPPHC = Up-peak handling capacity over a five-minute period.

The UPPHC is calculated assuming cars fill with passengers (p) to 80% of the contract capacity.

Governing Equations for the lift design ((Alexandris (1986)

(i) A simple expression developed for RTT is

$$RTT = 2Htv + (S + 1)\ ts + 2 + 2Ptp$$

Where s = means number of stops made above the ground floor

P = average number of passengers carried in each trip

t_p = time to transfer p passengers into the lift car

t_s = time associated with each stop

t_v = time taken to travel between two floors at contract speed.

t_u = time to transfer P passengers out of the lift car.

$$t_v = \frac{df}{v}$$

$$t_s = t_f(1) + t_c + t_o - t_v$$

$$t_p = \frac{t_p + t_u}{2}$$

P is taken as 80% of contract capacity (Alexandris (1986.)

t_f is a single floor jump time

t_o is the time to open the car doors (s + 1) times

t_c is the time to close the car doors (s + 1) times df is a standard interfloor height

V is the contract speed.

(ii).Another equations based expression developed for RTT (Jones, Basset (1923))

is RTT = $T_u + T_d + T_p + T_o$

$S_1 = S - S \frac{(S-1)^n}{S}$ 1

Where S = Maximum number of stops

N = Number of people (usually assumed as 80% of the contract capacity).

S_1 = probable number of stops

$T_u = S_1 \left(\frac{L}{SV} + 2v\right)$ 2

Where T_u = Upward Journey Time

L = Lift travel

V = Car speed

$T_d = \frac{L}{V} + 2v$ 3

T_d = downward journey time

T_p = 2n or T_p = 3n depending on the depth of the car 4

T_p = Passenger transfer time

$T_o = 2(S_1 + 1) \frac{W}{V_d}$ 5

T_o = Door Opening Time

V_d = Door Speed

W = Door Width

Passenger's arrival process

Observation is the only procedure that can be employed in obtaining data on the arrival pattern of passengers approaching a lift system at the main terminal of a high-rise building. Observation can be made, either over a consecutive number of days or on the same day for a consecutive a rectangular probability distribution function.

3. Computer-Aided Traffic Analysis of Lift Systems

Computer aided design (CAD) enables engineers and designers to use computers to assist in the decision of complex engineering problems. CAD involves three phases; input, computation and output. In the case of CAD for lift systems these phases comprise:

Input Phase: Enter: building data, lift system data, passenger data.

Computation Phase: Perform a discrete digital simulation of the lift system (time consuming).

Output Phase: Examine graphical output; spatial plots; carload; car interval; passenger waiting time: percentiles of waiting time. Examine: numerical tables.

3.1 Computer Analysis and Performance Evaluation based on Lift governing equation

The flow diagram that shows the computation of various lift parameter is shown below in Figure 2(a b) while figure 1 is the Ivory Tower building.

Case Study: Ivory Tower, University of Ibadan, Ibadan

Building Characteristics

Fig 1. Ivory Tower, University of Ibadan, Nigeria

Number of floors = 10

Floor to floor distances

Ground floor = 3.3m

First floor = 3.1m

Second floor = 3.1m

Third floor = 3.1m

Fourth floor = 3.1m

Fifth floor = 3.1m

Sixth floor = 3.1m

Seventh floor = 3.1m

Eight floor = 3.1m

Ninth floor = 3.1m

Tenth floor = 3.3m

Lift travel = 27.9m

(without considering the ground floor)

Location of the building – University of Ibadan

The building is for unified occupancy.

Population of the Building

Population in tower

Width=11m

Length=6m

Height to Height floor= 3.1m

Floor Area of tower=66m

Population= $\frac{no of floors \times floor area}{Net area}$

Using 100sf/person (9.29m^2),

Population= $\frac{8\times66}{9.29}$ =66.77 persons

Approximately 67 persons

Population in admin building

Width=68.8m

Length=9.2m

Height to Height floor= 3.1m

Floor Area of tower=632.96m^2

Population= $\frac{\text{no of floors} \times \text{Floor area}}{\text{Net Area}}$

Using 100sf/person,

Population= $\frac{3 \times 632.96}{9.29}$ =204.4 persons

Approximately 204 persons

Total population=Population in tower + population in admin building

= 67+204

=271 persons

Using a safety net of 25%,

$\frac{125 \times 271}{100}$ = 338.75 persons

Approximately 339 persons

Key design parameters

The following were determined in order to arrive at a suitable lift system for the building.

Average round trip time (RTT)

Interval (I)

Handling capacity (HC)

Preliminary Selections

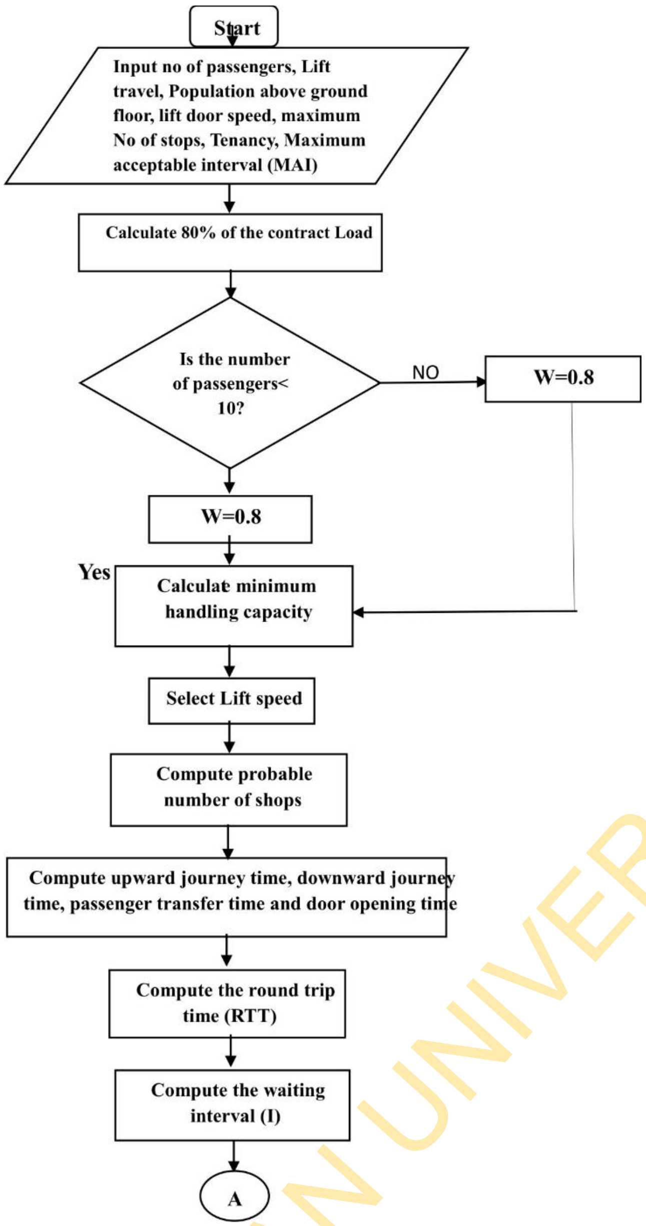
From standard tables, suitable speeds for the lift are 0.63m/s 1.0m/s and 1.6m/s and 2.0m/s. Calculations were done for cars of various sizes / loads (320kg-5persons,450kg-6persons, 630kg-8persons, 800kg-10persons etc.) until a suitable car size is determined.

Design Calculations

The required handling capacity per 5 minutes to handle a 25% of population flow rate.

$$\frac{25}{100} x\ 339 = 84.75 = 85 \text{ persons per 5 minutes}$$

Minimum handling capacity (MHC) = 85 people.



Start
Input no of passengers, Lift travel, Population above ground floor, lift door speed, maximum No of stops, Tenancy, Maximum acceptable interval (MAI)
Calculate 80% of the contract Load
Is the number of passengers< 10?
NO
W=0.8
W=0.8
Yes
Calculate minimum handling capacity
Select Lift speed
Compute probable number of shops
Compute upward journey time, downward journey time, passenger transfer time and door opening time
Compute the round trip time (RTT)
Compute the waiting interval (I)
A

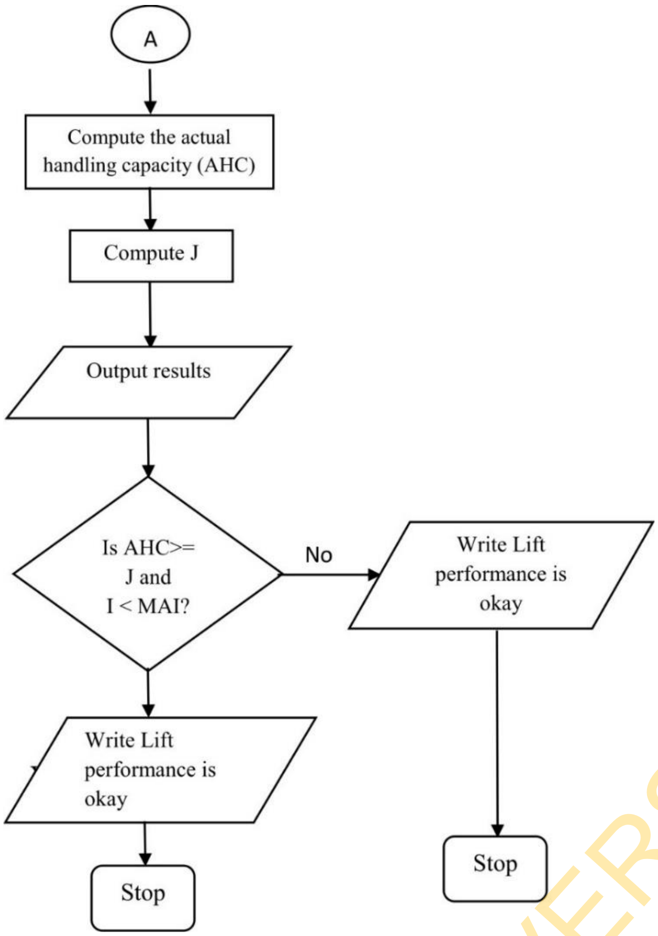


Figure 2a: Algorithm of FORTRAN IV programming for the lift performance analysis

4. Results and Selection

The summary of the result for the lift performance analysis is in here presented in Table 1 below

Table 1. Results of the lift performance analysis in summary

Weight	No of Passengers	Velocity (m/s)	Probable no of stops	No of lift	Round Trip Time	Handling Capacity (%)	Actual handling Capacity	Interval	Remarks
320	5	0.63	3	6	88.1	26.0	81.7	14.68	Interval doesn't fall within range
		1.0		5	69.2	24.5	86.7	13.8	"
		1.6		4	60.1	26.6	79.9	15.01	Interval is excellent Handling capacity is good
		2.0		4	58.6	25.9	81.9	14.65	Interval doesn't fall within range
450	6	0.63	9	6	100	23.7	89.8	16.71	Interval is excellent ,Handling

									capacity is excellent
		1.0		5	80.3	22.8	93.4	16.06	"
		1.6		4	71.2	25.2	84.3	17.8	Interval is excellent ,Handling capacity is good
		2.0		4	70.2	24.8	85.5	17.54	Interval is excellent ,Handling capacity is excellent
630	8	0.63	5	5	114	22.9	91.7	22.89	Interval is excellent, Handling capacity is excellent
		1.0		4	93.4	23.4	89.9	23.35	"
		1.6		3	84.3	28.1	74.7	28.11	Interval is good, Handling capacity is good
		2.0		3	83.7	27.9	75.3	27.9	"

800	10	0.63	5	4	116	25.7	82.4	29.11	"
		1.0		3	95.4	28.2	75.5	31.8	Interval is fair, Handling capacity is good
		1.6		3	86.3	25.5	83.4	28.78	Interval is good, Handling capacity is good
		2.0		3	85.7	25.3	84.0	28.57	"

Selection

For excellent services (Technically and economically) 4Nos. 6passengers lift are in here selected for the building.

Selected and lift specifications

From the lift service comparison table, the 450kg-6 passengers Machine room less traction lift at 2.0m/s is suitable for the building.

Lift Specifications

No of elevators	-	4 Nos.
Arrangement	-	Side by Side
Load	-	450kg – 6 passenger
Speed	-	2.0m/s

Total Travel	-	27.9m
Serving	-	9Stops, 9 Openings
Machine	-	Machine Room Less Geared traction type
Operation (Control System)-		Full collective group with independent service key switch
Drive/Control System		Variable frequency drive with microprocessor based control
Power Supply	-	A single speed, AC - 3 phase gearless motor, especially made to compromise the VVVF drive control system at: 400 volts and 50 Hz. -Insulation class "F" - Protection IP 21
Lift well size	-	1750mm x 1900-mm between finished walls per lift
Car (inside size)	-	1150mm wide x 1080mm deep with side and rear panels in skin plate from a standard range to approve colour.
Car façade	-	Brush stainless steel finish
Car ceiling	-	Carved false ceiling finished in white
Car Flooring	-	Hard rubber
Car options included	-	Digital position and direction Indicators

Illuminating car buttons

Overload safety device

Light ray door protection device (photocell)

Hand rails (stainless steel free standing)

Ventilation fan

Alarm bell

Skirting for Car	-	Stainless Steel
Car doors	-	Power Operated centre opening

door constructed in steel 800mm x 2000mm clear openings Finish-brushed stainless steel

Rope arrangement	-	2:1 single wrap
Entrance Surround	-	Small trims construction in steel.
Finish – prime Coat.		
Safety Gear	-	Governor Operated gradual type
	-	noise and thermal protection
	-	Earth leakage protection
	-	Voltage drop protection
	-	Over speed protection
	-	Phase failure and phase reversal protection
Buffers	-	Terminal buffers for Car and Counter weight
Other items includes	-	Digital hall position indicator and Entrance fire service
		Intercommunication between car and lobby
		Machine beam supplied and positioned by lift contractor for final fitting by others.

5. Conclusion

The traffic analysis and performance evaluation established 4Nos. 450kg, 6 passenger machine room less traction elevator at 2.0m/s are the most suitable lift system for the Ivory Tower University of Ibadan. This lift system will go a long way in mitigating the movement problems encountered by people in the building. It satisfies the condition of safety devices such as safety gear, buffers, light ray protection device, electric contacts and interlocks are installed in the lift system. The handling capacity of the lift system is found to be generally okay for the building. Manual computations for the design could be more laborious, rigorous and tedious, hence use of computer techniques to obtain optimum solutions is recommended.

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