

An Assessment of Time Performance Metrics of Lift Systems in Selected Public High-Rise Buildings in Abuja, Nigeria

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Abstract: Lift systems in high-rise buildings are often confronted with problems associated with optimum service delivery. The optimum performance of these systems in public high-rise buildings enhances the efficiency of vertical transportation systems. Time performance parameters like the Average Waiting Time (AWT), Transit Time (TRT), and Time to Destination (TTD) are amongst the key performance indicators for examining the performance of lift systems in high-rise buildings. This study assessed the performance times of lift systems of selected high-rise buildings in Abuja city with the view to enhancing the efficiency of vertical transport systems in buildings. Field measurements on the AWT, TRT, and TTD were performed and a well-structured checklist was used for the collection of relevant data on 14 selected high-rise buildings and 41 lift systems in the Central Business District (CBD) of Abuja city. A digital stopwatch was used to measure the AWT and TRT while TTD was derived from the simple computation of AWT and TRT. All the measured parameters were evaluated against the standard performance requirements for an ideal lift system. Findings from the study show that 100% of the lifts installed in these buildings are traction lift types with 90% having an average rated speed of 1.0m/s. Results from the analysis showed that 85.7% of the buildings have lift systems with AWT above the minimum standard requirement. Significant differences ($p < 0.05$) in the mean values of AWT, TRT, TTD were observed. Based on the findings, the assessed lift systems were considered to perform below the expected standard as the majority of buildings experienced long waiting times. This study has provided performance data for optimizing the service delivery of lift systems in high-rise buildings in Nigeria.

Keywords: Lift Systems, Average Waiting Time, Transit Time, Time to Destination, High-rise Building

1. Introduction

The rapid population growth and the need for modernization due to the current development of our cities have brought about an increase in the demand for high-rise buildings and the use of lift systems to enhance the overall performance of such buildings [1]. A high-rise building in the case of the Nigerian context as described by Aliyu et. al [2], is a building with a minimum of four floors. The use of staircases in high-rise buildings to support the movement of people and goods between floor levels has become challenging resulting in discomfort and accident of building users during occupancy period. To minimize this challenging

effect experienced in high-rise buildings, lift systems are often installed to enhance the comfort and safety of people and goods between different floor levels [3, 4]. Each day, more than 7 billion lifts journeys are taken in high-rise buildings all over the world [1]. Most architectures of the 20th and 21st centuries (Office towers, hotels, and high-rise apartments) would not have been functional or stood in their present form without the critical role of lift systems [2]. In addition, Challenger [5] affirmed that most building occupants depend on lifts to reach their destinations (terminal floor) in high-rise buildings.

Having highlighted the role lift systems play in vertical transportation, the type and quality of the system to be

provided are important factors for consideration at the pre-design or design stage of building designs [6]. Therefore, the performance of high-rise buildings both for single or multiple occupations requires the adequate performance of lift systems necessary to support the buildings, business activities, and its inhabitants [7].

The optimum performance of lift systems depends on the Average Waiting Time (AWT), Transit Time (TRT), and Time to destination (TTD) (Chattered Institute Building Services Engineers (CIBSE), 2010). For up peak (incoming traffic) conditions, at a constant arrival rate of 15% for 15 minutes, the AWT, TRT, and TTD of office buildings should not exceed the industry de facto standard of 30s, 60s, and 90s respectively [8]. In a commercial building, a trip of more than 90 seconds is annoying and a 120-second trip is the limit of tolerance. Table 1 shows the specified acceptable performance values of AWT and TTD of passengers in a lift system [9].

According to CIBSE [10], an ideal lift system performing as it ought to should serve a maximum number of people with minimum waiting time at the worst peak times to adequately disperse the population very fast. A waiting time of fewer than 20 seconds is excellent for optimum performance for a high-rise building. According to the

British Council for Offices [11], for all building classification and lift types, the AWT for conventional and destination control lift systems should be 30s or less and 25s or less, respectively, for a satisfactory performance level of lift. However, high-rise building users frequently complain about the long waiting times of lift systems, which is one of the key performance indicators of the system [12]. Similarly, at peak hours, residents often have issues regarding the waiting times being excessively long. Due to this, some tenants in the case of residential high-rise buildings threaten to break their leases and move out of the buildings [13].

Therefore, there is a need for periodic assessment of the performance of lift systems by professionals to ensure optimum performance of lifts in high-rise buildings in Nigeria [2]. The review of previous studies [2, 12-14] on lift systems indicates an alarming rate of long passenger waiting time of the systems in high-rise buildings with deviation from the primary purpose of transporting passengers at minimum waiting time without any delay. Therefore, this study aimed at assessing the performance times of lift systems in Nigeria with the view to enhancing the efficiency of vertical transport systems in buildings.

Table 1. Minimum Time Performance Metrics.

Building type	Average Waiting Time (sec)	Time to Destination (sec)
Central business district multi-tenant office building	<22 up peak and < 30 lunch	80 – 100
Central business district single-tenant office building	<22 up peak and < 30 lunch	80 – 100
Suburban office building	<25 up peak	100 – 120
Self-parking garage	<40	100 – 120
Hotel	<40	100 – 120
Residential	<45	100 – 120

2. Methodology

2.1. Research Design

The study adopts a field survey approach and a well-structured checklist was used to provide a guide on the lift parameters to be considered during measurement. The data was obtained from the selected samples in numerical values by using a digital Stopwatch. To achieve the desired study objectives, the following research procedures were developed and followed during the fieldwork:

- Select lift system through permission
- Locate measurement position in the study area
- Read and record measurements as observed from the device in the study area
- Organise data collected to carry out statistical analysis
- Presentation of the result (findings) obtain from analysis for interpretation and discussion

2.2. Study Area

The study was carried out in Abuja metropolis, Nigeria, lying between latitudes 8° 25' 00" – 9° 20' 00" North of the equator and longitudes 6° 45' 00" – 7° 39' 00" East of Greenwich Meridian with an altitude of 840 meters above sea level and a total area of 8, 000km². Abuja is the administrative capital of

Nigeria and the fourth most populous city in Nigeria, coming after Lagos, Kano, and Ibadan. It is regarded as the fastest growing city in Africa with an estimated population of 776,298 as of 2006 [15]. The city has a Central Business District (CBD) dominated by large corporate offices and three Arms Zone, encompassing the presidential Villa, Supreme Court, and National Assembly. The CBD is located at the center of Abuja phase 1 with Garki on the South, Maitama on the North, Wuse on the west, and Asokoro on the east [16]. The Central Area is dominated by high-rise buildings for different purposes such as commercial and residential as approved by the Federal Capital Development Authority (FCDA) and this serves as the basis for selecting Abuja as a study area suitable for this research work.

2.3. Population and Sample Size

The population of this study was based on the high-rise buildings with a specific focus on buildings with a minimum of 4 floors in the CBD of Abuja Metropolis. To arrive at the population size for this study, a field survey was carried out to access completed high-rise buildings in CBD with functional installed lift systems. The sample size for the study was obtained from a preliminary survey conducted to identify accessible high-rise buildings with functional lifts systems within the study area. This was due to the paucity of reliable data of definite population size of buildings with functional lift systems within

the study area. From the preliminary survey, 14 accessible high-rise buildings with 70 functional installed lift systems were identified and used as the population frame for the study.

2.4. Sampling Technique

The purposive sampling technique which is a type of

non-probabilistic sampling technique was adopted for this study. Table 2 presents details of the selected high-rise buildings in CBD, Abuja Metropolis. For anonymity, the selected high-rise buildings under study were represented by labels LA, LB, LC, LD, LE, LF, LG, LH, LI, LJ, LK, LL, LM, and LN.

Table 2. Selected High-Rise Buildings in CBD, Abuja Metropolis.

S/N	Building Name	No. of Floors	Approximate Height (m)	No. of Functional Lifts	No. of Lifts Selected for Study
1	LA	15	54	19	4
2	LB	12	49	15	4
3	LC	12	49	3	3
4	LD	10	39	2	2
5	LE	10	39	3	3
6	LF	8	33	3	3
7	LG	7	23	2	2
8	LH	5	24	3	3
9	LI	5	24	4	3
10	LJ	5	23	3	3
11	LK	5	23	4	3
12	LL	5	23	2	2
13	LM	4	20	3	3
14	LN	4	20	4	3
	Total			70	41

2.5. Data Collection Tool, Procedure, and Analysis

The collected data were primary in nature. The data collected includes performance metrics such as AWT, TRT, and TTD. A walkthrough survey of the selected high-rise buildings was conducted to collect data relevant to the physical aspect of selected samples which includes; building type, building height, the number of floors, lift types, lift capacity, lift age, machine location, rated speed, and lift category. Field measurement was carried out to monitor and measure the AWT, TRT, TTD, and door opening/closing time of the selected lifts during up peak period. To collect data, the location of the installed lobby of the lift system was first identified and passengers' arrival at the lift system was observed. The time for sampling was scheduled based on the worst-case traffic session of the building (up peak period) usually a period of 7:30 am-10:30 am for both Commercial and Administrative buildings within the sampling location. The calibration of the digital stopwatch used for taking

measurements followed. Calibration was done per the manufacturer's instructions. At every sampling point, the digital stopwatch was handheld at the lift lobby as described in the manufacturer's manual. Data was collected and recorded 3 times in the record sheet for each lift system at all sampling points. The resulting values were all collected as data and documented on a sampling checklist and record form. Lastly, the digital stopwatch was recalibrated automatically after successful measurement. This was done to ensure the accuracy of the results. Data from various standard guidelines sourced out through extensive literature reviews from various regulatory bodies were harmonized and used as a guideline for evaluating the AWT, TRT, and TTD during up-peak periods of onsite measurements (Table 3). Descriptive statistics and inferential statistics were used to compare means and significant levels of the lift system time performance parameters. The obtained means were merged into one statistical Product and Service Solution (SPSS) file for analysis.

Table 3. Prototype Standard for Lift Time Performance Metric Assessment.

S/N	Parameters	Acceptance Criteria	Source
1	Average waiting time (AWT)	< 35	[9, 10, 17]
2	Transit time (TRT)	≤ 60	[9, 10, 17]
3	Time to destination (TTD)	≤ 100	[9, 10, 17]

3. Results and Discussions

3.1. Lift System Characteristics

For this study, a checklist was used to characterize 41 lift

systems installed in the selected high-rise buildings. The checklist included lift system information such as lift type, lift brand, lift category, rated speed, and lift machine location. Table 4 shows the lift system characteristics at various locations.

Table 4. Lift System Characteristics.

S/n	Characteristics	Variables	Frequency (No)	Percentage (%)
1	Drive System	Traction lift system	41	100.0
2	Category	Standard lift system	27	65.9
		Panoramic lift system	11	26.8
		Cargo lift system	3	7.3
3	Machine Location	Machine room lift	25	61.0
		Machine room-less lift	16	39.0
4	Rated Speed	a) 1.0 m/s	17	41.5
		b) 1.5 m/s	20	48.8
		c) 2.5 m/s	4	9.8
5	Age	d) 1-4 yrs	3	7.3
		e) 5-8 yrs	29	70.7
		f) 9-11 yrs	7	17.1
		g) 12-15 yrs	2	4.9

As shown in Table 4, 41 (100%) of the lift type are electric traction lifts indicating that all the lifts studied are traction. Based on category, 27 (65.9%) of the lift systems are standard lifts, 11 (26.8%) are Panoramic lifts and 3 (7.35%) are cargo lift systems. This indicates that the majority of the lift across the selected high-rise buildings are standard lifts. Furthermore, based on machine room location, 25 (61.0%) are Machine Room (MR) and 16 (39.0%) are Machine Room-Less (MRL) therefore indicating that majority of the lift system operates from a machine room. According to Al-Sharif [14] and Jonathan et. al [18], the rated speed of lift systems is an index for achieving optimum performance of these systems in high-rise buildings. From Table 4, 17 (41.5%) of the lifts are preprogrammed with the rated speed of 1.0m/s, 20 (48.8%) are rated 1.5m/s and 4 (9.8%) are rated 2.5m/s indicating that majority of the lift system in the buildings are programmed with the rated speed of 1.5m/s.

The age of the lift system is also a factor to consider when assessing lift time performance as it affects the service delivery of the systems [2]. In terms of the age of these lift

systems, 3 (7.3%) of the lifts are within the age range of 1-4yrs, 29 (70.7%), within the age range of 5-8yrs, 7 (17.1%) in the range of 9-11yrs and 2 (4.9%) of the lift systems within the age range of 12-15 years. The majority of the lifts studied across the buildings are within the age range of 5-8 years from the time of installation.

3.2. Lift Performance Times Across Selected Buildings

The Average Waiting Time (AWT), Transit time (TRT), and Time to destination (TTD) should be considered as key performance indicators for examining lift system performance in a high-rise building. Moreover, the excellent performance level of lift systems in high-rise buildings should also fall within the industry *de facto* standard of 30, 60, and 90secs (AWT, TRT, and TTD respectively) [14]. The results of the onsite measurements of the mean values of AWT, TRT, and TTD of the lift systems of the selected buildings during up peak period are presented in Table 5.

Table 5. Lift System Time Performance Parameters across Selected Buildings.

Buildings	AWT (Sec) (Mean \pm S. E)	BM \leq 35sec	TRT (Sec) (Mean \pm S. E)	BM \leq 60sec	TTD. (Sec) (Mean \pm S. E)	BM \leq 100sec
LA	31.50 \pm 0.87 ^a	ST	26.00 \pm 1.15 ^a	ST	57.50 \pm 2.02 ^a	ST
LB	30.00 \pm 0.58 ^a	ST	27.50 \pm 0.87 ^{abc}	ST	57.50 \pm 0.29 ^a	ST
LC	51.50 \pm 3.17 ^{bcd}	UST	30.50 \pm 0.29 ^{cde}	ST	82.00 \pm 2.89 ^{bcd}	ST
LD	41.50 \pm 2.59 ^{abc}	UST	30.00 \pm 1.16 ^{bcd}	ST	71.50 \pm 1.44 ^{ab}	ST
LE	41.00 \pm 5.19 ^{ab}	UST	27.00 \pm 1.15 ^{ab}	ST	68.00 \pm 6.35 ^{ab}	ST
LF	47.50 \pm 5.49 ^{bcd}	UST	30.00 \pm 1.16 ^{bcd}	ST	77.50 \pm 4.33 ^{bcd}	ST
LG	51.50 \pm 3.17 ^{bcd}	UST	28.50 \pm 0.87 ^{abcd}	ST	80.00 \pm 4.04 ^{bcd}	ST
LH	55.50 \pm 3.75 ^{cd}	UST	27.00 \pm 1.16 ^{ab}	ST	82.50 \pm 4.91 ^{bcd}	ST
LI	60.00 \pm 8.66 ^d	UST	28.50 \pm 1.44 ^{abcd}	ST	88.50 \pm 10.10 ^{cd}	ST
LJ	47.00 \pm 3.46 ^{bcd}	UST	25.50 \pm 0.86 ^a	ST	72.50 \pm 4.33 ^b	ST
LK	58.00 \pm 1.15 ^d	UST	32.00 \pm 1.73 ^c	ST	90.00 \pm 0.58 ^d	ST
LL	43.50 \pm 5.48 ^{abc}	UST	28.00 \pm 0.58 ^{abc}	ST	71.50 \pm 4.91 ^{ab}	ST
LM	51.50 \pm 5.48 ^{bcd}	UST	31.50 \pm 0.29 ^{de}	ST	83.00 \pm 5.77 ^{bcd}	ST
LN	47.00 \pm 1.15 ^{bcd}	UST	27.00 \pm 0.58 ^{ab}	ST	74.00 \pm 0.58 ^{bc}	ST
F	4.459		3.848		4.772	
p-Value	0.000		0.001		0.000	

AWT-Average Waiting Time; TRT-Transit Time; TTD-Time to Destination; LEV-Levelling; BM- Benchmark; ST-Satisfactory; UST-Unsatisfactory. Data were analyzed using one-way ANOVA followed by Duncan's multiple comparison post hoc test. Values along the same columns with different superscripts a, b, and c are significantly different within the groups ($p < 0.05$).

The AWT of passenger (s) for most of the lift systems across the buildings are above the accepted standard performance requirements when compared with the benchmark. However,

LA and LB with a mean average waiting time of 31.5sec and 30.0sec respectively are considered to be the buildings with satisfactory passenger waiting time. Hence, indicating a long

waiting time of passengers for lift systems in building LC-LN. The TRT and TTD of the lift systems across the buildings are within the performance acceptance criteria value when compared with stated benchmarks. Hence, indicating satisfactory travel speed within all the buildings as it falls within the standard for optimum TRT and TTD stipulated by CIBSE and NEII [9, 10].

3.3. Lift System Performance Parameters Across Building Type

Table 6 presents the lift time performance parameters across the different building types studied (Commercial and Administrative). Commercial buildings are often characterized by a higher number of stops and high rated speed.

Table 6. Lift System Time Performance Parameters across Building Type.

Parameter	BM	ADMIN (Mean \pm S. E)	COMM (Mean \pm S. E)	p-Value
AWT (sec)	≤ 35 (sec)	47.92 \pm 2.49	46.19 \pm 2.19	0.606
TRT (sec)	≤ 60 (sec)	28.58 \pm 0.62	28.44 \pm 0.49	0.852
TTD (sec)	≤ 100 (sec)	76.50 \pm 2.79	74.63 \pm 2.42	0.615

AWT-Average Waiting Time; TRT-Transit Time; TTD-Time to Destination; ADMIN-Administration; COM-Commercial. Data were analyzed using an independent sample T-test. Values are significantly different within the groups ($p < 0.05$).

From Table 6, both commercial and administration buildings having these lift systems experienced long passenger waiting times with mean values of 46.19 and 47.92 respectively. In terms of other parameters like the TRT and TTD, both building type lift systems performed excellently as mean values were below stated

benchmarks.

3.4. Lift Performance Times Across Lift Category

The result in Table 7 shows lift performance metrics across the different lift categories.

Table 7. Lift Time Performance Metrics across Lift Categories.

Parameters	BM	Standard (Mean \pm S. E)	Panoramic (Mean \pm S. E)	Cargo (Mean \pm S. E)	F	P-value
AWT (sec)	≤ 35 (sec)	44.55 \pm 2.067	50.42 \pm 2.61	53.79 \pm 2.88	2.745	0.077
TRT (m/s)	≤ 60 (sec)	28.12 \pm 0.39	29.33 \pm 0.80	29.36 \pm 1.44	1.121	0.336
TTD (Sec)	≤ 100 (sec)	72.62 \pm 2.21	79.75 \pm 3.04	83.14 \pm 3.97	2.978	0.063

BM- Bench Mark; AWT-Average Waiting Time; TRT-Transit Time; TTD-Time to Destination.

Table 7 reveals that there is a long average waiting time (AWT) of passengers for the lift system across the different lift categories in the selected buildings in comparison with the stated benchmark. Other time performance metrics like the TRT and TTD across the different lift categories were observed to be acceptable. Nonetheless, the standard lift is considered to have the least mean value of AWT, TRT, and TTD.

3.5. Lift Performance Times Across Machine Location

Machine room (MR) lifts installed in buildings have higher distances and number of stops compared to the machine room-less (MRL) lifts. Lift systems in buildings with MR are often preprogrammed with higher rated speed. Furthermore, they have satisfactory door operation when compared with buildings having MRL lifts. The AWT, TRT, and TTD time performance parameters of the lift systems

based on machine location in the selected buildings are given in Table 8.

From Table 8, both machine room lifts and machine room-less lifts are considered to have long waiting times with mean values of 43.23 and 51.00 respectively. This result shows that though the AWT of the MR and MRL lift systems were above the benchmark, the machine location of lift systems has less or no impact on passenger waiting time at the lobby. The transit time and time to the destination of the MR and MRL lifts were observed to be satisfactory. The transit time and the time to destination play an important role in reducing traffic flow during lift operation in a high-rise building. The transit time and time to destination could be used during lift traffic analysis to improve the overall performance of the lift system in high-rise buildings. Also, the TRT and TTD are important indexes of lift performance when considering lift modernization in high-rise buildings.

Table 8. Lift System Time Performance Parameters for Lift Machine Location.

Parameters	BM	MR (Mean \pm S. E)	MRL (Mean \pm S. E)	p-Value
AWT (Sec)	≤ 35 (sec)	43.23 \pm 2.18	51.00 \pm 2.14	0.015
TRT (sec)	≤ 60 (sec)	27.52 \pm 0.49	29.58 \pm 0.49	0.005
TTD (sec)	≤ 100 (sec)	70.75 \pm 0.49	80.58 \pm 2.25	0.005

AWT-Average Waiting Time; TRT-Transit Time; TTD-Time to Destination; MR-Machine Room Lift and MRL Machine Room Less Lift. Data were analyzed using an independent sample test. Values are Significantly Different within the groups ($p < 0.05$).

4. Conclusion

This study has revealed that in high-rise buildings within Central Business District, Abuja metropolis, traction lifts are the commonly installed type of lift system with 90% of the traction lifts rated at the speed of 1.0m/s and 1.5m/s. From the selected buildings, 65.9% of the lifts installed are standard lifts and 39% of the lifts are lifts with machine room locations. The average waiting time (AWT) of passengers in 85.71% of the selected buildings is considered to be long as it is above the acceptance criteria. Other time performance metrics such as the transit time and time to the destination of the lift systems were observed to be satisfactory in all the selected buildings, building type, lift type, and lift machine location. Most significantly, the study concludes that the assessed lift systems were considered to perform below the expected performance standard as 85.7% of selected high-rise buildings experienced long passenger waiting times. The data collected in this study can be used for optimizing lift service delivery. Future research should consider exploring other methods of measurement and available equipment such as elevator meter and tachometer to measure and evaluate the AWT, TRT, and TTD of lift systems in Nigeria.

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