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The Influence of Pedestrian Circulation Strategies on User Experience in Train Terminals

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ABSTRACT

Global urbanisation is evident in Sub-Saharan Africa, especially Nigeria, where the population has steadily increased by 3.2% annually. This increment necessitates the adoption of sustainable public transportation, with rail transport leading the advancement. However, train terminals are fraught with complex and poorly implemented approaches to pedestrian circulation. This study evaluated the implementation of pedestrian circulation strategies within three existing train terminals in Lagos, Nigeria, aimed at determining their influence on optimal user experience. The research method employed in this study is a mixed-method approach, which entailed the distribution of survey questionnaires to 60 respondents. Thereafter, descriptive statistics were thoroughly carried out using the IBM Statistical Package for Social Sciences (SPSS) version 27. The results show that the pedestrian circulation strategy that influenced user experience the most within the selected train terminals was the connection of corridors and lobbies with other facilities. Therefore, it is recommended that horizontal pedestrian circulation strategies should be appropriately spatially planned and dimensioned to accommodate high pedestrian traffic scenarios within train terminals.

1. INTRODUCTION

The interconnection of services, transportation modes and utilities make up the complex entities known as cities. These cities result from the increment of global urbanisation, while creating the need for the adoption of urban public transportation, which will viably substitute personally owned vehicles while elevating air quality [1]. Internationally, transportation terminals, which are public buildings, are now a social issue of high significance to ensure that all the users are uniformly prioritised [2]. The uniform rate at which the population increases in Nigeria is 3.2% annually, which has led to meaningful national development while fostering environmental transformation [3]. Within the last decade, there has been a paradigm shift to focus on improving the public architecture for optimised benefits [4, 5]. Therefore, the proper design and management of train terminals known as "beating hearts and nodes" of passengers within railway networks cannot be underemphasised, as their prominent issues include exceeding their maximum capacity during peak periods and complex patterns of pedestrian circulation [6, 7].

Railway infrastructure has existed before the full development of most cities and within the transportation network, most passenger journeys either begin or stop within them as they are "traffic distribution points with dense crowds" [8, 9]. For the last fourteen years, there has been an exponential surge in global rail passenger traffic from 2,440,732 million passengers to 4,068,548 million passengers, and to effectively cater for this population, improved railway infrastructure, which addresses evolving circulation patterns through the proper planning of pedestrian circulation, remains pertinent [10, 11]. Within buildings and along additional areas of the built environment, the safety and efficiency of rail public transportation systems can be impacted by the ease of navigation by pedestrians and available facilities [12, 13].

However, there is currently a literature gap on how user experience within train terminals is influenced by pedestrian circulation as existing studies, such as Pu [14] analysed train and pedestrian movements using an integration simulation approach for insight into station capacity using oversimplified digital models and investigating movement only along train tracks causing a segregation between rail and pedestrian capacities. Similarly, Hänseler [13] sought to enhance the empirical relationship between train timetables and pedestrian movements by traffic monitoring, but there was no thorough assessment of the vertical circulation strategies, like stairs or escalators. Fadel et al. [15] focused on the requirements of pedestrian circulation within multi-modal transportation hubs with emphasis on user-friendly information systems, without exploring the pedestrian density impact on the overall circulation efficiency of train terminals. Mubarak and Muhammad [16] also did not adequately incorporate the quality of terminal infrastructure and known influences of crowd behaviour to provide a better insight into congestion issues. The impact of the behaviour of rail passengers on operational components was analysed by Rüger [17], and the findings were generalised without adequately addressing barrier-free design within transport terminals.

Therefore, this study aims to evaluate the implementation of pedestrian circulation strategies within existing train terminals with a view to determining their influence on optimal user experience in such facilities. To achieve this, the following research questions were curated:

i. Which pedestrian circulation strategies are currently in use in existing train terminals?
ii. How effective are these pedestrian circulation strategies when the train terminals are at maximum capacity?
iii. To what extent do the existing wayfinding, signage systems, and other technologies efficiently manage and guide users within these train terminals?
iv. In which ways do these pedestrian circulation strategies influence the overall user experience within train terminals?

The conceptualisation and spatial design of future train terminals by built industry professionals characterised by well-configured pedestrian circulation patterns and user-centric facilities will be significantly improved on by this study's recommendations. Also, this study remains highly beneficial as train terminals are at the forefront of public transportation with a recent focus on attaining net-zero emissions from transport systems globally, and this study will provide an approach to effectively manage high passenger volumes. Furthermore, the ninth and eleventh Sustainable Development Goals (SDGs) are also advocated for through seeking the creation of sustainable and inclusive railway infrastructure.

2. LITERATURE REVIEW

In transportation architecture, such as train terminals, the constant movement of pedestrians is "wrapped up" by the provision of a static structure that caters to the users' active motion [18]. The principal facilities employed in embarking and disembarking people or goods from trains are train terminals, and lowering passengers' stress and anxiety levels through the creation of spaces that critically consider circulation, and movement is the criterion for optimum user experience [19, 20]. Proximity to the city centre is a pertinent factor for situating train terminals as they are more intricate in space and technical requirements, and their effectiveness is ascertained through the circulation systems and optimised pedestrian flow [21, 22]. Train terminals can be categorised into heading-type and pass-through terminal stations and comprise six (6) key areas: platforms, information systems, restrooms, ticketing offices, concessions, and access and egress points [20, 23]. The circulation area of train terminals, which are the spaces that facilitate the seamless flow of people, often reflects their overall spatial organisation while greatly affecting user experience through their space patterns [24, 25].

2.1 Pedestrian circulation in train terminals

The two principal means of pedestrian circulation within train terminals are vertical and horizontal circulation strategies. Entries, exits, atria and lobbies comprise horizontal circulation strategies, and the furniture placement and elements like columns significantly impact it, while the proper derivation of their width is crucial [22]. Conversely, lifts, ramps, escalators, travellators and stairs comprise vertical circulation strategies, facilitating translocation between various building levels [26]. There is usually a heightened sensitivity among pedestrians when utilising vertical circulation strategies, as delays are often anticipated when descending to a lower level rather than moving upwards.

Continuous movement, which eliminates returning to a pedestrian's familiar reference point, is an important aspect of pedestrian circulation within train terminals that cannot be underemphasised, and this is achievable by distinguishing paths using colours, sizing and finishes to create a focal point [26]. This is because the initiation of circulation is immediate and requires no conscious effort, as wayfinding due to an array of cognitive processes occurs when an individual arrives within any architectural space [27].

However, difficulty in wayfinding is mostly due to confusing over-extended pathways, bent corridors designed with many diversions and ambiguous signage and this clamours for multidisciplinary and user-friendly solutions, especially when train terminals are at their maximum capacity [28, 29]. Successful wayfinding has a single precursor: pedestrians' navigation through accurate decisions, moving them to their destination while attaining the intended reason for initiating movement. Wayfinding within train terminals has been found to be greatly aided by clear sightlines, proper zoning, placement of landmarks and appropriate signage while also strictly adhering to the principle of universal design for elimination of barriers [30-32].

2.2 Role of pedestrian circulation strategies in train terminals

Vertical circulation strategies should be easily discernible by pedestrians while being lively and engaging, as most train terminals utilise signage to resolve the low prioritisation of circulation strategies implemented in the design stage [33]. Within these vertical circulation strategies, the presence of bottlenecks has remained a prominent issue. However, these can be solved by their appropriate positioning, equipping them with adequate dimensions and preventing the intersection of pedestrians from moving in the opposite direction [34]. For lobbies as one of the horizontal circulation strategies, due to the presence of bi-directional traffic flow of pedestrians, funnel-shaped lobbies are recommended instead of rectangular lobbies as they effectively minimise crowd pressure [35]. Pedestrian circulation strategies' functions cannot be undermined because their absence or poor implementation leads to a marred user experience.

Safety of pedestrians within train terminals can be viewed through two lenses: the internal envelope of the building and within the site's premises. For pedestrians' safety within the train terminal's interior, positioning design obstacles like columns requires careful consideration of their impact on evacuation and accessibility [35]. Conversely, the most effective approach for enhanced safety within the site's premises is to utilise plantings to guide the movement of pedestrians [36, 37]. Some effects of congestion in train terminals were identified as extended train dwell times, reduced service quality due to queues along vertical circulation systems and potential dangers due to high pedestrian density on train platforms [36]. The proffered solutions include properly designed footpaths, queuing systems and barriers, and inclusive wayfinding systems [22].

Kabalan et al. [36] also identify three requirements for the fluidity implemented pedestrian circulation strategies within train terminals: optimal management system, monitoring system and dynamical system state. The dynamical system state involves the adoption of visual controls to provide intuitive knowledge regarding the system state. Monitoring pedestrian movement and finding insight into crowd dynamics for quick intervention while significantly minimising congestion propagation is entailed in the optimal pedestrian management system. Conversely, the monitoring system seeks several factors that could disrupt regular train terminal operations, such as unusual surges in pedestrian traffic levels [36].

2.3 Effective wayfinding and pedestrian circulation management in train terminals

Pedestrians are faced with decision-making as they navigate, and there are many choices, such as utilised path, walking speed, and taking either the lift, escalators or stairs, all of which affect the space use efficiency of the train terminal [25]. Within train terminals, those utilising such facilities for the first time may find certain areas unfamiliar and difficult to navigate because of swift pedestrian motion. Aside from its reduced implementation costs, static signage offers a plethora of advantages for pedestrian circulation, as it is the best option for displaying visual instructions about improved boarding and alighting and maps of the surrounding area [34].

One of the widespread methods of effectively managing pedestrian traffic is a qualitative assessment known as Level of Service (LOS) [38]. It involves a standard approach of dividing the passengers' arrival rate by the flow rate per unit within the limits of a predetermined LOS [32]. The average space provided for every pedestrian is the primary measurement of the effectiveness of LOS and by the adoption of six defined alphabets ranging from A to F, denoting the best and the worst, LOS can be effectively employed in crucial areas like concourses and platforms while elevating quality service and user experience in train terminals [38, 39]. However, utilising a predetermined LOS is fraught with the following:

i. Varying pedestrian walking speeds

A typical assumption of predetermined LOS standards is uniform walking speeds for all pedestrians, which constitutes a major design flaw in train terminals. This is due to the significant differences in the movement and navigation of pedestrians due to varying reasons like age, weight of luggage, physical ability and familiarity with the train terminal's facilities. During peak periods, when there is the convergence of diverse kinds of passengers, the varying walking speeds are more problematic [39].

ii. Disregard for the connection between the train terminal's separately designed facilities

The evaluation of facilities as separate entities instead of interconnected components of a holistic system is another critical problem with predetermined LOS. Pedestrian circulation between different train terminal components is not considered in this fragmented approach, causing significant operational inefficiencies and bottlenecks throughout the navigation process [39].

iii. Neglect of the changing passenger arrival process

The complexity of actual passenger behaviour is underestimated by the static or predictable pedestrian arrival circulation patterns when adopting a predetermined LOS standard. This is because many factors like special events, train schedules and weather conditions greatly influence the patterns of arriving passengers [39].

iv. Inability of facilities' serviceability to cater to pedestrians' demands leading to the block phenomenon in various train terminal facilities

In train terminals, the "block phenomenon" occurs when a certain component of the facility cannot handle passenger demands and consequently results in delays and congestion throughout the entire train terminal facility. A shortcoming of the predetermined LOS is that it often fails to effectively predict or prevent their occurrence due to the independent evaluation of facilities rather than system-wide consideration of interactions [39].

Three qualities in a pyramidal hierarchy are used in assessing user experience within any train terminal, the apex being safety and reliability, followed by speed and ease of wayfinding as the last; failure to meet this will drastically lower the quality of the user experience [40]. Therefore, an easy understanding of the internal layout of public buildings such as train terminals without requiring directions from other pedestrians and staff cannot be underemphasised [41, 42]. The three key components, which are areas, routes and critical elements, must also be properly managed for optimal user experience in train terminals [36, 43].

3. METHODOLOGY

This study was carried out to evaluate the implementation of pedestrian circulation strategies within existing train terminals in Lagos State, Nigeria and their influence on optimal user experience. It was achieved by a mixed-method approach in which the quantitative aspects involved randomly distributing closed-ended survey questionnaires to 60 respondents in December 2024 within three selected train terminals. However, only 55 responses were retrieved, representing 91.76% of the administered questionnaires.

From the aim and objectives of this study and careful analysis of the data pertinent to it, while also following preset criteria, only three red line train stations out of thirteen (13) train stations/terminals in Lagos, Nigeria, were chosen. This is referred to as purposive sampling. These three train terminals, which are part of the Lagos Metropolitan Area Transport Authority (LAMATA), represent distinct typologies while giving insight into the diverse characteristics that allow for a critical analysis of pedestrian circulation strategies in different urban contexts. The selection criteria utilised include: the incorporation of modern pedestrian circulation systems, spatial organisation and design of the train terminal alongside the platform facilities.

A high-capacity terminal typology is represented by the first selected train terminal, which is the Mobolaji Johnson Train Station. Currently, it serves as a major regional hub, thus making it ideal for analysing complex pedestrian circulation strategies and patterns under high-density conditions. The second selected train terminal, which is the Babatunde Fashola Train Station, represents a typology known as the suburban residential hub, which is characterised by unique challenges in relation to pedestrian circulation. It also provides the opportunity to study how unplanned development and the presence of informal commercial activities around the station affect its pedestrian circulation strategies. Lastly, a modern multimodal hub typology is exemplified through the third selected train terminal, which is the Ikeja Train Station. Its ultramodern bus-rail interchange system and design systems also allow for a comprehensive analysis of the horizontal and vertical pedestrian circulation strategies.

The questionnaire was culled from studies [44, 45] and comprised three subsections: socio-demographic characteristics of the respondents, satisfaction with the implemented pedestrian circulation strategies, and the last section, which assessed respondents' satisfaction level with the overall user experience within the train terminals. The questionnaire design adopted a 5-point Likert scale, which ranged from Highly Unsatisfied, Unsatisfied, Neutral, Satisfied and Highly Satisfied.

A non-probability-based sampling technique known as convenience sampling was used for the selection of the digitalised survey to respondents present at each train terminal. This entails the utilisation of a population's proportion regarding their availability during the stipulated period when the research was ongoing within the train terminals.

To ascertain the questionnaire's reliability, the ordinal variables were subjected to the Cronbach's Alpha Test, and it yielded a Cronbach's Alpha coefficient of 0.943, implying a highly significant reliability level, which is recorded in Table 1. The forty implemented pedestrian circulation strategies variables utilised in the analysis demonstrate strong cohesion based on the test, confirming the consistent measurement of an exact or similar concept. The eight user experience strategies recorded a Cronbach's Alpha value of 0.847. The IBM Statistical Package for Social Sciences (SPSS) version 27 was used to analyse collated data through a plethora of descriptive statistics, ranging from standard deviations and frequency computation to mean ranking. Thereafter, tables and charts are used to present the outcomes of the various analyses.

Table 1. Questionnaire instrument's reliability statistics

Variables	Cronbach's Alpha	Decision Rule	No. of Items
Pedestrian Circulation Strategies	0.943	a ⩾ 0.70	40
User Experience Strategies	0.847	a ⩾ 0.70	8

Anonymity and informed consent are the pertinent ethical considerations employed in this study. All the study's respondents gave their informed consent of their own free will, and the nature of their engagement was strictly voluntary without coercion. Additionally, priority was given to the anonymity of all respondents, and their responses were only adopted for this study's requirements.

4. RESULTS AND DISCUSSION

The analysis of the socio-demographic characteristics of the respondents is recorded in Figures 1-7. Males comprised a higher percentage of the respondents, with 52.7%, and the respondents were mainly aged between 21 and 30 years, with 50.9%. The respondents who partook in the survey questionnaire were mostly train terminal passengers, with 69.1% and 76.4% of the respondents using the train once to four times monthly. 63.6% of the respondents were full-time employees, and 43.6% had 1 to 5 years of work experience. Tertiary and postgraduate education had 49.1% each, making them the highest level of education attained by the respondents.

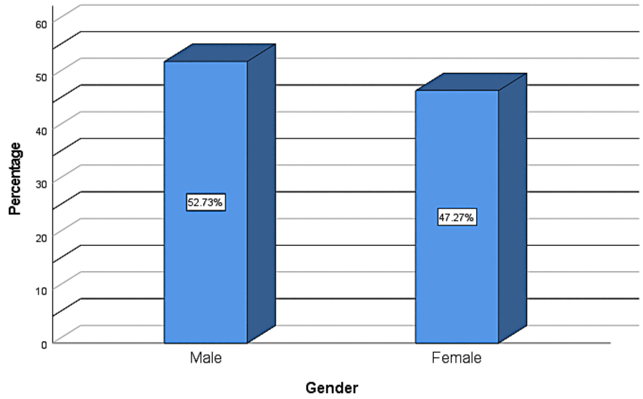

Figure 1. Gender distribution of respondents

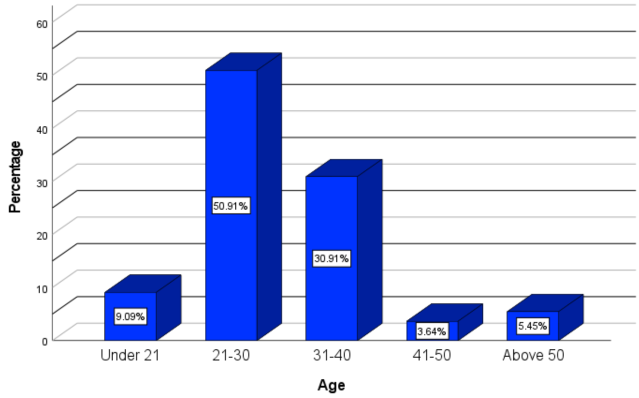

Figure 2. Age distribution of respondents

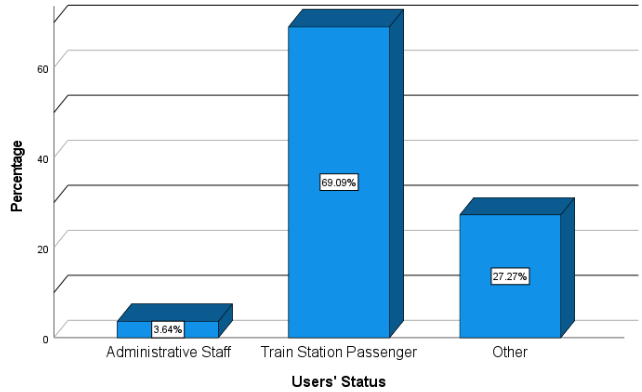

Figure 3. User status of respondents

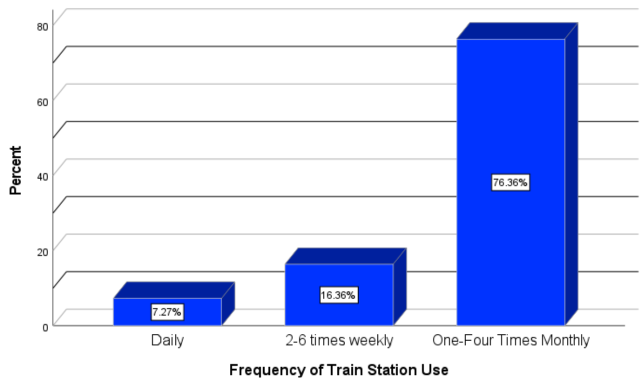

Figure 4. Respondents' frequency of train station use

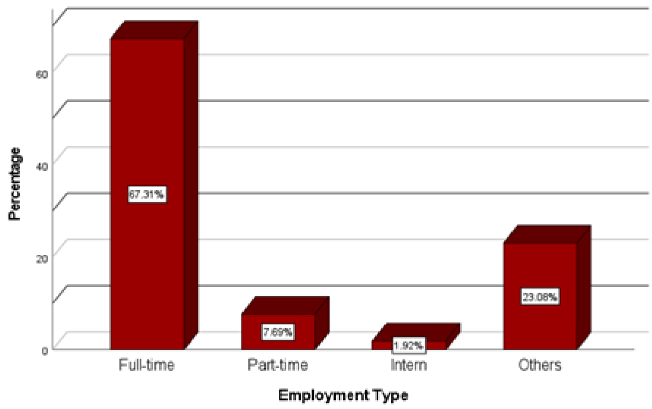

Figure 5. Respondents' employment type

Figure 6. Respondents' period of employment

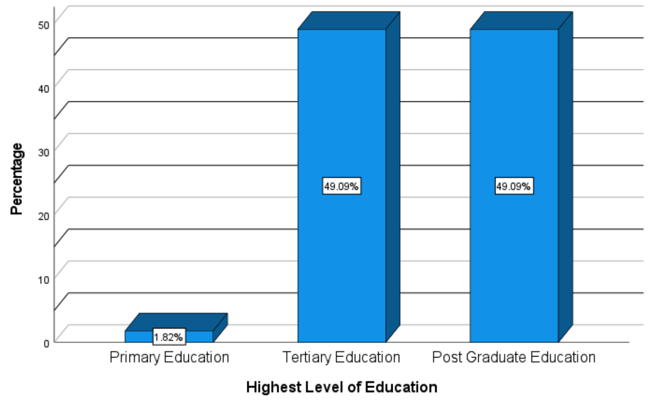

Figure 7. Respondents' highest level of education

For the three selected train terminals, a mean ranking of the pedestrian circulation strategies was computed, and the outcome is reported in Table 2. The most efficiently implemented strategy within the three train terminals was the ability of corridors and lobbies to lead to facilities within the building, with a mean of 3.9630. The easy identification of the entrance due to the shape of the train terminal ranked second, with a mean of 3.9455. The pedestrian circulation strategy with the least implementation efficiency was digital signage, with a mean of 3.4815. Therefore, it can be inferred that within train terminals, for an optimal pedestrian circulation experience, the availability of digital signage within the corridors and lobbies is a key pedestrian circulation strategy.

Table 2. Mean ranking for overall implementation of pedestrian circulation strategies in the train terminals

Descriptive Statistics	N	Mean	Std. Dev.	Rank
Corridors and lobbies connection with other facilities	54	3.9630	0.72588	1st
Ease of seeing the entrance due to the train terminal's shape	55	3.9455	0.80319	2nd
Availability of signage in the corridors and lobbies to show the location of other facilities in the building	55	3.8909	0.83161	3rd
Appropriate and legible signage	55	3.8727	0.92405	4th
Large train terminal entrance	55	3.8545	0.80319	5th
Accessible pedestrian pathways	55	3.8364	0.89781	6th
Signage in corridors and lobbies showing where the escape routes in the building are	55	3.8364	0.93815	7th
Movement of pedestrians in opposite directions to avoid crossflows	54	3.8333	0.79503	8th
Good access to the boarding gate from the entrance	55	3.8182	0.90453	9th
Adequate width of corridors and lobbies	54	3.7778	0.94503	10th
Availability of pedestrian pathways on the site	55	3.7636	0.85988	11th
Right location of the entrance to the train terminal	55	3.7636	0.81567	12th
Accessibility of corridors and lobbies from every part of the building	55	3.7636	0.94209	13th
Adequacy of the train's station main access door size	53	3.7547	0.87499	14th
Availability of signage showing the location of the staircases	53	3.7547	0.85273	15th
Use of repetitive patterns and colour schemes	55	3.7455	1.02231	16th
Presence of signage showing the location of the corridors and lobbies	55	3.7273	0.93203	17th
Closeness of the ramp to the entrance of the building	54	3.7222	1.03553	18th
Appropriate size of the treads	55	3.7091	1.03051	19th
Adequate number of staircase steps	55	3.7091	0.85359	20th
Availability of signage showing the entrance to this building	55	3.7091	0.87502	21st
Network circulation pattern in train station	55	3.7091	0.71162	22nd
Linear circulation pattern in train station	55	3.7091	0.83161	23rd
Easy access to staircases from the reception	55	3.7091	0.78582	24th
Wide pedestrian pathways	55	3.7091	1.10005	25th
Adequate size of porch to accommodate large crowds	54	3.6852	0.82013	26th
The porch is correctly positioned and oriented for easy ingress and egress	54	3.6667	0.82416	27th
Zoning of like functions for easy navigation	55	3.6545	0.92733	28th

Signage on-site, directing users to the various facilities	55	3.6545	0.98542	29th
Adequate quantity of ramps	54	3.6481	1.01233	30th
Comfortable shape/geometry of the ramp	53	3.6415	0.98243	31st
Adequate width of Elevators and Escalators	55	3.6364	0.98815	32nd
Availability of signage showing the location of the ramp	55	3.6364	1.02494	33rd
Right location of the staircases	55	3.6364	1.06046	34th
Sightlines are clear without any obstructions	54	3.6296	0.95752	35th
Curved circulation pattern in train station	54	3.6111	0.81070	36th
Placement of landmarks at specific locations	54	3.5556	0.81650	37th
Controlled movement of people using plantings	55	3.5455	0.99663	38th
Appropriate Number of Elevators and Escalators	54	3.5000	1.02331	39th
Digital wayfinding signage	54	3.4815	1.07705	40th

The first variable, which is the clear and adequate access points, comprises nine features, such as the availability of signage showing the building's entrance and easy access to the stairs from the reception. The last variable, which is escape signage, had only one feature, which is the presence of signage within corridors and lobbies, that shows the train terminal's escape routes. These results demonstrate that the application of eight variables for optimal user experience was effectively implemented in the train terminals, as recorded in Figure 8.

The regression analysis computed for a comprehensive insight into the influence of pedestrian circulation strategies within the selected train terminals is recorded in Figure 9. The regression was significant ($F = 9.058$, $p = 0.000$), and the predictors accounted for 96.3% (R square = 0.963) of the variance in users of the train terminals' satisfaction with the circulation strategies.

For the dependent variable, "overall user satisfaction", the ANOVA findings were based on the forty (40) pedestrian circulation strategies acting as predictors. The results in Table 3 show that by dividing the regression mean square by the residual mean square, the resultant computed F-value is 9.058. Therefore, the value shows the ratio of the model's explained variance to unexplained variance. With a significance level of < 0.001, the marginal significance line is indicated ($p > 0.05$).

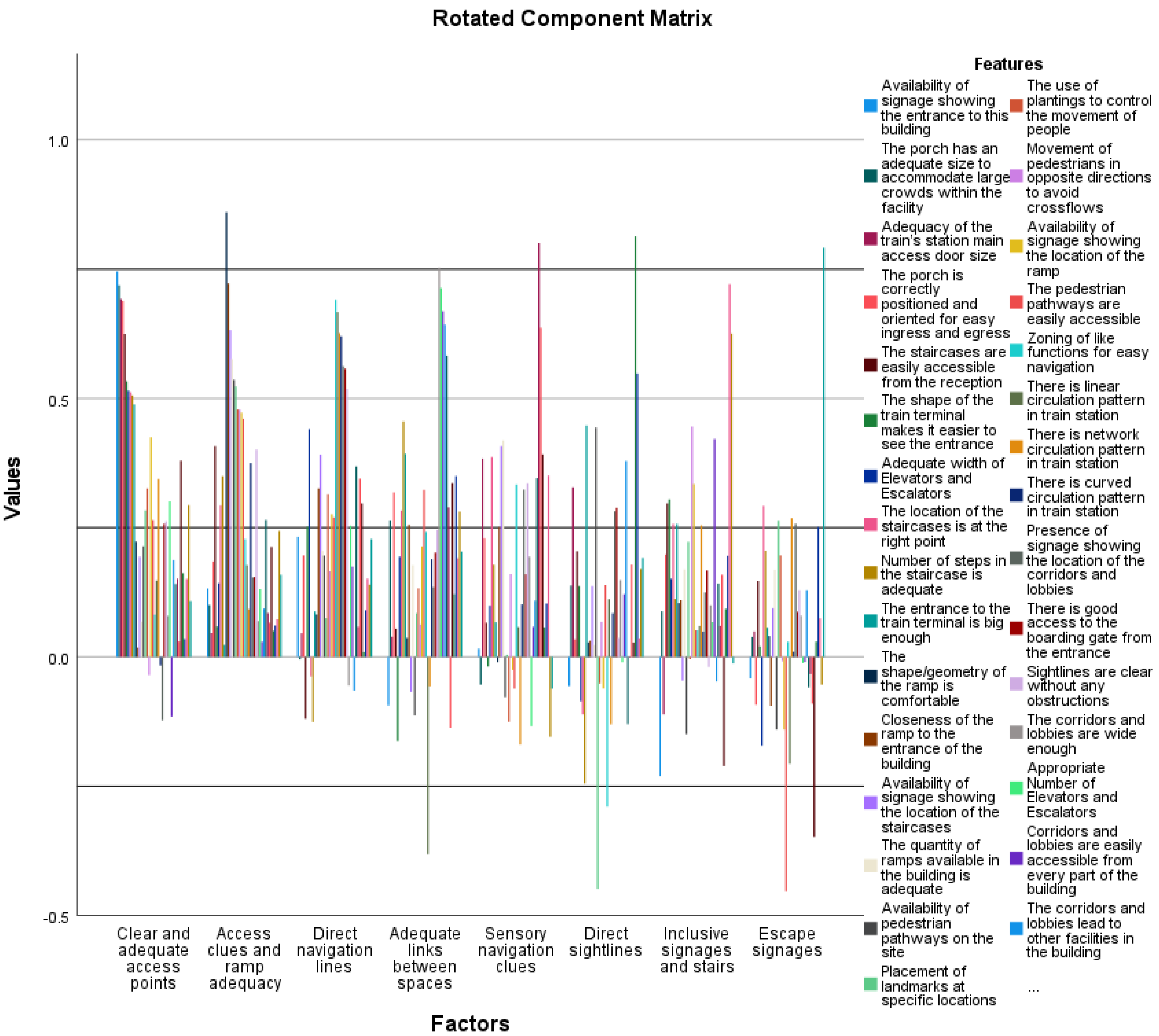

Figure 8. Rotated component matrix for pedestrian circulation strategies

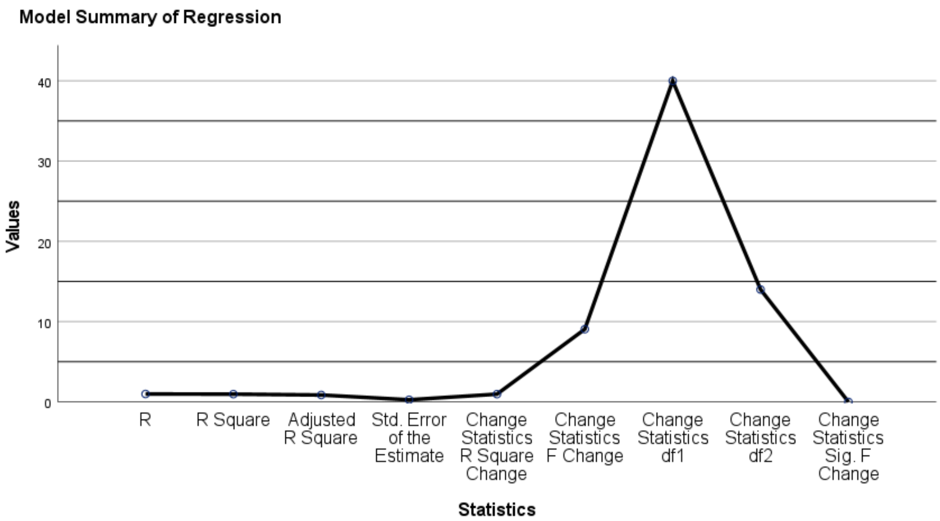

Figure 9. Model summary of regression

Table 3. ANOVA findings for the dependent variable

ANOVA[a]					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	24.797	40	0.620	9.058	< 0.001[b]
Residual	0.958	14	0.068		
Total	25.755	54			

Table 4. Coefficient for the dependent variable of overall user experience

Model	Unstand. Coefficients		Stand. Coeffic.	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.302	0.551		2.361	0.033
Corridors and lobbies connection with other facilities	0.126	.0122	0.132	1.036	0.318
Adequate width of corridors and lobbies	0.006	0.099	0.008	0.060	0.953
Accessibility of corridors and lobbies	0.037	0.121	0.051	0.310	0.761
Availability of signage in the corridors and lobbies to show the location of other facilities in the building	0.041	0.100	0.049	0.411	0.687
Signage in corridors and lobbies showing where the escape routes in the building are	-0.126	0.099	-0.171	-1.268	0.225
Presence of signage showing the location of the corridors and lobbies	-0.100	0.103	-0.136	-0.975	0.346
Good access to the boarding gate from the entrance	0.337	0.119	0.442	2.832	0.013*
Large train terminal entrance	-0.169	0.125	-0.197	-1.351	0.198
Right location of the entrance to the train terminal	-0.287	0.121	-0.339	-2.375	0.032*
Ease of seeing the entrance due to the train terminal's shape	0.121	0.091	0.140	1.321	0.208
Availability of signage showing the entrance to this building	-0.343	0.098	-0.435	-3.511	0.003*
Adequacy of the train's station main access door size	0.623	0.156	0.775	3.992	0.001*
The porch is correctly positioned and oriented for easy ingress and egress	-0.411	0.161	-0.486	-2.551	0.023*
Adequate size of porch to accommodate large crowds	-0.170	0.108	-0.200	-1.573	0.138
Appropriate size of the treads	-0.076	0.105	-0.114	-0.726	0.480
Adequate number of staircase steps	-0.340	0.113	-.0420	-3.005	0.009*
Right location of the staircases	0.074	0.089	0.113	0.828	0.422
Easy access to staircases from the reception	0.167	0.128	0.190	1.307	0.212
Availability of signage showing the location of the staircases	0.172	0.147	0.209	1.173	0.260
Comfortable shape/ geometry of the ramp	-0.009	0.091	-0.012	-0.096	0.925

Closeness of the ramp to the entrance of the building	-0.214	0.120	-0.319	-1.786	0.096
Adequate quantity of ramps	-0.126	0.105	-0.183	-1.204	0.248
Availability of signage showing the location of the ramp	0.110	0.104	0.164	1.056	0.309
Adequate width of Elevators and Escalators	0.560	0.095	0.802	5.921	0.000*
Appropriate Number of Elevators and Escalators	0.401	0.118	0.588	3.398	0.004*
Accessible pedestrian pathways	0.001	0.095	0.001	0.009	0.993
Availability of pedestrian pathways on the site	-0.108	0.104	-0.134	-1.036	0.318
Signage on-site, directing users to the various facilities	-0.229	0.082	-0.327	-2.783	0.015*
Wide pedestrian pathways	0.086	0.084	0.137	1.024	0.323
Controlled movement of people using plantings	0.102	0.088	0.147	1.165	0.263
Curved circulation pattern in train station	-0.010	0.133	-0.011	-0.072	0.944
Linear circulation pattern in train station	-0.378	0.118	-0.455	-3.194	0.006*
Network circulation pattern in train station	0.128	0.123	0.132	1.038	0.317
Sightlines are clear without any obstructions	0.102	0.099	0.140	1.032	0.319
Zoning of like functions for easy navigation	-0.109	0.149	-0.147	-0.735	0.474
Placement of landmarks at specific locations	0.049	0.088	0.057	0.550	0.591
Movement of pedestrians in opposite directions to avoid crossflows	0.371	0.119	0.423	3.122	0.008*
Appropriate and legible Signage	0.232	0.084	0.311	2.770	0.015*
Use of repetitive patterns and colour schemes	-0.065	0.125	-0.097	-0.522	0.610
Digital wayfinding signage	0.031	0.083	0.048	0.375	0.713

*Significant at $p < 0.05$

Table 4 illustrates that of all the forty assessed pedestrian circulation strategies, the adequacy of the train station's main access door size has the most significant influence on the overall user experience (Beta Coefficient = 0.623). Eleven (11) other strategies, such as availability of signage showing the building's entrance, adequacy of the train's main access door size, good access to the boarding gate from the entrance, right location of the entrance to the train terminal and adequate number of staircase steps significantly influence the overall user experience of pedestrians within train terminals.

The findings of this study converge with the results of studies [1, 44, 45], in which the authors emphasise the importance of seamless wayfinding and clear signage for optimal pedestrian circulation. Similarly, the creation of secure boarding/alighting areas and transfer areas is also crucial as it has a significant impact on user experience and the effectiveness of pedestrian circulation.

Specific design recommendations for pedestrian circulation with quantitative importance rankings were provided by Ibem et al. [44], as their findings include that the ease of seeing the entrance due to the train terminal's shape plays a major role in train terminals, which is also similar to this study's findings.

However, there are divergences in the literature [31, 38, 40] and this study's findings in preferences of technological solutions, such as the application of real-time passenger flow control systems and dynamic management of pedestrian traffic, as opposed to conventional modifications of train terminal infrastructure, like clear signage and proper platform configuration.

5. CONCLUSIONS

This study was conducted to evaluate the implementation of pedestrian circulation strategies within existing train terminals with a view to determining their influence on optimal user experience in such facilities. Four research questions were curated to achieve the study's aim. It was found that the adequacy of the train station's main access door size has the most significant influence on the overall user experience. The results also reveal that the most efficiently implemented strategy within the three selected train terminals was clear and adequate access points, while the least implemented strategy was escaping signage.

Based on these findings, the contribution to knowledge of this study is that when designing pedestrian circulation strategies, it should be properly planned and intricately executed, as it is a prerequisite to optimal user experience. This should be done as opposed to sole dependence on predetermined standards such as LOS, which has constituted a major design flaw in train terminals. Therefore, based on the findings of the study, it is recommended that horizontal pedestrian circulation strategies be appropriately dimensioned to accommodate high-traffic scenarios, while vertical circulation strategies in train terminals should be positioned strategically to avoid bottlenecks.

The limitation of the study is acknowledged, as the three train terminals evaluated are within Southwestern Nigeria, making certain aspects non-generalisable due to variations found in developed countries with the latest facilities, particularly high-speed rail terminals. However, the contributions of this study are not diminished in any way as the multidisciplinary approach to pedestrian circulation strategies and operational efficiency is explored, which are crucial to transportation architecture professionals as a benchmark for conceptualising user-centric train terminal facilities. Suggested areas of future research in pedestrian circulation include infrastructural and technological advancements for crowd management in intermodal passenger terminals.

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