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PERFORMANCE ASSESSMENT OF FOOTPATHS WITHIN WURUKUM MARKET AREA OF MAKURDI METROPOLIS, BENUE STATE, NIGERIA

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Abstract
The investigation of crowd behaviour, particularly pedestrian flow in public spaces such as markets in most developing countries, has not been given the needed attention for efficient and sustainable development. The Pedestrian Level of Service (PLOS) is an index used for performance assessment of pedestrianized systems. This research aims at assessing the performance of footpaths in the Wurukum market situated in Makurdi metropolis. The highway capacity-based method was used for evaluating the PLOS. Data collection involved random selection and identification of major footpaths in the market space as; A1, A2, A3, . . . A10, a measure of pedestrian flow rate and the effective width of sampled footpaths. Data analysis revealed that footpaths A1 and A4 had PLOS-B while others had PLOS-A at the base year (2019). Prediction of future performance of the sampled footpaths at traffic growth rates of 1%, 2%, and 3% per annum showed performance reduction over time. Though links performance at the base year (2019) were satisfactory, there was a systematic decrease in performance index over time as links A1, A2, A3, A4, and A5 recorded worse output compared to those of links A6, A7, A8, A9 and A10 which had relatively better performance for the predicted future years. Timely planning to expand market footpaths to accommodate the anticipated increase in pedestrian flow rate in the market was recommended for people-friendly and sustainable infrastructural development.
Keywords: Wurukum market, Footpaths, Pedestrian flow rate, effective width, Pedestrian Level of Service (PLOS).

1. Introduction
In every public space, pedestrian crowding creates discomfort to the occupants due to the significant impact of its externalities, such as a delay due to congestion and pollution in the form of noise and hazardous air. The description of crowding is a subjective perception of a facility used for a relatively high density of occupants within available space, be it on footpaths, at bus or train stations, in vehicles, etc. [1]. Pedestrian crowding in any public facility could be likened to vehicular traffic flow in a traffic network, often associated with congestions. Negative externalities caused by congested traffic flow include delay, high travel costs, pollution, physical discomfort, psychological burden, and perceived risk and insecurity, etc. [2], [3]. The satisfaction derived from the performance of a transport facility by the users is usually measured by a standard index known as the Level of Service (LOS). In other words, it is the qualitative or quantitative measure of the effectiveness of any transport facility. LOS is measured on a scale of A to F in a descending order where A denotes the best performance condition characterised with no delay and F the worst condition characterised with congestions and delays [4], [5]. This parameter refers to the Pedestrian Level of Service (PLOS) when analyzing pedestrian transport facilities [4]. The estimation of LOS of transport facilities employs the use of existing standard charts and tables, which were established from series of previous researches [6]. The pedestrianization or measure of PLOS of a footpath requires input

variables such as the effective linear space in meter square per pedestrian (m2/p), the flow rate in pedestrian per minute per meter (p/min/m), and average speed measured in meter per second (m/s) [4], [7], [8].
The general essence of investigating LOS of transport facilities is performance evaluation and maintenance decisions for effective and sustainable development. In other words, to check the economic or investment value, assess user satisfaction and safety [9]. Also, the study of crowding and pedestrianization in public spaces within city areas is relevant for effective infrastructural planning, design, and construction [10]. Pedestrian discomfort in the use of any facility stimulates rude behaviour, which affects route choice that may promote inappropriate use of public facilities [11], [12]. The consequences of inappropriate use of public facilities include reducing the actual life span of the designed specifications. In recent times, most cities have adopted sustainable development models [1], [3]. Sustainable development policy aims at solving today's problem without hurting tomorrow's need [13]. Human dynamism and inconsistent land-use policies are essential factors that necessitate periodic performance evaluation of public facilities for optimum performance (services) and proper planning. Town planners, traffic engineers, among other environmental professionals, are keen to understand the dynamism of city development. Therefore, the importance of investigating pedestrian behaviour in any public space using travel characteristics cannot be over-emphasized [14], [15].

This study aims at investigating the performance of footpaths within the Wurukum market area of Makurdi metropolis. Its specific objectives include; determine the pedestrian flow rate on footpaths within the market area, determine the PLOS of the footpaths, project future performance and propose possible measures for improved PLOS of footpaths within the market to attain sustainable development.

2. Material and Methods

2.1. Description of the study area

The Wurukum market is situated within Makurdi metropolis, the capital city of Benue State in Nigeria. The four coordinate points bounding the market area are; P1 (7043'32"N; 8032'52"E), P2 (7043'32"N; 8032'59"E), P3 (7043'24"N; 8032'53"E) and P4 (7043'24"N; 8032'55"E). Wurukum market is the major city centre market which serves an estimated human population of over 500,000 persons residing in Makurdi metropolis. The location of Makurdi metropolis is as shown in Figure 1;

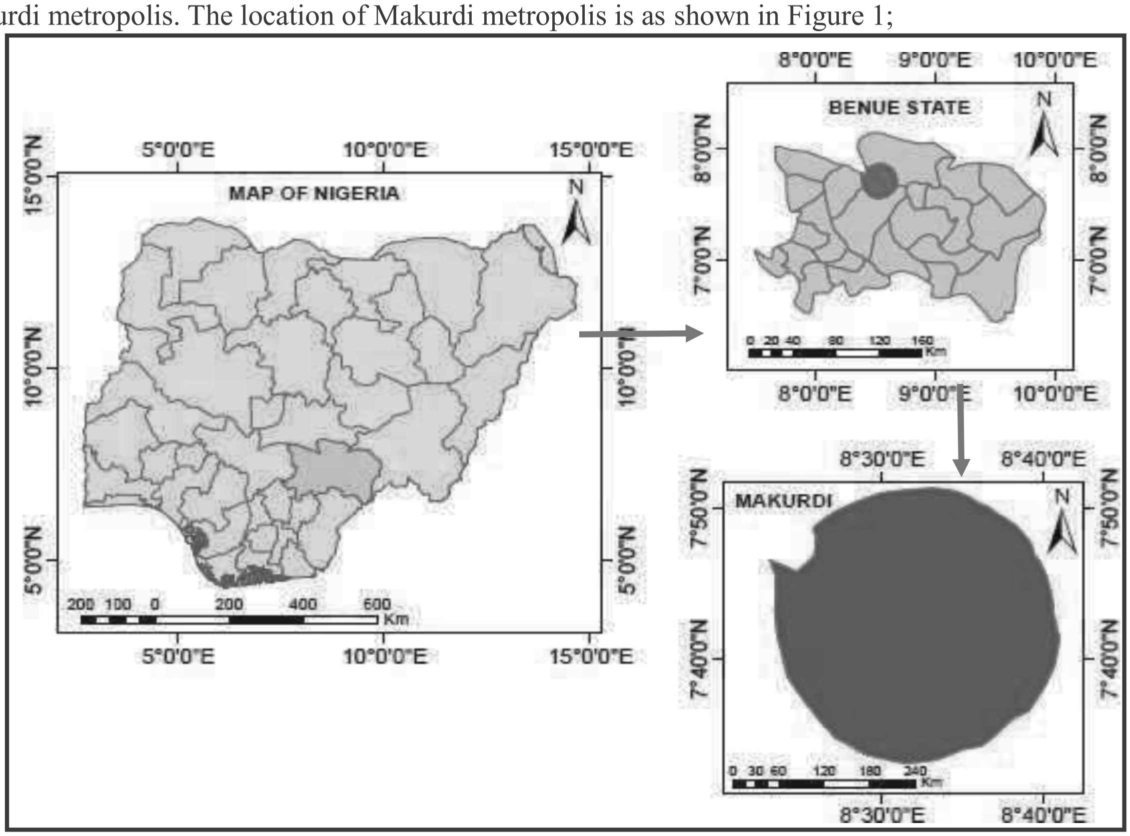

Figure 1: Location of Study Area

Daily, the market attracts an average influx number of persons estimated at 28,000 from 7:00 am to 6:00 pm through its 11 major entry points. The total land area of the market measures 43 000 m^2 approximately. The market area is characterized by several footpaths linking various shops and stalls within the market. Ten (10) footpaths were randomly selected and identified as footpath A1, A2, A3, . . . A10 for this study. The location and layout details of the Wurukum market is as presented in Figure 2;

Figure 2(a): Location of Wurukum Market in Makurdi Metropolis

Figure 2(b) Layout of Wurukum Market

Figure 2(c): Sectional View of Selected Footpaths in Wurukum Market

Figure 2: Study Sites

2.1 Data collection and analysis

This involved the measurement of geometric features of sampled footpaths to obtain average effective widths and determination of location coordinates using a handheld Geographical Positioning System (GPS) device for reference purposes. The effective width of the footpath was measured as its continuous minimum space without obstruction caused by obstacles placed by the sellers, such as tables, hangers, chairs, etc., outside the shops and stalls. Figure 3 presents the measure of effective width on a typical footpath.

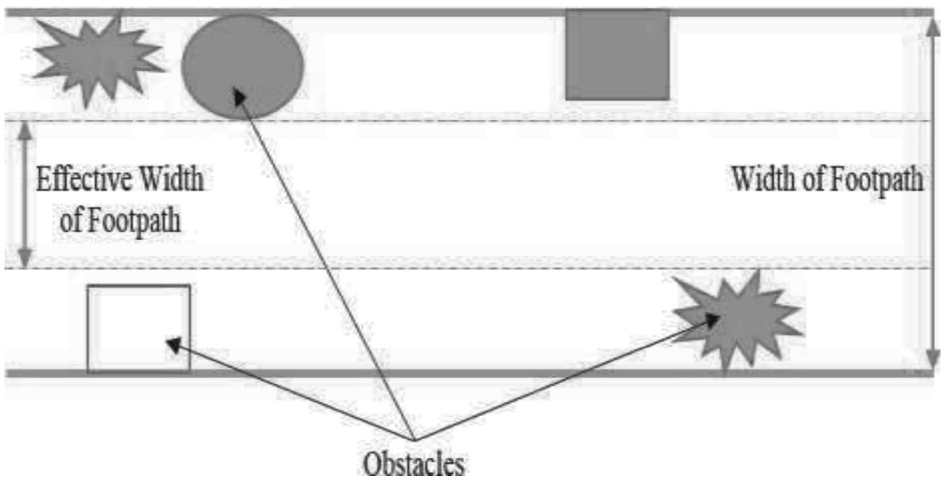

Figure 3: Measure of Effective Width of a Footpath

The geometric measurement of footpath widths was carried out using a steel measuring tape. The count of pedestrian traffic flow on the sampled footpaths from 7:00 am to 6:00 pm per day at intervals of 15 minutes was used to obtain estimated pedestrian unit flow rate measured in pedestrian per minutes per meter (p/min/m). According to HCM [4], the pedestrian unit flow rate of each footpath was estimated using Equation 1;

$$p = \frac{V_{15}}{15\, x\, W_E} \tag{1}$$

where p is the pedestrian unit flow rate measured in pedestrian per minute per meter (P/min/m), V_{15} is the peak 15 minutes pedestrian flow measured in pedestrian per 15 minutes (P/15min) and W_E is the Effective width of footpath measured in meters (m).

According to Rouphail and Allen [7], the standard scale used for condition classification of public facility PLOS is as presented in Table 1;

Table 1: Classification of PLOS [7]

PLOS	Unit Flow Rate (p/min/m)
A	≤ 14
B	14 – 21
C	21 – 33
D	33 – 49
E	49 – 60
F	> 60

Considering pedestrian traffic growth rate of 1%, 2%, and 3% on the footpaths, a projected future pedestrian flow rate was estimated using Equation 2;

$$P = P_0 e^{r.t} \tag{2}$$

where P is the projected pedestrian unit flow rate (P/min/m), P_0 is the initial pedestrian unit flow rate at base year (P/min/m), e is the natural logarithmic constant (2.71828), r represents the growth rate (%), and t is the projection period (year).

3. Results and Discussion

The pedestrian flow rate on randomly selected footpaths identified as links A1 – A10 within the Wurukum market area from 7:00am – 6:00pm is as presented in Table 2;

Table 2: Pedestrian Flow Rate on Footpaths

Time	Pedestrian Flow Rate on Footpaths (P/15 min.)									
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**
9:15am	245	67	66	134	99	84	44	51	72	142
9:30am	223	89	60	119	125	92	71	64	64	130
9:45am	287	67	71	155	145	71	87	66	94	124
10:00am	301	82	92	130	161	68	92	89	81	113
10:15am	289	86	87	160	163	94	60	54	83	171
10:30am	346	89	109	158	177	90	72	98	98	118
10:45am	295	90	119	172	185	84	83	74	102	115
11:00am	302	86	83	162	150	87	98	98	94	119
11:15am	316	107	86	173	151	101	107	104	115	151
11:30am	284	87	119	168	161	100	119	89	85	123
11:45am	324	101	106	172	170	125	89	115	112	144
12:0 noon	321	115	93	177	184	100	93	124	109	128
12:15pm	342	121	92	169	208	123	104	99	94	167
12:30pm	298	108	130	219	217	96	84	112	114	142
12:45pm	328	105	94	186	206	121	114	141	116	131
1:00pm	287	102	122	201	215	158	101	103	92	121
1:15pm	311	100	92	171	196	114	69	114	94	191
1:30pm	291	96	113	212	222	108	93	94	122	184
1:45pm	304	122	134	198	181	101	141	120	105	156
2:00pm	290	95	102	174	200	112	172	94	109	171
2:15pm	314	122	143	216	210	158	148	144	99	215
2:30pm	325	120	119	188	215	121	173	94	119	174
2:45pm	309	111	93	217	204	126	119	101	116	189
3:00pm	347	98	148	205	176	131	76	98	100	200
3:15pm	328	112	112	177	211	144	94	104	110	210
3:30pm	298	128	79	189	217	119	114	114	111	209
3:45pm	364	125	172	204	191	131	141	115	117	187
4:00pm	337	126	92	211	201	84	89	97	113	182
4:15pm	324	112	165	168	172	146	121	105	95	194
4:30pm	309	157	188	124	188	112	88	118	118	124
4:45pm	312	133	201	182	219	79	109	125	152	158
5:00pm	321	131	143	161	164	113	87	91	122	183
5:15pm	296	84	84	154	172	84	98	81	100	194
5:30pm	300	88	92	127	142	94	69	76	98	122
5:45pm	319	79	88	126	127	68	94	93	94	144
6:00pm	295	94	85	123	144	93	91	72	85	71
Statistics										
Max.	**364**	**157**	**201**	**219**	**222**	**158**	**173**	**144**	**152**	**215**
Mean	**307.8**	**103.8**	**110.4**	**171.7**	**179.7**	**106.4**	**100.1**	**98.1**	**102.9**	**155.5**
Min.	**223**	**67**	**60**	**119**	**99**	**68**	**44**	**51**	**64**	**71**
S.D	**30.39**	**21.75**	**36.28**	**30.31**	**33.08**	**25.11**	**31.11**	**23.31**	**18.77**	**37.32**

Table 2 revealed the descriptive statistic of pedestrian flow rates on footpaths in the Wurukum market. The estimated maximum flow rate on each footpath which represents the worst case scenario in the market was considered for this analysis. This scenario influenced pedestrian route choice in the market and affected travel time significantly, as pedestrians tried to avoid congestion within the crowded footpaths and adopted longer routes during shopping within the market. The computation of PLOS for the present (base year - 2019) and projected years ahead at the market is as presented in Table 3;

Table 3: Projected PLOS of Footpaths in Wurukum Market Area

Growth Rate (%)	Years	PLOS									
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
0%	2019	B	A	A	B	A	A	A	A	A	A
1%	2024	B	A	A	B	A	A	A	A	A	A
	2029	B	A	A	B	A	A	A	A	A	A
	2034	C	A	B	B	B	A	A	A	A	A
	2039	C	B	B	B	B	A	A	A	B	B
2%	2024	C	A	A	B	B	A	A	A	A	A
	2029	C	B	B	C	B	A	A	A	B	B
	2034	D	B	C	C	C	A	A	B	B	B
	2039	E	C	C	D	D	B	B	B	C	C
3%	2024	C	A	B	B	B	A	A	A	A	A
	2029	C	B	B	C	B	A	A	A	B	B
	2034	D	C	C	D	C	B	B	B	C	C
	2039	F	E	E	F	E	C	C	D	D	D

Table 3 revealed that the performance of footpaths within the market in the base year (2019) was satisfactory. This status depreciated over time with an assumed projected pedestrian traffic growth rate of 1%, 2%, and 3% on all sampled links for a period of Twenty (20) years in the future. Footpaths A1, A2, A3, A4, and A5 indicated poor performance over time hence called for maintenance priority for improved performance, while those of A6, A7, A8, A9, and A10 showed relatively better performance in the future years. The poor performance of links A2 and A4 was majorly attributed to insufficient effective width. At the same time, those of A1, A3, and A5 were due to pedestrian high travel demand. Links A6 – A10 had relatively wider effective width with moderate travel demand, hence performed averagely satisfactory for a forecasted period of 20 years.

4. Conclusion

This study carried out a performance assessment of footpaths within the Wurukum market area in Makurdi metropolis, Benue state of Nigeria. The pedestrian flow rate on some selected footpaths within the market area was estimated from a manual traffic count and physical inspection of geometric features to establish effective width. Results of PLOS analysis for the base year (2019) and projected years at traffic growth rates of 1%, 2%, and 3% indicated good performance at the base year, which failed overtime considerably on links A1, A2, A3, A4, and A5, while links A6, A7, A8, A9, and A10 had a relatively better-forecasted performance. The performance of footpaths in the market was affected by the effective width and travel demand. The poor performance of footpaths A1, A2, A3, A4, and A5 in the future years was revealed, which called for efficient and sustainable planning strategies and implementation such as widening the effective width of the affected footpaths and collapse of some stalls to acquire more space that could be used for creating new footpaths to help improve the PLOS over time. This will prevent congested situations that could make footpaths unbearable due to crowding, which may impose negative externalities on the users.

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