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CHARACTERISATION AND MODELLING OF PEDESTRIAN FLOWS IN HOSPITAL AND ACADEMIC ENVIRONMENTS

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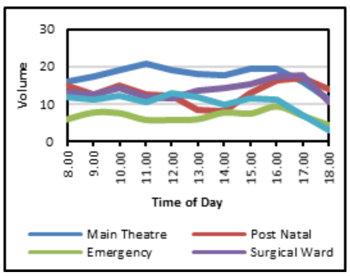
Graphical abstract



Abstract

This paper examined pedestrian characteristics in two urban facilities namely a teaching hospital and a university campus. The aim was to determine if pedestrian flow features in these facilities differed from those in downtown areas. The objectives were to measure pedestrian flow rates and model their walking behaviour. Eleven sites located within these facilities were selected for study. The results indicated that the male walked faster than the female in the university campus while the female was faster in the hospital environment. Also the university campus saw more groups of pedestrians in the traffic mix than was the case in the hospital environment where 93% of the pedestrians were in single files. The male walked faster than the female by 7% in the university environment while the female were faster by 4% in the hospital environment. The modelling effort showed that the free walking speed in the university environment was 68.052 m/min with a critical density of 3.15 ped/m^2. That of the hospital environment was 75.099 m/min and a critical density of 4.36 ped/m^2. Since the speed-density relationships for the two facilities revealed a highly randomized plot, the data was fit to the normal distribution and pdf and cdf were used to assess the quality of the flow. For the university environment the results showed that 15% of the combined pedestrians walked below 56.88 m/min while 50% of the pedestrians walked below 66.67m/min and 85% walked below 72.50 m/min. Similarly, the results of the hospital environment showed that 15th percentile of the combined pedestrians walked below 69.75 m/min. The median speed of pedestrians was 72.50 m/min while 85% of the pedestrians walked below 75.25 m/min. In both cases, the 15 percentile speeds were 14% and 18.5% less than the median speeds in both facilities respectively. Thus flow breakdowns are unexpected in the two facilities.

Keywords: Pedestrian characteristics, flow, density, walking speed, group size, male, female

1.0 INTRODUCTION

Considerable efforts have been devoted to pedestrian studies in urbanized areas with a view to understanding their needs and movement patterns. Pedestrian flow is characterized by personal features such as moving, stopping, waiting, walking in groups, reneging in a movement, or engaging in cross movement. Thus pedestrian movement could be complex and could involve personal decision making unpredictable by observers. Inspite of the advancement in technology, walking cannot be eliminated as a mode of transport and it is the mode upon which every trip ultimately depends on.

There is an abundance of pedestrian studies addressing several issues such as crossing behaviour at roadways, movement in indoor walkways, outdoor walkways, sidewalks, mid-block crossings, signalized intersection crossing, behaviour by gender or age etc. Pedestrian walking behaviour in specific facilities such as transit terminals, shopping malls, railway terminals and university campuses have also been undertaken in order to understand the features of pedestrians in these facilities. Whereas these studies provide general insights to pedestrian movements, their behaviour within built facilities remain to be explored.

In this study, two urban facilities that generate large pedestrian movements were examined for the efficacy of movements within them. These are a teaching hospital and a university campus. A teaching hospital attracts large people who visit the different sections of a hospital on daily basis. Even though they may arrive into the hospital in vehicles, their movements within the hospital units are mainly pedestrianized. The provisions for their movements in the hospital as well as the efficacy of their movements' vis-à-vis the special needs of patients involved in these movements would need to be understood.

A university campus also attracts diverse groups of people for academic pursuits as well for business and employment opportunities. Thus large groups of people traverse the campuses in different directions and these movements need to be understood for effective design of facilities and for safe evacuation in times of emergency.

The aim of this study was to see if pedestrians in these environments had peculiarities different from their counterparts' in downtown areas. The objectives of this paper were three fold; to examine the flow rate of pedestrians over the period of the day for the two facilities, to determine pedestrian characteristics in the two facilities and to model the walking behaviour of pedestrians for the two situations. The rest of the paper is organised as follows; section 1 introduces the subject of the paper while section 2 presents a review of the literature on the subject. Section 3 details the data collection procedure adopted for the study and in section 4 the results and modelling effort is presented. The conclusions end the paper in section 5.

2.0 LITERATURE REVIEW

Pedestrian characteristics studies and modelling have been extensively studied in the literature. These studies range from consideration of pedestrians along roadways, indoor and outdoor walkways, crosswalks and crosswalks at signalized intersections. Some studies have also been devoted to pedestrian movements in schools, university campuses, shopping malls, downtown areas and transit terminals. Pioneering empirical studies on pedestrians is attributed to Older [1] and Fruin [2] who considered shoppers in outdoor walkways and commuters in indoor walkways respectively in their studies. More recent empirical studies have been carried out by Chandra and Bharti [3]. They carried out a detailed study on pedestrian walking speeds at seven locations that included Sidewalks, Wide-sidewalks, Precincts and Carriageways. They found that there was no significant difference between pedestrian walking and crossing speeds.

Papadimitriou [4] developed a theoretical framework for modelling pedestrian road crossing behaviour and found that in general there was increased probability of crossing at pedestrian crossings with or without mid-block and at signalised crossings. Furthermore the probability of crossing increased on roads with low volumes. Jodie and Lam [5] modelled pedestrian signalized crosswalks in Hong Kong and found that the design walking speed for signalized crosswalks could be varied by the effects of the bi-directional pedestrian flows.

Alhajyaseen and Nakamura [6] developed a methodology for estimating the required crosswalk width at different pedestrian demand combinations and a pre-defined Level of Service. The developed models were utilized to generate the fundamental diagrams of pedestrian flow at signalized crosswalks. Jian Hong Yea *et al*. [7] investigated the impact of gender, age and luggage-carrying on walking speed of pedestrians in a subway station in Shanghai. It was found that except for older pedestrians, males walk faster than females by 5–7%. Middle-aged pedestrians walk slower than the young by 6–8%, and older pedestrians walk slower than the young by 18–24%. Compared with no luggage, small luggage only reduces mean walking speed by 2–3%. For medium luggage, large luggage and trolley cases, the decline rates of walking speeds were 5–8%, 10–14%, and 3–8% respectively.

Hongfei *et al*. [8] conducted a pedestrian flow characteristics study in a comprehensive transport terminal with model calibration of the flow parameters. Guo *et al*. [9] used reliability analysis to describe the pedestrian safety crossing behaviour at signalized crosswalks in an urban traffic environment. The results indicated that most pedestrians show distinct time-dependent reliability but a few pedestrians are too impatient to wait for the signal lights changes. Asano *et al*. [10] built a microscopic model of pedestrian behaviour using a two player game and assumed that pedestrians anticipate movements of other pedestrians in order to avoid collision. The results of the simulation model were compared with experimental and observed data in a railway station. Several characteristics of pedestrian flows such as traffic volume and travel time in multidirectional flows, temporal–spatial collision avoidance behaviour and density distribution in the railway station were reproduced in the simulation. Guo *et al*. [11] developed a predictive pedestrian route choice model with physical congestion during the evacuation of indoor areas with internal obstacles. The method can be used to predict the evolution of pedestrian flow over time and space in indoor areas with internal obstacles and to investigate the collection, spillback, and dissipation behaviour of pedestrians passing through a bottleneck.

Aside these modelling efforts many other studies have addressed pedestrian characteristics and these include Griffiths *et al.* [12] who revealed that the crossing speed at un-signalized crossing produced a mean walking speed of 103.20 m/min for the young, 88.20m/min for the middle-aged, and 69.60m/min for the elderly. Tanaboriboon *et al.* [13] investigated school age children in Singapore in crosswalks and found their crossing speeds to be similar to the elderly pedestrians at 54.0m/min. Similarly, they noted that the males walked faster than the females by 3.78% with the walking speed declining with increasing age. Polus *et al.* [14] investigated the properties and characteristics of pedestrian flow on sidewalks in Haifa (Israel) and found that walking speeds of men were significantly greater than those of women. Similarly, Tanaboriboon and Guyano [15] observed walking speeds on a signalized intersection in Bangkok and found crossing speeds of male pedestrians to be 78.60m/min and those of female pedestrians to be 73.80m/min. In a Swedish study on pedestrian characteristics, Bowman and Vecellio [16] opined that 15 percent of the older pedestrians crossed at speeds below 42m/min. In a Canadian study by Coffin and Morrall [17], they recommended a design speed of 60m/min to be used at mid-block crossings with a large proportion of older pedestrians. Further studies by Knoblauch *et al*. [18], Tarawneh [19], and Carey [20] all found higher crossing speeds by younger pedestrians than the older age groups consistent with higher speeds for males than females.

Finally Gitelman *et al*. [21] studied pedestrian accidents related to infrastructure characteristics in Israel and found that system tream net of pedestrian fatalities rather than spot treatment could alleviate the high incidence of pedestrian accidents in Israel.

3.0 DATA COLLECTION

This study involved a comprehensive data collection for eleven sites for the two facilities examined. Five sites in side a Teaching Hospital (Aminu Kano Hospital) and six in a University Campus (Bayero University, Kano). The pedestrians were observed for speed and flow as well as their walking behaviour. All the observation points were walkways in the two facilities. Pedestrian behaviour was segregated into male and female. The coding employed for the two facilities are shown in Table 1. The flow rate was measured every 30 minutes by noting the number of pedestrians that passed the observation points during the observation period which lasted from 8.00 am to 6.00 pm daily for seven days during the month of July 2014. The speed and flow rate measurements were manually captured while video technology was used for observing the pedestrian behaviour. In all cases, the observation period was during daylight, weekdays and weekends and during normal weather conditions for a typical pedestrian behaviour.

Table 1 Study sites code

Facility	Site Code	Target
Hospital	H01	Main Theatre
Hospital	H02	Post-Nata/ Gynecology
Hospital	H03	Emergency Unit
Hospital	H04	Male/Female Surgical Wards
Hospital	H05	Orthopedic
University	U01	Female Hostel
University	U02	Commuting Students
University	U03	Library
University	U04	Lecture Theatre
University	U05	Academic Corridor
University	U06	Male Hostel

The sample size for the university environment was 1532 while that of the Hospital environment was 1070. The video shootings were then used to identify groups of walking pedestrians. All pedestrians that stopped, reneged, or otherwise did not complete the trip along the measured course were abandoned. To determine the speed, a pedestrian was timed in a pre-determined measured course of 30 m which had been found to be consistent with pedestrian behavior in a pilot study. A randomly selected pedestrian that passed along the selected sites was timed at the entry and exits points of the measured course. Figure 1 shows a typical layout for the study site, while Figures 2 and 3 show pedestrians at the Bayero University Campus and Amino Kano Teaching Hospital, respectively.

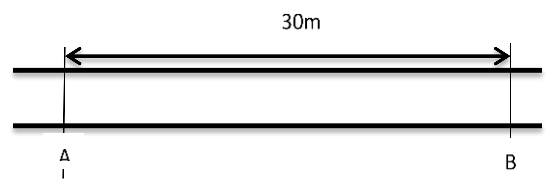


Figure1 Typical site arrangement for study

Figure 2 Pedestrians at the Bayero university new campus

Figure 3 Pedestrians at Aminu Kano Teaching Hospital

4.0 RESULTS AND DISCUSSION

The results of the volume study for the two facilities are shown in Figures 4 and 5. Pedestrian flows along site U01 carries the highest volume with peak flow at 12.00 pm as shown in Figure 4. There were no distinct volume trends for the remaining five sites in the Academic environment. Clearly the flows for sites U02, U04 and U05 terminate at 15.00 pm due to cessation of activities at the sites. Site U02 is located in the path of commuting students who approach a ground transportation access area for departure off-campus. Sites U04 and U05 are located in academic core areas for observation of students accessing a lecture theatre and movement between academic faculties respectively. Sites U01, U03 and U06 are located at the male hostel area, the University Library and the female hostel areas respectively. It must be mentioned that sites U01 and U06 are not located in the male and female hostel areas to capture gender based flows. Like the other sites, the flows are mixed.

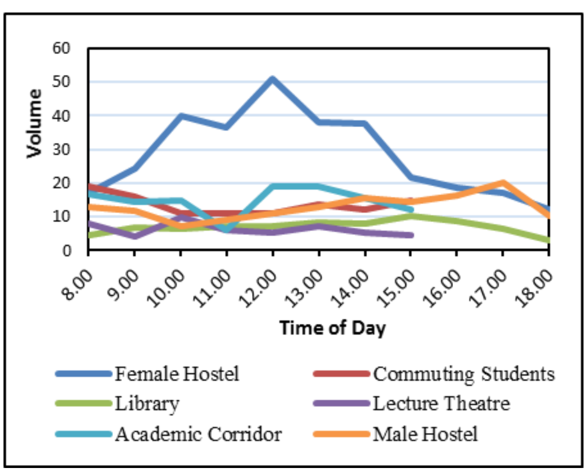


Figure 4 Flow profile at Bayero university new campus

The flow profiles for the hospital environment are shown in Figure 5. Pedestrians moving in the direction of the main theatre recorded the highest flows followed by pedestrians going to the surgical wards. The emergency wards recorded the lowest flows during the period of data collection. Observations were also made of groups of pedestrians that walked together in the two facilities.

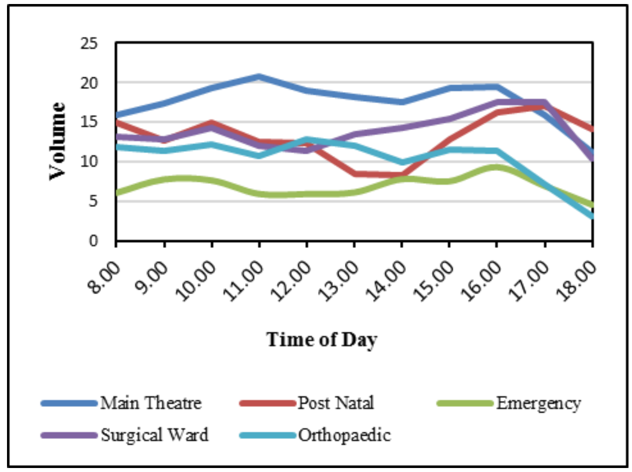


Figure 5 Flow profile at teaching hospital

In the academic environment, the largest groups encountered were six and these occurred at sites U01 and U02 respectively as shown in Table 2. Thus 73.8% of the sample were single file pedestrians, 16.4 percent were double file pedestrians, 4.2% of pedestrians were moving in threes, 3.2% pedestrian quadruples were observed while 1.3% of the pedestrian movement were in fives and 1.1% walked in groups of six. Site U01 was seen to contain pedestrians of all group sizes, followed by commuting students who filed out in various groups towards the transportation access area.

Table 2 Group size distribution for academic environment

Site	Group Size of Pedestrians in Academic Environment					
	1	2	3	4	5	6
U01	367.75	60.85	10.90	4.00	2.77	1.78
U02	203.30	44.20	4.85	2.16	1.14	1.00
U03	117.70	2.70	1.31	2.00	0.00	0.00
U04	83.55	2.40	1.31	1.00	0.00	0.00
U05	204.10	7.70	3.25	1.93	0.00	0.00
U06	153.50	7.55	3.00	1.25	0.00	0.00
Total	1129.90	125.40	21.65	12.34	3.91	2.78

In the hospital environment, single file pedestrians constituted 93%, double pedestrians were 4%, pedestrians walking in three pairs were 2% and those that walked in groups of four were 1% as shown in Table 3. All the sites recorded pedestrians in groups of four with site H01 having the highest proportion. Again site H01 recorded the highest number of pedestrian groups for all the sites. No observation was made for group sizes of five and six in the hospital environment. In all the sites, pedestrians in groups above six were adjudged to be a crowd and did not meet the objectives of the study.

Table 3 Group size distribution for hospital environment

Site	Group Size of Pedestrians in Hospital Environment					
	1	2	3	4	5	6
H01	258.35	11.40	4.18	2.29	0.00	0.00
H02	184.10	8.40	3.58	2.00	0.00	0.00
H03	95.20	6.15	3.32	1.92	0.00	0.00
H04	200.10	6.85	4.65	2.13	0.00	0.00
H05	156.55	5.70	3.58	1.75	0.00	0.00
Total	894.30	38.50	19.31	10.09	0.00	0.00

4.1 Pedestrian Characteristics

The characteristics of the flows for the two facilities and for both male and female pedestrians are summarised in Tables 4 and 5. Table 4 shows the pedestrian flows, walking speeds and the corresponding densities for the university environment. Clearly, male pedestrians moving to and from the female hostel area recorded the highest flow followed by students in the core academic of speed, male students moving in the direction of the theatre walked fastest, followed by commuting male students. Those walking towards the library seemed to be more relaxed and hence walked slowest. Female pedestrians walked fastest in the vicinity of their hostels and tended to slow down elsewhere in the campus. Commuting female students and those in the core academic areas increased the tempo of their walking but still fell short of the walk rates in their hostel. The combine walking speed pattern of the pedestrians (both male and female) showed that academic area was highest, followed by pedestrians moving around the male hostel block. Commuting students walked at 64.83 m/min behind those of female hostel and male hostel at 66.90 m/min and 66.45m/min respectively.

In the hospital environment, the main theatre attracted the most pedestrians with an average of 9.13 ped/min followed by pedestrians heading to the surgical wards with a flow rate of 7.13 ped/m/min as shown in Table 5. The least flow rate was in the direction of the emergency unit. In terms of the speed characteristics the male walked fastest towards the orthopedic unit with a speed of 72.62 m/min. This is followed by the emergency unit and post natal clinics with 71.43 m/min and 70.19 m/min respectively. The female walked fastest in the direction of the emergency unit with 75.11 m/min followed by the surgical wards 74.06 m/min and the post-natal clinics 73.70 m/min respectively. The combined walk rates however, indicated pedestrians in the hospital environment walked fastest towards the orthopedic unit with a speed of 74.28 m/min. The pedestrians walked rate towards the emergency unit was 73.56 m/min followed by the surgical ward pedestrian with a speed of 72.88 m/min.

Male pedestrians walked faster to all facilities in the university environment while female pedestrians prevailed in the hospital environment. The characteristics of the pedestrians in the university environment is summarised in Table 6. The average volume for the university is 7.01 ped/m/min with a density of 0.11 ped/m^2. The speed profile shows the male pedestrian to move faster than the female by 7% and the combine flow by 3%. The range of speed for the male is highest for the university environment.

Table 4 Pedestrian characteristics in the academic environment

Site Code	Location	Volume	Average Density	Mean Walking Speed (m/min)		
	University	PED/m/min	PED/m^2	Male	Female	Combine
U01	Female Hostel	15.11	0.23	66.55	64.52	64.83
U02	Commuting	6.81	0.10	67.40	62.69	65.36
U03	Library	3.72	0.06	62.21	58.43	61.67
U04	Lecture Theatre	3.16	0.05	69.80	61.51	64.58
U05	Academic Core	7.96	0.12	67.33	63.71	66.90
U06	Male Hostel	6.37	0.11	67.10	61.29	66.45

Table 5 Pedestrian characteristics in the hospital environment

Site Code	Hospital Environment	Volume	Average Density	Mean Walking Speed (m/min)		
	Location	PED/m/min	PED/m^2	Male	Female	Combine
H01	Main Theatre	9.13	0.13	68.31	72.22	69.71
H02	Post-Natal	6.53	0.09	70.19	73.70	71.61
H03	Emergency Unit	3.53	0.05	71.43	75.11	73.56
H04	Surgical Wards	7.13	0.10	70.15	74.06	72.88
H05	Orthopedic	5.20	0.07	72.62	73.04	74.28

In the hospital environment, the female walked fastest surpassing the male by 4% and the combined flow by 2%. The summary of the pedestrian characteristics is shown in Table 7. The walk rate in the hospital environment surpassed that of the university environment for all combination of pedestrians, suggesting that pedestrians in the hospital environment walked purposely towards their destinations. This may not be unconnected with the lifesaving activities at the destination ends of their trips.

On the other hand, pedestrians in the university environment walked more slowly in spite of the numerous academic activities that are time dependent and should spur students to be purposeful in walking. Consequently, the academic environment is slightly denser than the hospital environment..

Table 6 Summary of pedestrian characteristics in the university environment

Location	Characteristics	Mean Walking Speed (m/min)		
		Male	Female	Combine
University Environment	Mean Walking Speed	66.73	62.03	64.97
	Standard Deviation	4.48	4.16	4.85
	Range: High	76.75	66.50	69.20
	Low	60.18	53.42	55.83
	Density (Ped/m²)		0.11	
	Volume (Ped/m/min)		7.01	
	Sample Size		1,532	

Table 7 Summary of Pedestrian Characteristics in the Hospital Environment

Location	Characteristics	Mean Walking Speed (m/min)		
		Male	Female	Combine
Hospital Environment	Mean Walking Speed	70.54	73.63	72.41
	Standard Deviation	2.61	2.09	2.80
	Range: High	73.93	75.54	72.43
	Low	66.95	70.70	67.01
	Density (Ped/m²)		0.09	
	Volume (Ped/m/min)		6.30	
	Sample Size		1,070	

4.2 Modelling of Pedestrian Characteristics

Pedestrian flow parameters need to be modelled in order to be able to predict flow conditions and to design counter measures to prevent flow breakdown. Similar to Alhassan [22] and Alhassan and Edigbe [23], modelling flow conditions using the quadratic equation yield results that completely describe the traffic state. The maximum flow rate as well as the critical density can both be determined with ease. The bivariate relationships between speed and density, volume and density and speed and flow would have to be explored to know the traffic state parameters of interest for quantitative and qualitative analysis. The empirical speed-density data were used to plot the speed-density scatter diagram. This was fitted with a trend curve to see the relationship between speed and density for pedestrians in both the academic and hospital environments as shown in Figure 6 and Figure 8 respectively.

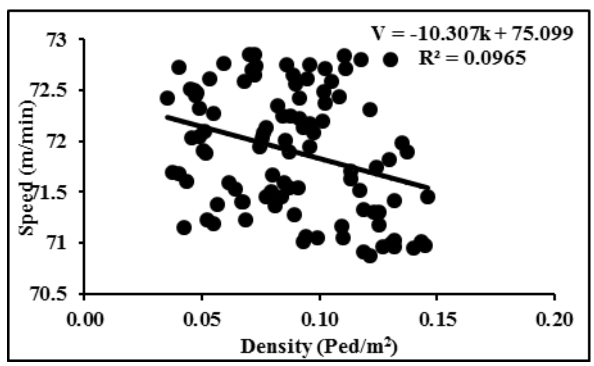


Figure 6 Speed-density scatter plot at teaching hospital

The scatter diagram as shown in Figure 6 reveals that the walking speed of pedestrians is highly random within the facility given the R^2 value of 0.096 obtained. No trend can be established between speed and density of pedestrians. Therefore it may be worthwhile to attempt to fit the speed data to a probability distribution function and hence carve out a way for understanding the walking speed pattern for pedestrians in the hospital environment.

The flow rate-density plot of pedestrians in the hospital environment is shown Figure 7. The trend plot and equation can be used to see a relationship between pedestrian volume and density. However, the free flow speed predicted in Figure 6 given as equation (1):

$$V = -10.307k + 75.099 \quad (1)$$

is 75.099 m/min with maximum density of 7.29 Ped/m². The critical density above which the flow rate could turn into the congested state as predicted by equation (2):

$$q = -8.615k^2 + 79.099 - 0.0987 \quad (2)$$

in Figure 7 is 4.36 Ped/m². The R^2 value associated with equation (2) is 0.999 indicating a strong correlation between pedestrian volume and density.

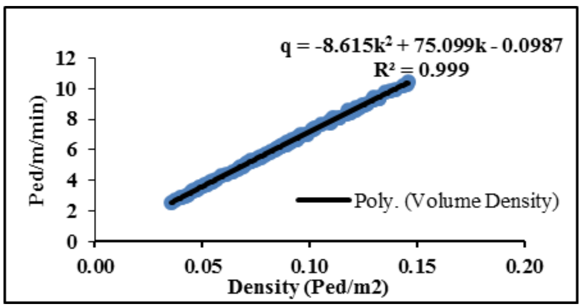


Figure 7 Volume-density plot at teaching hospital

In the case of the university environment, the speed-density scatter diagram fitted with a trend curve is shown in Figure 8. The model of equation (3) for the speed-density predicts a free walking speed of 68.052 m/min and a critical density of 3.55 Ped/m². The R^2 value associated with the linear equation in Figure 8 is 0.0057.

$$V = -4.1862k + 68.052 \quad (3)$$

The scatter points in this figure have a very poor correlation between speed of pedestrians and their density. Similar to the hospital environment, there is a need to seek alternate ways of understanding the relationship between speed and density of pedestrians in the university environment for qualitative analysis. This could be attained using a probability distribution to fit the speed data. The flow-density scatter diagram also fitted with a trend curve for the academic environment is shown in Figure 9. The equation (4) has a R^2 value of 0.989 suggesting a strong relationship between flow and density. The critical density above which congestion could set in is 3.15 Ped/m².

$$q = -10.805k^2 + 68.052k - 0.5118 \quad (4)$$

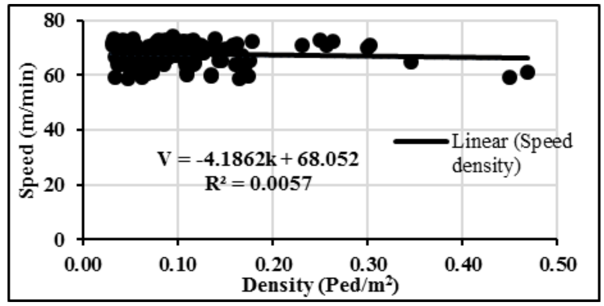


Figure 8 Speed-density scatter plot at university environment

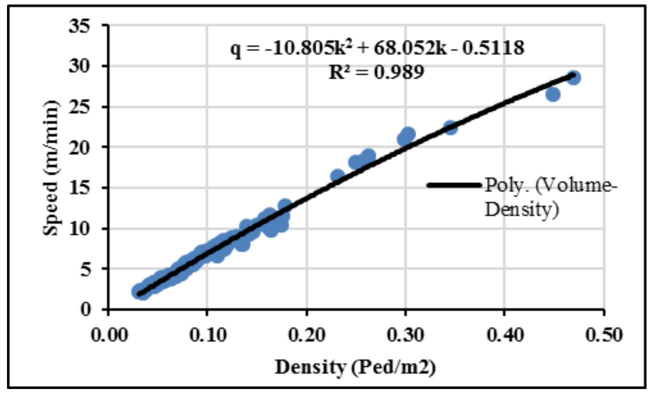


Figure 9 Volume-density plot at teaching hospital

4.3 Fitting Pedestrian Walking Speed Data to Distributions.

In view of the randomness of the speed-density data shown in Figures 6 and 8 for both Academic and Hospital environments, it is necessary to explore probability distribution functions that can best fit the speed data. The speed parameter is widely acknowledged as a continuous variable and hence would require a continuous distribution function to describe it. The normal distribution easily lends itself for selection and has thus been used to fit the pedestrian speed data. The probability density function and the cumulative distribution function plots for the academic environment are shown in Figures 10 and 11.

The model parameters of the normal distribution are μ = 66.72 m/min and σ = 5.97. The model mean value differs from the empirical data value by 0.01% for male pedestrians, 7.0% for female pedestrians and 2.6% for the combined speed of pedestrians. The cumulative frequency distribution for the academic environment shown in Figure 11 is used to understand the speed distribution of pedestrians in the facility.

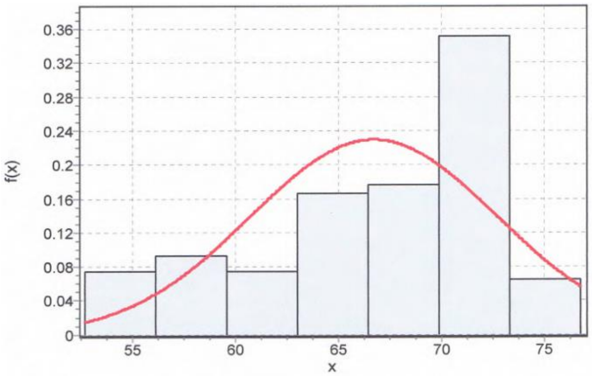


Figure 10 The PDF of speed for the academic environment

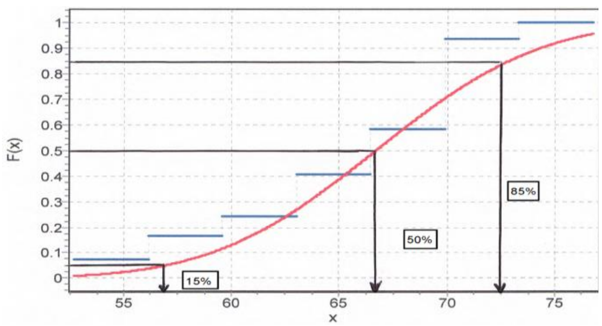


Figure 11 The CDF of speed for the academic environment

It shows that 15% of the combined pedestrians walked below 56.88m/min while 50% of the pedestrians walked below 66.67 m/min and 85% walked below 72.50 m/min. To ensure that the flow is not impeded by slow moving pedestrians at shared space locations, it would be necessary to widen the walkway.

The pedestrian speed data fitted to the normal distribution function for the hospital environment is shown in Figures 12 and 13 for the PDF and CDF respectively. The model parameters for the hospital environment are μ = 72.53 m/min and σ =2.758. This surpassed the male pedestrian speed in the hospital environment by 2.74%, but was less than the female by 1.52%. The combine speed of both male and female pedestrians was less by 0.17%. The cumulative distribution function of the speed data is shown in Figure 13. Like the University environment, 15th percentile of the combined pedestrians walked below 69.75 m/min. The median speed of pedestrians was 72.50 m/min while 85% of the pedestrians walked below 75.25 m/min.

The 15% walking speed in the university environment was less than the mean hospital environment speed by 18.5%. The median and 85th percentile speed were also higher in the hospital environment than the university environment by 8.0% and 3.65% respectively. Generally therefore, the pedestrians in the hospital environment walked faster than those of the university environment. However, the university environment contained higher number of walking pedestrian groups than the hospital environment and this may account for the observed phenomenon.

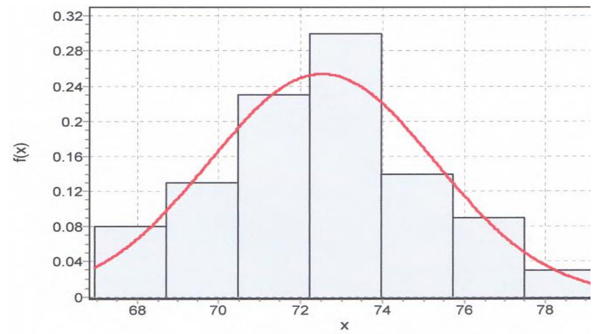


Figure 12 The PDF of speed for the hospital environment

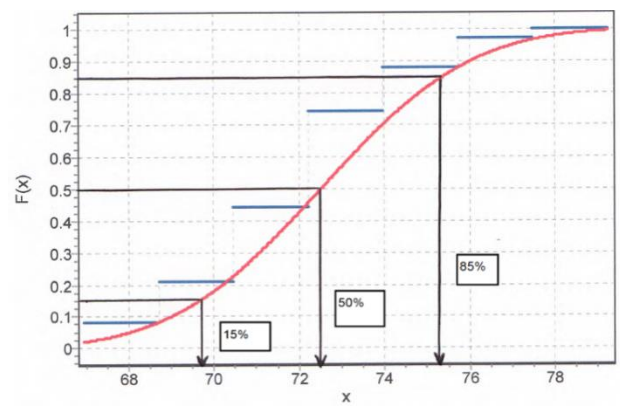


Figure 13 The CDF of speed for the hospital environment

5.0 CONCLUSION

The findings from the study can be stated as follows:

- Male pedestrians in the university environment walked fastest 69.80m/min when heading to the lecture theatre while female pedestrians walked faster 64.52 m/min when entering or exiting their hostel block. The combine walk rate 66.90 m/min was highest in the academic core area. The female hostel area recorded the highest flow rate of 15.11 Ped/min with a density of 0.23 Ped/m^2.
- The pedestrian group size distribution in the university environment showed 74% to be walking in singles, 16% for double, 4.2% for triple, 3.2 for group size of four, 1.3% for group size of five and 1.1% of pedestrians walked in groups of six.

Generally the male walked 7% faster than the female in the university environment.

- The speed-density relationship of pedestrians gave a R-squared value that cannot be relied upon to predict the quality of pedestrian flows. Instead, the speed data was fit to the normal distribution to see the speed distribution for qualitative analysis. 15 percent of the pedestrian population walked below 56.875 m/min, 50% walked below 66.667 m/min and 85% of the pedestrian population walked below 72.50 m/min. The 15 percent walking speed of 56.875 is only 14% of the mean speed and considering the pedestrian density of 0.11 Ped/m^2, the quality of flow is not likely to be compromised.

- In the hospital environment the female walked faster than the male towards all the units of the hospital, walking fastest towards the emergency unit at 75.11 m/min. The male walked faster towards the orthopedic unit with 72.62 m/min. The combined walk rate was 74.28 m/min in the direction of the orthopedic unit.

The flow rate was highest in the direction of the main theatre with 9.13 Ped/m/min with a density of 0.13 Ped/m^2.

- The group size distribution in the hospital environment gave single pedestrians as 83.6%, pedestrians walking in pairs as 7.2%. Three groups of pedestrians comprise 5.4% of the population while pedestrians in groups of four were 3.8%. Non five or six groups of pedestrians were observed in the hospital environment.
- The model equation for speed-density of pedestrians gave a R-squared value of 0.0057 indicating that it could not be relied for prediction. The speed data for the hospital environment was then fitted to the normal distribution. The 15 percent population of the pedestrians walked below 69.75 m/min, the 50th percentile walk rate was 72.50 m/min and the 85th percentile walk rate was 75.25 m/min.
- Since the 15th percentile population walk rate was only 3.82% less than the mean walk rate in the hospital environment, the quality of the flow is not likely to be compromised in shared space locations.

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