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PEDESTRIAN TRAVEL SPEED: CASE STUDY OF TOM MBOYA STREET IN NAIROBI KENYA

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ABSTRACT

The time interval in the operation of a transit system denoted travel time. To enhance public transportation space, and flow evaluations are essential to improve accessibility and mobility. The pedestrian speed is a significant parameter in analysis, design, and most important characteristic. The studies identify relative factors affecting walking to fulfil the gaps of understanding at-grade pedestrian speed and improvement needs. According to literature, mixed pedestrian group crossing speed range from 1.2 m/sec to 1.3 m/sec [13]. [23] stipulate walking speed range of 1.07 m/sec to 1.37 m/sec reliant on temperature, crowd size, surface texture, and sidewalk population.

The study finding established 1.14 m/sec crossing speed, at-grade maximum speed ranges from 1.17 m/sec to 1.26 m/sec for all gender, tentatively the study findings show an average 0.89 m/sec at-grade speed. Walkway operates at LOS D results recommends an adjustment to LOS C although effective footpath width is 1.95 m, more restriction exists along the sidewalks. The approximate pedestrian of 1.60 m^2/ped conveying 49 Ped/min/m to 75 Ped/min/m achieved. And the hostile street environment, inappropriate NMT regulations, and social attitude affect walking. The footpath operates at LOS D instead of the suggested enhancement to LOS C or higher based on pedestrian volume since it has a 1.95 m efficient walk width and area of 1.60 m^2/ped, sufficient to convey 49 Ped/min/m to 75 m^2/ped.

Key Words: Pedestrian Travel Speed, Flow Rate of Pedestrian and Pedestrian Walkway LOS.

INTRODUCTION

Walking speed and space are fundamental movement features in urban mobility and are indicators for urban congestion and essential for evaluating travel time. Pedestrian acknowledgment forms initial requirements for traffic engineers and urban planners. For

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optimal operation, level of service (LOS) evaluation indicates performance level. The LOS is a qualitative evaluation measure of traffic flow, utilizing speed and space management. Speed is essential in determining the mode frequency and operational timing of all urban transportation systems. Most findings exist on cross points studies although; limited research on at-grade pedestrian speed informs the walkway service. In public transportation, speed and space are vital in gauging facility performance levels. Consequently, zoning pedestrian source and concentration areas enable extraction on movement, design flow characteristics such as speed, space flow, and density.

However, Tom Mboya Street is in the dense centre of a vibrant Nairobi town (Kenya). Walking dominates all modes of transport, leading to low pedestrian velocities and overcrowding. Majorly the unidentified parking, hawking points, unlawful matatu (Commuter bus service operating similar to para-transit) stations, invasions, obstacles, dust dominates the area, and restrictive footpath affects the speed of the pedestrian and LOS. The demerits of NMT usage along Tom Mboya street outlined in the problem statements necessitate review and identifying necessary solutions to promote walking and uplifting NMT sustainable development. Necessitating the development of the test hypothesis. Outlining the singularity in transport infrastructure use; to enhance speed, flow, pedestrian activities, and attraction are impactful in LOS management. The null hypothesis relieves subject matters addressed, to satisfy hypothesis statements, achieved research questions; are urban mobility and congestion a factor of pedestrian speed, the contribution of space impact on flow? The objectives specifically include; examine and determine the average speed, mean speed flow rate of pedestrians and evaluate pedestrian footpath LOS. Limited to at-grade pedestrian need areas, their effects, and interaction with others users evaluates footpath usage needs and focusing on variable at-grade speed of individual pedestrians.

1. LITERATURE REVIEW

The reviews outline existing background knowledge by other researchers, drawing study gaps locally, worldwide and identify variables statements and models to understand pedestrian mode, focusing on objective statements.

a) At – Grade Walking Speed Study

Pedestrians within the Nairobi Koma Rock area registered a crossing speed of 1.41 m/sec although, the findings lacked a model validation framework, nevertheless though NMT facilities exist [17]. The results exceed the 1.40 m/sec proposed crossing speed [8]. More researchers established factors influencing walking speed. Young pedestrians less than 20 years achieve 1.24 m/sec faster, opposed to pedestrians above 50 years. However, the intermediate age group attains 1.20 m/sec. Density and speed are exponentially allied and fault by lack of explicit variable verification framework [21]. [2] evaluated urban and rural walking manners. Males age above 13-years – 60-years likely attains 1.45 m/sec walking speed, walking faster than women. Contrary to the urban where women age 7-years to 12-

years group walk faster, at 1.46 m/sec, and the speed affected by land use, age, and sidewalk availability influence.

b) Pedestrian Crossing Speed Study

Footbridge usage is gaining popularity along the major corridor where crossing facilities exist. Pedestrians use 1.56-minute walking at an average speed of 0.74 m/sec to cross the entire Uthiru footbridge in Nairobi. With average ascending and descending speed of 0.58 m/sec (utilizing 0.69 minutes) and 0.76 m/sec (0.45- minutes) respectively, the facility lacked people with disability (PWD) structures [11]. [13], Joogo road in Nairobi is a mix-use facility with existing walking and cycling lanes. Pedestrians cross two-lane carriage of 7 meters at an average speed of 1.20 m/sec to 1.30 m/sec waiting time of 16 seconds for an adequate grossing gap to exist. The findings adopt observational techniques marred with inadequate sampling information and model validation. Gauging usability for pedestrian crossing point at major arterial roads in Nairobi, [12] postulate pedestrian speed of crossing of 1.20 m/sec along Kenyatta avenue and 1.13 m/sec along University way. The values exceed 1.02 m/sec endorsed by [5]. The pedestrian areas at the cross point rely on the signal timing duration. Thus, the finding showed an area of 0.72 m^2 and 3.5 m^2 tentatively along Kenyatta avenue and the University Way. The values are within 0.6 m^2 – 3.5 m^2 endorsed by Fruin [6].

[3], examined signalized and non-signalized crosswalks in Malaysia – Kuala Lumpur 1.39 m/sec crossing speed attained at the non-signalized cross point. And suggestive of signalized crossing speed of 85^{th} and 15^{th} percentile range of 1.31 m/sec, 1.53 m/sec, and 1.09 m/sec correspondingly. While at a non-signalized cross point similarly, percentiles are 1.39 m/sec, 1.63 m/sec, and 1.15 m/sec in turns with rampant age influence on speed and higher speed achieved at signalized points. [4], at a crosswalk, younger pedestrians are faster than old pedestrians in Portland, Oregon, USA. Achieving average speed of 1.51 m/sec, despite 15th percentile speed of 1.24 m/sec and 1.07 m/sec for young and old pedestrian. For design, 1.2 m/sec speed, suggested when elder lies are less than 20 percent suggested by [6]. [18], identify the pedestrian mode (age and gender), infrastructure (location, platform, and terrain), and environmental (cloudy, sunny, or raining) challenges as walking impediments. It is essential to consider all the factors.

c) Level of Service (LOS)

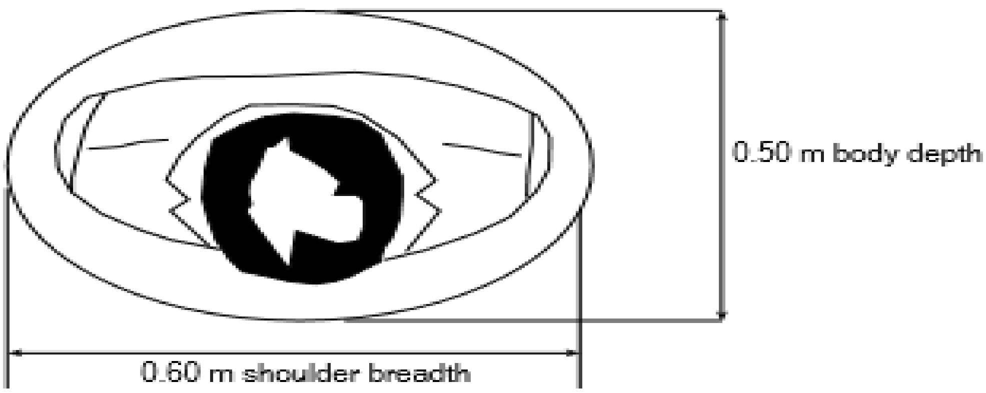
The level of services (LOS) is a qualitative metric, the descriptor of road user traffic stream operational conditions and traffic flow quality perception [7]. Pedestrians usually walk in groups, voluntarily or involuntarily, owing to controls along the path, movement purpose, and footpath geometry, leading to inflow fluctuations. The platooning is the effect of short-term flow fluctuations. LOS ranged from A to F, and pedestrians can use LOS A to choose their preferred speed, which means that the facility and the path are in good operating condition. When at LOS F, walking speed is severely limited with frequent, inevitable contacts, which means the facilities operate poorly [7]. Although [10] gives LOS measurement scales through quantitative walking environment descriptions, although result interpretation is challenging. The finding preceded [20] illustration suggested protection, safety, suitability, well-being, steadiness, system rationality, and desirability as factors affecting LOS. Koma rock zone (Nairobi area) utmost footpath function at LOS F with 94 ped/min/m flow rate [16] contrasting to 79 ped/min/m attained in Nairobi CBD cross point influence by periodic variation [12]. [11] Acknowledge LOS F as the operation capacity of Uthiru footbridge, recommending improvement to LOS C where stream flow controls are necessary. [14], pedestrians prefer the route with more right of way divergent to the signalized cross point in Sapporo - Singapore. Through step-wise regression analysis, factors affecting intersection, estimate pedestrian LOS at corner and cross point, to improve NMT usage, were examined. Equation 1 model was adopted yielding variable tried are tiresome to develop. Accentuation by [17] assesses pedestrian LOS 15 minutes counts of pedestrians passing a specified point afterward, reducing the figure to one minute further dividing with effective width.

$$\text{Pedestrian LOS at crosswalks} = 7.842 + \sum_{i=1}^{3}\sum_{j=1}^{3} Dij\,\partial ij - (0.037 * Pd) - 0.0031Pb \qquad (1)$$

Where: Dij – categorical scores linked to the jth level of the ith characteristic, ∂ij - 1 if the jth level of the ith characteristics exists, Pd - pedestrian delays in seconds, and Pb – number of pedestrians- bicycle interactions.

d) Pedestrian Body Ellipse and Walking Space

The space and width of the footpath should accommodate user body size. These human body proportions are defined by body ellipse, defining the dimension in terms of body depth and breadth (shoulder breadth) of regular dimension pedestrian. It is significant in space requirement assessment for footpath development. Figure 1 demonstrates the simplified boy ellipse dimension of area 0.30 m^2 [5]. Figure 2 illustrates the zones required for movement. The pacing zone is significant in step making while the sensory precinct (zone) impacts forward steps. The space requirement is firmly attached to speed and space relationships, also useful to determine LOS.



Source: Fruin (1990)

Figure 1: Body ellipse Plan view

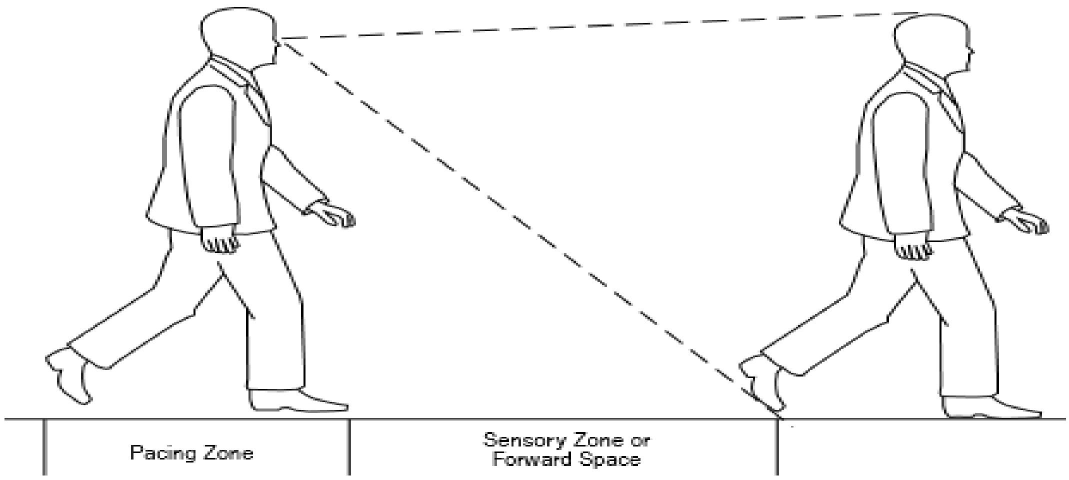


Figure 2: Pedestrian Walking Space.

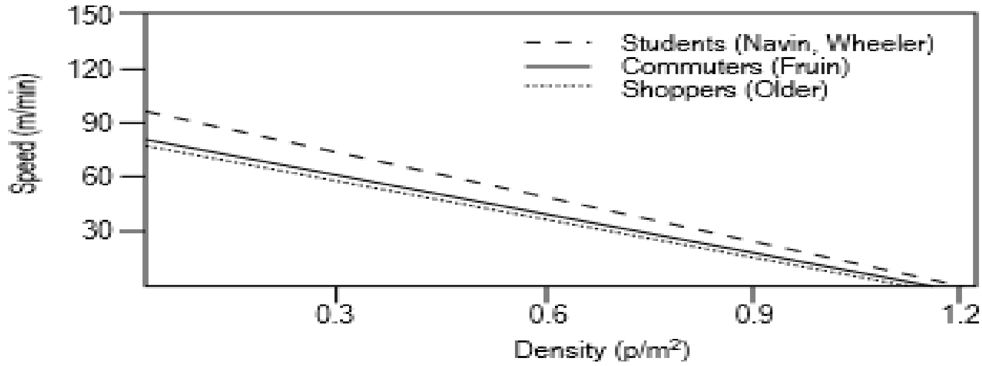
(Pacing zone: - Spaces available for making steps. Sensory zones the distance between the toe of pedestrian of subsequent pedestrians)

Source: Fruin (1990)

e) Pedestrian Flow Relationship

1. Pedestrian Speed - Density Relationship

The rate of change of pedestrian density is inversely proportional to speed. Available space impact mobility and speed for the students, commuters, and shoppers expressed in Figure 3.

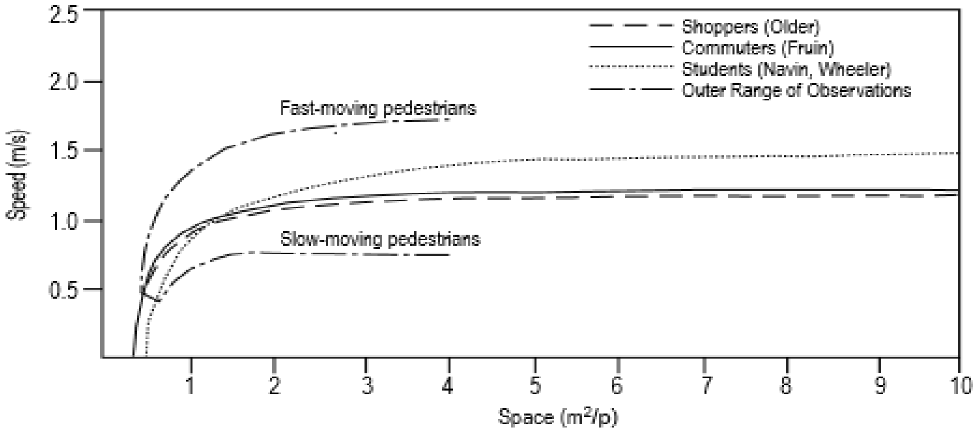


Source:Pushkarev andZupan (1971)

Figure 3: Association Amongst Pedestrian Speed and Density

2. Pedestrian Speed - Space Association

Figure 4 shows the association among speed and space criteria fundamentally used for LOS evaluation [7]. [17], suggest that as space increases, a higher walking speed of 1.8 m/sec achieved. At space of more than 4.0 m^2/ped reduced to less than 3.5 m^2/ped, flow is comparable. Correspondingly, as the space per person increases, pace choice ability increases.

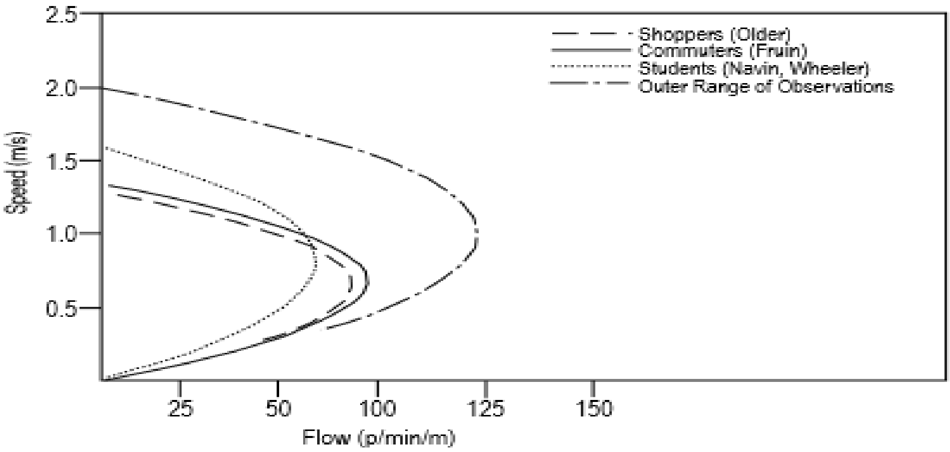


Source: Pushkarev and Zupan (1971)

Figure 4: Pedestrian Speed-Space Linkage

3. Pedestrian Speed - Flow Relationship

Figure 5 shows the link between pedestrian travel speeds and flow. As flow increases and speed declines, crowding results in speed decline [17].



Source: Pushkarev and Zupan (1971)

Figure 5: Association Amongst Pedestrian Speed and Flow

4. Pedestrian Flow - Density Relationship

[7], reveals the linkage between density, speed, and flow equivalent to vehicle traffic flow stream, illustrated by Equation 2:

Vped = Sped *Dped (2)

Where: V_{ped} – Unit flow rate (ped/min/m), Sped – Pedestrian speed (m/min), and D_{ped} – Pedestrian density (ped/m^2). The most suitable expression for [17] uses mutually beneficial density or space as follows:-

Vped =Sped/M (3)

Where: M – Pedestrian space m^2/ped

[17] Propose a peak of 15 minutes of pedestrian count with certain variables of width used in determining the unit flow rate, as shown in Equation 4.

$Vp=V_{15}/(15*W_E)$ (4)

Where: W_E – Effective footpath width (m), V_{15}– peak 15min flow rates, and V_p – Pedestrian unit flow rates (ped/min/m), When space falls below 0.4 m^2/ped flow rate all moves effectively stop at the least allocation of space of 0.2 m^2/ped, expresses the technique of LOS evaluation.

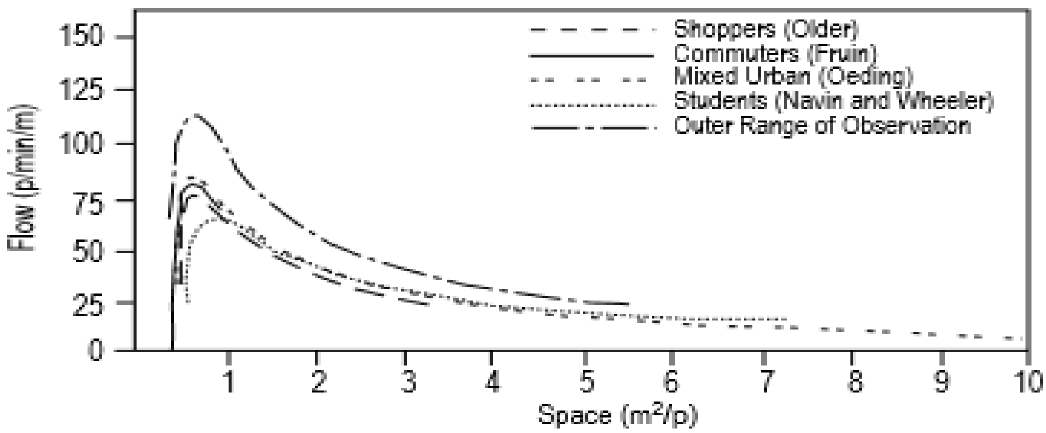


Figure 6: Association amongst Flow and Spaces of Pedestrian

F) Effective Footpath Width

Effective width is the proportion walkway utilized by pedestrians devoid of shy distance and obstruction. Effective walking width use to analyze the flow, [1] recommends

2.4 m and 1.5 m width for commercial buildings and clear sidewalks. However, lane conception does not apply to NMT study of the effect of abreast and unidirectional pedestrians need consideration. Pedestrian passing one another needs space not less than 0.8 m width, although pedestrian who knows one another use space less than 0.7 m, the likelihood of body sway occurs [17]. Equation 5 evaluates effective width [7].

Effective walkways width $W_E = W_T – Wo$ (5)

Where: W_E – Effective walkway width (m), W_T– Total walkway width (m), and Wo – the sum of the width and shy distance from obstructions.

3. RESEARCH METHODOLOGY

The study adopts regression analysis to appreciate, examine pedestrian speed, and the result presented graphically and manual data collection technique adopted. Isolated individual pedestrian speed evaluated, independent variable, and existing empirical models used, to examine speed parameters. The manual speed count technique was employed, and the speed and travel information was derived and omitting the effect of the unilateral movement. The results adopt a microscopic model to explain discrete pedestrian speeds, space using flow and speed equations from the past literature. Microsoft Excel enables analysis of the collected pedestrian information.

The results are graphical to show an appropriate display of the flow. Through a questionnaire, socioeconomic information was collected and analyzed. Physical inspection and street inventory assessments were conducted in the study area to collect street information such as; sidewalk geometry, identification of survey areas, street lighting provisions, pavement conditions, crossing points, vehicle sightlines, and Land use. Pedestrian travel data gathered from varieties of sources during desktop research. These sources include published and unpublished documents and articles. Standard data collection forms obtain from [7] were used for data acquisition. Pedestrian walking speed, gender, age amides other evidence gathered and reported. Footpath users are classified; pedestrians, cyclists, and motorists. Manual time recording using a stopwatch for pedestrian passing marked segment at predetermined length recorded, subsequently interviewed after passing the marked section to capture pedestrian attributes such as socioeconomic status. This chapter summarizes test procedures and variable verification framework.

4. RESULTS AND ANALYSIS

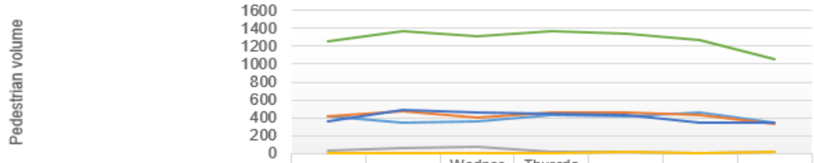
a) Volume, Age Group, Journey Purpose of Pedestrian

The footpath user volumes were to establish flow utilization through the manual count method to examine unidirectional flow, to identify critical peak flow periods. With a 15-minute interval, the capacity (volume) was represented, in hourly and weekly data, with daily flow considered in 15 minutes (Table 1). A total of 1280 pedestrians were counted every 15 minutes on average. Figure 8 shows the change in pedestrian volume over each 15-minute interval. Figure 7 illustrates the weekly average pedestrian flow, with a graphical representation in Figure 8 and Table 1.The largest group of pedestrians interviewed were between 25 years to 35 years, which accounted for 28 percent, 26 percent of interviewees in 35-year to 40-year, while 16 percent of respondents over 40 years of age. Individual trips from home to the CBD were established by asking pedestrians their trip purpose. The trips were categorized as: - work, business, shopping, school, entertainment, and others. Students were the largest group, accounting for 23 percent of the total interviewee. While 17 percent were on business trips and 27 percent were on a work trip. Leisure travel accounts for 13 percent of all trips. Mode choice derived mainly due to financial constraints, comfort, efficiency, exercise, lack of PSV, and among other reasons. Pedestrians majorly preferred walking at 34 percent due to walking comfort and 25 percent financial constrain. The desirability of the area for shoppers drew 17 percent, the majority being on a purchasing quest.

Day of the week	Average pedestrian in 15 minutes interval					
	Male	Female	Children	Physically challenged	Crossing pedestrian	Total pedestrian
Monday	422	421	38	6	367	1255
Tuesday	345	468	57	9	489	1368
Wednesday	356	404	78	8	465	1311
Thursday	434	456	15	12	450	1367
Friday	412	457	17	16	432	1334
Saturday	467	431	12	8	348	1266
Sunday	341	336	18	16	346	1057
					Average	1280

Source: Authors (2020)

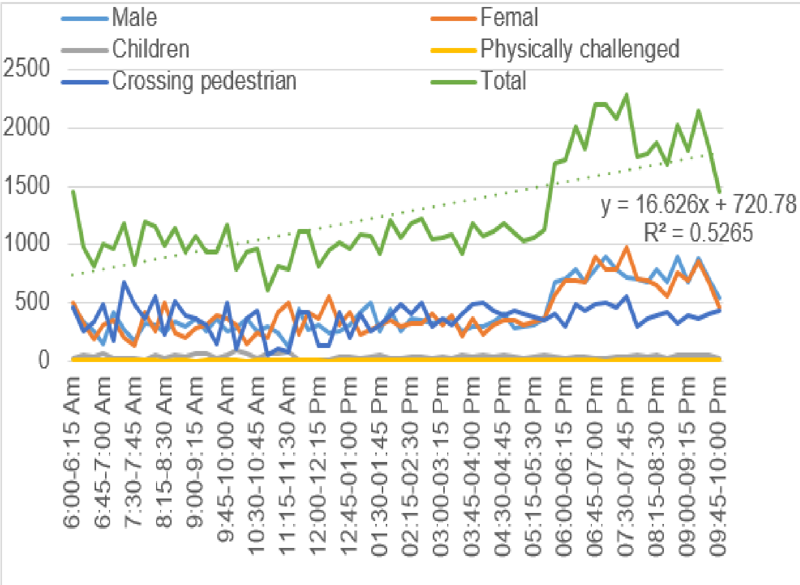
Table 1: The Average pedestrians flow in 15-minutes intervals.



	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average pedestrian in 15 minutes interval Male	422.453125	345	356	434	412	467	341
Average pedestrian in 15 minutes interval Female	420.8125	468	404	456	457	431	336
Average pedestrian in 15 minutes interval Children	38.171875	57	78	15	17	12	18
Average pedestrian in 15 minutes interval Physically challenged	6	9	8	12	16	8	16
Average pedestrian in 15 minutes interval Crossing pedestrian	367.078125	489	465	450	432	348	346
Average pedestrian in 15 minutes interval Total	1255	1368	1311	1367	1334	1266	1057

Source: Author (2020)

Figure 7: Average flow of pedestrian in 15 minutes counts.



Source: Authors (2020)

Figure 8: Pedestrian count for every 15 minutes.

b) Pedestrian Walking Speed

The footpath was marked randomly with caution not to impact the movements and speeds of the pedestrian. The distance between marked bollard posts acts as the speed screening point, and the duration measured using a digital stopwatch. Equation 6 calculated was used to compute the pedestrian speed. The maximum pedestrian speeds reached in Tom Mboya Street Postal stage counter station range from 1.20 m/sec to 1.31 m/sec high speed recorded on Monday. The average footpath speeds documented were 0.91 m/sec - 0.97 m/sec moreover, the haste (speed) linearly decreases as the week progresses (See Table 2 and Figure 8).

$$S = D/T \qquad (6)$$

Where S – Segment speed m/sec, D – Segment distance (m), and T – Time (sec)

No	Day of the week	Speed Maximum (M/sec)	Speed Minimum (M/sec)	Speed Average	Level of service (using table 3)	Sample size
1	Monday	1.31	0.59	0.95	E	26
2	Tuesday	1.27	0.67	0.97	E	26
3	Wednesday	1.20	0.64	0.92	E	26
4	Thursday	1.23	0.59	0.91	E	26
5	Friday	1.24	0.64	0.94	E	26
6	Saturday	1.26	0.59	0.93	E	26
7	Sunday	1.29	0.61	0.95	E	26

Source: Authors (2020)

Table 2: Pedestrian speed – Posta stage

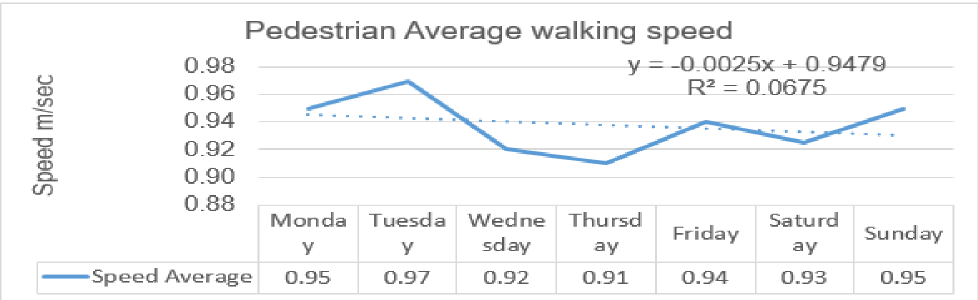


Figure 9: Pedestrian speed measured at Posta stage

i) Observed At-grade Walking Speed and Crossing Speed

The walking speed varies with time of day due to street congestion. However, genders impact these speeds. At the peak time, low flow speed dominates since different activities block the flow of the pedestrian. The result shows males achieving an average 0.96 m/sec speed and a maximum speed of 1.26 m/sec, while females attain 1.03 m/sec. The highest achieved walking speed is 1.30 m/sec. The mean walking speed was 0.89 m/sec. Although most women walk with handbags, this luggage has a negligible effect on walking speed. At the intersection between Mboya and Luthuli Street, one leg of a 7 m wide road pedestrian crossing speed was examined and analyzed. Trying to cross speed was gender-based. The obtained results were faster for women than for men when crossing the road. The mean speed of crossing for men was 1.17 m/sec, whereas women register 1.10 m/sec. However, the average pedestrian crossing speed was generally 1.14 m/sec. It takes 4.3 seconds and 8.6 seconds consecutively to cross each lane which implies pedestrian cross running.

c) Pedestrian Level of Service

Table 3 illustrates the footpath width of 1.95 m used by 1280 pedestrians on both sides every 15 minutes. The average speeds from the findings suggest the LOS E [7], utilizing an area of 1.60 m2/ped. And an average pedestrian speed of 0.89 m/sec for the speed assessment. Assessment of the existing track features in Table 3 suggests LOS D. The data analysis fulfills the objective needs, sufficient for study discussions with inference drowned from the literature review.

Item	**Parameter**	**Formula**	**Calculation**	**Results**	**Remark**
Effective walkway width	Curb width Street furniture width Building protrusion Inside clearance	W_E=W_1-W_2	$\mathbf{W_E}$= W_T - W_B = 1.95m	1.95m	Values obtained from the site Equation 5
Pedestrian Peak Volume, V_P		V_P =1280 ped		1280 ped	
The total length of the walkway		L = 1050m		1050m	Road length measured manually
The effective walkway area		WA = W_E*L	=1.95*1050 = 2047.5 m^2	=2047.5 m^2	
Average pedestrian space		APS =Area/V_P	Area =2047.5/1280 =1.60m^2/ped	=1.60m^2/ ped	
LOS equivalent				LOS D	Result obtained from table 5

Source: Authors (2020)

Table 3: Walkway width evaluation

5. DISCUSSION OF THE RESEARCH FINDINGS

A) Pedestrian Volume and Space

The analysis of pedestrian volume helped in commuter design as well as safety. Because of regional transit access, land use mix, and job density, the number of the pedestrian in the area is increasing. [19], showed that planning and design usually represent peak flow during the peak period of the season. The finding acknowledges that pedestrian requires 1.28 m^2 to make a step. Assessments of existing road structures and changes in road development strategy were obligatory to accommodate many of the pedestrians in Nairobi CBD [15]. The study determined a pedestrian area of 1.60 m^2/ped required for LOS D. As a result, street redesign is necessary to improve the LOS C route (Table 3). As space reduces to less than 0.4 m^2/ped, the flow rates rapidly decrease. At the smallest capacity, planning of 0.2 m^2/ped to 0.3 m^2/ped, movements become impossible [7].

However, pedestrians over 40 years of age contribute 7 percent to the footpath. Further, other techniques need to be related to the findings. Age-including demographics influence choice and travel behavior. Age affects travel distances, where older people travel less than young people [22]. Aged people do not generate as many trips as young people [9]. This trend is in line with the age-related theory advanced by [22] and [9] versus the rate of travel or distance commutations.

B) Walkway Density and Space

Every pedestrian uses an area of 1.60 m^2/ped. In this area, movements are restricted and progressively reduced. Table 3 suggested LOS D with a flow rate of 33 Ped/min/m to 49 Ped/min/m. [7] established that at LOS D and pedestrian speed is restricted. And careful steps movement made to excuse on-coming pedestrians. Standard user ellipses of 0.5 m by 0.6 m having a total surface area of 0.3 m^2, which would be the practical average for standing areas and space for a single pedestrian.

In assessing the shopping facilities, an area of 0.75 m^2, utilized as bumper zones for every pedestrian, and 400 ped/h default flow was recommended [7]. The unexpended physical space, contacts with others are frequently unavoidable. The acceptance space of 75 ped/min/m or 4,500 ped/h/m is rational if the local data does not exist. At this capacity level, walking speeds of 1.14 m/sec, deemed acceptable [7]. With an irregular and unbalance flow, cross-flows and reverse-flows movements were nearly impossible. The enhancements to LOS C increase pedestrian space from 2.2 m^2/ped to 3.7 m^2/ped, with a rate of flow of 23 ped/min/m to 33 ped/min/m. This LOS level was enough to allow unidirectional flow [7].

Level of Service	Space (m^2/p)	Flow rate (p/min/m)	Average Speed (m/s)	V/C ratio
A	≥ 5.6	≤ 16	> 1.3	≤ 0.21
B	3.7 - 5.6	16 – 23	1.27 - 1.30	> 0.21 - 0.31
C	2.2 - 3.7	23 – 33	1.22 - 1.27	> 0.31 - 0.44
D	1.4 - 2.2	33 – 49	1.14 - 1.22	> 0.44 - 0.65
E	0.75 - 1.4	49 – 75	0.75 - 1.14	> 0.65 - 1.00
F	≤ 0.75	Variable	≤ 0.75	Variable

Source: HCM (1998)

Table 4: Average LSO flow for the sidewalks

C) Pedestrian At-grade Walking Speed and Crossing Speed

The finding hypothesizes the maximum pedestrian speed of 1.17 m/sec to 1.26 m/sec, with an average walking speed of 0.89 m/sec for different age groups. [17] Recommend 1.5 m/sec to enhance free flow and crosswalk speed of 1.14 m/sec. Male pedestrians, for example, males crossed at a speed of 1.17 m/sec, while 1.10 m/sec for females. [11] Established a 0.74 m/sec at-grade crossing speeds between two highways separated by separation barriers, it takes 1.56 minutes to cross the footbridge at-grade, at a mean time of 1.06 minutes. A pedestrian crossing a 7-meter carriageway takes 5.5 seconds, according to [13], with pedestrian crossing speeds ranging from 1.2 m/sec - 1.3 m/sec at busy crossing points with a variety of age groups for pedestrians. [12], found that pedestrian speed of 1.20 m/sec on Kenyatta Avenue and 1.13 m/sec on University Way was exceeding. [5] thesis recommendation of 1.02 m/sec pedestrians on this street walk slower than on other road segments in Nairobi, according to studies published in the literature, Table 6 summarized the study results. According to [3], the average speed for pedestrians in Malaysia at a non-signalized crosswalk is 1.39 m/sec. In Malaysia, the mean 85th and 15th percentiles pedestrian speeds at crosswalks with signals are 1.31 m/sec, 1.53 m/sec, and 1.09 m/sec, respectively, while non-signalized crosswalk pedestrian speeds, 1.39 m/sec, 1.63 m/sec, and 1.15 m/sec exhibiting slow walking.

Crossing speed (m/sec)	Walking speed (m/sec)	Space (m^2/ped)	Flow (peds/min/m)	LOS
1.14	0.87	1.60	33 -49 (from table 4)	D

Source: Authors (2020)

Table 5: Pedestrian study data summary

Conclusions

The average pedestrian walking speed ranged from 0.87 m/sec to 0.93 m/sec at an area of 1.60 m^2/ped with 1.14 m/sec pedestrian crossing speed at a time interval of 8.6 seconds, at a flow rate of 49 to 75 Ped/min/m. The findings provided a 1.95 m effective walking width, with an operating capacity of LOS D. From the results, improvement was essential to LOS C, and impediment along the path affects LOS.

RECOMMENDATIONS

The logical approach was applied to address NMT challenges. This research demonstrates that analyzing pedestrian speed gives more insight into the effectiveness of walking time, how pedestrians perceive and interact with their environment. Footpath improvement must be incorporated into all road development plans in Kenya to improve pedestrian travel speed and achieve the recommended level of service.

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