Pedestrians' Sidewalk Development and Level of Safety in Ikeja Area, Lagos Nigeria

Bashiru Adisa Raji[1], Muse Olayiwola Solanke[1], Taiwo Kareem Alli[1]

[1]Department of Transport Management, Olabisi Onabanjo University, Ago-Iwoye, 120107, Nigeria

Abstract Safe and accessible pedestrian sidewalk is significant to sustainable infrastructural development and industrialisation of core of cities in world over. Studies have shown that safety of pedestrian on walkways aid their ability to shop more than sitting in the comfort of their vehicles. The study modelled the influence of lateral separation (LS) (sidewalk separation); volume of motor vehicles (VM); speed of motor vehicle (SM) and vehicular access to adjoining properties (VA) on pedestrians' level of safety (PLS) along the streets of core area of Ikeja. Fifty-six (56) road segments were observed, measured and field information obtained analysed. Though, LS, VM, SM and VA contributed about 58.1% to (PLS) in Ikeja, the results further revealed that PLS increased with LS distant vehicles (β_{sd}=0.60, t_{sd}=5.14), but decreased with higher VM (β_{vv}=0.20, t_{vv}=1.73) and SM (β_{sp}=0.07, t_{sp}=0.76). It was recommended that a standardised distance of LS from moving traffic and its wideness; the required SM of vehicles and increased investment on pedestrian facilities in urban centre will improve pedestrian safety and as well promote sustainable industrialisation since pedestrian form major traffic of the industries.

Keywords Inc Level of Service, Lateral Separation, Volume of Vehicles, Adjoining properties

JEL R4, R41

1. Introduction

Spatial movement comprises of both motorized and non-motorized mode, while motorized mode includes cars, trucks, buses, motorcycles, and so on, non-motorized mode include pedestrians and bicycling [14]. In world over, roadways consist of dissimilar kinds of motorised and non-motorised vehicles that operate at diverse accelerating capacities [6].

For the most vulnerable populations the trend towards increased motorization is harmful. Increase automobiles use; do add to road traffic accidents which often escalate the well-being of commuters in terms of environmental externalities. Crash statistics has shown that the growing pattern of motorisation has endangered exposed motorway consumers such as bikers and walkers due to their neglect over the years [8].

Sustainable transportation systems involve mobility and accessibility planning that also focuses on pedestrians and cyclists, not vehicles only. Pedestrians and cyclists also use these spaces, to move toward their right-of-way which gives room for easy movement. Inaccessibility and immobility pedestrians and cyclists space deficiencies have increased pedestrian and cyclists' level of safety [12]. "[2]" described pedestrians as people who use other means of movement apart from automobiles such as walking, riding model cycles on designated walkways and people who descending from other means of transportation. "[1]" sees pedestrian as "any person wishing to travel by foot, wheelchair, or electric scooters, throughout the community. In modern times, pedestrian is mostly referring to as people traveling on foot especially in an area also used by cars. Concisely, pedestrian is any person that travels by foot, and this involves walking [13].

Lagos is among the world's fastest-growing cities. It is projected to be the world's third largest megacity with an annual growth rate of 6% and population that falls between 18 million and 20 million. Lagos GDP growth in dollars was in excess 80 billion in 2010. It could have been eleventh largest economy in Sub-Saharan Africa if it were to be a country. It is the fiscal powerhouse of Nigeria, with wide-ranging financial activities, which added about 62% to non-oil of the nation's GDP [5].

A good transportation network connects people and improves the economy of a city. It was meant to be socially, politically, and environmentally friendly. Major urban problems particularly in Lagos arises due to the fact that most inhabitants prefer to use personal vehicles as means of transportation in order to ease and improve their social status thereby increases motorization and congestion. Increase motorization thus encourages decentralization, space extension and infrastructural expansion [15].

Goal 9 of the SDGs is to develop robust infrastructure, encourage comprehensive and justifiable development and nurture modernization. By 2030 one of the objectives is to develop efficient, effective, and improved industrialization,

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facilities nationally and internationally in order to promote growth and social well-being for all. But the available infrastructure in Lagos especially road is greatly overstretched and if this trend persists; negate Goal 9 of SDGs that promotes sustainable infrastructural development and industrialization.

Adequate mobility and accessibility are necessary for sustainable transport infrastructure and services. This is because mobility is the ability of people to move from one point to the other in terms of distance and prompt arrival times. Therefore, social and economic opportunities depend on accessibility that is determined by money, time, dis-comfort and the risks associated with it. Non-motorised mode (walking and bicycling) thus provides simple and friendly environment to gain entrance to public transport and many facilities [6].

In recognition of the targets of Goal 9 of SDGs and the role of pedestrian traffic in activities such as businesses, public institutions, commercial activities, trading, residential, recreational and creation of employment, Lagos State Government (LSG) of Nigeria in April 2018 design Non-Motorised Transport (NMT) policy is to aid wellbeing, care and convenience of walking and use of bicycles in the state in Lagos through allocation of reasonable motorway space in transport projects that accommodate non motorised and communal conveyance in the development, and strategy [6]. Achieving NMT policy, LSG aims at creating judicious access to communal conveyance and discourages the usage of private automobiles, by constructing not less than 470 km of Mass Rapid Transit (MRT), 900 km of walkways, and 300 km of bicycle paths. However, the existing traffic situations in Lagos involve heavy vehicular traffic and motorists experience difficulties to move and park. Consequently, cars are parked in a disorderly manner along sidewalks, street corners and pedestrian thresholds creating serious bottlenecks and traffic congestion within the city. These difficulties are more pronounced in the city's central business district.

The phenomenon also presents itself in suburban business centers as well. In relation to these problems is the increase demand for pedestrian trips, inadequate pedestrian facilities, and non-availability of pedestrian trips information as well as model that can assist in the decision processes. Therefore, this study is an attempt to model the existing situation in order to contribute to policy direction of NMT policy of the state by creating insight into NMT users' (particularly the pedestrian) likely safety problem in the use of available facilities and areas NMT policy needs to give priority when upgrading existing facilities in order to achieve sustainable infrastructural development and industrialization in the state.

2. The Study Area

Pedestrian activities occur all over Nigeria, but they are more noticeable in urban areas. Ikeja (Figure 1) in the city of Lagos is chosen for this study.

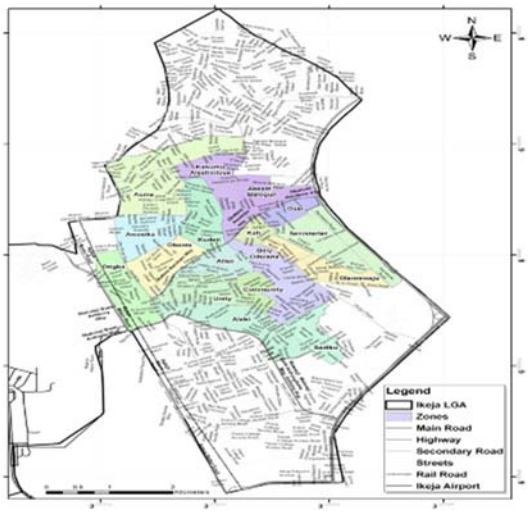

Figure 1. Map of Ikeja with carved zones

Lagos stands out as one of the 36 states in Nigeria with the highest concentration of industries and commercial activities with explosive population.

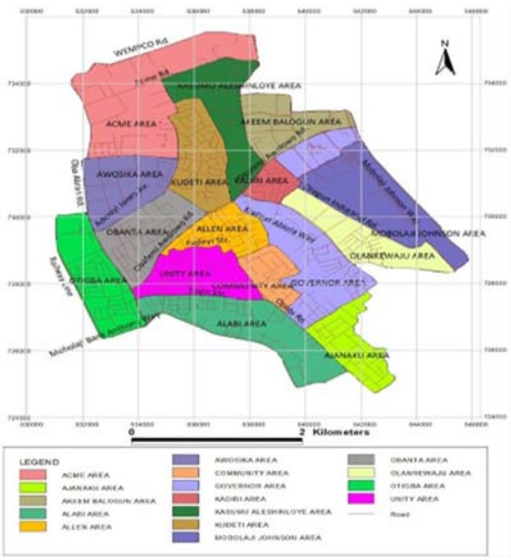

Figure 2. Map of carved zones

The choice of Ikeja is due to its high intensity of businesses and commercial activities, its roles as the capitals of Lagos state's attribute as the country's commercial nerve also makes it the most unpredictable in terms of pedestrian and vehicle traffic [10, 11]. Lagos is also ranked as one of the fastest growing urban area in Africa and 7th in the world [4]. Lagos State and Ikeja Local Government Area, the amount of pedestrian and vehicular traffic generated daily in and out of Ikeja, has made pedestrian and vehicular congestion a recurrent problem, parking problems is clearly prominent while pedestrian circulation during the day is critical.

The study area is the core economic area of Ikeja. It is bounded in the west by Lagos-Abeokuta and Agege Motorway, in the east by Lagos – Ibadan expressway, south by Mobolaji Bank Anthony way, north by WEMPCO road (Figure 2). The area was however delineated into seventeen zones and each zone is named after a popular street in the zone.

3. Methodology

In LSG 2018 NMT policy, safety of pedestrians as well as cyclists is one of the most basic necessities desired to support and expand non-motorised mode of transport. In an attempt to model NMT users' particularly pedestrian level of safety (PLS) multiple regression analysis and modified [7] model was adapted.

3.1. Variables Affecting Pedestrian Walking Environment

Modelling non-risk level of people walking depends solely on the threshold (Level of Service) along roadside walking environment and this entails: (i) provisions of sidewalks and walkways with buffer zones to separate pedestrians from the roadway; (ii) provisions of street furniture and marked crosswalk; (iii) provisions of curb ramps and transit stop; (iv) provisions of roadway lighting and (v) provisions of pedestrian underpasses and overpasses. There is also a general believe that PLS in a road strip is centred on a composite variable. These independent variables had been quantified as performance measure by Landis et al, 2001 which has also been subjected to extensive research. The variables are:

1. Sidewalk Availability
2. Pedestrian segregation from automobiles
3. Obstructions and shield between foot-travelers and automobiles
4. The number and composition of motor vehicles
5. Impact of speed of vehicles, and
6. Driveway frequency and magnitude.

The following variables, however, appear in a long list of variables thought to have affected the degree of protection of pedestrian (pedestrian's level of safety-PLS) in the streets and they are:

1. *Side Segregation - substructure that demarcate people from automobiles traffic*: These include (i) availability of sidewalks, (ii) breadth of walkways, (iii) shields demarcating walkway and automobile ways, (iv) availability of blockades in the shield area, (v) availability of on-street parking, (vi) breadth of motorbike lane aside main mobile lane.
2. *The volume of vehicular traffic*
3. *Speed effect of automobiles*
4. *Influx of vehicular traffic that is proportion of automobiles in the traffic*
5. *Incidence and capacity of Driveway access*

In section 3.2, variables itemised in this section were used to explain pedestrian safety level in Ikeja area of Lagos.

3.2. Analysis of Pedestrian Safety Level Model in Ikeja Area

Pedestrian level of service is a threshold for free flow of pedestrian movement on walkways and this serves as surrogate for determining pedestrian level of safety along roadside [3, 9]. Developing the model, fifty-six (56) road sections where pedestrian activities predominate were selected in the seventeen (17) zones understudy. Field measurements and observations rather than pedestrian perceptions were employed in developing the model under the following subheadings:

3.2.1 Availability of Walkway and Side Segregation

In facilitating pedestrians' protection and ease of movement on roadway, provision of a privately demarcated space to walk is highly significant. The presence of a sidewalk greatly affects pedestrian's sense of protection or comfort. In addition, the importance of walkway varies depending on the location substructure guarding it (i.e., side segregation) with respect to automobiles traffic [7]. For example, where there are walk-ways in Ikeja, the lateral separation changes as a result of buffer zones that either serve as drainage or on-street parking.

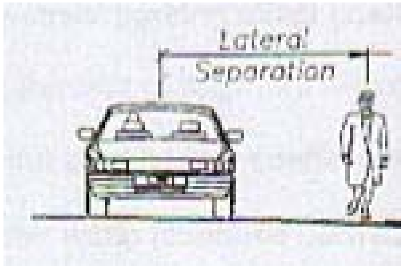

Figure 3. Walking along with vehicle

In general, side segregation termed lateral separations by [7] is presented in figure 3, figure 4, figure 5, figure 6 and 7. Figure 4 and figure 5 showed the effect of lateral separation, which has influence on pedestrian sense of safety with distance from moving traffic. Figure 5, figure 6 and figure 7 showed typical barriers within the roadside buffer and figure 8 showed pictorial depiction of roadway in Ikeja that lacks buffer zone and walkways.

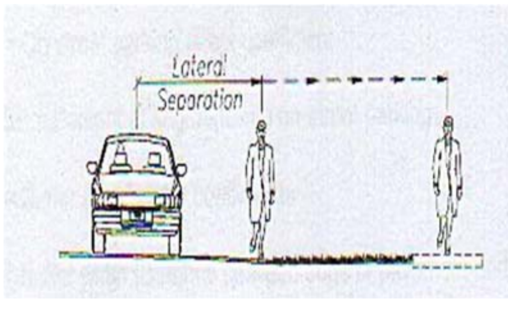

Figure 4. Separated by buffer zone

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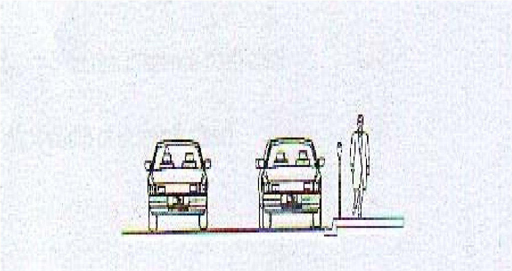

Figure 5. Separated by parked vehicle

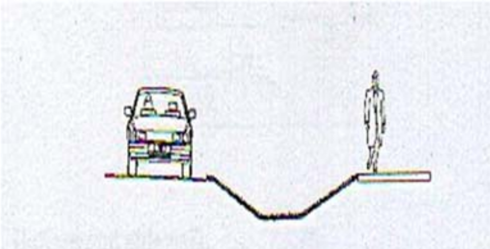

Figure 6. Separated by parked vehicle

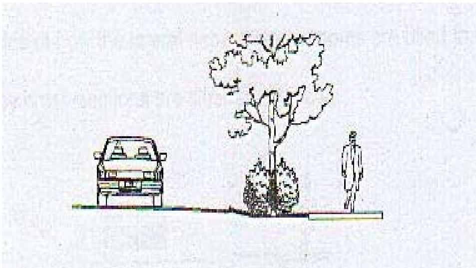

Figure 7. Separated by trees

Figure 8. Typical roadway in Ikeja

Mathematical expression that explains elements of lateral separation, barriers, buffers, and presence of walkways as expressed by [7] and modified to reflect the situation in Ikeja is presented in next equation (1):

$$LS = W_{OL} + W_{SBL} + f_{OPC}(\%OSP) + f_{BAC}(W_{BW}) + f_{SWC}(W_{WOS}) \quad (1)$$

Where:

LS = Lateral separation

W_{OL} = Breadth of outside lane (metre)

W_{SBL} = Width of shoulder or bike lane (metre)

f_{OPC} = Coefficient of roadside parking

$\%OSP$ = Percentage of a section of roadside parking

f_{BAC} = Barrier area coefficients

W_{BW} = Barrier breadth (distance between edge of pavement and sidewalk, feet)

f_{SWC} = Sidewalk availability coefficient

W_{WOS} = Breadth of walkway (feet)

Quantifying the basics of lateral separation as shown in equation 1 is illustrated in figure 9.

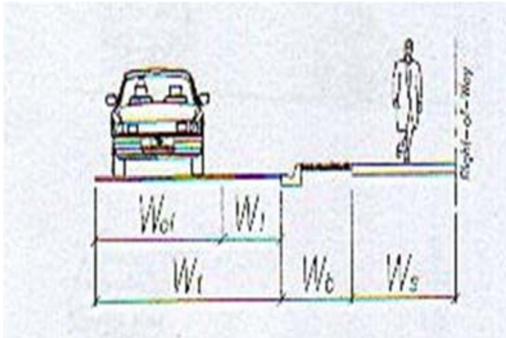

Figure 9. Quantification of Lateral Separation Basics
Source: Landis et al (2001)

Where, $W_{OI} = W_{ol}$, $W_{SBI} = W_l$, $W_{BW} = W_b$ and $W_{WOS} = W_s$. From previous equation, when there is no roadside parking, the % OSP becomes nothing. Then the lateral separation equation (2) becomes:

$$LS = W_{OL} + W_{SBL} + f_{BAC}(W_{BW}) + f_{SWC}(W_{WOS}) \quad (2)$$

In situation where there is roadside parking, its consequence as an obstruction is measured in equation above. But where there are no barred shoulders or scenery barrier, then the terms W_{SBL} and W_B becomes zero. Then, the lateral separation equation is shortened into next equation (3).

$$LS = W_{OL} + f_{OPC}(\%OSP) + f_{SWC}(W_{WOS}) \quad (3)$$

In the circumstance where there is on-street parking, but there is no bike lane, W_{SBI} equal zero then the lateral separation equation is streamlined into next equation (4).

$$LS = W_{OL} + f_{OPC}(\%OSP) + f_{BAC}(W_{BW}) + f_{SWC}(W_{WOS}) \quad (4)$$

In the case where there is no sidewalk, no bike lane, no striped shoulder or buffer, then lateral separation equation becomes equation 5.

$$LS = W_{OL} + f_{OPC}(\%OSP) \quad (5)$$

In the case where there is no sidewalk, no bike lane, no striped shoulder or buffer, and no on-street parking then lateral separation equation change to equation 6.

In the 56 points of the road sections in the study area, many of the road networks or streets are characterised with no sidewalk, no bike lane, no striped shoulder or buffer and with the operation of Lagos State Traffic Management (LASTMA) officers in Ikeja roadways, most of the roadways and streets are free of on-street parking.

In the road sections where there are sidewalks, equation 2 was used to compute LS. Where there are no sidewalks, no bike lane and no striped shoulder or buffer, equation 5 was used to obtain the values of LS. Furthermore, equation 6 was used where there is no on-street parking, no sidewalks, no bike lane and no striped shoulder or buffer. The equations used to compute LS Ikeja road segments are equations 2, 5 and 6 that is

$$LS = W_{OL} + f_{OPC}(\%OSP) + f_{SWC}(W_{WOS})$$

$$LS = W_{OL} + f_{OPC}(\%OSP) \quad \text{and} \quad LS = W_{OL}$$

3.2.3 Motor Vehicle Volume

The rate at which automobiles passes people walking on roadside is represented by the outside lane increases and also serves as variable. As the moving rate of vehicles increases, pedestrians' safety level may rise or decline. So, the outcome of vehicular increase was computed using equation 7:

$$TV = \frac{Vol_{15}}{L} \qquad (7)$$

Where:
TV = Traffic Volume
Vol_{15} = Average traffic during a fifteen (15) minute period
L = Total number of (through) lanes (for road or street)

Equation (7) assumes a 50/50 directional (manoeuvring) distribution. In cases where the directional distribution is other than 50/50, equation (8) was used. The difference between the two equations (i.e. 7 and 8) is that while equation 8 uses a directional factor with "L_d" (total number of directional through lanes), equation 7 uses "L" (totals number of through lanes).

3.2.3 Effect of Speed

Pedestrians' safety level may be raised or decline as vehicular speed increases. Thus, vehicular traffic is established as a variable likely to influence people walking. Therefore, the speeds of moving vehicles along 56 road segments were recorded using speed radar gun.

3.2.4 Driveway Access Rate and Capacity

Influx of vehicles into adjoining properties on road has shown in many studies to have influence on pedestrian level of safety. In this study, drive access frequency to adjoining properties was recorded through observations of passing motor vehicles along the road segments. Based on the measurement of the discussed variables, PLS in Ikeja is model in the mathematical expressions in equation 8.

PLS = C + b_1*f (lateral separation factors) +* b_2*f (traffic volume) +* b_3*f (speed) +* b_4*f (driveway access frequency and volume) +* $b_n f(x_n) + \alpha$ (8)

Result of field measurements and observations using equation 8 is discussed in next section 4.

$$TV = \frac{Vol_{15}}{L_d} \times D \qquad (9)$$

Where:
Vol_{15} = Fifteen (15) minutes traffic average

L_d = Number of road or street with through lanes

D = Manoeuvring influence

In this study equation 7 that is: $TV = \llbracket Vol \rrbracket\_15/L$ was used to compute the values motor vehicle volume along each road sections selected in the study area.

4. Results and Discussion

The results of the observations and measurements of 56 road sections in Ikeja using equation 9.is presented in table 1. and provide values obtained for LS, MV, SM and VA during field observations.

Table 1: Effects of Pedestrian Level of Safety on Explanatory Variables along Road Segments in Ikeja

Variables	Coefficients	t-statistics	p>value
Lateral Separation lin (LS)	0.596	5.139	0.000
Motor Vehicle Volume (MV) lin $(\frac{Vol_{15}}{L})$	0.204	1.732	0.000
lin (Speed of Motor Vehicle) (SM)	0.072	0.756	0.089
lin (Driveway access frequency and volume (VA)	- 0.067	- 0.745	0.453
Constant	-2.355	- 4.363	0.460
Model Adjusted (R^2)	0.581		
Model F-Ratio	20.089		
Level of Significance	0.05		

Source: Authors' Field Survey

Table 1, shows that two of the explanatory variables (LS and MV) used in the model are statistically significant at 5% confidence level. The results of PLS model of road sections in Ikeja area of Lagos is in line with statistical significance of LS and MV and in paltriness with VA in works of Landis et al, 2001 but not in SM. Although, increase in speed influence PLS and this is shown in the positivity of the regression coefficient of the variable. Thus, the model for Pedestrian Level of Service (PLS) of road sections in Ikeja is given as:

$$PLS = -2.355 + 0.596lin\left[Wol + f_{OPC}(\%OSP) + f_{SWC}(W_{WOS})\right] + 0.204lin\left(\frac{Vol_{15}}{L}\right) + 0.072lin(SMV)$$

From the model, lateral separation is significant (β_{sd}=0.60, t_{sd}=5.14). The result shows that lateral separation increase pedestrian level of safety. As lateral separation increases, pedestrians' level of safety increases. In other words, the availability of sidewalk ensures level of safety which is aided by the presence of barriers such as roadside swale, on street parking and a line of trees. Figure 5 to 9 show that, the distance between motor vehicle traffic and pedestrian is much, therefore, pedestrians feel protected and safe.

The outside lane which indicates the volume of automobiles moving pass people walking in the results was also significant (β_{vv}=0.20, t_{vv}=1.73). As volume of motor vehicles passing pedestrians along road segments in the study area increases (β_{vv}=0.20, t_{vv}=1.73) the pedestrians' level of safety decreases. This often occurs when barriers at the buffer area are removed or there is no sidewalk and pedestrians shared width of outside lane *(W_{OL})* with motor vehicles as shown in Figures 10 and 11. Pedestrians' level of safety tends to decrease because pedestrians are exposed to road traffic accident. In other words, lateral separation increases pedestrian level of safety while motor vehicle volume decreases it.

Figure 10. A section of road in Ikeja

The results of the model also revealed that speed of motor vehicle traffic is insignificant (β_{sp}=0.07, t_{sp}=0.76) in the model but has positive coefficient which implies that pedestrian safety level is strongly influenced by automobiles. Pedestrians' sense of safety tends to be high when there seems to be for instance congestion (Figure 8). This is because the speed of vehicle is lower in the study area.

In case of vehicular access to adjoining properties, pedestrian level of safety increases with decline of vehicular access to adjoining properties along roadside walking environment in the study area. Despite statistical insignificance of the explanatory variable, decrease in vehicles accessing adjoining properties will increase pedestrian sense of safety because of lack of sidewalks and buffer that can protect pedestrians from being knocked down by vehicles accessing adjoining properties. Thus, increase or decrease in vehicular access to ad-joining properties along pedestrian roadside walking environment will definitely has effect on the level of safety of pedestrians.

Figure 11. Another section of the road in Ikeja

The adjusted R-square of the model (R^2=0.581) revealed a goodness fit of the explanatory variables to the level of safety along the sampled road segments in Ikeja. It indicated that the explanatory variables (lateral separation, automobiles volume, speed of vehicle, rate and capacity of driveway access) contributed (58.1%) justification to pedestrian sense of safety along roadside walking environment in Ikeja. Similarly, the F-Ratio ($F_{52}^{3} = 20.089$) of the model is also significant at 5% confident level. The results of the model show that the level of explanations ($R^2 = 0.581$) and variability ($F_{52}^{3} = 20.089$) of pedestrian level of safety is high across road segments in Ikeja.

5. Summary and Conclusions

The safety level of people walking by roadside model in Ikeja showed that distance of pedestrian from moving vehicle (lateral separation) and volume of vehicles are significant. Speed of moving vehicles and driveway access frequency and volume are insignificant in the explanation of factors that influence pedestrian safety on roadside walking environment in Ikeja. The study further showed that pedestrian sense of safety increases as the distance between vehicle and pedestrians increases. The study further revealed that pedestrian's level of safety decreases with increasing volume of motor vehicles and motor vehicle's speed. The results of pedestrian level of safety along road segments in the study area showed that heavy presence of traffic does affect pedestrian level of safety and social network; thereby discouraging people not to walk.

In spite of insignificance of two of the explanatory variables, the variables jointly contributed about 58.1% to explanation to pedestrian level of safety along roadside walking environment in Ikeja thereby left 41.9% variables that are not accounted for. Thus, a search into unexplained variation will assist in examining comprehensive variables that influence pedestrian sense of safety along roadside walking environment. The knowledge will assist policy makers particularly in LSG NMT policy that has just being written during implementation.

Pedestrian footpaths or sidewalks are very important in road network design. The aspect of our route, however, is the most neglected. Regarding the targets of Goal 9 of SDGs that intend to promote upgrading of infrastructure and overhaul industries to make them sustainable, safety and security of pedestrians that form the ingress and egress of industrial, institutional, residential, and commercial activities of the core urban areas needs the attention of decision makers during upgrade. In any road network that involves human and vehicular movement, safety and security, comfort and quality of the footpath and other pedestrian facilities influence the decision of pedestrians to walk and as well make use of such facilities.

In order to safeguard pedestrians and cyclists for sustainable transportation that encourages infrastructure development and industrialisation of the city like Lagos, it is essential for proper implementation LSG NMT policy. Pedestrian *Level of safety model in Ikeja* thus provides a guide to urban and transport planners and LSG NMT policy decision makers to look on: (i) the distance between sidewalks and moving traffic; (ii) the type protective device that should be provided at any given time and place; (iii) the breadth sidewalk (iv) when and where to allow on-street parking or shoulder lane and (v) when, where to pedestrianized urban centre in order to discourage vehicular movement and encourage walking as well as cycling.

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