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Modelling Passengers' Influence on Commercial Motorcycle Riders' Speed Behaviour in Ondo City Nigeria

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ABSTRACT

Speed violation has been identified as the most common behaviour among motorcycle riders and a major contributing factor to motorcyclists' crash severity in Nigeria. This study investigated the influence of passenger characteristics on the speed behaviour of commercial motorcycle riders in Ondo city, Nigeria using Artificial Neural Network Modelling (ANN) technique. Descriptive statistics revealed that 84% of the riders carried only one passenger while 54.4% of passengers were youths. The study further revealed that more males use commercial motorcycles as means of public transport than females with a very low (10%) percentage use of helmet. In terms of traffic characteristics, the average minimum and maximum flow at the ten sites selected for study were 329 veh/h and 1840 veh/h respectively with the maximum percentage of motorcycles in traffic being 70%. The ANN model adopted found traffic flow as the most important variable influencing riders' speed, followed by road width and percentage of motorcycle in traffic. Generally, the model found passengers' characteristics to have less than 20% normalized importance on riders' speed choice variations. The result of this study can serve as a useful source of information for effective and sustainable traffic speed management in Nigeria.

1. INTRODUCTION

Commercial motorcycle has gained dominance as a viable means of transportation in developing countries especially in low income communities (Rome *et al.*, 2011). Several researchers have opined that low cost of motorcycles relative to four wheeled vehicles, easy maneuverability in the often chaotic road environment found in most low and middle income communities, poor access to public and private facilities, fuel economy, bad road, traffic congestion, poor town planning to mention but a few are factors influencing the mass acceptance of motorcycle as a means of public transport in low income communities in developing countries (Hsu *et al.*, 2003). This holds true in Nigeria with an estimated 8 million registered commercial motorcycles popularly called Okada (Premium Times, 2014).

However, the increase in commercial motorcycles have raised a lot of safety concerns considering the fact that motorcyclists are vulnerable road users. In the event of a crash involving a motorcyclist and other motorized vehicles, the motorcyclists face higher risk of injury or fatality (Akinleye *et al.*, 2015; Mannering and Grodsky, 1995; Plasencia *et al.*, 1995; Dandona *et al.*, 2006; Sreedharan *et al.*, 2010). Motorcyclists (which comprise the rider and passengers) are about 35 times more likely to die than passenger car occupants and 8 times more likely to be injured in the event of a crash (NHTSA, 2017). Radin *et al.*, (1995) also opined that riding a motorcycle is 17 times more dangerous than driving a passenger car. An average of 20.5% of road crashes recorded in Nigeria yearly involve motorcycles (FRSC, 2018). Speed violation has been identified as the most common behaviour among motorcycle riders and a major contributing factor to motorcyclists' crash severity in Nigeria and the rest of the world (Aarts and Schagen, 2006; Ibitoye *et al.,* 2007; Steg and Van-Brussel, 2009; Ogunmodede *et al.,* 2012; Ipindola, 2019). Riding at unsafe speed have higher crash probability (Broughton *et al.,* 2009). Understanding the factors influencing the speed behaviour of riders, especially commercial motorcycle riders in Nigeria has the potential to inform sound decisions in speed management measures, thus improving the safety and sustainability of motorcycle as a mode of public transport.

Recently, researchers are beginning to investigate the factors influencing motorcycle riders behaviour particularly speed behaviour, considering its high correlation with crash severity. Factors such as: motorcycle characteristics, roadway/environment characteristics, traffic characteristics and riders' characteristics have been investigated. Abdul *et al.*, (2017) investigated the effects of road characteristics, motorcyclists' riding behaviour, motorcyclists and motorcycles' characteristics on the occurrence of riding with excessive speed. They observed that 42.2% of the observed motorcycles exceed the speed limit and 28.6% of them go beyond the 85th percentile of the traffic speed. Their result further revealed that the majority of variation in the speed outcome (56.5%) is influenced by the rider, followed by 31.2% by location and 12.2% by the motorcycle. Their study indicates that motorcyclists' characteristics, riding behaviour and riding environment are of more importance than the type of motorcycle as regarding excessive speeding. The effects of road and road environment on speed choice of motorcycle riders have been documented. The factors affecting motorcyclists' speed behaviour in different types of motorcycle lanes have been investigated (Abdul and Fujii, 2011). They inferred that factors such as size of motorcycle, types of lane, operating speed and safety perception affect motorcyclists' speed behaviour.

Several modelling techniques have been employed to model the behaviour of motorcycle riders. Regression techniques have been applied to predict the behaviour of riders in developed countries. Recently, advances in the field of Artificial Intelligence (AI) has extended the use of Artificial Neural Networks to the field of transportation and traffic engineering (Abdel-Aty and Abdelwahab, 2014; Jadaan *et al.,* 2014). Whereas previous researchers have modelled the speed behaviours of motorcycle riders in developed and developing countries, little has been documented on passengers' influence on the speed behaviour of commercial motorcycle riders in low income communities of a developing country like Nigeria. To gain a better understanding of motorcycle riders' behaviours, it is valuable to extend our focus to the influence of passengers on rider's behaviour. A high percentage of countermeasures (education, enforcement and engineering) is focused on motorcycle riders, understanding the influence of passengers on riders' speed behaviour has the potential to inform sound and holistic engineering countermeasures that will improve the safety and sustainability of motorcycle as a mode choice in low income communities.

More so, the use of motorcycle in developed countries is different from developing countries. Whereas motorcycle is majorly used for leisure in developed settings, they are mostly used for public transport in developing countries where they share the same space and compete with passenger cars and other four-wheeled vehicles (Ipindola and Falana, 2019). It is therefore important to calibrate models localized and consistent with the conditions prevalent in Nigeria. The aim of this study was to model the influence of passengers on commercial motorcycle riders' speed behavior in Ondo town of Ondo State, Nigeria, using ANN technique. One of the primary advantages of neural network when compared to classical statistical techniques is their flexibility and lack of distributional assumptions. For example, neural network can be used to predict both categorical and continuous outcomes. The suitability of Multilayer Perceptron Neuron (MLP) in modelling the influence of passengers on the speed behaviour of commercial motorcycle riders is explored. This study focuses on commercial motorcycles because of their wide use for public transportation and high exposure to crash risks.

2. METHODOLOGY

Study Area

Ondo City in Ondo state Nigeria was selected for study (Figure 1). Ten road sections with varying road geometry, traffic characteristics, land use and socioeconomic characteristics and comprising straight segments far from the influence of intersections with good surface conditions were selected for study. The sites selected and their respective geographical locations and land use characteristics are presented in Table 1.

Map Legend

Selected study locations

Major arterials

Minor roads within study area

Fig. 1: Map of Ondo City Showing the Major Road Networks and Study Locations Dotted in Red (Source: Google Map Software, 13.05.2019)

Table 1: Study Locations, GPS Coordinates and Land Use Characteristics

S/n	Location	GPS coordinate	Land use
1	Yaba Street	7.104845, 4.849626	Mixed
2	Akure Garage	7.112966, 4.856555	Commercial
3	Barracks Road	7.05461, 4.50349	Mixed
4	UNIMED (Ayeyemi Street)	7.085450, 4.829990	Mixed
5	Sabo Market	7.088725, 4.817120	Commercial
6	Fagun Estate	7.096339, 4.817980	Residential
7	Ondo Civic Centre	7.095423, 4.821536	Commercial
8	Gani Fawehinmi Street	7.102670, 4.837090	Mixed
9	Surulere Street	7.099005, 4.839682	Residential
10	Central Mosque	7.094473, 4.837670	Mixed

Data Collection

In order to achieve the aim of this study, i.e. predicting the influence of passengers' on commercial motorcycle riders' speed behaviour, a smart video camera was used to conduct traffic survey at ten carefully selected locations at case study during off peak periods under clear weather and dry pavement conditions. The video camera was positioned where it could capture a travel distance of 50 meters in both directions without obstructing the flow of traffic and the riders were not aware of the data collection process. The data collection was conducted between 11am and 2pm daily from Monday to Friday for each site selected. The video data collected was afterwards transferred to a computer system and the dependent and explanatory variable data extracted using Kinovea (video analysis software).

The video analysis software distributes the video into picture frames to a detail of 0.04 seconds per frame, which made it possible to extract the traffic and passengers' characteristics. Commercial motorcyclists were differentiated from other riders through their conspicuous orange coloured uniforms. Visible passenger characteristics were also observed and recorded. The riders' speed was calculated by dividing 50m by the time taken to cover the distance for each rider. The extracted data was transferred to Microsoft Excel for further analysis. Statistical Package for Social Sciences (SPSS) 22 was subsequently employed for descriptive statistical analysis and predictive model estimation. Road width was measured for the selected locations of study using measuring tape. Land use was characterized considering 100m parallel distances at both sides of the road. Areas with more residential buildings than business centers were categorized as residential, while areas with more shops and business centers were categorized as commercial. Areas with even distribution of residences and business centers were classed as mixed land use.

Variable Selection

The dependent variable for this study is the operating speed of riders while the explanatory variables include: number of passengers, gender of passengers, age of passengers, passengers carrying luggage, passenger carrying a baby, use of helmet by passengers, traffic flow, percentage of motorcycles in traffic, road width and land use. These variables were selected because they were measurable from the traffic survey. The variables and their codes are presented in Table 2.

Table 2: Model Variables and Their Respective Codes

Variable	Code
Number of passengers	Continuous
Gender of passengers	0 if male, 1 if female, 2 if others (MM, FF, MF)
Age of passengers	0 if child, 1 if youth, 2 if adult, 3 if others
Helmet use	0 if yes, 1 if no
Passengers carrying luggage	0 if yes, 1 if no
Operating speed	Continuous
Passenger Carrying a child	0 if yes, 1 if otherwise
Road width	Continuous
Traffic flow	Continuous
Percentage of motorcycle in traffic	Continuous
Land use	0 if Residential, 1 if commercial, 2 if mixed

ANN Model Development

MLP rule consisting of three layers: input layer, hidden layer and output layer was employed in developing a motorcycle riders' speed behaviour model. MLP is a feed forward network in which information flow from input side and pass through the hidden layers to the output layer to produce outputs. Many studies have shown that MLP is a universal approximator. A MLP with one hidden layer is capable of approximating any finite nonlinear function with very high accuracy (Schalkoff, 1997).

In training MLP, the inputs of the first layer is multiplied by weighted coefficients that would be any randomly selected number and then entered into the neurons in the second layer. Any neuron functions in two ways as shown in equations 1 and 2:

i. Calculating the sum of the inputs, defined as neti
ii. Inserting the sum in a function called "activation function".

$$net_i = \sum w_{ij}.x_i \tag{1}$$

$$out_i = F(net_i) \tag{2}$$

Where:

out_i is neuron output,

w_{ij} is weighted coefficient from i-th neuron of the first layer to j-th neuron of the second layer,

x_i is i-th neuron input

Hyperbolic tangent, sigmoid and identity functions are the three activation functions used in this study as described by the mathematical expression in equations 3, 4 and 5.

$$out = tanh(net) \quad (3)$$

$$out = F(net) = sig(net) = \frac{1}{1+e^{-net}} \quad (4)$$

$$out = net \quad (5)$$

This process continues in the rest neurons of the middle layer and finally the outputs generated in the last layer. During learning, the error between network output and target output is calculated and again sent from the last layer to the previous one and thus the weight coefficients corrected using equations 6 and 7. this process is called" error-back-propagation". Once again the network generates output, using the new weight coefficients and also calculates the reducing error and back propagates it into the network until the error reaches to its least value that is the desired value, after many epochs.

$$w_{ij}(t + 1) = w_{ij}(t) + \eta\delta p_i{}^o p_j \quad (6)$$

$$\delta p_i w_{ij}(1 + t) = w_{ij}(t) + \eta\delta p_i{}^o p_j + \alpha[w_{ij}(t) - w_{ij}(t-1)] \quad (7)$$

Where:
$w_{ij}(t + 1)$ is weight coefficient in step t + 1, from neuron *i* to neuron *j*,
$w_{ij}(t)$ is weight coefficient in step t, from neuron *i* to neuron *j*.
η is learning coefficient
δp_i is difference between desired output and network output in neuron *p* of layer *j*
${}^o p_i$ is the output of neuron p of layer *i*
${}^o p_j$ is the output of neuron p of layer *j*
α is momentum coefficient
$w_{ij}(t-1)$ is the weight coefficient in step t – 1, from neuron *i* to neuron *j*.

In developing the network for this study, the data set was divided into three parts namely: training (70%), testing (15%) and validation (15%) as shown in Table 3. Cases were randomly assigned based on relative number of cases. The training process involves making the network adapt to the data and usually involves the use of a training algorithm. Gradient descent was used in training the network for this study.

Table 3: Case Processing Summary for MLP Model

	N	**Percentage (%)**
Training	1470	70.0
Testing	309	14.7
Holdout	321	15.3
Total	2100	100

Model validation

Two measures were used to assess the performance and hence the validity of the models developed. The first measure is the coefficient of determination (R^2). The R^2 is a measure of the strength of the relationship between variables. The second measure is the magnitude of relative error between the predicted and observed values. The error values between the observed survey results and the predicted results with the ANN model are expressed by equation 8.

$$\text{Relative Error} = \frac{Mo - Mp}{Mp} \times 100 \quad (8)$$

Where Mo is the observed mean value of motorcycle riders' operating speed and Mp is the predicted mean value of riders' operating speed. A 5% threshold was set as the acceptable level of error values for this study.

3. RESULTS AND DISCUSSION

The descriptive statistics of traffic characteristics at the selected study sites is presented in Table 4. Minimum traffic flow was found to be 329 vehicles/hour, while the maximum traffic flow was found to be 1840 vehicles/hour. The minimum rider's speed was 30 km/h while the maximum was 104 km/h, this is in tandem with (Akintayo and Agbede, 2009; Ipindola and Falana, 2019). The minimum percentage of motorcycle in traffic at the time of survey was 40% while the maximum was 70%. Several researchers have opined that economy, accessibility and flexibility are among the factors influencing the proliferation of commercial motorcycles in Nigerian cities and townships (Olaore, 2011; Olubomehin, 2012).

Descriptive Statistics of Passenger Characteristics

The result of passenger characteristics survey carried out at the ten chosen sites of study is presented in Tables 4 and 5. Eighty four (84) percent of the commercial motorcycles surveyed were carrying one passenger each while 13.5% were carrying two passengers. Passengers generally believe that it is unsafe for riders to carry more than one passenger, but some of them still go ahead to carry more than one passenger especially during unfavourable weather conditions and traffic gridlock. In terms of age of passengers, majority (54.4%) were youths who perceive motorcycle as a fast and cheap mode of transport. Only 28.9% of passengers comprised adults. Adults in this context are people of the age 50 years and above. They often prefer taxi and tricycles as their mode of public transport.

Fifty (50) percent of passengers observed were males while 34.1% were females, others were either two or more passengers comprising male and female. The use of helmet by riders and passengers in the case study was very low. Several factors such as socioeconomic, religious, cultural belief, lack of political will, poor enforcement etc. could be responsible for this statistics but this is outside the scope of this study. The percentage of passengers baring luggage was 10%. Commercial motorcycle riders plying township routes are often reluctant to carry passengers with luggage because of inconvenience and balance unlike their counterparts plying local farm roads. In terms of land use 52.4% comprised mixed, while 23.8% comprised residential and commercial each respectively. Generally, land use in most Nigerian townships are mixed and this makes transportation planning an uphill task.

Table 4: Descriptive Statistics of Traffic Characteristics

Characteristics	Min	Mean	Max
Flow (veh/h)	329	1068	1840
Percentage motorcycle	40%	54%	70%
Speed	30	61.55	104
Road width	6.5	8.58	11.4

Table 5: Descriptive Statistics of Independent Variables

Characteristics	Percentage
Number of passengers	
1	84.0
2	13.5
3	2.2
4	0.2
Age of passengers	
Child	0.7
Youth	54.4
Adult	28.9
Others	16.0
Gender	
Male	49.9
Female	34.1
Others	16.0
Use of helmet	
Yes	4.0
No	96.0
Passenger with luggage	
Yes	10.0
No	90.0
Passenger carrying a baby	
Yes	2.3
No	97.7
Land use	
Residential	23.8
Commercial	23.8
Mixed	52.4

Correlation Analysis

Pearson correlation analysis was conducted on the variables to be included in the model. Ten variables namely: traffic flow, percentage of motorcycle in traffic, land use, road width, number of passengers, age, sex, passenger carrying luggage and passenger carrying a baby were all found to correlate with the operating speed of riders at 0.01 level of significance (2-tailed) and were therefore included in the model development.

Multilayer Perceptron Network

Network Information

The multilayer perceptron network developed for this study comprised of one input layer with ten units (covariates) excluding the bias unit, one hidden layer with seven units excluding the bias unit and one output layer (dependent variable) with one unit (Figure 2). Several activation functions were tried in the input and output layers and the results presented in Table 4. The best combination that gave the best fit were hyperbolic tangent and sigmoid functions at the hidden and output layers respectively and this architecture was selected as the final model. The summary of the network information is presented in Figure 3.

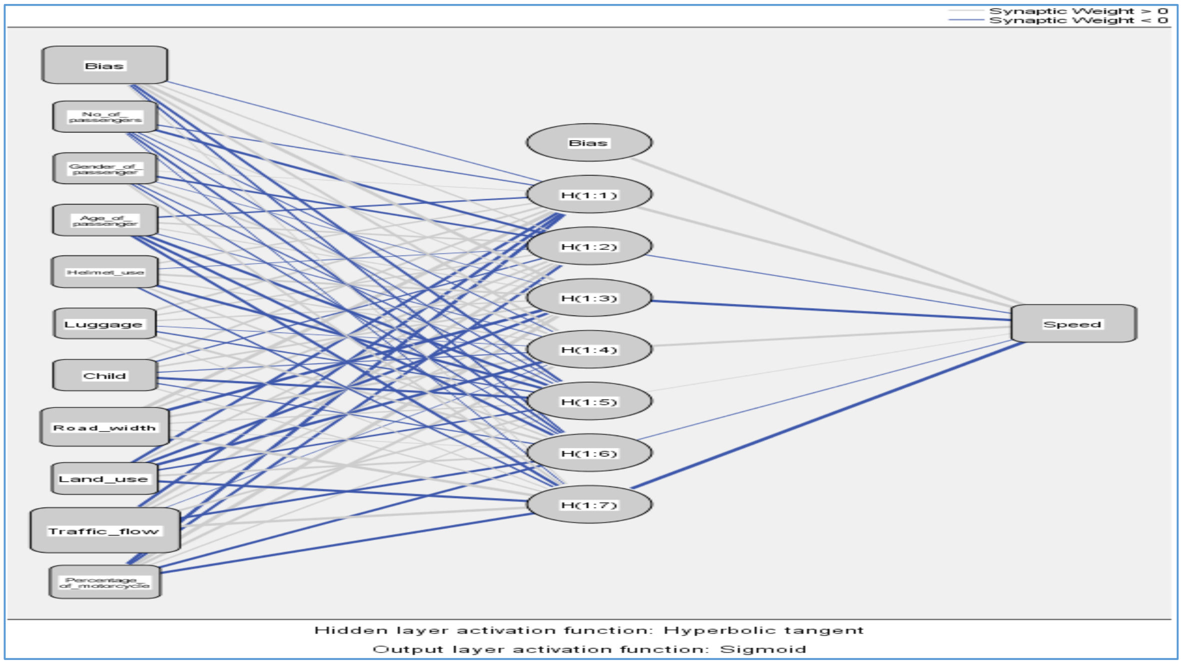

Fig. 2: Multilayer Perceptron Network Architecture (source: SPSS Software, 18.09.2019)

Network Information

Input Layer	Covariates	1	No_of_passengers
		2	Gender_of_ passenger
		3	Age_of_passenger
		4	Helmet_use
		5	Luggage
		6	Child
		7	Road_width
		8	Land_use
		9	Traffic_flow
		10	Percentage_of_ motorcycle
		Number of Units[a]	10
		Rescaling Method for Covariates	Normalized
Hidden Layer(s)		Number of Hidden Layers	1
		Number of Units in Hidden Layer 1[a]	7
		Activation Function	Hyperbolic tangent
Output Layer	Dependent Variables	1	Speed
	Number of Units		1
	Rescaling Method for Scale Dependents		Normalized
	Activation Function		Sigmoid
	Error Function		Sum of Squares

a. Excluding the bias unit

Fig. 3: Multilayer Perceptron Network Information (source: SPSS software, 18.09.2019)

Model Results

The summary and results of the MLP models developed for this study is presented in Table 6. The best performing network (ANN 3) selected for predicting commercial riders' speed behaviour gave a correlation coefficient of 0.44 (Figure 4). This result indicates that only 44% of the variations in commercial motorcycle riders' speed behaviour can be explained by passenger, road geometry and traffic characteristics. This may be as a result of other influential factors such as riders' emotions, perception of safety etc. that are not considered or captured by the scope of this study.

Table 6: Result of ANN Models with Different Activation Functions

Model	Architecture	Activation Function (Hidden layer)	Activation Function (Output layer)	RE Training	RE testing	RE Holdout	R^2
ANN 1	10-7-1	Hyperbolic tangent	Identity	0.693	0.657	0.690	0.32
ANN 2	10-7-1	Hyperbolic tangent	Hyperbolic tangent	0.634	0.643	0.617	0.36
ANN 3	**10-7-1**	**Hyperbolic tangent**	**Sigmoid**	**0.578**	**0.504**	**0.666**	**0.44**
ANN 4	10-7-1	Sigmoid	Sigmoid	0.698	0.618	0.622	0.32
ANN 5	10-7-1	Sigmoid	Hyperbolic tangent	0.692	0.775	0.775	0.30
ANN 6	10-7-1	Sigmoid	Identity	0.643	0.587	0.618	0.37

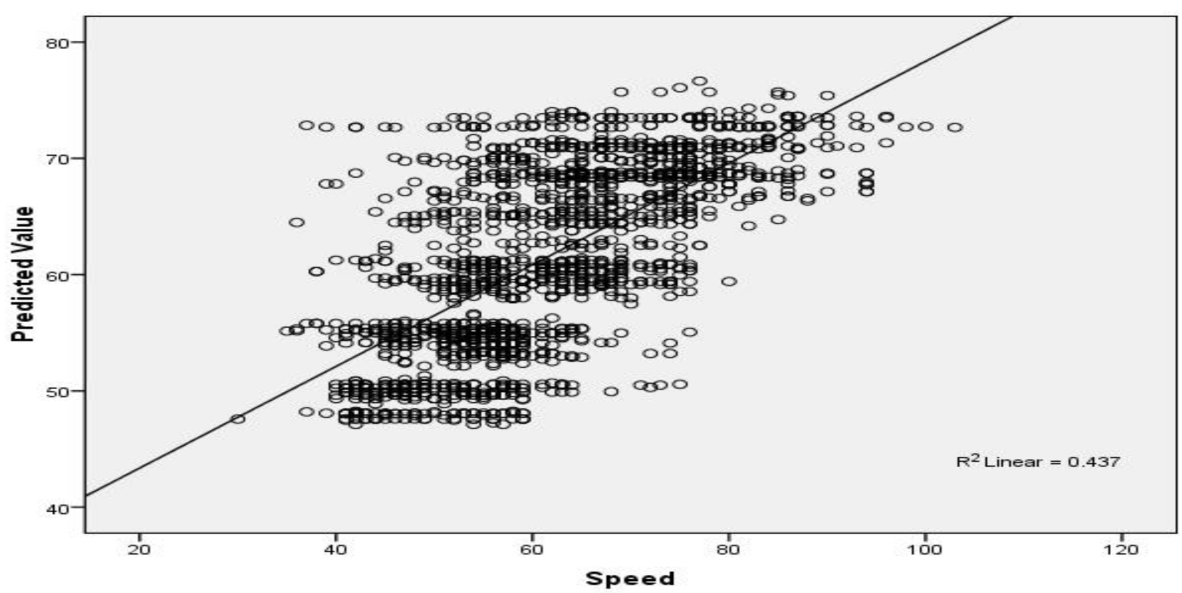

Fig. 4: Fitness Curve of ANN Model (source: SPSS software, 18.09.2019)

Sensitivity Analysis

The result of sensitivity analysis performed to determine the importance and effect of the independent variables on the output of the network is presented in figure 5. Traffic flow was found to be the most important characteristics influencing the speed behaviour of commercial motorcycle riders, followed by road width and percentage of motorcycle in the traffic. The most important passenger characteristics found to influence riders' speed was helmet use, followed by age of passenger and passenger carrying a baby. The use of helmet to a large extent indicates the level of safety consciousness in riders and passengers. There is need for transport agencies at state and local levels to double their efforts at ensuring helmet use compliance. Gender of passenger was the least important variable influencing riders' speed. Generally, passenger demography had little influence on the speed behaviour of riders' at the case study.

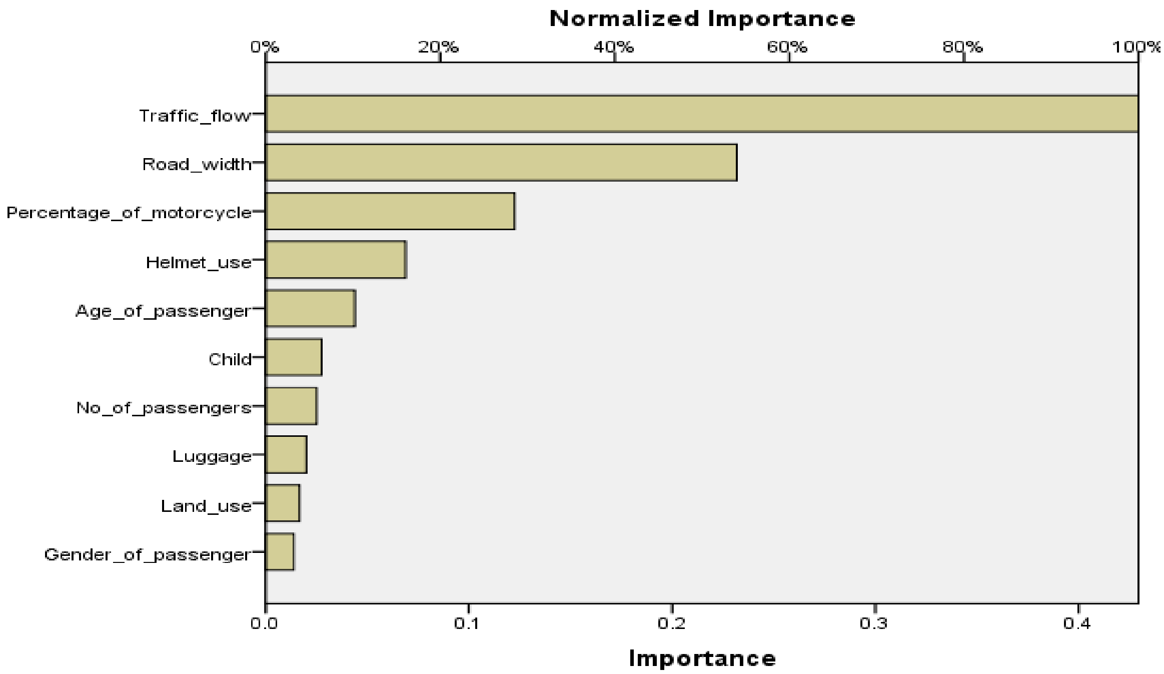

Fig. 5: Normalized Importance Result of Independent Variables (source: SPSS software, 18.09.2019)

4. CONCLUSION

In this study ANN model has been employed to investigate the influence of passengers' on the speed behaviour of commercial motorcycle riders in Ondo city, Nigeria. The MLP network didn't performed satisfactorily at predicting the impact of passengers' characteristics on riders speed behaviour. This may be due in part to other influential factors like riders' emotions, perception of safety etc. which are outside the scope of this study. However the results obtained indicate that traffic flow was the most significant characteristics influencing the speed behaviour of commercial motorcycle riders in the case study. Generally, passenger characteristics had less than 20% normalized importance on the variation in speed behaviour of riders. The result of this study can serve as a useful source of information for transportation planners, traffic engineers and researchers in making decisions that engender sustainable public transportation in developing countries. Future research can expand the scope of this study by considering different types and categories of roads, socio-economic characteristics of passengers, motorcycle characteristics, different seasons and times of the day.

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