American Journal of Engineering and Technology Management
2024, Vol. 9, No. 3, pp. 56-65
https://doi.org/10.11648/j.ajetm.20240903.12

Research Article

Influence of Side Friction on Average Width Loss in Urban Roads Links; A Case Study of Nakuru Town

Edwin Mararo Lekariap*, Zachary C. Abiero-Gariy, Timothy Nyomboi

School of Civil, Environmental & Geospatial Engineering at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya

Abstract

This study investigated the impact of side friction factors on the reduction of effective carriageway width in urban road links in Nakuru Town, Kenya. Linear regression models were developed for each road link, revealing a strong positive relationship between the frequency of side friction factors and the average carriageway width reduction (AVWR). The prediction models highlighted the varying influence of specific side friction factors, such as pedestrians, entry and exit maneuvers, parked vehicles, motorbikes, and bicycles, on AVWR across different road segments. The findings emphasize the importance of context-specific analysis and tailored interventions to effectively address traffic congestion in urban areas, as the complex interplay of side friction factors necessitates comprehensive approaches to traffic management. Regression analyses were conducted on data from 11 major arterial roads, considering factors like pedestrian activity, entry/exit maneuvers, parking situations, and presence of motorbikes, bicycles, and tuk-tuks. Results showed significant positive correlations for most links, with pedestrians, entry/exit maneuvers, and parked vehicles consistently contributing to carriageway width reduction. However, the impact of motorbikes and bicycles varied across locations, underlining the need for location-specific strategies. The study also revealed the intricate interplay among side friction factors, necessitating a holistic approach to traffic management. By understanding these relationships, urban planners and traffic managers can develop targeted strategies to mitigate the impact of side friction factors, improve traffic flow, and enhance overall road network efficiency.

Keywords

Side Friction, Carriageway Width, Traffic Congestion

1. Introduction

One of the major parameters of the roadway affected by side friction is the effective width. The effective width can be defined as the roadway specifically designed for use by motorized traffic [6]. As a result of limited space available for the various urban area activities, encroachments into the roadway are frequently experienced. These activities make it difficult for vehicular traffic to comfortably use the entire designated road - width and therefore tend to shift towards the center of the road.

A study by [6] on the causes of reduction of effective roadway width as a result of side friction in Dhaka city show that densely populated urban areas experience significant levels of side friction effects compared to areas with low population density.

*Corresponding author: lekariap@gmail.com (Edwin Mararo Lekariap)

Received: 13 June 2024; **Accepted:** 13 September 2024; **Published:** 26 September 2024

The percentage in effective width loss is estimated by the formula:

$$\%\,Effective\ width\ loss = \left(\frac{d}{D}\right) \times 100$$

Where, d is the reduction in effective roadway width as a result of a specific side friction element and, D is the effective roadway width at the point of measurement.

The study carried out an assessment of the width loss of the roadway due to various causal factors including:

Roadside stalls.

Roadside cycle rickshaw parking.

Roadside bus parking.

Poor parking/double parking on roadside car parks by private car owners.

Below are extracts of the summary of findings from the study:

Table 1. *Reduction of roadway width due to on - road car parking. (Islam et al. 2018).*

Route name	Width loss (m)	Total Width (m)	%Width Loss	Average Width Loss
Mirpur 1 –Technical	4.88	12.20	40.00	
Technical–Shyamoli	3.37	11.27	29.90	
Shyamoli - Asadgate	3.10	16.50	18.27	24.20%
Asadgat – Dhanmondi27	3.24	16.53	19.60	
Dhanmondi27 - New market-	2.15	16.20	13.27	

Table 2. *Reduction in roadway width due to cloths and other human - wear stalls.*

Route name	Width loss (m)	Total Width (m)	% Width Loss	Average Width Loss
Mirpur 1 - Technical	1.82	2.80	65.00	
Technical - Shyamoli	1.20	3.20	37.50	
Shyamoli - Asadgate	1.35	3.11	43.41	59.74%
Asadgate– Dhandmondi27	1.75	2.50	70.00	
Dhandmondi27- Newmarket	2.12	2.56	82.81	

Table 3. *Reduction in roadway width due to double parking.*

Route name	Type	Width loss (m)	Total Width (m)	%Width Loss	Average Width Loss
Mirpur 1 –Technical	C+R	7.89	12.20	64.67	
Technical – Shyamoli	C+Mo	7.65	11.27	67.88	
Shyamoli –Asadgate	C+C	4.90	16.50	29.70	44.49%
Asadgate – Dhanmondi27	C+Cn	4.85	16.53	29.34	
Dhanmondi27 – Newmarket	Cn+R	5.00	16.20	30.86	

Here, C=Private car, Mo=Motorcycle, R= Rickshaw, Cn=CNG.

From the above findings, the study concludes that loss in effective road width is a critical question that needs urgent action without which the city of Dhaka would cease to function. In retrospect, the study emphasizes the role of urbanization and rural – urban migration in the side friction phenomenon.

Despite the degree of accuracy and authenticity of these findings, it is important to understand that different urban areas have different characteristics. Vehicle parking for example is well coordinated and managed in other cities and therefore might not be a major causal factor of side friction.

Another study carried out by the American Ministry of Transport illustrated the variation of road capacity and loss of effective roadway width due to parked vehicles per km. The table below is a summary of the relation as conducted by the Ministry of Transport, U.S.A 1965 on the effect of parked vehicles on highway capacity:

Table 4. *Parked vehicle per Km verses Loss of effective roadway width.*

Parked Vehicle Per Km	**3**	**6**	**31**	**63**	**125**	**312**
Effective loss of carriageway (m)	0.9	1.2	2.1	2.55	3.0	3.6

Parked Vehicle Per Km	3	6	31	63	125	312
Loss of capacity at 25 km/h	200	275	475	575	675	800

It can be seen that the greater the number of parked vehicles per kilometer by the roadside, the greater the loss in capacity of the highway.

2. Objectives of the Study

To assess the average width loss due to side friction in urban road links.

3. Research Methodology

A reconnaissance field survey was conducted in order to pinpoint particular segments of the roadways that were sampled. Using purposive sampling, the roads that would be sampled for the research were chosen. Care was made to make sure that the selected road portions are representative of the various side friction variables in order to collect data on site-specific factors. Time constraints limited the selection of particular highways and sites in this section, which were chosen based on those findings. First, a variety of traffic flow characteristics, including flow intensity (volume/capacity ratio), traffic mix, the proportion of heavy vehicles, and side friction levels, were taken into consideration while choosing roadways. Second, the physical and geometric qualities of the roadways were taken into consideration when choosing them. Although the physical, environmental, and traffic factors had a major role in the selection of roads, the study sites/segments were chosen based on stricter criteria, such as straight alignment, level terrain, and easily visible side frictions.

Numerous collector roads that connect to the arterial routes and various arterial roads connect Nakuru Town to other nearby towns. The eleven main arterial routes surrounding Nakuru town were the sites of data collection for this study, as indicated in table 5.

Table 5. *Major Arterial Roads (Links) considered around Nakuru town.*

Link	Length (Km)	No. of travel lanes	Functionality class
Nairobi - Nakuru - Eldoret Highway	15.2	4lane-2way	A8
Nakuru - Nyahururu Road	7.2	2lane-2way	B21
Nakuru - Kabarak Road	8.9	2lane-2way	B17
Nakuru - Elementaita Road	5.7	2lane-2way	D1264
Oginga Odinga Road	11.6	2lane-2way	J2
Moi Road	3.0	2lane-2way	D1265
Nakuru - Njoro Road	5.6	2lane-2way	B18
Nakuru - Bangladesh Road	3.9	2lane-2way	J4
Lanet - Ndundori Road	6.9	2lane-2way	B20
Kaptembwa – Nakuru Road	2.95	2lane-2way	J5
Nakuru PGH Road	2.05	2lane-2way	K3

In Nakuru Town, urban roadways could be categorised as local, collector, or arterial streets. Major traffic movements with high volumes and high design speeds were reserved for arterial roadways. Collectors were classified as primary or secondary and had a decreased mobility function. The main purpose of local roadways was accessibility. The two-lane, two-way and four-way roadways were the subjects of the investigation. Common lane widths were 3.0 – 3.5 metres for collector and local roads, and 3.5 – 3.7 metres for arterials. The majority of collector and arterial highways have partially paved shoulders.

Major arterials had speed restrictions ranging from 50 to 80 km/h, depending on where they were in the town, while most collectors had speed limits of less than 50 km/h, and most minor roads had very few speed limit signs. On downtown streets, which are local roadways that primarily serve accessibility needs, parking lanes were typical. Outside the Central Business District (CBD), collector and local roads were mostly distinguished by unpaved and undesignated sidewalks. Generally speaking, this study was only appropriate for a portion of the observed network, particularly the arterial and feeder roads.

The Nakuru-Eldoret Highway, Nakuru-Nyahururu Road, and Nakuru-Nakuru Highway were intended to feature full level access control, per the Road Design Manual. For pragmatic and budgetary considerations, the degree of access on this road may likewise be lowered to partial control. Full or partial control, with the option to reduce it to partial control, was the desired level of access for the following roads: Nakuru - Nyahururu Road, Kabarak Road, Elementaita Road, Oginga Odinga Road, Moi Road, Nakuru - Njoro Road, Nakuru - Bangladesh Road, and Nakuru - Ndundori Road.

The main survey was conducted for a period of three months. From May to July 2023 when the weather was favorable to do the study specifically during the dry weather conditions. Prior to the main survey site visits had been made to all the roads under study. The team drove to all the 11 roads where key observations were made in identification of the main friction factors in these sections. Sites where the actual data was collected from were also identified during this period. The time schedule of conducting the survey in the stated roads is as provided in the table below. A total of 66 field hours were used in carrying out a survey on the frequency of friction factors, 168 hours in collecting data on traffic characteristics using metro count road side units and 33 hours in surveying the impact of the friction factors on carriage way width. In determination of the frequency of friction factors data was collected three times a day i.e., morning (0800-1000hrs), noon (1100-1300hrs) and evening (1500-1700hrs). To determine the traffic characteristics, the installed roadside units collected data continuously for 7 days. The width reduction as a result of friction factors was also recorded in three sessions in a day i.e., morning (0800-0900hrs), noon (1200-1300hrs) and evening (1600-1700hrs).

Geometric characteristics of the road were measured using a measuring tape. This was done physically by the surveyors measuring the distances directly. To obtain the cross-sectional dimensions of the road links the surveyors measured the distances by one crossing to the other side with the tape measure and recording the reading from the tape measure directly. Since there were challenges in getting exact perpendicular dimensions the accuracy of the data about the carriageway width was to 100mm. Other features of the road including the meridian width, side walk width and pavements were also measured directly and the dimensions recorded in form of a sketch. Carriage way width reduction as a result of friction factors was measured by directly measuring the dimensions of the extent of encroachment when the exact factors were available and for factors that we could not measure directly like some public service vehicles (PSV) the regions were marked and measured once the friction factor had moved. The sketch below shows how the measurements were carried out.

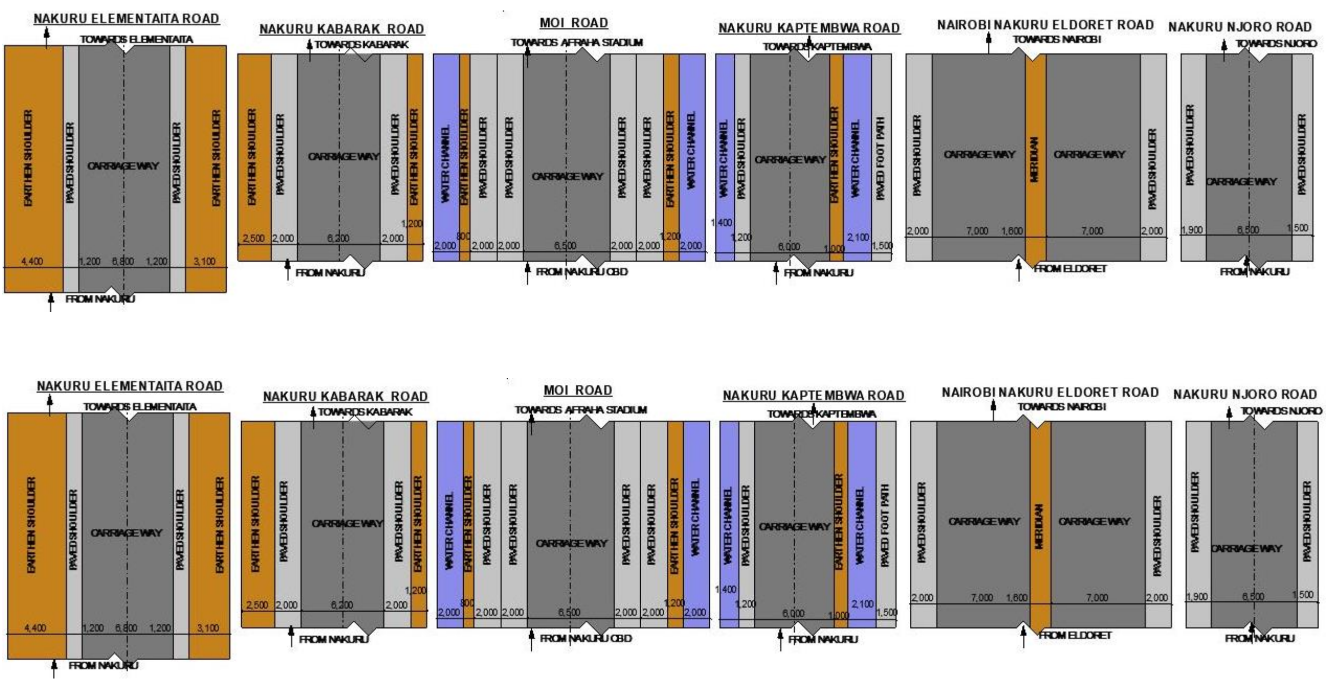

Figure 1. *Geometric properties of carriageway width sketches.*

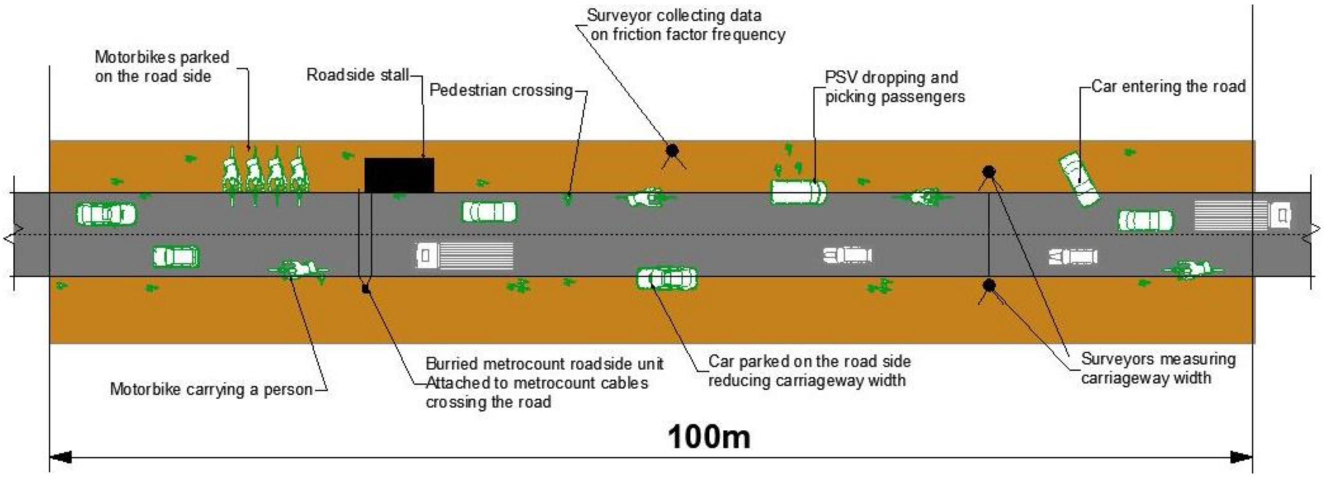

Figure 2. *Overview of the data collection exercise.*

3.1. Data Analysis

Side friction factors (SFF) had a significant impact on carriageway constriction. To quantify the relationship linear regression models were developed. Correlation was done between these SFF and AVWR and it was established that the variables were highly related. Since correlation showed the degree of relationship, we developed regression models to determine how the frequency of side friction factors affects carriageway width reduction. Since data was collected for each road link, the modelling of the relationship was done for all the road links and then the whole data as a whole. Tables 6 and 7 below shows a sample of the model data obtained from SPSS.

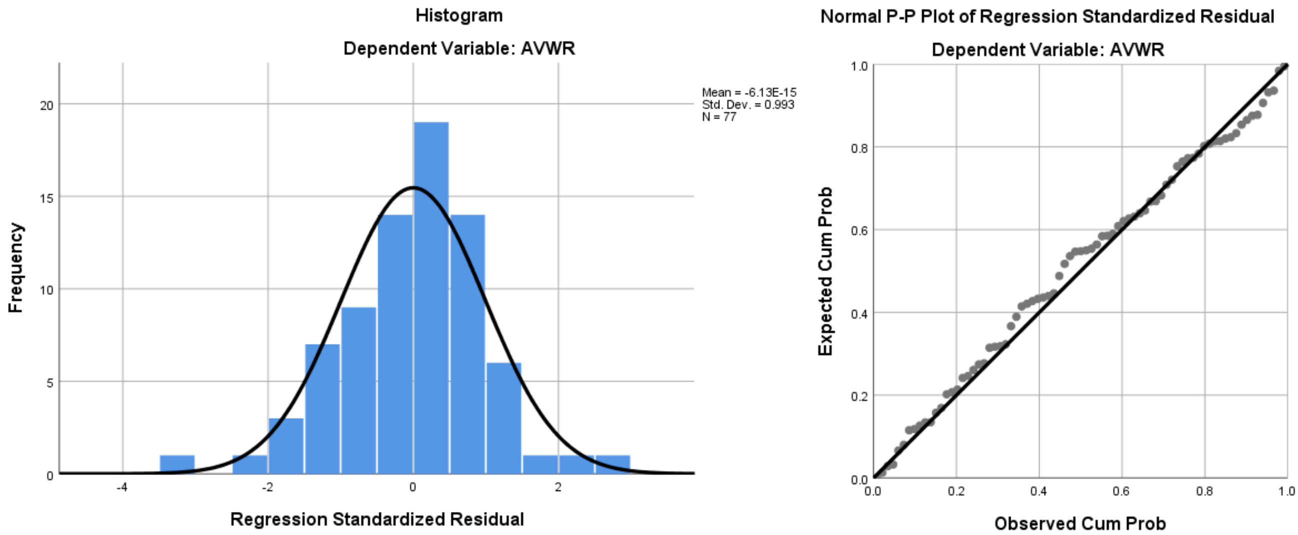

Figure 3. *Regression standard residual plots.*

Table 6. *Sample model data obtained from SPSS.*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.878[a]	.770	.767	42.61545	1.545

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	456736.044	1	456736.044	251.496	.000[b]
	Residual	136205.726	75	1816.076		
	Total	592941.770	76			

The process involved the statement of a hypothesis and testing of the hypothesis to prove its validity. The problem and hypothesis were as;

The problem: To investigate if the frequency of side friction factors has a significant impact on the average carriageway width reduction.

Hypothesis: H1-There is a significant impact of the frequency of side friction factors on the average carriageway width reduction.

The developed hypothesis was testing if the frequency of occurrence of the side friction factors has a significant impact on the average carriageway width reduction. SFFF was regressed on predicting the dependent variable average AVWR to test the stated hypothesis. From the obtained results the computed P was less than 0.05 thus the impact of SFFF on AVWR was significant. This indicates that SFFF plays a significant role in predicting AVWR. Before modelling the relationship of all the sites, the relationship in each site was considered and the values recorded in the table 7. F (1,75) = 251.496, p<0.05 251.496, R value of 0.77 meant 77% change in AVWR can be accounted for in F.F frequency. P value from ‘anova’ table was .000. With a 95% interval confidence and P< 0.05 show the significance of the relationship is valid. T value was greater than 1.96 and this further vindicated the significance of the results. The different road links showed different relationships as shown in table 7.

Table 7. *Relationship between Side friction factor frequency and average width reduction.*

ROAD LINK	Regression weights	R^2	P-value	Hypothesis Supported	
Oginga Odinga	FFF-AVWR	.27	.000	Supported	AVWR=0.37FFF+1135
Moi	FFF-AVWR	.008	.099	Not Supported	AVWR=-3.52FFF+1328.617
Kaptembwa	FFF-AVWR	.295	.021	Supported	AVWR=1.595FFF+1122.521
Kabarak	FFF-AVWR	.487	.028	Supported	AVWR=1.232FFF+1040.24
Nyahururu	FFF-AVWR	.770	.000	Supported	AVWR=1.539FFF+1117.066
Njoro	FFF-AVWR	.509	.072	Supported	AVWR=2.363FFF+992.998
Bangladesh	FFF-AVWR	.212	.304	Supported	AVWR=2.849FFF+1045.737
Elementaita	FFF-AVWR	.333	.175	Supported	AVWR=1.568FFF+1016.17
NKRELD	FFF-AVWR	.18	.000	Supported	AVWR=0.574FFF+1161.111
PGH	FFF-AVWR	.146	.017	Supported	AVWR=0.963FFF+1143.601
Lanet Ndundori	FFF-AVWR	.667	.025	Supported	AVWR=3.123FFF+1034.845

The regression analysis conducted in the study aimed to determine the impact of side friction factor frequency (SFFF) on the average carriageway width reduction (AVWR). By developing regression models for each road link, the study sought to test the hypothesis that the frequency of side friction factors significantly influences AVWR. The hypothesis was formulated based on the problem statement, which aimed to investigate the relationship between SFFF and AVWR. This aligns with the findings from previous literature, which identified side friction factors as significant contributors to carriageway constriction and traffic flow disruption ([10, 3, 1]).

The regression results indicated that there was indeed a significant relationship between SFFF and AVWR for most road links, as supported by the high R-squared values and low p-values. For example, Nyahururu and Kabarak road links showed strong correlations between SFFF and AVWR (R^2 = 0.770 and 0.487, respectively), indicating that a substantial proportion of the variability in AVWR can be explained by

SFFF. This supports the hypothesis that the frequency of side friction factors has a significant impact on AVWR.

These findings are consistent with the literature, which suggests that SFFF, such as pedestrians, vehicle parking, and entry/exit maneuvers, contribute to carriageway constriction and traffic flow disruption [10, 3, 1]. The regression models developed in the study provide empirical evidence of these relationships, further supporting the notion that SFFF play a crucial role in predicting AVWR in urban road links.

However, it's worth noting that some road links, such as Moi and Bangladesh, showed weaker correlations between SFFF and AVWR, suggesting that other factors may also influence carriageway width reduction in these locations. This variability in results underscores the complexity of urban traffic dynamics and the importance of considering site-specific factors in traffic modeling and analysis.

3.2. AVWR Against FFF Scatter Plot

A scatter plot of average carriage way width reduction was plotted against friction factor frequency. Figure 4 shows the scatter plot with a line of best fit. The line of best fit shows that the analyzed data was linear. However, this was not totally true since increase in frequency of friction factors increased the effect of those factors on the effective carriageway width up to a certain point. After reaching the maximum value further increase in the frequency does not lead to an increase in carriageway constriction as vindicated by the scatter plot curve. The curve tends to flatten after reaching the peak. This is attributed to the fact that since all factors were contributed by people, they are conscious of the fact that there needed to be left enough width of carriageway for vehicles to pass even if it will be at low speeds.

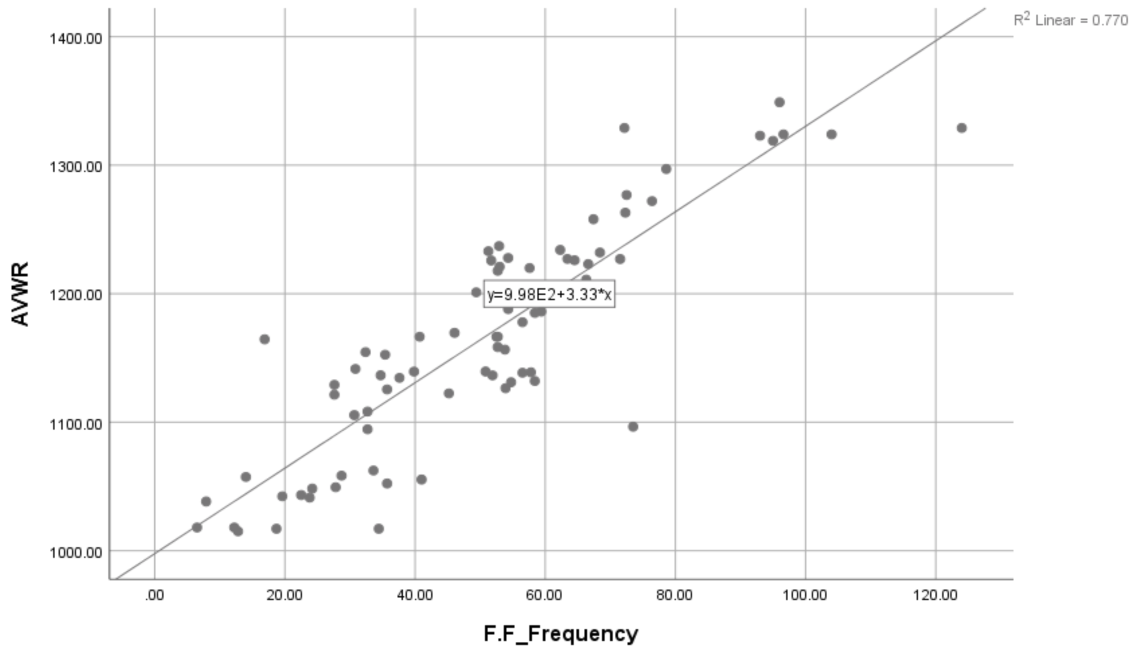

Figure 4. *AVWR against FFF Scatter plot.*

3.3. Average Width Reduction and Side Friction Factor Frequency

Previously the regression models developed contained all friction factors frequency as a whole. In order to determine the effect of the specific SFF on the reduction of carriageway width, the variables were grouped to the different SFFs. This resulted to six variables including pedestrians, entry and exit maneuvers, parked vehicles, motorbikes, bicycles and tuk-tuks. The collected data was reduced in an excel worksheet to obtain data from each site and the actual observations made from site. In the sorted data, it was concluded that when the friction factors were analyzed together with their effect the relationship was not significant in some sites. This meant that the increase in the frequency of the friction factor did not directly translate to increase carriageway constriction.

Most of the studied road sections had large enough side pavements that facilitated the movement of pedestrians without directly reducing the carriageway width. However, when these friction factors were regressed with the average width reduction on the road links it was determined that the relationship was linear up to a certain value. This can be observed from the scatter plot in figure 4 showing the relationship. When the frequency of a factor say pedestrians is high it affects other factors like motorbikes which stop on the road thus reducing the carriageway width. From the models developed as shown in table 8 below SPSS was used to generate the models. The effect was compared to that developed considering all the road links together.

In order to determine the impact of the friction factors combined, it was decided to combine all of the factors into one via a regression model to determine equations predicting their total impact to reduction of carriage way width. One unit of measure called AWR was used. The name was arbitrary adopted from the word average width reduction. Regression analysis was therefore performed with Average width reduction as the dependent variable and all the friction factors as the independent variables. The following equation was applied:

$$AVWR=X+A(PED)+B(ENX)+C(TUK)+D(BIC)+E(MOT)+F(PAR)$$

where;

A, B, C, D, E and F are regression coefficients for the associated variables.

X is the regression constant generated in the regression model.

PED- No of pedestrians (No./100m/hr.)

ENX-Entry and exit maneuvers (No./100m/hr.)

TUK- No of Tuk-tuks parking, dropping or picking passengers. (No./100m/hr.)

BIC- No of Bicycles parking, dropping or picking passengers. (No./100m/hr.)

MOT- No of Bicycles parking, dropping or picking passengers. (No./100m/hr.)

PAR-No. of vehicles parked on the road side. (No./100m/hr.)

In the table, the factors that showed negative correlation were excluded in the determination of AVWR since a negative correlation implied that increase in the frequency of these factors resulted to a decrease in the reduction of carriage way width.

Since in the earlier developed models all of them showed a positive relationship therefore these cases were treated as an anomaly and not considered. Those factors with low significance were considered in the determination of AVWR based on the assumption that these factors could contribute to carriageway width reduction when combined making them relevant.

Table 8. *Summary of Average width reduction prediction models.*

Road Link	AVWR Prediction model
O. Odinga	AVWR=976.457+0.541(PED)+1.26(ENX)+0.699(TUK)+0.193(BIC)+0.485 (MOT)+1.77(PAR)
Moi	AVWR=868.684+0.810(PED)+1.449(ENX)+0.567(TUK)+0.314(BIC)+0.072 (MOT)+0.614(PAR)
Kaptembwa	AVWR=951.885+0.597(PED)+0.813(ENX)+0.256(TUK)+1.192(BIC)+0.295 (MOT)+0.322 (PSV)+0.508(PAR)
Kabarak	AVWR=942.977+0.013(PED)+0.626(ENX)+0.574(TUK)+0.425(BIC)+1.261 (MOT)+0.371 (PSV)+0.57(PAR)
Nyahururu	AVWR=885.476+0.532(PED)+1.125(ENX)+0.371(TUK)+0.524(BIC)+0.078 (MOT)+0.524 (PSV)+0.146(PAR)
Njoro	AVWR=923.832+0.237(PED)+0.854(ENX)+0.367(TUK)+0.619(BIC)+0.072 (MOT)+1.071 (PSV)+0.521(PAR)
Bangladesh	AVWR=958.251+1.972(PED)+0.852(ENX)+0.983(TUK)+0.714(BIC)+1.36 (MOT)++0.579(PAR)
Elementaita	AVWR=859.429+0.731(PED)+1.876(ENX)+0.271(TUK)+0.642(BIC)+0.821 (MOT)+0.634 (PSV)+0.574(PAR)
NKRELD	AVWR=837.421+0.852(PED)+1.327(ENX)+0.631(TUK)+0.542(BIC)+0.371 (MOT)+1.091 (PSV)
PGH	AVWR=907.324+0.763(PED)+0.814(ENX)+0.532(TUK)+0.171(BIC)+0.253 (MOT)+0.429 (PSV)+0.638(PAR)
Ndundori	AVWR=998.853+0.42(PED)+1.677(ENX)+0.993(TUK)+0.619(BIC)+1.627 (MOT)+0.814(PAR)

The prediction models for average width reduction (AVWR) across various road links provide valuable insights into the relationship between specific side friction factors and carriageway width reduction. Upon analyzing these models, it becomes apparent that pedestrians, entry and exit maneuvers, and parked vehicles consistently emerge as significant contributors to carriageway width reduction across multiple road links, indicating their universal impact. This finding aligns with previous studies [10, 3] which have highlighted the importance of considering these factors in traffic management strategies.

Discussing each model individually, it's observed that the O. Odinga road link model shows a strong positive relationship between side friction factors (SFFs) like pedestrians, entry and exit maneuvers, and parked vehicles with AVWR. This is in line with the findings of [3], who identified on-street parked and stopping vehicles, slow-moving vehicles, and haphazard pedestrian movements as common frictional elements affecting traffic flow.

Moving on to the Kaptembwa road link, the model suggests a notable impact of bicycles on AVWR, which may be attributed to the specific characteristics of this road segment. This finding echoes the insights from [3], who identified various activities and objects as major causes of side friction on roads in Dhaka, including parking on the road and stalls along the road.

Considering the Nyahururu road link, the model indicates a strong positive relationship between pedestrians and AVWR, underscoring the importance of pedestrian traffic in urban congestion. This aligns with the observations of [8, 11], who demonstrated that accidents, often related to pedestrian-vehicle interactions, are a significant cause of death and disability worldwide.

Turning to the Bangladesh road link, the model reveals a substantial influence of pedestrians and motorbikes on AVWR, consistent with the findings of the [3], regarding the influence of parked vehicles on highway capacity. Their study showed that a higher number of parked vehicles per kilometer results in greater loss of effective carriageway width and capacity.

Examining the NKRELD road link, the model underscores the importance of pedestrians and entry and exit maneuvers in influencing AVWR. This reflects the findings of [2], who studied the capacity drops on urban arterials due to curbside bus stops in New Delhi, India. They found that on-line bus stops, which involve frequent entry and exit maneuvers, can reduce road capacity by 8%-13%.

The PGH road model demonstrates significant coefficients for pedestrians and parked vehicles, emphasizing their role in carriageway width reduction. This aligns with the Indonesian Highway Capacity Manual's approach, as described by [4, 5, 7], which considers factors such as pedestrian movements, parking and stopping cars, and exit/entry vehicles in determining side friction values.

Lastly, the Ndundori road model highlights the influence of entry and exit maneuvers and motorbikes on AVWR. This corresponds with the observations of [11] who investigated the situational characteristics of fatal pedestrian accidents and found that a higher proportion of such accidents occurred at non-signalized intersections, demonstrating the importance of vehicle-pedestrian infrastructural interactions.

Considering the comparative discussion across various road links, it's evident that while certain side friction factors such as pedestrians and entry and exit maneuvers consistently contribute to carriageway width reduction across different locations, the significance of other factors such as motorbikes and bicycles may vary depending on local conditions. This underscores the importance of context-specific analysis and tailored interventions to address traffic congestion effectively, as suggested by [11], who acknowledged the need for more research in developing countries on the relationship between accident rates and design standards.

Furthermore, the variation in regression coefficients across models highlights the complex interplay of side friction factors in urban traffic dynamics, emphasizing the need for comprehensive approaches to traffic management. This complexity is further illustrated by the findings of [9], who examined the impact of side frictions on travel speeds and level of service of rural highways in India, concluding that operational speed reduced by 50% within market areas due to the presence of side friction elements.

In conclusion, the analysis of AVWR models across various road links provides valuable insights into the complex relationship between side friction factors and carriageway width reduction. The consistent significance of factors such as pedestrians, entry and exit maneuvers, and parked vehicles across multiple road links emphasizes the need for targeted interventions to mitigate their impact on traffic flow and road capacity. Future research should focus on developing context-specific solutions that address the unique challenges posed by side friction factors in different urban environments.

4. Conclusion

This study investigated the impact of side friction factors on the reduction of effective carriageway width in urban road links in Nakuru Town, Kenya. Linear regression models developed for each road link revealed a strong positive relationship between the frequency of side friction factors and the average carriageway width reduction (AVWR). The prediction models highlighted the varying influence of specific side friction factors, such as pedestrians, entry and exit maneuvers, parked vehicles, motorbikes, and bicycles, on AVWR across different road segments.

The findings emphasize the importance of context-specific analysis and tailored interventions to effectively address traffic congestion in urban areas. The complex interplay of side friction factors in urban traffic dynamics necessitates comprehensive approaches to traffic management. By understanding the relationship between side friction factors and carriageway width reduction, urban planners and traffic managers can develop targeted strategies to mitigate the impact of these factors on traffic flow and improve overall road network efficiency. This study provides valuable insights into the influence of side friction factors on carriageway width reduction in urban road links, highlighting the importance of considering local conditions and adopting a holistic approach to traffic management.

Abbreviations

AVWR	Average Carriageway Width Reduction
BIC	Bicycles
CBD	Central Business District
ENX	Entry and Exit maneuvers
MOT	Motorbikes
PAR	Parked Vehicles
PED	Pedestrians
PGH	Provincial General Hospital
PSV	Public Service Vehicles
SFF	Side Friction Factors
SFFF	Side Friction Factor Frequency
SPSS	Statistical Package for the Social Sciences (likely)
TUK	Tuk-Tuks

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Bhat, M. A., Bali, E. S., & Lohani, T. K. (2019). Impact of road side frictional elements on average travel speed and level of service for an urban two-lane street. *International Journal for Technological Research in Engineering, 6*(7), 1–5.

[2] Chand, S., Chandra, S., & Dhamaniya, A. (2014). Capacity drop of urban arterial due to a curb side bus stop. In *Proceedings of the International Conference on Sustainable Civil Infrastructure*. ASCE India Section.

[3] Chiguma, M. L. M. (2007). *Analysis of side friction impacts on urban road links: Case study Dar-es-Salaam* [Master's thesis, Royal Institute of Technology]. Stockholm, Sweden.

[4] Directorate General of Highways, Republic of Indonesia. (1997). *Indonesian Highway Capacity Manual*.

[5] Gulivindala, P., & Mehar, A. (2018). Analysis of side friction on urban arterials. *Transport and Telecommunication, 19*(1), 21–30.

[6] Islam, M., Al Razib, S., Hasan, M., Ali, S., Monir, O., & Hasan, M. (2018). Cause of reduction of effective roadway width due to side friction in Dhaka City. *American Journal of Traffic and Transportation Engineering, 3*(1), 6–17. https://doi.org/10.11648/j.ajtte.20180301.12

[7] Munawar, A. (2011). Speed and capacity for urban roads: Indonesian experience. *Procedia - Social and Behavioral Sciences, 16*, 382–387. https://doi.org/10.1016/j.sbspro.2011.04.459

[8] Murray, C. J. L., & Lopez, A. D. (1996). *The global burden of disease: A comprehensive assessment of mortality and disability from diseases, injuries and risk factors in 1990 and projected to 2020*. Harvard School of Public Health.

[9] Pal, S., & Roy, S. K. (2016). Impact of roadside friction on travel speed and LOS on rural highways in India.

[10] Pallavi, G., & Apran, M. (2018). Analysis of side friction on urban arterials. *Transport and Telecommunication, 19*(1), 21–30.

[11] Richard, R., & Bent, T. (2004). *Road engineering for development* (2nd ed.).

[12] WHO. (1999). *World health report: Making a difference*. World Health Organization.