EVALUATION OF THE ROLE OF THE URBAN PLANNING RELATED FACTORS ON THE OCCURRENCE OF TRAFFIC ACCIDENTS IN URBAN AREAS IN SOUTH AFRICA - A CASE STUDY IN BLOEMFONTEIN CITY

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ABSTRACT

Traffic safety is a major challenge in most of cities in South Africa particularly on the arterial roads passing through the sub urban areas. The major contributing reasons for the occurrence of traffic accidents emphasized include human related factors, road related factors and vehicle related factors. However, the influence of the urban development related factors such as, land use and urban functions, urban form, urban pattern, accessibility, and density on the occurrence of traffic accidents have been least explored, particularly in the sub urban residential areas of the cities of South Africa. Therefore, this paper pertains to investigate the influence of various urban related factors on the occurrence of vehicular traffic accidents on the sub urban arterial roads of a South African city. The investigation was conducted by considering Bloemfontein City as the study area and by employing survey research methodologies, statistical analyses, development and consequent application of empirical regression models. It was revealed that level of accessibility (number of accessible roads) from residential areas to arterial roads is the major variable, which causes traffic accidents. Road geometry variables like median and road width influence the occurrence of traffic accidents to a certain extent. However, variables belonging to land use and urban functions, urban form, urban pattern, location of important urban functions in convoluted areas, and density of population have relatively lesser impact. Reduction in the number of access roads from the sub-urban residential areas to the arterial roads, provision of adequate medians in roads with no divided facility along with urban planning interventions, such as, appropriate urban pattern, and avoidance of location of urban functions in convoluted areas will enable reduction in the occurrence of traffic accidents and improve road safety in the cities of South Africa.

Keywords: Traffic accidents, Suburban areas; Sub arterial roads; Urban planning; Accessibility; Urban functions, Urban pattern

1. INTRODUCTION

Traffic safety is increasingly becoming a major challenge in most of the cities in South Africa. More than 10 000 fatal accidents occur every year on the roads of the South Africa besides huge number of the major and minor non fatal accidents (RTMC, South Africa, 2008). The majority of these accidents occur on the roads of the cities particularly on the arterial roads. It is also observed that the arterial roads passing through the sub urban residential areas are more vulnerable to vehicular traffic accidents (Burger, 2012). According to several studies across the world, the major contributing reasons emphasized are human related factors (Abdel-Aty and Radwan, 2000; Collins and Chambers, 2005; Sabey and Taylor, 1980), road related factors (Dumbaugh and Rae, 2009; Marks 1957; Papayannoulis, Gluck, Feeney, Levinson, 2000; Rui, Yingshi, Wei, Hongyun and Yong, 2009) and vehicle related factors (Rui et al., 2009; Sétra, 2007). However, the influence of the urban development related factors such as, land use and urban functions, location of urban functions, urban form and urban pattern, accessibility, and population density (Choocharukul, Van, & Fujii, 2008; Fujii and Ga¨rling, 2005) on the occurrence of traffic accidents have been least explored, particularly in the sub urban residential areas of the cities of South Africa. The objective of this paper is therefore to explore the influence of various urban planning related factors on the occurrence of vehicular traffic accidents on the sub urban arterial roads of a South African city.

The investigation was conducted by employing survey research methodologies, development and consequent application of empirical regression models. Bloemfontein City was considered as the case study for this purpose, and its suburban arterial roads (U3- minor arterials, COTO, 2012 South Africa) were used for the traffic survey and assessment of occurrence of accidents. It was revealed that level of accessibility (number of accessible roads) from residential areas to arterial roads is the major variable, followed by urban road geometry variables, such as, median and road width, which cause traffic accidents. However, variables belonging to land use and urban functions, urban form, urban pattern, location of important urban functions in convoluted areas, and population density have relatively lesser impact.

The analysis revealed that a reduction in the number of access roads from the sub urban residential areas to the arterial roads, provision of median in the roads without divided facilities and improvement of road widths as per design standards will enable reduction in the occurrence of traffic accidents and improve road safety in the cities of South Africa. Besides, although urban planning related parameters have lesser impact, it is found that urban planning interventions, such as, appropriate urban pattern like linear pattern or grid iron pattern with loop roads and avoidance of location of commercial urban functions requiring mixed land use in convoluted areas will also assist in improving road safety.

2. INFLUENCE OF URBAN DEVELOPMENT ON VEHICULAR TRAFFIC ACCIDENTS: EVIDENCE FROM LITERATURE REVIEW

Vehicular traffic accident risks are observed to be significantly higher on the roads outside the city centre or as the sprawl increases and generally occur in the suburban areas particularly on the suburban arterial road links and junctions (Mohamed, vom Hofer, & Mazumder, 2014; Vorko-Jovic et al, 2006). For example, Mohamed, vom Hofer &, Mazumder, (2014) found that a 10% increase in the sprawl index (lower the sprawl indices higher the sprawl in the cities) leads to a decrease of 5.56 injuries and fatalities per 10,000 residents. Of these, a reduction of 4.48 and 1.07 injuries and fatalities per 10,000 residents is attributable to sprawl in its own jurisdiction and sprawl from neighbouring jurisdictions, respectively (Mohamed, vom Hofer & Mazumder, 2014). So, it was emphasised that planning and design of cities, suburban areas, neighbourhoods, housing and buildings involve many variables, which could influence the occurrence of vehicular accidents (Miranda-Morenoa, Morency, & El Geneidy, 2011; Retting, Weinstein, Williams & Preusser, 2001). The availability of social and economic urban functions, the neighbourhood design, the design of the streets, and the overall organisation of road traffic control and management constitute some of the most important variables, which essentially influence the frequency and severity of vehicular traffic accidents (Miranda-Morenoa, Morency, El Geneidy, 2011; Retting et al, 2001).

Besides, a study by Dunphy and Fisher (1996) on the relationships between urban densities, the socio-economic characteristics of residents, and their travel characteristics revealed that there is a general tendency for less driving in higher-density regions, which was also corroborated by other scholars. The analysis led to the conclusion that a positive relationship between density, transit usage, and household travel exists (Dunphy et al 1996; Mohamed, vom Hofer, & Mazumder, 2014). Handy (1996) also hypothesised that urban form is an external factor that could encourage or discourage the use of vehicles and walking trips to destinations, depending on the motivations and limitations of people to carry out their urban functions, thereby influencing the occurrence of vehicular traffic accidents. It was noted that the more an individual travels, the higher the chance of being involved in an accident (Handy, 1996).

According to Chakrabarty (2007), while evolving solutions to vehicular accident problems, large variations in the resource-efficiency indicators need to be viewed and the solutions that meet the specified criteria or goals for the efficient and equitable solution to both the mounting urban development and urban traffic problems should be selected. In this context arguments have emerged to reduce individual motor vehicle travel behaviours (Miranda-Morenoa, Morencyb, El Geneidy 2011). However, at the micro-level, question arises about the role that suburban areas or local neighbourhood design plays in determining travel behaviour. Some scholars argue that neighbourhoods should encourage more walking, transit trips, and shorter trips that would reduce vehicular traffic accidents (Feng, Lovegrove, 2012; Daniel, Bandoe, Eric & Miller 2000). Similarly, a reduced road network connectivity within the suburban neighbourhoods results in a reduction of physical and vehicle-related activity (Badland, Schofield, & Garrett, 2008; Daniel et al 2000). In this regard, studies have also revealed that there is a positive relationship between high street connectivity with the increased levels of walking for commuting

purposes on the major arterial roads leading to important functional areas, such as schools, commercial, civic centres, etc., (Feng, Lovegrove, 2012; Geurts, Thomas, & Wets, 2005).

Likewise, the number of accidents, injuries and fatalities in a jurisdiction increases with the magnitude of sprawl in neighbouring jurisdictions (Mohamed, vom Hofe, Mazumder 2014). Thus, route directness could alleviate accident problems in suburban arterial roads or neighbourhoods of a city (Badland et al 2008). Another element that was highlighted in literature is the road geometry of urban roads (Camacho-Torregrosa, Pérez-Zuriaga, Campoy-Ungría, García-García, 2013). For instance, Bester and Makunje, (1998) found that an increase in lane and shoulder width and traffic volume leads to a decrease in the accident rate. However, on the other hand an increase in traffic lanes and intersections increase the number of vehicular traffic accidents in an area (Papayannoulis, Gluck, Feeney, Levinson, 2000). Also, accident rates are less for a divided facility compared to an undivided facility, whereas steep descending gradients may cause braking problems for vehicles and impair road safety (Rui et al., 2009; Sétra, 2007). Thus, it is revealed urban planning parameters and characteristics of urban areas along with the characteristics of urban roads need to be considered while investigating the ways to improve road safety in cities.

3. THE STUDY AREA

Bloemfontein City in South Africa is chosen as the study area for this investigation. It is the capital city of the Free State province and has been the judicial capital of the country since the year 1910. According to the latest census Bloemfontein is the largest city in the Free State province, having a population of about 850 000, which is about 24% of the total population of the region and have a population density of 104 people per square kilometre (Statistics SA, 2011). Most of the people (more than 80%) live in the suburban areas and commute daily to different parts of the city.

Spatially, the city comprises of 26 suburban residential areas. Each of the suburbs of the city has a unique urban pattern and land use. The various land uses in the city are residential, commercial, industrial, civic, open space, and/or mixed land uses. The city has a designated CBD, which is dominated by commercial and administrative functions. The area on the periphery of the CBD is mostly of mixed land use having mixed functions, which include commercial, civic, recreational and residential activities. Towards the outer parts of the city, the areas are predominantly occupied by residential areas with mixed land use.

The city has a hierarchical road network system with major arterial, minor arterial, collector roads as well as local streets and cul-de sacs. The road patterns are mostly grid iron or loop pattern and in some cases the combination of the two. However, in some parts linear, organic and mixed pattern of road network are observed. All parts of the city are accessible and the major arterial roads of the city act as the network distributor for the roads linking the outer suburbs to the city centre. The arterial roads passing through the suburbs connect to the major arterial roads of the city. Besides, these suburban arterials act as thoroughfares in the suburban residential areas linking the collector roads and the local streets to provide access to the residents.

The majority of the roads are paved, although some residential areas have unpaved roads or poorly maintained paved roads. The major modes of travel in the city are personal/individual-driven motor cars. A large number of people (about 60%) use their own vehicles for their daily travel, while the others use public transportation systems, such as local taxi or bus services (Household survey 2011). According to the reports of the police stations in the study area, a major share of the total accidents (about 45%) that occurs in and around the city is experienced on the suburban arterial roads. It is also noted that some of the sub urban arterial roads of the city experience a large number of vehicular traffic accidents, which range from 17-127 on an average annually in the last six years (2005-2011). Thus, this investigation focuses on the assessment of causes of occurrence of accidents and improvement of road safety on the suburban arterial roads of the city.

4. METHODOLOGY: SURVEY, DATA ANALYSIS AND MODELING

A survey research methodology followed by relevant statistical analysis and regression modelling approach were applied in this study. Data were collected from both primary and secondary sources. Primary field survey was conducted to get first hand data at the study area level. For this purpose out of the twenty six suburbs of the city, four important suburbs (Fichardtpark, Pellissier, Universitas, and Langenhovenpark) representing the city were chosen. These suburbs were selected on the basis of a set of selection criteria, such as the functional importance of the area with the availability of major urban functions and consequent land use, population and population density, urban pattern, vehicle ownership, accessibility, the complexity of the road network, the location of arterial thoroughfares inside the residential area, and most importantly the occurrence of number of accidents. These areas are densely populated, and perform relatively higher levels of urban commercial and civic functions, with the location of market complexes, schools and universities, hospitals and entertainment areas, all of which require higher vehicular movement. Further, these four suburban areas have experienced the occurrence of higher number accidents in the last six years.

Three kinds of primary surveys, such as, household surveys, traffic surveys, and road geometrical parameter surveys were conducted in these selected suburban areas. The household survey was conducted among 270 households in the above mentioned selected areas (sub urban areas) of the city by using systematic stratified random sampling process. The samples are selected based on the parameters, such as, intensity of road uses either by vehicles or walking, vehicle ownership, and direct or indirect experiences of traffic accidents in order avoid uncertain and subjective answers regarding the parameters, which influence traffic accidents. The traffic surveys which include speed and volume surveys were conducted at important sections of the arterial roads passing through the suburban areas. The surveys were conducted continuously for sixteen hours a day (6.00 am to 22.00 hours) for seven days in a week, which includes both week days and weekends.

Similarly, physical road surveys were conducted at important road sections and junctions of the sub-urban arterial roads in the four selected suburban areas to determine the road geometry parameters (road width, shoulder width, lane width, number of lanes, kerbs, curvature, median width, gradient, sight distance and road

surface condition) in order to establish whether any relationship exists between geometric aspects of the urban roads and occurrence of the vehicular traffic accidents.

Furthermore, secondary data pertaining to traffic and occurrence of traffic accidents in the study area from the year 2005 to 2011were collected from various sources, such as, published and unpublished documents from the Police stations of the study area, reports of the Department of Police and Road Transport, Free State, reports of the Mangaung Metro Municipality and Statistics SA (2011). The traffic accident data collected includes all the vehicular and pedestrian accidents (both fatal and nonfatal) as registered in the police reports. The investigators collected the data themselves and while collecting the data they conducted discussions with the police and traffic officials to confirm the type of accidents, location, degree of severity of the accidents, and to eliminate uncertainties and vagueness, if any available in the reports.

The data collected were statistically analysed to observe the causes of accidents and major parameters responsible for the occurrence of accidents. The causation of accidents was established by concurrent agreement of three statistical analyses, such as, perception index of road users; correlation coefficients between the traffic accident and road geometry, urban planning and traffic related parameters; and linear regression modelling and trend analyses.

The traffic accidents data used in the various analyses is the average number of traffic accidents occurred per kilometre of the road length. While calculating the average number of accidents, first the total number of accidents occurred in particular road over a period of one year was calculated (as obtained from police and accident records) and then divided by the total length of the road.

The perception index (PI) of the road users was developed by employing weighted average index method. The PI was developed by using the values assigned by the respondents as obtained from the household survey. The variables were grouped under four categories such as, land use and urban functions, urban pattern, urban road geometry and other urban development related parameters. Each variable's influence is assessed in a scale of 0 to 1.The respondents were asked to assign values to each variable, which influence the occurrence of the accidents based on their perception and/or direct and indirect experience on the accidents in a scale of 0 to 1. While developing this index care was taken to exclude irrelevant, subjective and uncertain responses. The model used for development of the perception index is given as below.

Perception weighted average index= PI $= \frac{\sum Pi * Ni}{\sum Ni}$

Where, Ni = number of respondents, Pi = index values provided by the respondents in a scale of 0 to 1 as observed from household survey.

Also, correlation coefficients between the number of traffic accidents and various dependent variables under road geometry, urban planning and traffic related variables were conducted to eliminate the less influential and insignificant variables causing accidents. Also, Variance Inverse Factor (VIF) test was conducted to

observe the co-linearity among the dependent variables. Followed by, linear regression models between the number of traffic accidents and major independent variables were developed, the results were examined as well as trend analysis were conducted to determine the influence of the major variables on the accidents and their implications on the reduction of traffic accidents.

5. RESULTS AND DISCUSSION

5.1 Major urban planning related control variables on the occurrence of vehicular traffic accidents

The various urban development related variables, which influence the accidents were initially analysed based on the perception index (PI) and is presented in the Table 1. It was revealed that under land use and urban functions, areas under mixed land use and commercial activities have relatively higher influence on occurrence of vehicular traffic accidents followed by areas under residential areas. The areas under civic and industrial activities have lesser impact on the occurrence of accidents. However, as the perception index of almost all the variables under land use and urban functions are low (around 0.5 or less) their overall impact on the occurrence accidents in urban areas is found to be low. Similarly, organic pattern (irregular) and mixed pattern of urban pattern has relatively higher influence on the accidents followed by grid iron pattern. As against, areas with linear pattern and grip iron with loop pattern of roads have minimal impact. Again, since the perception index scores of most of the variables are meagre (varying between 0.33 and 0.53), the overall impact of urban pattern on the occurrence of accidents are seemed to be marginal. Similarly, the influences of urban form, density of population and location of sub urban areas on traffic accidents are also found to be low. However, accessibility (accessible roads from residential areas to arterial roads) has much higher greater influence (0.77) on the occurrence of vehicular traffic accidents. Besides under the road geometry category, road width, number of lanes, median width, and availability of medians are the major road related parameters which are responsible for occurrence of accidents. Therefore, the perception index revealed that urban development related variables, such as, accessibility, road width (as number of lanes is a function of road width), median width (presence of medians is a function of median width) on the roads largely influence occurrence of accidents in the arterial roads of sub-urban areas of the Bloemfontein City. Thus, these variables can be considered as the major influential parameters causing traffic accidents in the study area.

The physical survey of the roads elements of the sub-urban areas revealed that most of the other urban road related parameters, such as lane, width, kerbs, shoulder width, curvature, gradient, sight distance, types and design of junctions, and condition of roads, more or less confirm to the provisions of the design standards recommended by South African National Road Authority Limited (SANRAL, G2 manual, 1-304) and Guidelines for Human Settlement Planning And Design, Roads: Geometric design and layout planning (Chapter 7, p1-41). Therefore, obviously they have lesser impact on the occurrence of traffic accidents as seen from the PI analysis in the Table 1.

Table 1: Urban development related variables influencing vehicular accidents (based on perception index)

Parameters	Index values	Parameters	Index values
Land use and urban functions		**Road related**	
Commercial	0.52	Road Width	0.67
Residential	0.48	Number of lanes	0.65
Industrial	0.32	Lane width	0.52
Civic	0.45	Presence of medians/Dividers	0.60
Mixed	0.55	Medians width	0.55
Urban pattern		Kerbs	0.44
Linear	0.33	Shoulder width	0.30
Grid Iron	0.46		
Grid Iron and loops	0.36	Curvature	0.24
Radial	0.39	Gradient	0.24
Organic	0.51	Sight distance	0.45
Mixed	0.53	Types of Junctions	0.33
Other parameters		Condition of road	0.30
Accessibility (Number of access roads)	0.77		
Urban form	0.40		
Location	0.35		
Density	0.47		

(Source: Primary Household Survey, 2011)

5.2 Correlation and Regression model analysis and influence of the major urban planning related control variables on the occurrence of vehicular traffic accidents

The correlation coefficients between the number of accidents and various urban development variables, and VIFs are given in Table 2. It is found that occurrence of number of accidents correlates reasonably highly with the number of access roads (0.81), and fairly correlates with road width (0.61) and with median width of roads (-0.54). The variables having lower or insignificant correlation coefficients (<0.50) were ignored for further analysis. These three variables are observed to be fairly independent as they have shown lower correlations among each other and the VIFs values are within the acceptable range (absolute values are observed to be less than 4 except between dependent and independent variables). So these three major variables are considered for further analysis to observe their degree of influence of the occurrence of traffic accidents in the sub urban arterial roads of the city. It is here to note that speed and traffic volume (Average Daily Traffic (ADT)) are considered as the traffic related variables; since this study basically focuses on the urban planning related variables, the analyses of the influence the speed and ADT were kept out of the scope of this paper. (*However, it will be worthwhile to mention that ADT (0.77) and speed (0.71) fairly correlate with the occurrence of traffic accidents. Besides it is found that if the speed is increased from the maximum allowed speed of 60 Km/h, the occurrence of number of accidents increases at a fairly high rate with the*

increase in speed (i.e., there is an increase of 1.33 times higher than the occurrence of the current minimum number of accidents for every 5km/h increase in speed). Similarly if the ADT increases, the occurrence of accidents increases at a rate of 1.64 times of the current minimum number of accidents per every 500 passenger car units (PCU) increase.)

Table 2: Correlation coefficients between number of accident occurrences and urban planning related variables and Variance Inverse Factor (VIF) test results

	Correlation coefficients				Variance Inverse Factors (VIFs)			
Parameters	Number of accide-nts	Accessibility	Road width	Median width	Number of accide-nts	Acces-sibility	Road width	Median width
Number of accide-nts	1.0	0.81	0.61	-0.54	6.16	-3.51	-2.56	1.40
Access-ibility	0.81	1.0	0.31	-0.49	-3.51	3.46	1.06	-0.12
Road width	0.61	0.31	1.0	-0.08	-2.56	1.06	2.18	-0.69
Median width	-0.54	-0.49	-0.08	1.0	1.40	-0.17	-0.69	1.64

Furthermore, regression models were developed between occurrence of accidents as the dependent variable and each of the influential variables, such as access roads, road width and median width, which could be able to provide the trend and predict their level of influence on occurrence of accidents. The models and their results are presented below.

5.2.1 Relationship between for traffic accidents and accessibility

The model for relationship between for traffic accidents and accessibility is presented in equation (Eq.) 1.

$y = 2.422x_1 + 2.411$ ……Eq. (1)

$r^2 = 0.89$

Where y= number of accidents, x_1 is number of accessible roads per km.

Figure 1 shows the trend analysis of regression model and behaviour between number of accidents and number of accessible roads to the arterial roads. As observed, the number of accidents will increase 2.33 times from its minimum with the introduction of each access road to the arterial roads. The trend also shows that the occurrence of number of accidents is much higher with increase in number of access roads. So, the number of access roads has significant impact on the occurrence of accidents and needs to reduced or controlled in order to improve road safety.

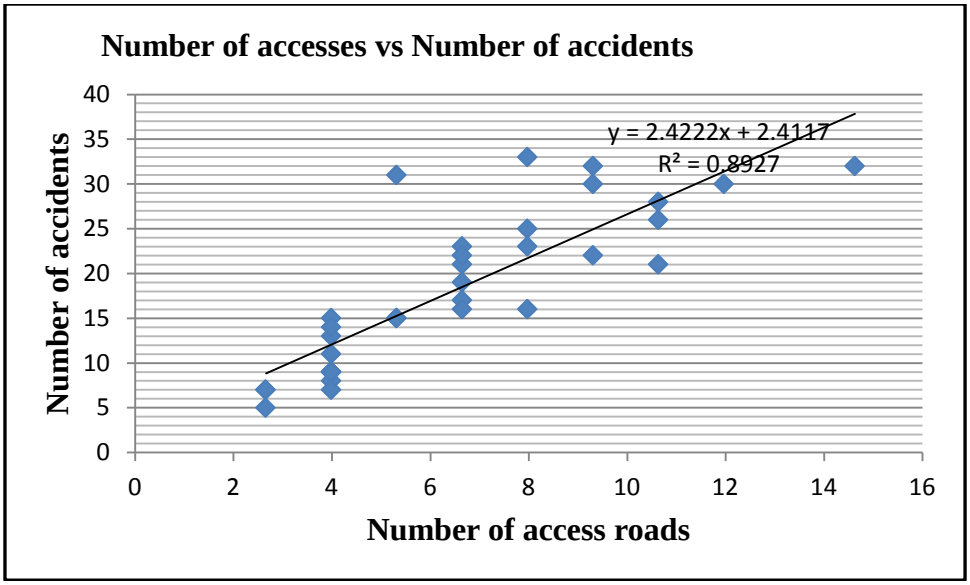

Figure 1: Influence of accessibility on occurrence of traffic accidents

5.2.2 Relationship between for traffic accidents and road width

The regression model between occurrence of number of accidents and road width is given in the equation 2. While developing the model it is considered that road width is a function of number of lanes and lane widths and road width is the sum of widths of all the lanes in the road segment.

$y = 3.2177x_2 - 3.8247$ ……Eq. (2)

$r^2 = 0.66$

Where y= number of accidents, x_2 is road width in meters.

It is seen from the Figure 2 that the variation of occurrence of accidents with road width is marginal except exceptional cases. As shown from the trend analysis occurrence of accidents are concentrated on the roads width varying from 6 m to 8 m, although there are exceptional cases, such as, higher number of accidents occur in relatively higher width roads. This anomaly could be attributed to the influence of other variables, which could include speed and Average Daily Traffic (ADT) or behavioural factors. Thus, road width has relatively lesser influence of the occurrence of accidents on the urban arterial roads of sub urban areas of Bloemfontein; however, its influence can not be undermined altogether while considering development of traffic safety interventions.

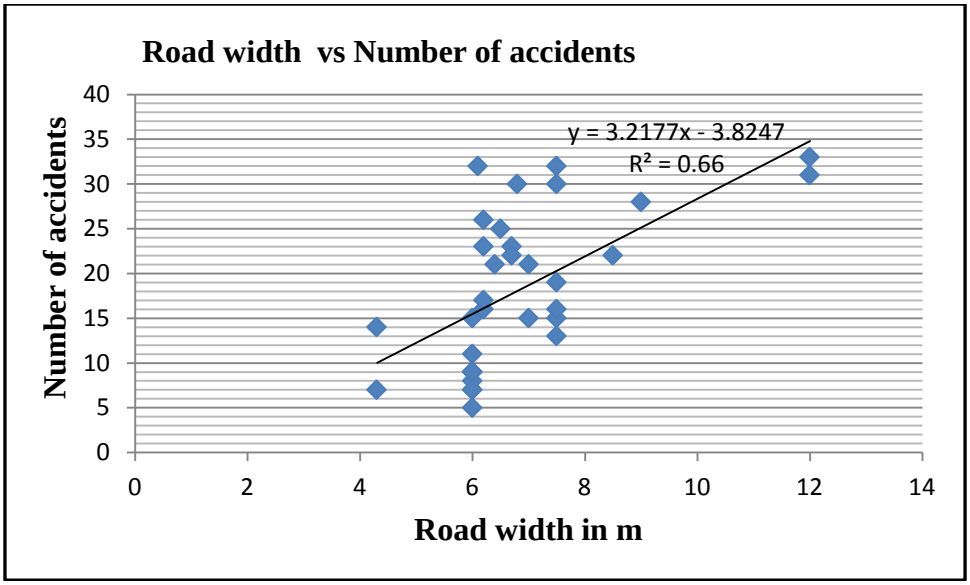

Figure 2 Influence of road width on occurrence of traffic accidents

5.2.3 *Relationship between for traffic accidents and median width*

Equation 3 presents the regression model between occurrence of accidents and median with of the roads.

$y = -3.3219x_3 + 28.66$……Eq. (3)

$r^2 = 0.67$

Where y= number of accidents, x_3 is median width in meters

From Figure 3 it is observed that number of accidents is higher on the roads where there are no median facilities and the number of accidents reduces with increase in median width. However, it is also seen from the trend analysis that while the presence of medians does not necessarily rule out the occurrence of accidents, their absence has a significant influence on the higher occurrence of accidents. Besides, as observed from physical road geometry and traffic surveys, the volume of pedestrians on the sub urban arterial roads are found to be very meagre, and the medians act as the refuse centres for the pedestrians during the road crossings. It is apparent that the presence of medians lessens the occurrence of accidents involving pedestrians, although, not conclusively. So provision of medians particularly on the roads without divided facility and increase of median width to at least to the minimum recommended widths as per standards (SANRAL, G2 manual, 1-304; Guidelines for Human Settlement Planning and Design, Roads: Geometric Design and Layout Planning (Chapter 7, p1-41) for urban roads are expected to alleviate the occurrence of on the suburban arterial roads of the city.

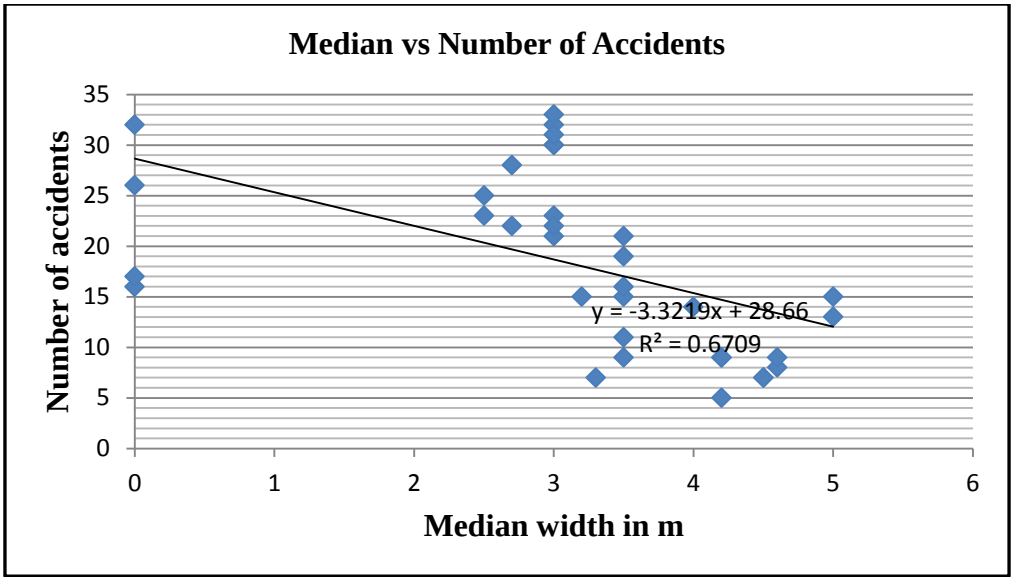

Figure 3: Influence of median width on occurrence of traffic accidents

6. CONCLUSION

The investigation conducted pertains to evaluate the role and influence of urban planning related variables on the occurrence of traffic accidents in the Bloemfontein City. It was therefore important to establish the various causes of the traffic accidents in the city. A survey research methodology and relevant statistical analyses were adopted to conduct the analyses. The causation between the traffic accidents and various urban planning related variables were established by the concurrent analyses of the PI, correlation coefficients, VIF test, regression analyses and trend analyses. It is apparent that a number of urban planning related parameters influence the occurrence of traffic accidents in the arterial roads of suburban roads of Bloemfontein City.

Among all the variables, accessibility is the major variable, which contributes largely to the occurrence of accidents followed by inadequate road width, absence of medians or low median width on the roads. Also, a variable like number of lanes, which is a function of the road width do influence the occurrence of accidents to a certain extent. However, most of the land use and urban function variables have lesser influence on the occurrence of accidents except mixed land use and commercial activity areas. Similarly, it is found that urban pattern do not contribute much to the occurrence of accidents, however, the grid iron pattern with loops and linear pattern urban areas perform better than other types of urban pattern, such as, organic (irregular), radial, and mixed. The significance of urban form, density and location of urban areas on the occurrence of accidents seems to be low. Likewise, most of the other urban road related parameters, such as lane, width, kerbs, shoulder width, curvature, gradient, sight distance, types of junctions and condition of roads, have insignificant influence on the occurrence of accidents.

Therefore, this investigation revealed that reduction of the number of accessible roads to arterial roads passing through suburban areas is of utmost importance to reduce occurrence of traffic accidents. Besides, provision of medians on the roads having no divided facilities or improvement in the median widths, and to increase of

road widths (number of lanes and lane widths) as per design standards would able to reduce occurrence of accidents and improve road safety. In addition, restructuring of urban areas with mixed, organic or grid iron pattern can be done by tweaking of the road patterns, such as, providing loops and/or making them more linear. Similarly, as mixed land use and commercial activities can be concerns, their location can be avoided at convoluted areas in order to reduce occurrence of traffic accidents in the arterial roads of Bloemfontein.

There are also a few limitations concerning this study. The major limitation is that the scope of the research was confined to the investigation of urban planning related parameters on the occurrence of traffic accidents in the Bloemfontein City. So, explicit analyses relating to influence of traffic related parameters, such as, speed and traffic volume and human related aspects were kept out of the scope of the investigation. Therefore, further research is needed to extend the study to those aspects of the study. Besides, a study also needs to be conducted by considering other urban areas of the country in order to generalise the research implications. However, the current research shows that some of the urban planning related parameters have significant influence on the occurrence of accidents on the arterial roads and need to be considered carefully while developing policy interventions to improve road safety in the urban areas of South Africa particularly in the Bloemfontein City.

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