EVALUATION OF TRAFFIC CONGESTION AND RE-ENGINEERING SOLUTIONS FOR CENTRAL AREAS OF SOUTH AFRICAN CITIES: A CASE STUDY OF KIMBERLEY CITY

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Abstract: Traffic congestion in and around the central business districts (CBD) of South African cities is a major challenge. Apparently, it is engendering undesirable consequences that include impeding vehicular flow, causing vehicular and pedestrian conflicts, escalating travel time, and frequenting vehicular crashes. So, using a case study of Kimberley city in South Africa, this study assessed the causes and degree of traffic congestion on the roads in and around the CBD area; and examined the impact of plausible re-engineering measures to alleviate the challenge. Survey research methods were used to collect data. Land use and urban functions influencing urban movements, road, and traffic scenario data were collected through physical and traffic survey at different selected road sections and junctions of the CBD area by following appropriate survey protocols. Besides, road user perception and travel behaviour survey were conducted among 208 (N= 208) road users by using random sampling process at important nodes of the city. Relevant empirical models were used to assess the causes and level of traffic congestion, and to examine the impact of re-engineering solutions on the current and forecasted traffic scenarios. Findings suggest an appreciable level of traffic congestion is experienced currently in some of the roads of the CBD area and the situation will be aggravated in future, specifically during the peak hours, whereas a number of roads are highly underutilised. Re-engineering solutions such as appropriate traffic assignment and modal split, i.e., traffic diversion ranging between 9.0% and 40.5% from different congested roads and restriction of plying of heavy vehicles on the congested roads during peak hours and assigning them to connected underutilised roads could ease traffic congestion, increase speed and reduce travel time and consequently enable optimal use of the majority of the roads in and around the CBD area of the city.

Keywords: central business district, traffic congestion, level of service, modal split, peak hours, traffic assignment.

1. Introduction

Traffic congestion has been a critical challenge in many cities across the world. It engenders a range of undesirable consequences that include negative economic impacts and environmental pollution (Rao and Rao, 2012; Sorensen et al., 2008; Wang, Gao, Xu, Sun, 2014). Many South African cities suffer from this challenge. Particularly, the central business districts (CBD) of a number of large and medium cities of the country are observed to be affected by the congestion challenges during different periods of the day. Kimberley city of Northern Cape Province of the country is a typical; example. The city, because of its unique physical, spatial, road network, economic characteristics, and requirement of mobility of heavy vehicles in addition to the normal city traffic experience critical traffic congestion challenge in its CBD area, particularly during the peak hours. Consequently, issues such as loss of economic benefits because of increase of travel times of vehicles in mining activities, delay in travel and change of travel pattern of local people for day to day activities, environmental pollution, and higher consumption of fuel and anxiety of people to travel top CBD area during business hours have emerged. In addition, experiences of different policy interventions such as creation of additional road infrastructure, Travel Demand Management measures, reinforcement of public transportation system, congestion pricing, encouragement of non-motorised transportation system, limiting parking facilities, etc., which have been tried in different cities of the world suggest that, these solutions have met mixed successes. Besides, they require creation of infrastructure, enforcement of certain constraints and restrictive measures and change in mobility behaviour, which is sometimes unacceptable by people and also incurs huge investment, making such projects economically unsustainable and socially unacceptable. This warrants acceptable and cost effective remedial measures to alleviate the traffic congestion challenges in the city. However, before evolving remedial interventions, it is necessary to assess the level of traffic congestion and reasons thereof; understand the perspective influence of the solutions that could assist in evolving strategies to meet the challenges. Therefore, the objective of this paper is to explore the causes and degree of traffic congestion on the roads in and around the CBD area; and examine the impact of plausible re-engineering measures to alleviate the challenge. The study was conducted by using Kimberley city of South Africa as a case study. A survey research method and relevant statistical and empirical models were used for the conduct of the investigation. . The study revealed that an appreciable level of traffic congestion is experienced currently in some of the roads of the CBD area and the situation will be aggravated in future, specifically during the peak hours, whereas a number of roads are highly underutilised. Re-engineering solutions such as appropriate traffic assignment and modal split, i.e., traffic diversion ranging between 9.0% and 40.5% from different congested roads and restriction of plying of heavy vehicles on the congested roads during peak hours and assigning them to connected underutilised roads could ease traffic congestion, increase speed and reduce travel time and consequently enable optimal use of the majority of the roads in and around the CBD area of the city.

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2. Literature Review

Traffic congestion occur when traffic is delayed due to the presence of excess number of vehicles on the same portion of the road way at a particular time because the number vehicles trying to use the road exceeds the design capacity of the road (Department of transportation U.S., 2005, p. 1; Link et al. 1999, p. 9). As a result, there shall be long queues of vehicles, vehicles move slower than the normal or "free flow" speeds and at constant start and stop basis. It also results into delay in the overall traffic movement in a road network and the traveller fails move in a desirable manner (ECMT, 1999; Goodwin 2004; Levinson et al., 1997; Lomax, 1990; Lomax, Turner and Schunk, 1997; Taylor, 2003;). The traffic can be recurrent, non-recurrent and of pre-congestion state (Banjo, 1984; Chakwizira, 2007; HCM, 2000).
The reasons for traffic congestion can be grouped into three broad categories, such as, traffic influencing events, traffic demand and physical road features. Traffic incidents, work zones and weather are the traffic influencing events. Traffic incidents include vehicular crashes, breakdowns, debris in travel lanes, events that occur on the shoulder or roadside, etc. A construction activity on the roadway is the example of a work zone. Reduced visibility, bright sunlight on the horizon, presence of fog or smoke, wet, snowy or icy road way are the examples of poor weather. Traffic demand includes fluctuations in normal traffic, such as day to day variability in demand and special events. Physical highway features include road way physical and geometrical characteristics, poor traffic control devices and physical bottlenecks (capacity) of the road (Talukdar, 2013; United States, 2005, pp.1-2). There are several indicators, which are used to assess the level of congestion on the roads. One of the major indicators, which mostly favoured is the total amount of delay encountered calculated across all traffic from the difference between the actual speed encountered and free flow speed (Dft, 2000, 2000b; Dijker, Piet, Bovy, and Vermijs, 1998; Dodgson, Young, and van der Veer, 2002; Grant-Muller, 2005). It was believed to be advantageous in providing a better picture of how changing traffic levels and different policy packages can affect time lost to congestion, although delays are measured purely in terms of vehicle journey time and no allowances are made for differences in occupancy rates, values of time, or for additional factors, such as additional operating or environmental impacts that congestion can generate. Similarly, other simple measures relating to speed are also used to indicate congestion, particularly for a motorway environment (Grant-Muller, 2005). These indicators include mean journey times, variability of journey times, throughput (total number of vehicles per time interval that pass a point on the carriageway), queue lengths, speed differential between lanes and delay per hour/day (Graham and Glaister, 2004; Grant-Muller, 2005; Grant-Muller & Laird 2006; Noland and Polak, 2002). Besides, the congestion reference flow (a quantified measure of congestion for a link -junction must be considered separately) and the level of service (LOS) are other basic congestion measures applied widely in some countries like USA and Scotland, (Highways Agency, 1997; State-wide Planning Scenario Synthesis, 2005).
In the city level, the concentration of trip destinations in a small area – particularly CBD of the cities poses the challenge of providing large transportation capacity in limited physical space, while preserving the historical, political, cultural, economic and environmental heritage/values of the areas. It is evident that a larger share of trips flow to the city centres and they are found to grow exponentially with the city size. Simultaneously, CBDs are characteristically areas of high concentration of activities, and space is scarce. Thus, a dichotomy of high demand for transportation capacity in a geographic environment where space is limited does exist (Das and Keetse, 2015; Lascano Kezic, Durango-Cohen, 2012).
The various approaches such as supply management, land use management and transportation demand management have been resorted to alleviate the challenge (Ceylan and Bell, 2004; Gao and Song, 2000; Meyer, 2003; Stevanovic et al., 2013; Yang and Bell, 1998; Zanjirani Farahani et al., 2013). However, according to critics of this method, majority of the traffic jams are caused by accidents and events – not because of lack of capacity (STPP, 2001), so adding capacity to alleviate the problems becomes controversial on account of induced demand argument and the environmental and health effects of additional travel and land consumption (Gifford, 2005). Besides, supply management methods do little to mitigate congestion caused by non-recurring incidents. Land-use management describes the use of growth management, planning, and zoning to promote local density to encourage transit. Transit oriented development and high-density land use are both examples of this type of management. Similarly, land use management measures are criticized for two major challenges- that increased congestion is created by high-density development, and it takes long time to change land-use patterns and behaviors; they also doubt regarding the connection and causality between the two (Taylor, 2002). Transportation demand management (TDM) strategy institute largely financial incentives and disincentives to encourage motorists to use alternate routes, times and modes, or to defer trips entirely in order to reduce the demand for traffic facilities. TDM measures include congestion pricing, park-and-ride lots, high-occupancy-vehicle lanes, high-occupancy-toll lanes, employer commute option programs, telecommuting, alternative work schedules, and traffic calming measures. Of all the measures, congestion pricing tends to be both most effective and politically legitimate as a funding source (Gifford, 2005); however, due to the cost it places on drivers, it is one of the hardest methods to implement (Bass, 2008).
Besides, meticulous traffic design, use of technology – use of intelligent traffic system, Global Positioning System (GPS), inter vehicle communication and vehicle simulator, and variable message signs approaches are the other ways, which are used to reduce traffic congestion (Alterkawi, 2006; Chen, Yu, Zhang, Guo, 2009; Das and Keetse, 2015; Furth, Muller, 2009; Hardjono, 2011; Salicru, Fleurent, Armengol, 2011; Santos, Coutinho-Rodrigues, Current, 2008; Yin, Lam, Miller, 2004). Efficient vehicle routing, punctuality of routes and diversion of vehicles are also considered as other options to alleviate traffic congestion particularly in the congested urban areas. Although, some research has been done in this area, the focus is limited to a number of prototype problems, and the literature on vehicle routing –

segregation of vehicular traffic (modal split), optimal traffic assignment on different alternative roads and reengineering of the traffic system at the local level, and their impact on the road network – congestion and travel time under the effect of combination of the parameters is scarce (Cordeau, Laporte, Savelsbergh, Vigo, 2007). However, with increased growth of traffic flow, it is crucial to develop cost-efficient policies, which would alleviate traffic congestion and address negative externalities in terms of environmental impact and cost to the economy (Watling, Milne, Clark, 2012; Das and Keetse, 2015).

3. Case Study: Kimberley city

Kimberley City of South Africa was considered as the study area for this study (Figure 1). It is the capital city of the Northern Cape Province of the country and is situated on the latitude 28.7419°S and longitude 24.7719° E. It is known for its diamond mining activities. However, in recent years the economic functions of the city are changing because of the reduced mining activities. The city has a combined urban population of more than 225000 (Census, 2011). It has a total of 48 suburbs, which includes districts and townships and has a designated CBD. The city is connected to various major cities of the country, such as, Johannesburg, Pretoria, Cape Town, and Bloemfontein by national roads. It is also found that the city is about on an average of 800 km from some of the major cities in South Africa, i.e. Cape Town, Polokwane, Nelspruit and the town of Springbok. Apparently the city is the central point of the country from the road network point of view.

The CBD performs important urban functions of the city. It provides facilities for both commercial and administrative activities. Spatially, it is bounded by Quinn Street in the East, Cecil Sussman/Quinn Street in the North, Cecil Sussman/Bultfontein road in the west, and Lennox Street in the South, and is considered as the primary focused study area of the investigation. The arterial roads, which generally influence the traffic movement in the CBD area, are Long, Barkly, Bishop, Carter, Schnidtsdrif, Memorial and Transvaal Roads (Figure 1). As mentioned above these roads in an around the CBD area are under heavy pressure because of the combined movement of heavy vehicles in and out of the city and normal inter and intra city traffic resulting to inefficient traffic movement.

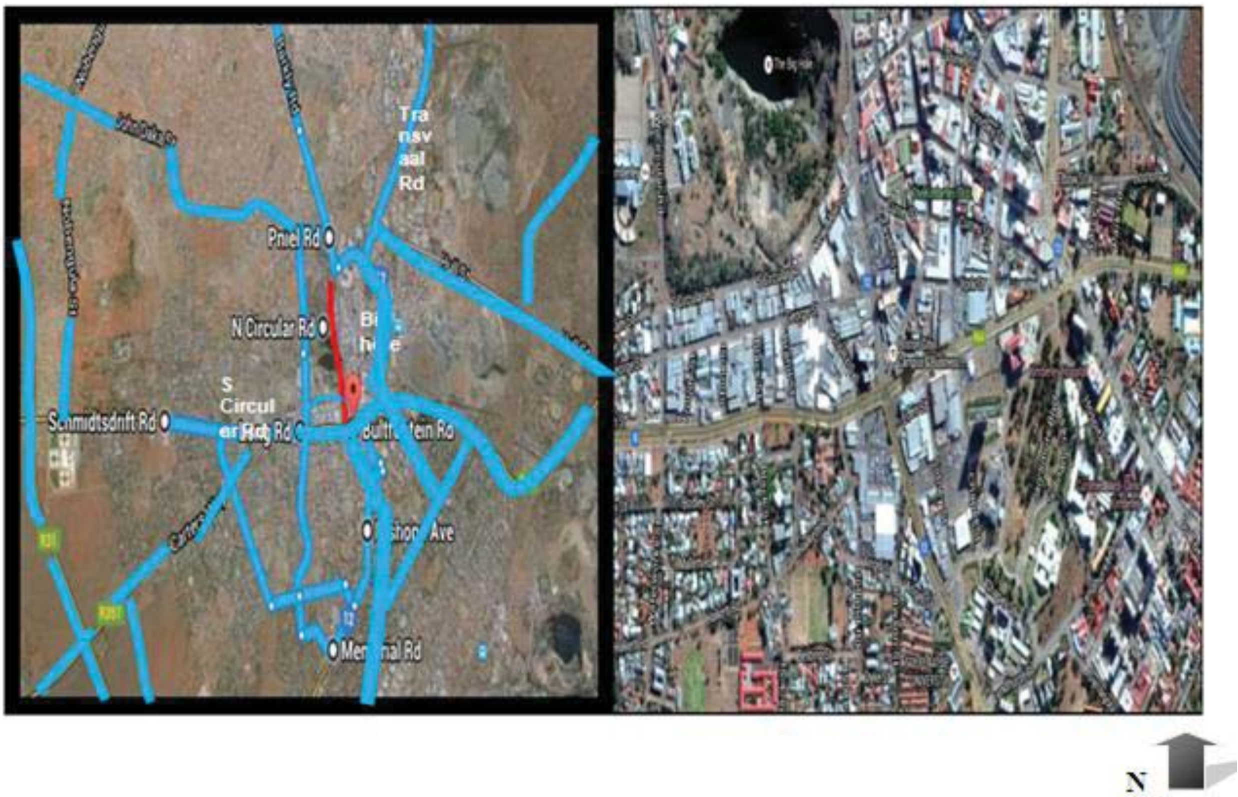

Fig. 1.
Road Network in the CBD Area of Kimberley City

4. Research Methodology

Since the investigation requires field data and road users' perception, a survey research method followed by quantitative analysis by use of statistical and empirical mathematical models suitable for analysing the traffic scenarios on the roads in and around the CBD area of city is observed to be most relevant (Kadiali, 2008). So, data were collected from primary and secondary sources. The primary data were collected from road user survey and traffic survey. The surveys were conducted by using established survey methodology applicable for transportation and traffic planning and design purposes. The collection of data from primary sources was essential because structured and up-to-date statistical data of important parameters with regard to traffic scenarios in the study area were not available. Moreover, the perception of road users and the opinion of stakeholders are essential for the development of strategies and policy interventions for alleviation of traffic congestion and efficient and smooth flow of traffic.

A number of relevant variables were taken into consideration for identification of suitable sites to conduct the surveys. Traffic surveys that included volume, speed, queue length at traffic junctions; travel time; delay time and speed changes of traffic were conducted at different locations on the important roads passing through and around the CBD area. The criteria used for selection of these roads include the importance of the road, its proximity and influence on the CBD and associated urban functions, volume of traffic, traffic flow pattern, speed of vehicles, congestion level and safety level. Based on these parameters, traffic surveys were conducted on the following roads: Long Street, Barkley Road, Bishop`s Road, Carter`s Road, Schmidtsdrift Road, Transvaal Road impacted by Pniel Road, Barkley section 2 impacting Transvaal Road, Main Street, Memorial Road, Du Toitspan Street, Lyndhurst Street, North Circular Street, South Circular Street and Cecil Sussman Street (refer Figure 1). Besides, road user perception and travel behaviour survey were conducted among 208 (N= 208) road users by using random sampling process at important nodes of the city.

The data collected were statistically analysed by the use of descriptive statistics, tabulation and significance tests. The determination of traffic congestion indicators such as traffic transmission index (Q index), LOS, travel time index (TTI), segment delay time (Ds), were done by applying the empirical models. Forecasting of traffic and simulated scenario analyses were then conducted with the aim to develop policy/ strategic interventions.

Using the values assigned by the respondents as obtained from the road user survey, a perception index (PI) of the road users was developed by employing a weighted average index method. The variables were grouped under four categories, namely land use and urban functions, urban pattern, road geometry and other urban development related parameters. The influence of each variable was assessed according to a scale of 0 to 1. Based on the perceptions and / or direct and indirect experience of respondents regarding transportation and traffic systems, urban movement challenges and traffic congestion scenarios, they were asked to assign a value in a scale of 0 to 1 to each variable which influences the occurrence of traffic congestion. The model used for the development of the perception index is presented below.

$$\text{Perception weighted average index} = (PI) = \frac{\sum Pi * Ni}{\sum Ni} \quad (1)$$

Where; Ni: number of respondents, PI: index values provided by the respondents in a scale of 0 to 1 as obtained from the road user survey.

5. Findings and Discussion

5.1. Perception index of factors causing congestion

Perception index (PI) was computed based on road users' perception on various factors that could cause congestion on the roads. A PI value of ≥0.70 is considered as highly influential, whereas a PI value between 0.5 and 0.7 (0.5<PI<7.0) is considered as moderately influential. Any PI value less than 0.5 (PI< 0.5) is taken as less influential in causing congestion. The various broad parameters considered for these analyses include physical road factors, spatial/ land use and urban function factors, traffic factors, behavioural factors, environmental and emergency factors.

Table 1 presents the perception indices of the various factors under each broad parameter. It is thus found that indices on road parking facilities (PI=0.76), and type of junctions (PI=0.74) are the major physical and road factors which significantly influence congestion on the roads in and around the CBD area of Kimberley. Unavailability of space near junctions (PI=0.68); availability of commercial functions (PI=0.54); and availability of traffic nodes such as bus stops, taxi stops and civic/administrative functions (PI=0.54) are the spatial variable that influence congestion. Similarly, traffic volume (PI=0.78) and type and composition of vehicles (PI=0.72) – particularly the plying of heavy vehicles (large trucks), traffic speed (PI=0.54) and traffic calming measures such as speed breakers (PI=0.52) – are perceived to be the major traffic related variables which significantly cause traffic congestion. Similarly, influence of alcohol and nausea on driver (PI=0.68); disrespect of traffic rules and regulations by road users (PI=0.62); unruly driver behaviour (PI=0.64); poor physical and mental condition of driver (PI=0.62); lack of knowledge of traffic rules (PI=0.56) under behavioural factors and occurrence of accidents (PI=0.66) under environmental and emergency factors which contribute largely the traffic congestion in the CBD area of the Kimberley city.

Variables such as lack of median facilities; unavailability of pedestrian crossing facilities; poor road conditions; lack of pavements/ footpaths; informal commercial activities; building offset; encroachment of roads; building size; pedestrian volume; traffic signs and pavement marking; stop signs; traffic rule enforcement such as speed traps, road blocks and unscheduled stops; and environmental factors such as heat, rain, storms and slippery roads; are perceived not to cause congestion on the roads of the study area.

Table 1
Perceptions of Public and Road Users Regarding the Parameters Influencing Traffic Congestion

Parameters	Index values	Rank	Parameters	Index values	Rank
Physical road factors			***Spatial/ Land use/ urban function factors***		
Capacity/Road width/ Lane width	0.55	5	Availability of commercial function	0.54	2
Number of lanes	0.58	3	Encroachment of roads	0.33	6
Footpaths/ pavements	0.35		Availability of civic/administrative functions	0.52	3
On-road parking facilities	0.76	1	Inadequate space available near the junctions	0.68	1
Median facilities	0.48	6	Building size	0.32	
Road condition	0.42	7	Building offset	0.38	5
Pedestrian crossing facilities	0.48	6	On-road informal commercial activities	0.47	4
Type of junctions	0.74	2	Availability of traffic nodes such as bus and taxi stops	0.54	2
Turning radius at junctions	0.56	4			
Traffic factors			***Behavioural factors***		
Traffic volume	0.78	1	Knowledge of traffic rules	0.56	4
Type and composition of vehicles	0.72	2	Respect of traffic rules and regulations	0.62	3
Traffic speed	0.54	3	Driver behaviour	0.64	2
Pedestrian volume	0.46	6	Driver's physical and mental condition	0.62	3
Signalling, pavement markings, signage control	0.44	7	Influence of alcohol and nausea	0.68	1
• Traffic signs and pavement marking	0.36	9	***Environmental and Emergency related factors***		
• Stop signs	0.41	8	Accidents	0.66	1
• Traffic calming measures such as speed breakers	0.52	4	Rain and storms	0.27	5
			Heat	0.28	3
• Traffic rule enforcement such as speed traps	0.48	5	Slippery roads	0.19	5
			Road blocks and unscheduled stops	0.44	2
Re-engineering measures for reduction of traffic congestion					
Availability of information through Information and Communication Technology (ICT)	0.43	10	Changing the traffic pattern	0.67	3
Segregation of heavy and light vehicles (Modal split)	0.73	2	Making one way streets	0.57	6
Diversion measures (Traffic assignment: choosing a different route)	0.76	1	Closure of roads (partial)	0.33	15
Use of public transportation systems	0.52	8	Segregation of vehicular and pedestrian traffic	0.36	14
Off-street parking provision	0.58	5	Improving the road infrastructure		
Removal of on-street parking system	0.56	7	• Improving junctions	0.66	4
Pedestrianisation of the whole CBD	0.32	16	• Increasing lane width	0.39	13
Pedestrian facilities in major areas	0.24	17	• Increasing number of lanes/road width	0.46	9
Improvement of signalling system	0.4	12	• Provision of pedestrian islands	0.43	10
Installing cameras/ videography	0.46	9	• Provision of footpaths/ pavements	0.42	11
Creation of traffic awareness and improving driver/user knowledge on traffic rules and regulations	0.56	7	Any other - please specify	-	

Source: Based on the statistical PI analysis from road user data collected, 2015

5.2. Level of congestion

The congestion analysis in the area was conducted by using empirical models such as segment delay, TTI, Q index and LOS particularly during peak hours. It is noted that the city experience two peak hours in the day such as (1) from 7.00-8.30 hours (in the morning) and (2) 16.00-17.30 hours (in the evening) and the major roads passing through the CBD area are found to be significantly congested during these periods. Table 2 presents the congestion levels on the roads of in and around the CBD based on the four mentioned analyses. According to the segment delay analysis, maximum delay occurs on Long Street followed by Transvaal Road impacted by Pniel. Moderate delay occurs on Bishop Street and Barkley section 2 impacting Transvaal Road and other roads do not experience much segment delay. The TTI analysis indicated that road sections close to the CBD such as Long Street, Transvaal impacted by Pniel Road, Barkley section 2 impacting Transvaal Road, and Schmidtsdrift Road are under severe pressure, followed by Bishop`s Road. The Q indices show that Long Street, Transvaal Road impacted by Pniel Road, Bishop`s Road and Barkley section 2 impacting Transvaal Road have relatively high congestion levels. Roads such as Schmidtsdrift Road, Cecil Sussman Road, Memorial Road and Lyndhurst Street are moderately congested. The LOS of various roads show that both Transvaal Road (influenced by Pniel Road) and Long Street are highly congested (LOS F); and Bishop`s Road could become a cause of concern (LOS C) in the current scenario. The LOS of various roads during peak hours show in the future scenario (in the projected year of 10 years from current) revealed that the level of congestion levels in Transvaal Road (influenced by Pniel Road) and Long Street will be further aggravated. The situation of Bishop`s Road will also become worse (LOS D). Carter`s Road, Barkley Street impacting Transvaal Road and Schmidtsdrift Road could also become cause of concern. All other roads are will be least congested. Thus, it is found that Maximum congestion occurs on Long Street and Transvaal Road, are experiencing critical congestion particularly during the peak hours of the day, and likely to be further aggravated in future whereas the scenario of Bishop`s Road is expected to become critical in future.

Table 2
Level of Congestion on Different Roads (Peak hours)

Roads	Segment (Ds)	Travel Time Index (TTI)	Traffic Transmission index (Q index)	V_p/C Current scenario	LOS (Peak hours) Current	V_p/C Future scenario	LOS (Peak hours) Future scenario	Level of Congestion
Long	92.06	2.5	266.67	1.24	F	1.48	F	HC
Barkley	6.66	1.66	600.00	0.21	A	0.25	A	LC
Bishop	34.71	2.00	227.27	0.74	C	0.88	D	MC
Carter	14.20	1.62	411.11	0.49	A	0.58	A	LC
Schmidtsdrift	27.97	2.22	337.50	0.49	A	0.58	A	MC
Barkley section 2 impacting Transvaal	30.81	2.22	300.00	0.54	A	0.64	B	MC
Memorial	10.96	1.76	377.78	0.31	A	0.37	A	LC
Transvaal influenced by Pniel	79.69	2.22	245.45	1.40	F	1.66	F	HC
Du Toitspan	7.01	1.62	493.33	0.24	A	0.29	A	LC
Main	2.54	1.50	533.33	0.11	A	0.13	A	LC
Lyndhurst	3.68	1.58	380.00	0.14	A	0.16	A	LC
North Circular	1.35	1.33	450.00	0.09	A	0.10	A	LC
Cecil Sussman	10.71	1.88	355.56	0.26	A	0.31	A	LC

5.3. Intervention measures to alleviate traffic congestion

According to the perceptions of the road users (Table 1) on the remedial solutions revealed that diversion of vehicles from congested roads (PI= 0.76), modal split (segregation of heavy vehicles from normal cars) (PI= 0.73) and changing traffic pattern (PI= 0.67) are the major re-engineering interventions which could alleviate traffic congestion in the study area. It is also perceived that provision of off-street parking (PI= 0.58), removal of on-street parking (PI=0.56) and one-way streets could assist in the reduction of congestion. Furthermore, under the improvement of road infrastructure, road users perceive that the junctions should be improved (PI= 0.66). Moreover they are of opinion that the creation of traffic awareness and improving driver/user knowledge on traffic rules and regulations (PI=0.56) and improvement of public transportation (PI=0.52) are essential challenges that need to be looked at. According to road users, measures such as availability of information through Information and Communication Technology (ICT), closure (partial) of certain road segments segregation of vehicular and pedestrian traffic, pedestrian facilities in major areas, pedestrianisation of the CBD area, improvement of the signalling system, and installation of cameras/ videography may not assist in reducing congestion as well as fully acceptable..

Moreover, significant tests were conducted to establish the relationship between the two important re-engineering policy intervention scenarios (1) adequate traffic assignment through traffic diversion from congested roads to relatively free roads and (2) segregation of vehicles (modal split) and level of traffic congestion (V/C) on the important congested roads in the CBD area. The tests were conducted by using t- test and p (one-tailed and two-tailed) values (significance test) for a confidence level of 95% ($\alpha \leq 0.05$). Table 3 presents the results of t-test and p vales. The table indicates that under the different policy interventions of traffic diversion and assignment on the one hand and modal split on the other hand, the p values (both one-tailed and two-tailed) are significantly low (<0.05) for $\alpha \leq 0.05$. It thus establishes that (a) segregation of traffic (modal split) will appreciably reduce traffic congestion in terms of improved LOS, less travel time and reduced delay on the roads of the CBD and (b) optimal traffic assignment (diversion to alternative roads) will significantly reduce traffic congestion in terms of improved LOS, less travel time and reduced delay on the roads of the CBD.

Table 3
Relationship Between Policy Interventions Scenarios and Congestion Level

Policy intervention scenarios for alleviation of congestion	T value	df	p*	p**
Traffic diversion and assignment: Normal hours - current scenario	7.007	27	0.00000008	0.00000016
Traffic assignment and percentage traffic diversion: Peak hours - current scenario	6.72	27	0.00000016	0.00000033
Combination of modal split and traffic assignment: Peak hours - current scenario	7.10	27	0.00000006	0.00000012

*Note: *One- tailed, **Two- tailed*

A comparative analysis based on simulated scenarios of different policy interventions suggests that normal hours do not need any policy interventions in the current situation. However, a minimum of 20.77% of traffic from Long Street and 28.80% from Transvaal Road should be diverted during the peak period. In addition about 15.11% of the traffic from Bishop Street, 12.73% from Barkley Road, 9.0% from Barkley section 2, 14.10% from Carter Road and 20.77% from Cecil Sussman road can be diverted. All the vehicles diverted can be assigned in proportions of 12.23%to Memorial Road, 20.77% to Du Toitspan Street, 20.77% to Lyndhurst Street, and 25.80% to Main Street. Similarly, during peak periods in the projected years (in ten years time- in the year 2026), a minimum diversion of 33.71% of the traffic from Long Street and 40.05% from Transvaal Road should be executed. About 17.79% of the traffic from Bishop Street may be diverted. Consequently, about 25.0% of the diverted traffic may be assigned to Memorial Road and Barkley Road impacted by Pniel Street and 28.43% may be equally assigned to Du Toitspan, Lyndhurst, and Main Street in order to reduce the traffic congestion and make proportionate distribution to reduce under utilization of in CBD area of the city. In future (the projected year), necessary provision should be made not to allow all the heavy vehicles to ply on Transvaal Road (Phakamile Mabija Road) and Long Street during peak hours and these vehicles may be assigned to roads such as Main Street, Du Toitspan and Lyndhurst Street.

6. Conclusion and further research

Traffic congestion is observed to be a challenge in the Kimberley City particularly in some of the roads in the CBD area, which needs interventions to alleviate the challenge. So this study was conducted to examine the levels of traffic congestion in both current and future scenarios and explore plausible re-engineering solutions to reduce the congestion level in the CBD area. The study was conducted by use of a survey research method and statistical tests and empirical. It is found that two of the roads Long Street and Transvaal Road are highly congested and are expected to worsen more in future. Another road Bishop's road is expected to become critical in near future. Since all other roads have lower level of LOS, they seem to be under utilised. In this regards traffic assignment - diversion vehicles in appropriate proportions (such as a minimum of 20.77% in current and 33.71% in future from Long Street and 28.80% in current and 40.05% in future from Transvaal Road) and assigning them to least congested roads such as Memorial Road, Barkley Road impacted by Pniel Street, Du Toitspan, Lyndhurst, and Main would reduce traffic congestion appreciably. Besides it is necessary not to allow all the heavy vehicles to ply on Transvaal Road and Long Street during peak hours in future and these vehicles may be assigned to roads such as Main Street, Du Toitspan and Lyndhurst Street. However, the study was limited to analysis of traffic congestion and re-engineering solutions and the preparation of detailed traffic management plan was kept out of the scope of this research, which the authors are keen to take as a part of their further research plan.

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