Reduction of Traffic Congestion and Carbon Emissions Through Park and Ride Transportation System

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Abstract*—Traffic congestion results in low vehicular speed, longer trip time, queuing, and blockage of movement coupled with increased demand of space beyond the road capacity. The transportation sector causes 13% of the emissions of greenhouse gas (GHG). It is a sector which is still developing. The fumes from cars contributes majorly to GHG emission. This work investigated park and ride facility as an optimal means of ameliorating congestion and hectic traffic situation within the City of Tshwane's Central Business District (CBD) with a view to lowering greenhouse gases and their impacts on the climate. Traffic counts were conducted on heavily congested routes leading to the CBD and structured questionnaires were administered within the CBD. Carbon Dioxide (CO_2) emitted by traffic within the City of Tshwane Metropolitan Municipality (CTMM) was estimated and the amount of CO_2 to be reduced by using park and ride facilities was determined. Traffic volumes on the selected routes indicated a heavy reliance of over 70% on passenger cars as a mode of entry and exit to the CBD of the city. The survey conducted also showed that about 89% of the people interviewed may be delayed by traffic jams when they are going to work. Fifty-four percent of the respondents indicated intention to use park and ride facilities provided it would guarantee safety, security and reliability. The study also revealed that the use of park and ride transportation system may reduce 96.2% carbon emission by cars traveling along the A Re Yeng Bus Rapid Transit (BRT) line in the city. Park and ride may be further researched for the feeder systems of the A Re Yeng BRT and within townships in the city of Tshwane Metropolitan Municipality.

***Keywords*—climate; greenhouse gases; passenger cars; traffic count; vehicular speed**

I. INTRODUCTION

Traffic congestion occurs on the road or highway due to increase in the number of vehicles moving on the road.Low speed, incessant queuing of vehicles and increased arrival time to reach the destination characterizes traffic congestion.

High energy is used up when there is traffic congestion, this leads to emission of high quantities of carbon monoxide (CO) as a result of combustion within the automobile engines.When carbon monoxide burns in the presence of oxygen (O_2), the product is Carbon dioxide (CO_2) [1]. Traffic congestion and variations in vehicle speeds impact greatly on the emission ofCO_2 [2].South Africa is one of the first twenty countries with the highest emission of greenhouse gases in the world [3]. The transport sector emits greenhouse gases heavily due to the combustion of diesel and petrol fuels used by automobiles [4].

The effects of traffic congestion and the resulting emitted CO_2 on climate change can be minimized through the implementation of park and ride transportation system, which is a modest transportation solution [5]. Park and ride conveniently affords facilities for parking cars at locations outside the city centre. The car parks are connected to public transportation systems within the CBD [6]. Intermodal scheme is another name for the park and ride scheme [5]. Park and ride facilities are usually designed to ameliorate congestion in areas with high concentration of traffic. It serves cities, towns and designated areas by providing parking facilities for locations of interests like stadia, amusement parks and airports. Public transit improvements, highoccupancyvehicles (HOV) and ride sharing are supported by Park and ride scheme [7]. Park and ride facilities improve cycling and enhance reduction of trip time [7]. Park and ride reduces congestion of vehicles on the carriageways; parking demand within the CBD; trip duration and expenses of vehicles and emission of greenhouse gases, energy combustion and the impacts of noise on the environment [7].

The Population, location, land use and work force of an area determines how successful the park and ride facilities would serve [8].

According to [9], 35, 35 and 30% of the entire transport are for mobility, private and public facilities respectively. Though private transportation is the most convenient means of transportation and has continued to increase, it had led to increase in traffic congestion and accidents especially during peak periods. Increase in the number of private vehicle is not a sustainable solution to transportation problem in Tshwane.

Tshwane [10] has been working tremendously to improve its transportation system and integrate all modes of private and public; motorized and non-motorized transportation systems to afford commuters ease of accessibility, safety, economy and gain in time.

The main objective of this research is to reduce traffic congestion and its attendant greenhouse effects in the environment of Tshwane and making it a healthy environment through the development of park and ride facility.

II. STUDY AREA AND METHODS

Tshwane region in the province of Gauteng in the Republic of South Africa was used as the case study for this research. Tshwane is the largest metropolitan municipality and the capital city of the South Africa.

Secondary data for the study area were collected fromgovernmentdepartments while questionnaires were distributed to people within the region of Tshwane.Data collected and used for this research work include:

i. Orthor-photos generated from GIS: The geographic information system, known as GISgenerated dataofroadsandstormwater which was obtained from the Infrastructuretechnologyinformationmanagementdivision of theCTMM.TheMrSIDviewerprogram was used to view the orthor-photos. A map showing City of Tshwane Metropolitan Municipality is presented in Figure 1.

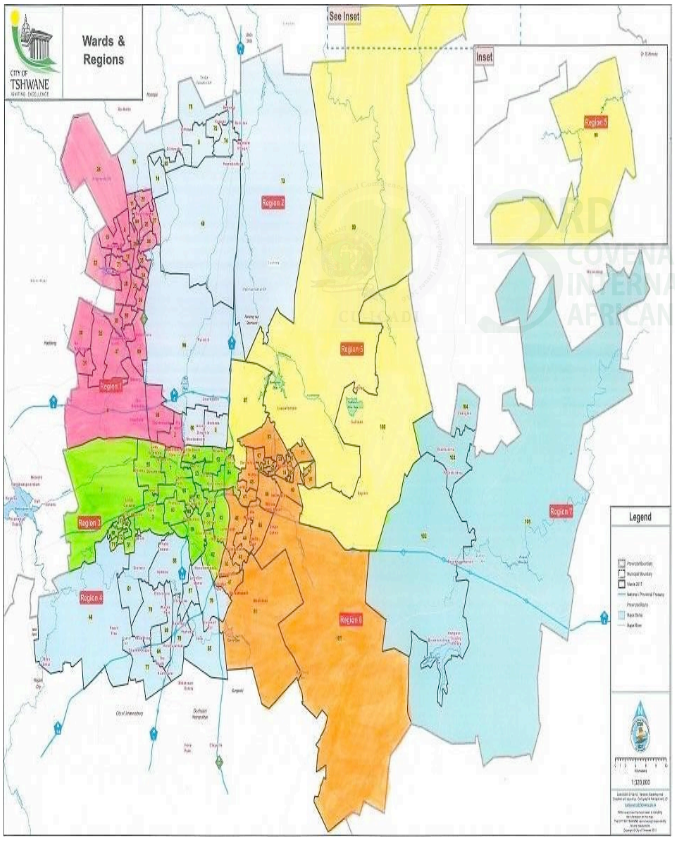

Figure 1: A map showing City of Tshwane Metropolitan Municipality

iiTrafficvolumedata: A 12 hour (06:00to18:00) Manual traffic count was done at the four major intersections leading to the region of Tshwane's CBD in line with [11]. The count was conducted between Monday,March 5,2012andFriday,March 9,2012. The traffic count method used for enumerating automobiles was the classifiedcount. It was conductedonNelson Mandela, Struben, Pretorious and PaulKrugerStreets.Observations were made on the turning of the vehicles at intersections on DFMalan and StrubenStreets;Boom and PaulKrugerstreets;Hamiltonand Pretoriusstreets;andWillow and NelsonMandelastreets.

iiiFeedbackdatafromquestionnaires: A5 paper - Structured Questionnaires containing 11 questions was distributed to 318 respondents within the Tshwane region of South AfricafromMonday to Friday.

The answers to the questions asked were provided in the multiple choice format out of which respondents indicated their choice against each question.

iv. Data for Volumes of Fuel sold and consumed: The information on air pollution as obtained from the records of the volume of fuel sold were given by the energy department of the CTMM and calculated as follows:

$$MtCO_{2e} = \sum(f_p * EF_p) + (f_d * E \quad [1]$$

where:

= *petrol volume*

= *factor for petrol emission*

= *diesel volume*

= *factor for diesel emission*

= *Equivalenceof Carbon di Oxide in Mega Tonnes*

The total quantity of carbon di oxide resulting from combustion of a litre of diesel or a litre of petroldepends on the equivalent chemical constituents in the fuel. An assumption was made that a litre of petroleum product emits 2.36 and 2.60 kg of $CO_{2e}$of petrol and diesel respectively. Hence, the values wereused as emission factor for petrol and diesel respectively [12]. Therefore, the emission factors of diesel and petrol are 2.60 and 2.36kg respectively from $CO_{2e}$and was used for the determination of carbon emitted from diesel and petrol. The contents of methane (CH_4) and nitrous oxide (N_2O)were not used for the determination of the emitted carbon though they are part of the gases that emits the green house effects.

III. DISCUSSION OF RESULTS

A. Transportation Layout Plan and Park and Ride Facilities

The Are Yeng BRT lines shown in figure 2 was used as the transportation layout plan. It meets the accessibility requirements to areas of priority and dedicated lanes with high service level for transit expected of the park and ride [8].

Parameters used for the identification of land used for park and ride facilities were virgin pieces of land adjacent to the proposed or existing A Re Yeng BRT route; vacant land along the main streets in Tshwane; expropriation or rezoning for land acquisition and ownership; and impacts of the public transportation system on traffic patterns.

Available lots of land for park and ride schemes facilities arepresented in table I and figure 2.The proximity and adequacy of the identified available spaces for the implementation of the park and ride scheme in Tshwane is presented in table II.

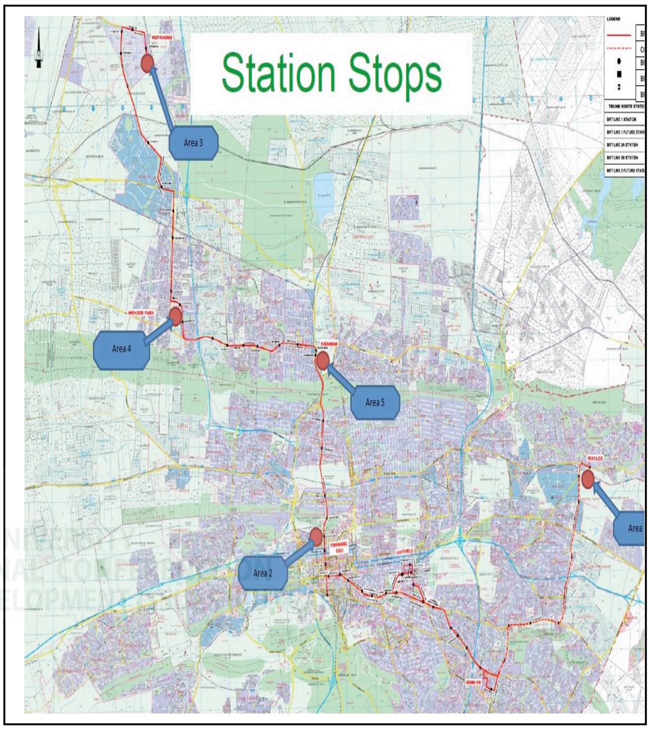

Figure 2: LocalityplanindicatingtheidentifiedIntersections(Source:MapStudio,2012)

TABLE II. DIFFERENT LOCATIONS FROM CBD

Area	Distance from designated area to CBD
Area 1	17 km
Area 2	3 km
Area 3	26 km
Area 4	16 km
Area 5	7.5 km

B. *Carbon Emission Estimation*

Research [13], has shown that for private vehicle car, the fuel consumption is 14.71 litres per 100km in congested traffic and8.241 litres per 100km in unrestricted traffic.

Volvo bus [14] indicated a fuel consumption of 26 litres per 100km for the average speed of 60km/h on their buses. The assumption that for a private car or vehicle, 8.241 litres of fuel is consumed in 100km distance for unrestricted flow of traffic and 14.71 litres of fuel is consumed in 100km distance for congested traffic was utilized for design and operation of Traffic in Tshwane.For the first segment of the trip, the fuel consumption rate was taken as 8.241 litres for a distance of 100km while for the second segment, the fuel consumption rate was taken as 14.71 litres for a distance of 100km in the morning. The inverse was taken for afternoon trips.For the determination of carbon emitted for a litre of fuel, the average value of emissions of petrol and diesel was used. Hence, 2.48kgCO_{2e} was utilized as the fuel emission factor of vehicles entering and exiting the region of Tshwane for the calculation of Carbon emitted. The available spaces were used to determine the capacity of the facility. The total number of passengers a bus could take was 65. All park and ride facilities were assumed to be operating at full capacity.

TABLE I. AVAILABLE SPACE FOR PARK AND RIDE FACILITY

Space	Area located	Proprietor	Accession	Along BRT lane	Impacts Traffic
Vlakfontein 329JR	Mamelodi	CTMM	Assigned	*	*
Ombre 636JR	Paul Kruger Str.	CTMM	Assigned	*	*
Klipkruisfontein	Soshanguve	CTMM	Assigned	*	*
Ext 507, Erf 394	Wonderpark	Private	Seizure	*	*
Wonderboom	Annlin	Private	Seizure	*	*

The value of the emission factor used for standard buses was 2.6kgCO_{2e} while 26 litres of fuel was assumed to be consumed for 100 km distance for unrestricted traffic flow. The assumption for the consumption factor was that the bus rapid transit would be travelling on its dedicated lane. The energy department of the region of Tshwane gave the data for results of air pollution within the city.TablesIII and IVshow the records of estimated carbon emitted in Tshwane and South Africa respectively between years 2005 and 2014. The results indicate increment in the greenhouse gas emitted as shown in figure 3.

The city of Tshwane in 2014 contributed 4.439 MtCO2e or 7.2% of South Africa's 61.009 MtCO2e as estimated from the fuel volume sales consumption data.The total amount of greenhouse gas emitted in Tshwane between 2012 and 2013 was 13.180 MtCO_2e. Industrial pollution contributed most to greenhouse gas emission with 4.100 MtCO_2e which represents 31.11% of the entire GHG emissions. Transportation activities was second highest contributor to

GHG emission with 4.061 MtCO2e emission representing 30.82% of the total GHG emission [15]. This figure is very close to the carbon emissions estimated for the year 2013 at 4.366 MtCO2e as shown in Table III.

TablesV and VI show the carbon emission by cars and buses respectively. The two vehicles moved the same distance from their origin to destination.

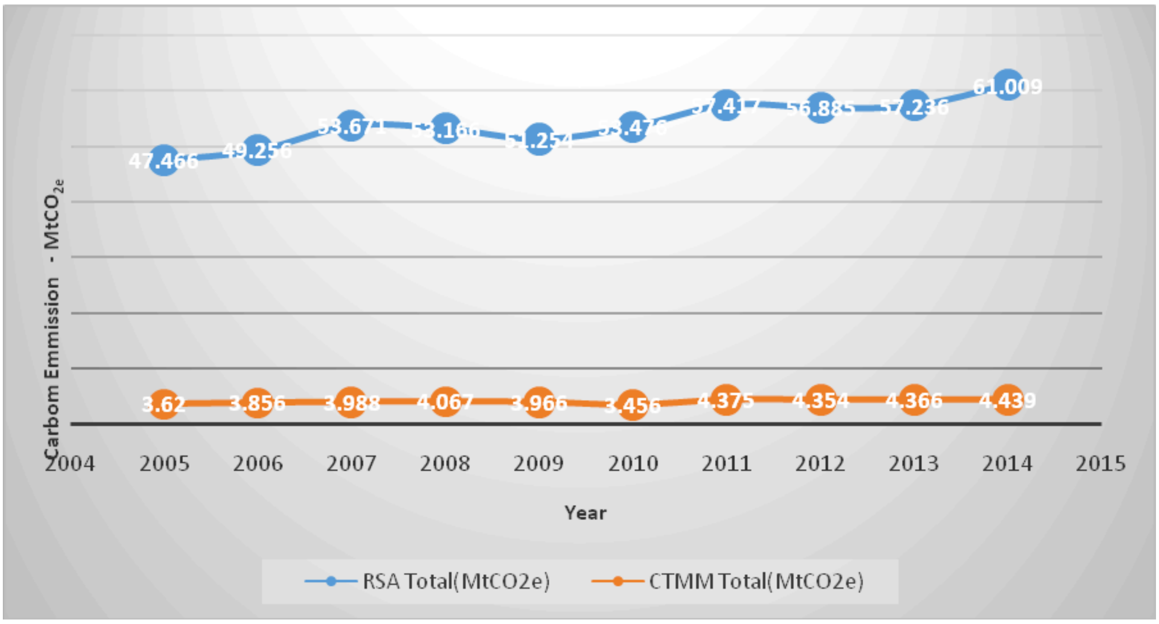

Figure 3: Carbon emission estimated from RSA and CTMM Annual Fuel Sales volumes and consumption

TABLE III. EMITTED CARBON FOR TSHWANE CITY FROM ANNUAL SALE OF FUEL FROM 2005 TO 2014

Year	Diesel (litre)	Petrol (litre)	Carbon produced from Diesel (kg of CO_{2e})	Carbon produced from Petrol (kg of CO_{2e})	Total Carbon produced Diesel (kg of Co_{2e})	Total Carbon produced from Petrol (kg of Co_{2e})	Total Carbon produced ($MtCO_{2e}$)
2005	455 128374	1 032 522 138	1 183 333 772	2 436 752 245.68	3 620 086 018	3 620 086.018	3.620
2006	537 571 166	1 041 667 593	1 397 685 032	2 458 335 519.48	3 856 020 551	3 856 020.551	3.856
2007	583 543 659	1 047 123 983	1 517 213 513	2 471 212 599.88	3 988 426 113	3 856 020.551	3.998
2008	653 686 754	1 003 270 446	1 699 585 560	2 367 718 252.56	4 067 303 813	4 067 303.813	4.067
2009	597 929 385	1 021 620 026	1 554 616 401	2 411 023 261.36	3 965 639 662	3 965 639.662	3.966
2010	564 580 485	842 620 954	1 467 909 261	988 585 451.44	3 456 494 712	3 456 494.712	3.456
2011	724 834 772	1 055 244 617	1 884 570 407	2 490 377 296.12	4 374 947 703	4 374 947.703	4.375
2012	740 176 729	1 029 548 505	1 924 459 495	2 429 734 471.80	4 354 193 967	4 354 193.967	4.354
2013	753 757 478	993 799 248	2 020 522 296	2 345 366 225.28	4 365 888 521	4 365 888.531	4.366
2014	777 123 960	1 024 607 025	2 020 522 296	2 418 072 578.26	4 438 594 874	4 438 594.874	4.439

TABLE IV. EMITTED CARBON FOR THE REPUBLIC OF SOUTH AFRICA FROM ANNUAL SALE OF FUEL FROM 2005 TO 2014

Year	Diesel (litre)	Petrol (litre)	Carbon produced from Diesel (kg of CO_{2e})	Carbon produced from Petrol (kg of CO_{2e})	Total Carbon produced Diesel (kg of Co_{2e})	Total Carbon produced from Petrol (kg of Co_{2e})	Total Carbon produced ($MtCO_{2e}$)
2005	8 116 573 441	11 170 710 222	21 103 090 946.60	26 362 876 123.92	47 465 967 070.52	47 465 967.07052	47.466
2006	8 707 405 264	11 278 412 253	22 639 253 686.40	26 617 052 917.08	49 256 306 603.48	49 256 306.60348	49.256
2007	10 141 584 286	11 568 813 336	26 368 119 143.60	27 302 399 472.96	53 670 518 616.56	53 670 518.61656	53.671
2008	10 385 030 955	11 086 938 407	27 001 080 483.00	26 165 174 640.52	53 166 255 123.52	53 166 255.12352	53.166
2009	9 437 131 324	11 321 186 218	24 536 541 442.40	26 717 999 474.48	51 254 540 916.88	51 254 540.91688	51.254
2010	10 170 466 384	11 454 711 308	26 443 212 598.40	27 033 118 686.88	53 476 331 285.28	53 476 331.28528	53.476
2011	11 224 553 285	11 963 310 914	29 183 838 541.00	28 233 413 757.04	57 417 252 298.04	57 417 252.29804	57.417
2012	11 228 716 399	11 733 080 659	29 194 662 637.40	27 690 070 355.24	56 884 732 992.64	56 884 732.99264	56.885
2013	11 890 350 007	11 152 866 181	30 914 910 018.20	26 320 764 187.16	57 235 674 205.36	57 235 674.20536	57.236
2014	13 168 816 974	11 343 566 879	34 238 924 132.40	26 770 817 834.44	61 009 741 966.84	61 009 741.96684	61.009

TABLE V. ESTIMATED CARBON EMISSION BY CARS USING PARK AND RIDE FACILITIES

Areas located	Distance from location to CBD (km)	Consumption on 1st segment of Journey (ℓ)	Consumption on 2nd segment of Journey (ℓ)	Total Journey Consumption (ℓ)	Carbon Emission Factor (kg CO_{2e})	Carbon Emission per Journey per Car (kg of CO_{2e})	Total Available Parking space	Total ($kgCO_{2e}$)	Total ($MtCO_{2e}$)
1	17	0.700	1.250	1.951	2.48	4.838	2000	9676.142	
2	3	0.124	0.221	0.344	2.48	0.854	1000	853.777	
3	26	1.071	1.912	2.984	2.48	7.399	2000	14798.905	
4	16	0.659	1.177	1.836	2.48	4.553	2000	9106.957	
5	7.5	0.309	0.552	0.861	2.48	2.134	2000	4268.886	
Total Carbon emitted in January								38704.5664	
Total Carbon emitted for the whole Journey (monthly – single trip)								774091.328	0.00077
Total Carbon emitted for the whole Journey (monthly – return trip)								1548182.656	0.0015
Total Carbon emitted for the whole Journey (annual – single trip)								9289095.936	0.009
Total Carbon emitted for the whole Journey (annual – return trip)								18578191.87	0.018

TABLE VI. ESTIMATED CARBON EMISSION BY BUSES USING PARK AND RIDE FACILITIES

Areas located	Distance from location to CBD (km)	Total Fuel consumed(ℓitre)	Carbon Emitted (kg CO_{2e})	Carbon Emission per Journey per Bus (kg CO_{2e})	Total Buses required for available space	Total ($kgCO_{2e}$)	Total ($MtCO_{2e}$)
1	17	4.400	2.60	11.492	31		
2	3	0.780	2.60	2.028	15		
3	26	6.760	2.60	17.578	31		
4	16	4.160	2.60	10.816	31		
5	7.5	1.950	2.60	5.070	31		
Total emission for the whole Journey							
Total emission for the whole Journey (monthly – single trip)							
Total emission for the whole Journey (monthly – return trip)							
Total emission for the whole Journey (annual – single trip)							
Total emission for the whole Journey (annual – return trip)							

If all the car users presented in Table Vutilize the park and ride scheme for their journey within Tshwane, South Africa and move to the central business district by public buses, 96.2 % of the estimated carbon emitted within the Tshwane environments would be prevented.

A bus can take only a little space in the traffic and congestion on the road. Buses have modestdimension, they are light and manoeuvrable. They can aid quick, smooth and convenient response to prevailing or changing demands without requirement for specialised infrastructure [16].

IV. CONCLUSIONS

This paper shows that the carbon emission as estimated from the fuel volume sales indicate that the emissions are on the increase annually. The city of Tshwane in 2014 contributed 4.439 $MtCO_{2e}$ or 7.2% of South Africa's 61.009 $MtCO_{2e}$ as estimated from the fuel volume sales consumption data.

The use of park and ride transportation system will reduce 96.2% carbon emission by cars traveling along the A Re Yeng BRT line. Buses emit only 3.8% of the emissions by cars. Park and ride can be used to effectively reduce the problems of traffic congestion and the resulting emission of greenhouse gas which have a negative effect on the environment of Tshwane. It will ameliorate inadequate parking facilities within the City.

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