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Ameliorating Traffic Congestion and Impact on Climate Change with Park and Ride Transport

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Abstract: Traffic congestion occur as more vehicles ply the road and result in reduced travel speed, increased travel time, unnecessary queuing, obstruction on travel path and impediment to traffic flow. Thirteen per cent of greenhouse gases (GHG) emitted are caused by the transportation system which continues to grow. Fume emanating from vehicles contributes greatly to the emission of GHG. Park and Ride was investigated within the Central Business District (CBD) of Tshwane with a view to improving the traffic congestion and reducing the effects of GHG on the climate. Traffic counts and questionnaires distribution were done on the major access routes to the CBD. The quantities of carbon dioxide (CO_2) emitted by traffic and that would be reduced when park and ride system is implemented in the City of Tshwane Metropolitan Municipality (CTMM) were determined. Results of traffic volume counts showed high dependence of more than 70% of people on passenger cars as the mode of transit within the study area. It also revealed that almost 89% of the interviewed population are delayed by traffic, on their way to the work place in the morning. Fifty-four per cent of the people interviewed showed readiness to utilize the park and ride facility if their safety and security would be guaranteed. Furthermore the study showed that 96.2% of CO_2 emitted could be reduced by the implementation of the park and ride system on the A Re Yeng BRT and also in the major cities of Tshwane.

Keywords: Greenhouse gases, traffic congestion, traffic flow, traffic volume, travel speed.

1. Introduction

Traffic congestion is usually experienced when heavy traffic is attracted to or generated from towns and central business districts (CBD), due to day-to-day activities of people and struggle for survival. It also leads to high energy consumption, causing high carbon-monoxide (CO) emissions from internal combustion of automobile engines. Carbon monoxide a colourless, odourless, tasteless but toxic gas poisons the lungs of human beings when inhaled through breathing mechanism and displaces oxygen from the blood stream. The normal supply of oxygen is truncated and the heart functions at great risk (Carbon Monoxide, 2011).

Increase in vehicular traffic causes reduced speed of movement, queuing, and delayed arrival time. The aforementioned phenomena characterize traffic congestion. Great energy is utilized or used up in traffic congestion. This results in emission of great quantum of carbon monoxide (CO) due to combustion of fuels by the engine of automobiles. Carbon dioxide (CO_2) results from the burning of carbon monoxide (CO) in the presence of oxygen (Carbon Monoxide, 2011).

Traffic congestions causes variation in vehicular speeds and enhances the emission of CO_2 (Barth & Boriboonsomsin, 2010). The Republic of South Africa is listed among the twenty leading countries generating greenhouse gases emission in the world (Energy Information Agency, 2010). Interestingly, the combustion of petrol and diesel of automobiles, in the transportation sector, emits great quantum of greenhouse gases (Department of Environmental Affairs, 2010). Traffic congestion and the attendant emission of CO_2 could be reduced when park and ride transportation system, a modest traffic solution, is implemented (Spillar, 1997). Park and ride is a convenient system which allows vehicular parking out of the city. Such parking lots are integrated to the existing transportation system in the CBD (Lam et al. 2007).

Park and ride facility can also be called intermodal transportation scheme. The duties of the park and ride scheme changes swiftly with changes in traffic conditions (Spillar, 1997). Park and ride schemes are designed to eliminate congestion in urban areas with high traffic demands. Cities, towns and locations are connected with the provision of parking areas for the convenience of movements to important locations such as airports, amusement parks, recreation centers, shopping malls and stadia. High occupancy vehicles (HOV), public transport developments and ride sharing are proximate to park and ride facilities (Vincent & Hamilton, 2007).

The land use, location, population and work force of a particular area dictate the efficiency of the park and ride scheme (De Aragon, 2004).

According to De Aragon (2004). Park and ride schemes are classified by the functions they serve in the different locations where they are utilized. They can be generally described as follows:

- Remote – This is usually located at a far distance from major areas and residences. They are usually in rural communities.
- Suburban – This is situated near the outer edges of urban areas. Here the private vehicles are dominant while public modes of transportation such as rails, ferries and buses are mainly used to collect and distribute passengers.
- Local – This may be located along or near the end of a main transit. There is no provision for special or dedicated service, hence it is served by existing roads. The transit level may be low.
- Peripheral – This is situated at the CBD's edge or at areas where major events take place. Its main role is to enhance more parking by diverting commuters from entering areas that are congested and connecting them to large expanse of land in areas with free or cheap parking facilities.

Park and ride facilities are described by Spillar (1997) as follows:

- Informal – This is a simple and regular transit for commuters to park and access nearby streets or adjacent properties with ease and convenience.
- Exclusive – This is designed and constructed to serve the operation of the park and ride scheme. It is famous in urban areas with different modes of transportation such as taxis, buses, BRTs and rails
- Shared-use – This has multiple functions like parking site for private and commercial uses for schools, churches, communities and groups in smaller urban areas with less demands. It can be implemented within short time, it has low maintenance cost resulting from its low capacity.

The transportation means for the study area was grouped as 35% mobility, 35% private and 30% public facilities (Tshwane Integrated Development Plan, 2006). Private transportation is the most convenient transportation means and is on the increase. Its increase has continuously led to increase in accident and traffic congestion in the CBD, especially at peak periods. Increase in the number of private vehicles is however not sustainable in the CBD of Tshwane (Tshwane Integrated Development Plan, 2006).

Tremendous efforts had been made to ameliorate traffic congestion and improve the transportation system in Tshwane by integrating private and public, motorized and non-motorized transportation systems in order to achieve accessible, safe, secured and economic transportation with time gain (City of Tshwane Comprehensive Integrated Transport Plan, 2015).

The main aim of this work is to ameliorate the traffic congestion and the resulting greenhouse gases emitted, thereby reducing their effects on the climate change in the City of Tshwane. This will guaranty a safe, healthy and convenient environment through the implementation of park and ride scheme.

This work is an extension of (Rikhotso et al., 2016). The abstracts, main body and results had been extensively revised.

2. Study Area and Methods

Tshwane region, a cosmopolitan city in Gauteng province of South Africa was the study area for this research. Tshwane is the capital and also the largest metropolitan municipality of the Republic of South Africa.

Secondary data were sourced from the agencies of government. Structured questionnaire was distributed to people in the study area.

The specific methods used for the research are:

i. GIS data to generate orthor-photos.
ii. Traffic counts.
iii. Questionnaire method
iv. Determination of Carbon emitted from Sale and consumption of fuel.

Secondary data were sourced from the agencies of government. Structured questionnaire was distributed to people in the study area. The data collected for the work are as follow:

i.Geographic Information Systems (GIS) generated Ortho-photos: Data for the roads and storm water were retrieved from the division of infrastructure technology information management of the CTMM. The data were developed with the use of GIS. Ortho-photos were viewed using the MrSID viewer program as presented in the Tshwane municipality map in figure 1.

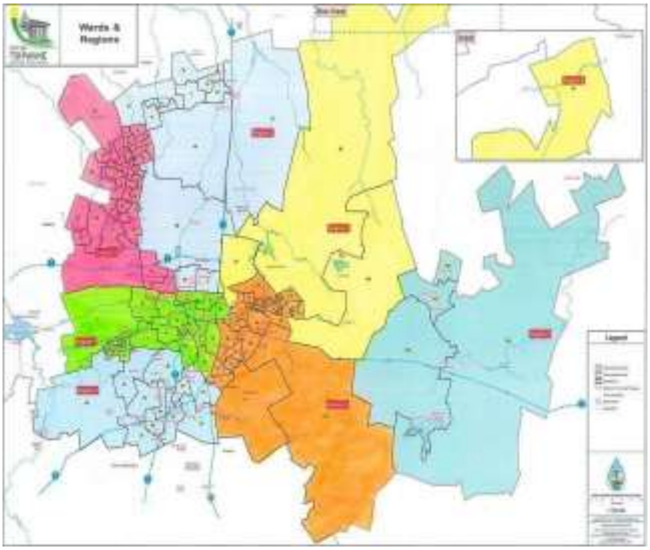

Figure 1: Map of the Metropolitan Municipality of the City of Tshwane.

ii. Traffic Counts: Data on 12 hour traffic volume were obtained from manual traffic counts conducted between 6am and 6pm at the four main access roads to the CBD of Tshwane as recommended by (Highway Capacity Manual, 2000). Traffic count was conducted from Monday, March 5 to Friday, March 9, 2012. The traffic count method used for enumerating automobiles was the classified count. It was conducted on Nelson Mandela, Struben, Pretorious and Paul Kruger Streets.

Observations were made on the turning of the vehicles at intersections on DF Malan and Struben Streets; Boom and Paul Kruger streets; Hamilton and Pretorius streets and Willow and Nelson Mandela Streets.

iii. Questionnaires: A set of well-structured questionnaire having eleven questions was rated and distributed to 318 respondents in the BCD of Tshwane between Monday and Friday.

The questionnaire had multi-choice answers for respondents to choose their answers against each of the questions asked.

The structured questions are summarized as follows:

1. Place of residence?
2. Nature of work or profession?
3. Transport mode used from home to work?
4. Work distance from home?
5. Trip time from home to work?
6. Are you held in traffic from home to work?
7. If answer to question 6 is yes, how frequent?
8. How much fuel will you use if you are going to work from home in your private vehicle?
9. Do you move alone or with friends, neighbor of family when you travel in your private vehicle?
10. If there is an improvement that will guarantee safety, reliability, efficiency and economy of the public transport, will you drop your private vehicle for the public vehicle? Are you aware that patronage of the public transport will enhance the reduction of the carbon emitted in the environment?
11. Will you park your private vehicle at a dedicated and safe place if there is provision of convenient, easy, cheap, reliable and safe public means of transportation from your home to work?

iv. Determination of Carbon emitted from Sale and Consumption of Fuel: The volume of fuel sold was obtained from department of energy of CTMM. The equivalence of the volume of carborn dioxide emitted was obtained from the relationship shown in equation (1).

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

where:

f_p = *petrol volume*

EF_p = *factor for petrol emission*

F_d = *diesel volume*

EF_d = *factor for diesel emission*

$MtCO_{2e}$ = *Equivalence of Carbon di Oxide in Mega Tonnes*

The quantity of CO_2 obtained from the combustion of a litre of petrol or diesel is dependent on an equivalence of chemical constituents of either the petrol or diesel. The assumption is that the equivalence for petrol is 2.36 of CO_{2e} while that of diesel is 2.60kg of CO_{2e} (Climate leaders greenhouse gas inventory protocol, 2008).

The values were used to determine the total volume of Co_2 emitted from petrol and diesel. Though nitrous oxide (NO_2) and methane (NH_4) are also gases that emit greenhouse effects, they were not used in the determination of carbon emitted.

3. Discussion of Results

3.1 Layout Plan for Park and Ride Transportation Scheme

Figure 2 presents the Are Yeng BRT routes utilized to generate the layout plan for the transportation scheme. The Are Yeng transportation route is direct, accessible and connects different areas with great importance because of the good level of service its dedicated lanes provides for safe, easy and convenient transit from its routes to park and ride facilities (De Aragon, 2004).

Lands identified for the implementation of park and ride scheme are lands adjacent to the existing or proposed A Re Yeng BRT route; vacant sites on the main roads of Tshwane; rezoning or expropriation for land ownership or acquisition and also effects of the public transportation system on existing traffic records.

Fallow plots of land available for park and ride facilities are shown in table I. The nearness and adequacy of the plots of land identified for use as park and ride transportation schemes are shown in table II.

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	*	*

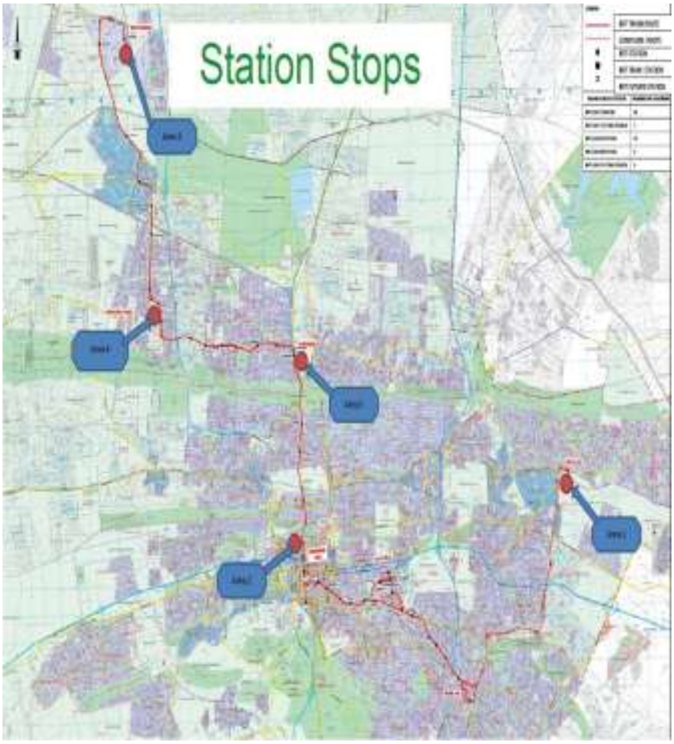

Figure 2: Map of the City of Tshwane Metropolitan Municipality

TABLE II: DISTANCE BETWEEN LOCATIONS AND 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

3.2. Estimation of Carbon Emissions

The fuel consumption for private vehicle car per 100km is 14.71 and 8.241 for congested and unrestricted traffics respectively (Treiber et al. 2007).

Volvo bus (2013) showed that the rate of fuel consumption for bus per 100km is 26 litres when the bus is moving averagely at a speed of 60km/h. The above assumption that a vehicle or private car consumes 8.241 litres of fuel to cover a distance of 100km when the traffic is unrestricted and 14.71 litres of fuel to cover the same distance when the traffic is congested was used in the design of Traffic flow in the Tshwane region.

The combustion rate of 8.241 litres of fuel was taken for the 100km in the first segment of the trip while the combustion rate of 14.71 litres of fuel was utilized for the 100km in the second segment of the journey in the morning. The reverse was utilized for the trips in the afternoon. To determine the quantity of emitted carbon per litre of fuel, the average value of the emission of petrol and the average value of the emission of diesel were used. Therefore the fuel emission factor used for the calculation of carbon emitted by vehicle both leaving and entering Tshwane is 2.48kg$CO_{2e.}$ The capacity of the facility was determined by the available spaces. While the park and ride facilities were assumed as operating at full capacity, the capacity of a passenger bus was taken as 65.

The emission factor used for buses was 2.6kgCO_{2e} and the fuel consumption rate of 26 litres was projected to be consumed by the bus for a distance of 100 km when the traffic flow is unrestricted. It was assumed that the consumption factor of the bus rapid transit would be constant as the bus would be travelling on its dedicated lane. Data of the air pollution within the city of Tshwane was given by the department of energy of the Tshwane region. The quantities of estimated carbon emission for Tshwane and the Republic of South Africa from year 2005 to 2014 are presented in tables III and IV respectively. There is a substantial increase in the greenhouse gases emitted as presented in figure 3.

The records of the fuel volume sale and consumption data in 2014 shows that the contribution of the city of Tshwane is 4.439 MtCO2e out of South Africa's 61.009 MtCO2e of carbon emission which is 7.2% (City of Tshwane greenhouse gas inventory, 2014).

From 2011 to 2013 the city of Tshwane emitted 13.180 MtCO2e. In 2012 the greatest contributor of the greenhouse gas emission then was from industrial pollution which produced 4.100 MtCO2e, which was 31.11% of the overall greenhouse gas emissions. The transportation sector was the next (second) contributor of greenhouse gas emission after the industrial pollution. The transportation sector contributed 4.061 MtCO2e which was 30.82% of the entire emissions of greenhouse gas (City of Tshwane greenhouse gas inventory, 2014). The numerical values of the emission of carbon for year 2013 slightly exceeded that of 2012 as the city of Tshwane produced 4.366 MtCO2e as shown in table III.

The estimated quantity of carbon emitted by cars is presented in table V while the estimated quantity of carbon emitted by buses is presented in table VI. Without recourse to the difference in the travel speeds of car and bus, the two vehicles will travel the same distance from one point to the other but their speed, rate of fuel combustion and the resulting carbon emission differ.

Assuming all the car users shown in Table V uses the park and ride facilities for their journey within Tshwane region of the Republic of South Africa and move to the central business district

(CBD) by public buses, 96.2% of the estimated carbon emitted in the region of Tshwane would be prevented.

A standard bus does not take much space on the highway and does not cause hectic traffic and congestion on the highway. The dimension and shape of buses are moderate, they are not heavy and can be easily manoeuvred. Buses may enhance convenient, smooth and quick responses to changing or prevailing circumstances or demands without requiring for special infrastructures (Chapman, 2007).

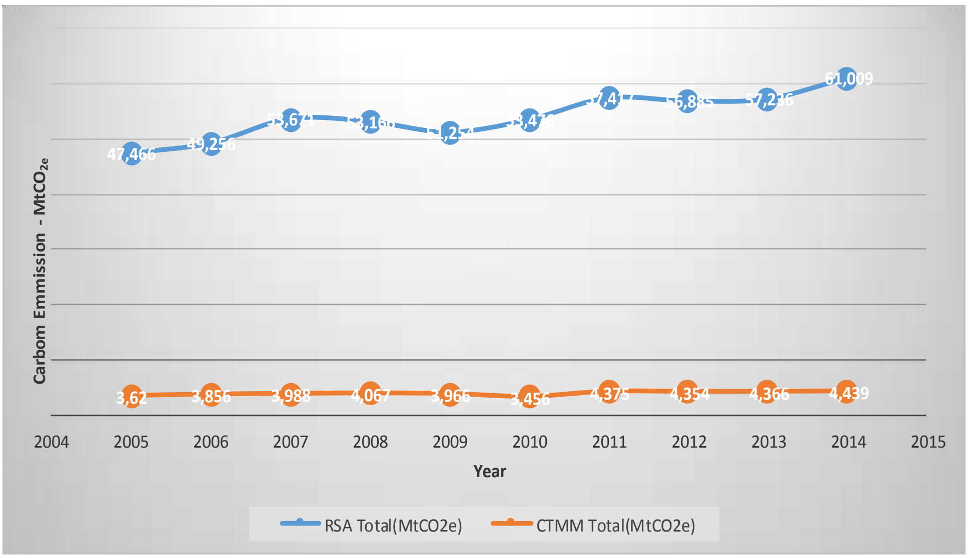

Figure 3: Carbon emission estimated from RSA and CTMM Annual Fuel Sales volumes and consumption

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 from 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 from 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 1st segment of Journey (ℓ)	Consumption 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	353.6	
2	3	0.780	2.60	2.028	15	31.2	
3	26	6.760	2.60	17.578	31	540.8	
4	16	4.160	2.60	10.816	31	332.8	
5	7.5	1.950	2.60	5.070	31	156	
Total emission for the whole Journey						1414.400	
Total emission for the whole Journey (monthly – single trip)						18288.0	0.0000282
Total emission for the whole Journey (monthly – return trip)						56576.0	0.0000565
Total emission for the whole Journey (annual – single trip)						339456.0	0.000339
Total emission for the whole Journey (annual – return trip)						648912.0	0.000679

IV. Conclusions

This work shows that the quantity of carbon emitted, as obtained from the estimates of the fuel volume sale and consumption, in Tshwane in particular and the entire Republic of South Africa is increasing annually. The city of Tshwane in 2014 contributed 4.439 $MtCO_{2e}$ or 7.2% of South Africa's 61.009 $MtCO_{2e}$ as obtained from the records of the fuel volume sales and consumption data.

Implementation of the of park and ride facilities in the Republic of South Africa will reduce 96.2% of carbon emission by private vehicles (cars) traveling along the A Re Yeng BRT route. Buses emit only 3.8% of the total emission while the remaining emissions come from cars. Park and ride scheme may be useful in effective reduction of the problems of traffic congestion and the resulting emission of greenhouse gas which have impacted negatively on the environment in Tshwane and the entire Republic of South Africa. If implemented, park and ride will surely ameliorate the insufficient parking facilities within the City, ease traffic flow and reduce emission of carbon which negatively affects the climate.

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